frontiers | Research Topics

Reviews in public health expenditure and performance

Edited by
Hai Fang

Published in
Frontiers in Public Health

ISSN 1664-8714
ISBN 978-2-8325-6234-5
DOI 10.3389/978-2-8325-6234-5

About Frontiers

Frontiers is more than just an open access publisher of scholarly articles: it is a pioneering approach to the world of academia, radically improving the way scholarly research is managed. The grand vision of Frontiers is a world where all people have an equal opportunity to seek, share and generate knowledge. Frontiers provides immediate and permanent online open access to all its publications, but this alone is not enough to realize our grand goals.

Frontiers journal series

The Frontiers journal series is a multi-tier and interdisciplinary set of open-access, online journals, promising a paradigm shift from the current review, selection and dissemination processes in academic publishing. All Frontiers journals are driven by researchers for researchers; therefore, they constitute a service to the scholarly community. At the same time, the *Frontiers journal series* operates on a revolutionary invention, the tiered publishing system, initially addressing specific communities of scholars, and gradually climbing up to broader public understanding, thus serving the interests of the lay society, too.

Dedication to quality

Each Frontiers article is a landmark of the highest quality, thanks to genuinely collaborative interactions between authors and review editors, who include some of the world's best academicians. Research must be certified by peers before entering a stream of knowledge that may eventually reach the public - and shape society; therefore, Frontiers only applies the most rigorous and unbiased reviews. Frontiers revolutionizes research publishing by freely delivering the most outstanding research, evaluated with no bias from both the academic and social point of view. By applying the most advanced information technologies, Frontiers is catapulting scholarly publishing into a new generation.

What are Frontiers Research Topics?

Frontiers Research Topics are very popular trademarks of the *Frontiers journals series*: they are collections of at least ten articles, all centered on a particular subject. With their unique mix of varied contributions from Original Research to Review Articles, Frontiers Research Topics unify the most influential researchers, the latest key findings and historical advances in a hot research area.

Find out more on how to host your own Frontiers Research Topic or contribute to one as an author by contacting the Frontiers editorial office: frontiersin.org/about/contact

Reviews in public health expenditure and performance

Topic editor
Hai Fang — Peking University, China

Citation
Fang, H., ed. (2025). *Reviews in public health expenditure and performance*. Lausanne: Frontiers Media SA. doi: 10.3389/978-2-8325-6234-5

Table of contents

frontiers | Frontiers in Public Health

TYPE Original Research
PUBLISHED 04 January 2024
DOI 10.3389/fpubh.2023.1192991

Check for updates

OPEN ACCESS

EDITED BY
Isaac Odeyemi,
Manchester Metropolitan University,
United Kingdom

REVIEWED BY
Ewunetie Mekashaw Bayked,
Wollo University, Ethiopia
Abdene Weya Kaso,
Arsi University, Ethiopia

*CORRESPONDENCE
Edosa Tesfaye Geta
✉ edotesfa@yahoo.com

RECEIVED 15 May 2023
ACCEPTED 12 December 2023
PUBLISHED 04 January 2024

CITATION
Geta ET, Lushe KA, Desisa AE, Terefa DR, Cheme MC, Shama AT and Lema M (2024) Determinants of community-based health insurance membership renewal decision among rural households in Kellem Wollega zone, Oromia regional state, Ethiopia: a community-based cross-sectional study. *Front. Public Health* 11:1192991. doi: 10.3389/fpubh.2023.1192991

Determinants of community-based health insurance membership renewal decision among rural households in Kellem Wollega zone, Oromia regional state, Ethiopia: a community-based cross-sectional study

Edosa Tesfaye Geta[1,2]*, Kifile Abdisa Lushe[1], Adisu Ewunetu Desisa[2], Dufera Rikitu Terefa[2], Melese Chego Cheme[2], Adisu Tafari Shama[2] and Matiyos Lema[2]

[1]Kellem Wollega Zonal Health Department, Dembi Dollo, Ethiopia, [2]Department of Public Health, Institute of Health Science, Wollega University, Nekemte, Ethiopia

Background: Despite the fact that community-based health insurance (CBHI) is a promising program to achieve the goal of universal health coverage (UHC), it faces challenges that are not only due to low enrollment but also due to membership renewal decision that impact its sustainability. Hence, the study aimed to identify the determinants of CBHI membership renewal decision among rural households in Kellem Wollega zone, Ethiopia.

Methods: The study was conducted in Kellem Wollega, Ethiopia, among rural households from March 30–April 30, 2022, using a community-based cross-sectional study design. An interviewer-administered structured questionnaire through face-to-face interviews was used. Using a systematic random sampling method, 551 households were selected making 540 (98%) response rates. The data was entered into EPI Data 3.1 and analyzed using SPSS 25 software. Descriptive statistics, binary, and multiple logistic regressions were performed. Using multiple logistic regressions, a significant association between the CBHI membership renewal decision and independent variables was identified, declaring the statistical significance level using a 95% confidence interval (CI) at $p < 0.05$.

Results: The overall rate of CBHI membership renewal decision among households was estimated to be 365 (67.6%, 95% CI = 63.7–71.5%). The factors that significantly influenced the households' membership renewal decision were family size (AOR = 0.46, 95% CI = 0.25–0.86), low literacy status (AOR = 0.28 95% CI = 0.12–0.64), lower than middle-level of wealth index (AOR = 9.80, 95% CI = 2.75–34.92), premium affordability (AOR = 4.34, 95% CI = 2.08–9.04), unavailability of services (AOR = 0.26, 95% CI = 0.12–0.55), trusting in health facilities (AOR = 5.81, 95% CI = 2.82–11.94), favorable providers' attitude toward members (AOR = 8.23, 95% CI = 3.96–19.64), good quality of service (AOR = 4.47, 95% CI = 2.28–8.85) and health care seeking behavior (AOR =3.25, 95% CI = 1.32–7.98).

Conclusion: The overall CBHI membership dropout decision rate among rural households was high, which could affect health service provision and utilization. Therefore, the insurance scheme and contracted health facilities should consider and work on family size and wealth status when membership premiums are calculated, the education level of households when creating awareness about the scheme, building trust in the contracted health facilities by providing all promised benefit packages of health services with good quality, and improving the attitude of health care providers towards the scheme members.

KEYWORDS

CBHI scheme, membership renewal decision, rural households, Kellem Wollega, Ethiopia

Introduction

Prompt access to health services that include prevention, treatment, rehabilitation, and promotion is essential with the exception of just a small portion of the population; this is not attainable in many countries without a successful system of health financing that determines if an individual can pay to utilize healthcare when necessary. The World Health Organization (WHO) provides recommendations for how countries could modify their financial systems to accelerate the process of moving to UHC while sustaining the progress that has been made so far (1).

Globally, countries have put UHC at the forefront of their health policies and plans while some of them have attained it, the majorities are still working towards UHC, and progress varies across countries (2, 3). Evidence shows that most low-income-countries (LMICs) have not been able to achieve the goals of UHC because of issues with weak public health care systems, building resilient health systems, financing health care and reducing financial risk, epidemiological and demographic issues, governance, and leadership (4).

How to pay for health services is a basic issue that must be addressed. Searching for a way to raise adequate resources is noticeably vital. Even though the major dependence of financial sources for the health system is on public funding, it is vital to guarantee access to healthcare while, at the same time, protecting families from catastrophic medical bills (5).

Consequently, it has been proven that health insurance enables people to feel more financially protected by reducing households' out-of-pocket medical expenses, catastrophic medical expenses, overall medical expenses, and poverty. Additionally, it protects household savings, assets, and consumption habits in a favorable manner (6).

A recently developed concept called CBHI promises to provide low-income rural households better access to high-quality healthcare and financial protection against the cost of illnesses. Many developing countries presently provide CBHI to their rural populations, and research on the program's effects on the well-being of the underprivileged in these areas is still ongoing (7).

A CBHI model can only partially assist countries in moving to UHC when it solely relies on small-scale, voluntary programs and small pools with little to no subsidies for the poor and vulnerable populations. This is despite the fact that CBHI is one method of organizing community initiatives (8).

Countries are working on CBHI, where risks are pooled and shared, to improve access to quality care, overcome catastrophic out-of-pocket expenses, and strengthen healthcare finance. To reach this, households could be convinced, enrolled in the insurance, and also renewed the membership, since a crucial aspect of achieving UHC is expanding a financial hazard pooling system that provides cross-subsidization in the health scheme, which is health insurance (9).

The government of Ethiopia introduced the CBHI scheme in 2011 in 13 districts of the four regions with large populations, namely Oromia, Amhara, SNNP, and Tigray, as a pilot project. After evaluating the feasibility and accomplishments of the program in the pilot districts, the government expanded its implementation to other districts. Currently, about 512 districts have implemented it; the aim is to enable the poor to get quality health services regardless of their economic status (10).

The decision to drop the membership also hinders risk pooling and resource mobilization for effective plan management and creates long-term sustainability issues. Only 2 million, or 0.2%, of Africa's 900 million potential members are enrolled. In sub-Saharan African (SSA) countries, with the exception of Ghana and Rwanda, the membership ratio is below 10% (9–11). In Guinea-Conakry, the initial enrollment rate of CBHI in 1998 was 8%, but this enrollment rate declined to 6% a year later and the main reasons for non-enrollment and dropout were scheme affordability, poor quality of care, and inability to pay the premium (5). Low enrollment, or the decision to drop out, and the presence of too few people in the scheme are endangering the sustainable progress of this reform in many countries, including SSA (12).

The development of the CBHI program faces a great challenge that is not only due to low enrollment but also due to high membership dropout decision rate, which causes the scheme to be unsustainable by decreasing its coverage directly (13, 14). A study conducted in Ethiopia documented that enrollment a year after initiation increased only from 41 to 48%. On the other hand, 18% of those who joined the program in its first year did not renew their membership the year after (14).

There are different factors that influence the households' decision to renew their CBHI scheme either positively or negatively that can be categorized into: socio-demographic and economic related factors, quality of health-related factors, CBHI scheme related factors,

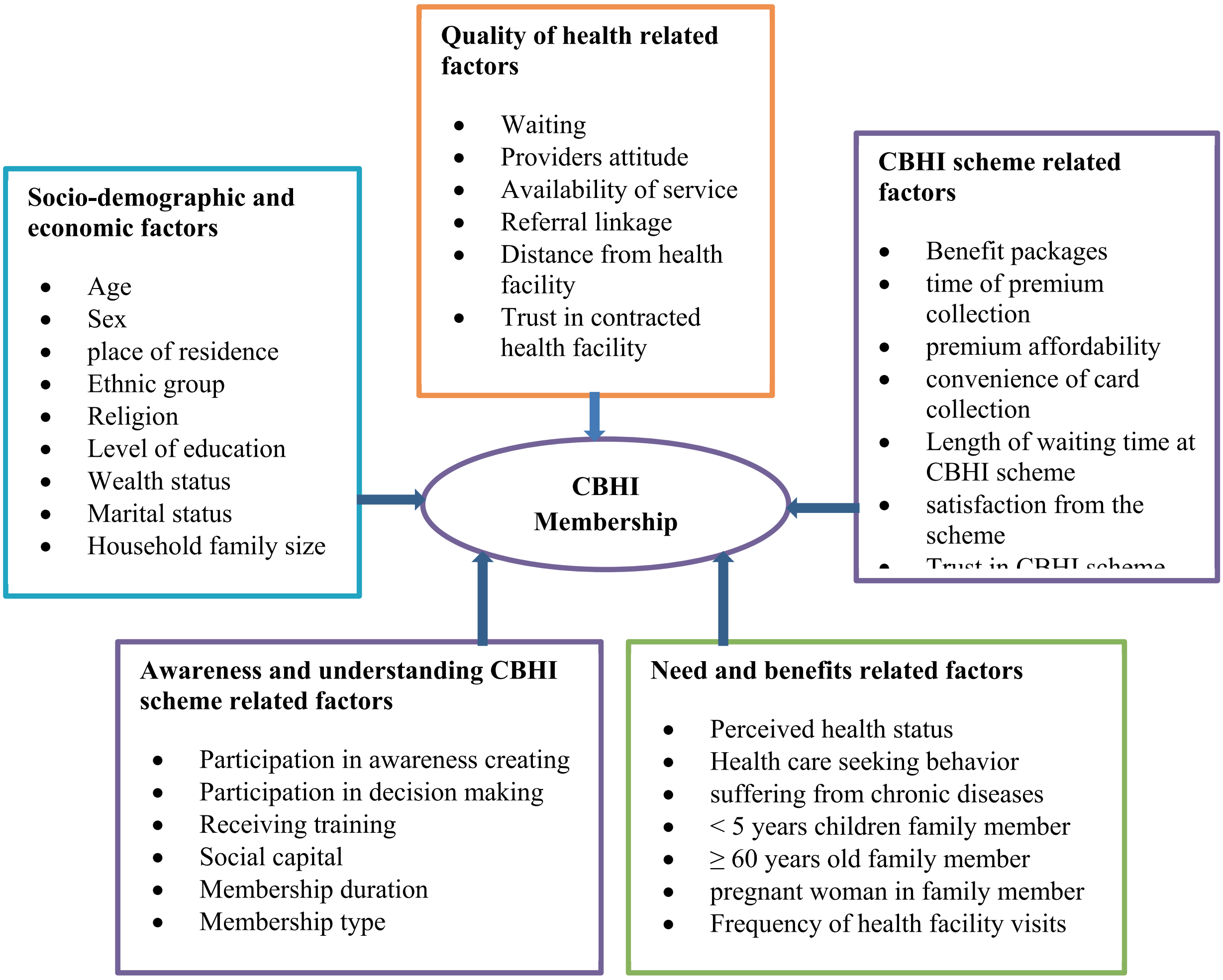


FIGURE 1
A conceptual framework of determinants of CBHI scheme membership renewal decision.

awareness and understanding of CBHI scheme related factors, and need and benefit related factors (Figure 1) (15).

In the Kellem Wollega Zone, the CBHI scheme was first implemented in 2011. During the study period, on average, the amount of the premium per household was 450 Ethiopian Birr (ETB) that was 8.67 US dollars. The coverage of CBHI membership was not improved, even though there have been more participants each year in the zone compared to the national average. Reports from the zonal health department showed that the enrolled members were not renewing their memberships on an annual basis in rural areas of the zone (16). Although initial enrollment is important, scheme sustainability clearly requires the decision of members on membership renewal. Hence, the study aimed to identify the determinants of community-based membership renewal decision among rural households in Kellem Wollega Zone, Oromia Regional State, Ethiopia.

Methods and materials

Study setting and design

The study was conducted in Kellem Wallaga, Oromia regional state, Ethiopia, among insured rural households from March 30, 2022, to April 30, 2022, using a community-based cross-sectional study design. The zone was one of the 20 zones of the Oromia regional state, which was established in 2007, and it had 12 districts, one of which was urban and the others rural. Dembi Dollo is the capital of the zone, which is located about 652 km west of Addis Ababa, the capital of the country.

The zonal health department's reports of 2019/2020 showed that six districts were implementing the CBHI scheme, and all of these districts have begun offering health services as part of this program. Seyo and Gidami districts began offering services in 2016, while the four remaining districts namely Dalle Sadi, Dale Wabera, Hawa Galan and Lalo Kile began doing so in 2020. They launched the CBHI in different year; 53.5% of the zone's population were enrolled in the CBHI. The two pilot districts were selected for this study because the remaining four districts have not yet started the CBHI membership renewal process.

The total population of the Gidami was estimated to be 112,190 and from a total of 7,010 households, only 3,225 (46%) were enrolled in the CBHI program. The community had five government health centers and 22 health posts that provide health services for the community. The total population of the Seyo district was 76,207, and from a total of 4,760 households, only 2,428 (51%) were enrolled in the CBHI program. The district had 6 government health centers and

24 health posts that provide health services for the community, according to the 2019/2020 zonal health department report (16).

Population and eligibility criteria

All households who were ever enrolled in the CBHI scheme in rural districts of Kellem Wollega Zone were considered as the source population. All households that were registered to the CBHI scheme and found in selected villages of the zone were considered as the study population, whereas the household head who ever enrolled in the CBHI scheme was considered as the study unit.

All households enrolled in the CBHI scheme in selected kebeles of the Kellem Wollega zone were included in the study, whereas all households who were members of the scheme but came from other areas, whose residence was less than 1 year, and those whose enrollment duration less than 1 year were excluded from the study.

Sample size determination and sampling techniques

Sample size was calculated by using the single population proportion formula, assuming 68.1% of the households made the decision to renew their CBHI membership (17), 95% CI, and a 0.05 margin of error. Since two-stage sampling was used, the 1.5 design effect was considered, $n = \frac{(Z\alpha/2)^2 p(1-p)}{d^2}$, where, n = calculated sample size, z = 95% CI, d = margin of error at 0.05, and p = proportion of households' membership renewal decision = 68.1%.

So, $n = (1.96)^2 \times 0.681(1-0.681)/(0.05)^2 = 334$, multiplying by 1.5 design effect and adding 10% non-response rate, the final sample size determined was 551.

Since the zone consisted of 12 districts and 256 rural kebeles, and six districts were implementing the CBHI scheme while the other four districts started to implement the scheme in 2020, presumably two districts that started implementing the CBHI scheme before 5 years ago when the study was conducted were selected. Then the required sample size was proportionally allocated to both districts, and by the simple random sampling method, kebeles (villages) were selected from both districts, and 30% of the total kebeles were selected from both districts. Accordingly, 6 kebeles out of 22 kebeles from Gidami district and 7 kebeles out of 24 kebeles from Seyo district were selected (Figure 2).

The lists of households having households or spouses with informal work were obtained from the district administration office (village register), and after getting the lists of households from each selected kebele, samples were selected by systematic random sampling to get the data required. Finally, the study participants were selected using systematic random sampling methods from the CBHI insurance scheme registration book list at every k^{th} household in the frame from each kebele until the sample size of that kebele reached the value shown in this formula: k = N/n. Accordingly, N = study households (5653), and n = calculated sample size (551); then k = 5653/551 = 7, every 7^{th} household was selected from each kebele. The lottery method was used to select the first households from 1 to 7 serial numbers.

Study variables

Community-based health insurance scheme membership renewal decision was considered as a dependent variable, whereas socio economic and demographic factors (age, sex, occupation, gender, religion, educational status, marital status, household size, wealth index, presence of under five children in households, and presence of the older adult in households), health and health services related factors (accessibility of health facility, availability of health service, utilization of health service, perceived quality of service, chronic disease, and recent illness episode), CBHI-related factors (benefit package, scheme experience, premium collection convenience time, duration of CBHI enrolment, affordability of premium collection, premium collection convenience time and duration of CBHI) (Figure 1).

Operational definitions

Membership renewal decision

Households who had CBHI scheme for more than 1 year and who were still enrolled in the time of the survey, and households that were enrolled in the 1st year of operation, dropped in the 2nd year of operation, and enrolled again in 3rd year of operation were considered as "*1 = Renewed*, otherwise *0 = Dropped*."

Understanding CBHI scheme

The participants were interviewed on 10 items (those who fall sick should consider membership in CBHI, only the very poor who cannot afford to pay can need to join the CBHI, under CBHI, you pay money in order for CBHI to finance your future health care, CBHI programs are like saving schemes; you will receive interest and get your money back, if you do not make claims through CBHI, your premium will be returned, all health care costs are covered by the CBHI program; Cronbach's Alpha (α) = 0.71). The respondents rated each item using a 3-points Likert's scale (correct, not correct, I do not know), and finally the overall mean score was calculated, with ≥ mean score categorized as *1 = high level of understanding*, < mean score classified as *2 = low level of understanding*.

Trust in CBHI scheme

The participants were interviewed on five items (community is involved in the management of local CBHI scheme, premium contributed by member used for CBHI purpose only, CBHI scheme is providing reimbursement service, the local CBHI management is trust worth, the CBHI scheme distribute ID card as early as members enrolled/return as early as they send for renewal; α = 0.91) using a 5-points Likert's scale (1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree) and finally the overall mean score was calculated and ≥ mean score categorized as; *1 = Good trust*, <mean score classified as, *2 = Poor trust*.

Trust in contracted health facilities

The participants were interviewed on 10 items (health facility provides all services expected to be given at its level, HF always has sufficient health professionals, HF has improved referral system, physical facility is visually clean, attractive and comfortable, health facility staff has sufficient competence to treat patients, HF staff is

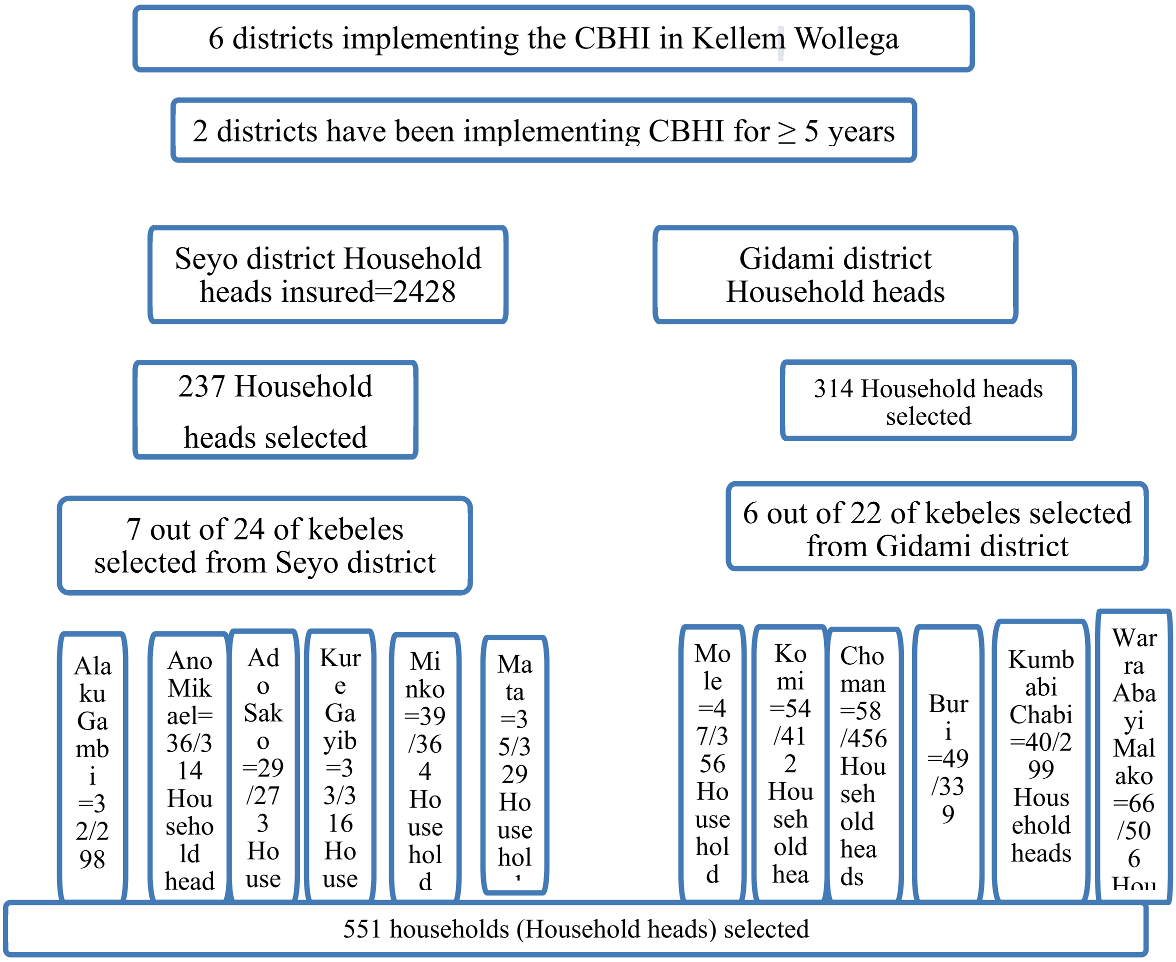


FIGURE 2
Schematic presentation of sampling procedure.

committed in providing services, HF provides service timely, HF is concerned for the need of CBHI members, and HF reliable in handling patient problems; α = 0.93) using a 5-points Likert's scale (1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree), and finally the overall mean score was calculated and ≥ mean score categorized as ***1 = good trust***, < mean score classified as ***2 = poor trust***.

Provider's Attitude towards CBHI member

The participant households were interviewed on 10 items (CBHI has a potential on promoting health care seeking behavior from modern health care institutions, CBHI protects house hold from unaffordable health care expenditure, premium payment for CBHI scheme is expensive, CBHI is a means of collecting revenue(profit)to the government, CBHI scheme members receive low quality of services than non-members, mistreatments of patients by the professional is common for members than non-members, I did not have trust in management and administration of CBHI scheme, CBHI is relevant only to promote health condition of the poor, health insurance is good to pool the risk of health expenditure within sick health, and CBHI should be advocate and scaled up to improve health condition of rural community; α = 0.74) using a 5-points Likert's scale (1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree), and finally the overall mean score was calculated and ≥ mean score categorized as, 1 = favorable < mean score classified as, 2 = unfavorable.

Community-based health insurance scheme experience

The participants were interviewed on 6 items (the local CBHI agent tries hard to solve CBHI implementation problems; CBHI members have the right to guide and supervise the activities of CBHI management activities; the CBHI benefits package meets the requirements of my households; I am satisfied with the experience of the local CBHI office when I go to register; I am satisfied with the local CBHI office when I go to pay regular contributions; and members of CBHI are treated the same as non-members; α =0.91) using a 5-points Likert's scale (1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree), and finally, the overall mean score was calculated and ≥ mean score categorized as, 1 = good experience, < mean score classified as, 2 = poor experience.

Quality of health services at contracted health facilities

The households were interviewed on four items (availability of adequate drugs, availability diagnostic/laboratory services, improvement in waiting time to get services, and improvement in referral system; α = 0.82) using a 5-points Likert's scale (1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree), and finally the overall mean score was calculated and ≥ mean score categorized as 1 = good quality, < mean score classified as, 2 = poor quality.

Affordability of the premium

The participant households were interviewed on four items (time interval of premium payment is convenient for my household, the CBHI registration fee is easily affordable, the CBHI regular contribution is easily affordable, and received promised benefit package during membership; α = 0.801)using a 5-points Likert's scale (1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree), and finally the overall mean score was calculated and ≥ mean score categorized as: 1 = affordable, < mean score classified as: 2 = unaffordable.

Household wealth index

Households' asset data was collected based on the kinds of assets they owned. Then factor scores were derived using principal component analysis (PCA), and based on the composite scores of the wealth index, the households were categorized in to five equal groups (quintiles) based on their rank wealth status. Accordingly, *1 = Extremely poo*r: the 1st quintile(0–20% of the range), *2 = Poo*r: the 2nd quintile (20–40% of the range), *3 = Middle leve*l: the 3rd quintile (40–60% of the range), *4 = Rich:* the 4th quintile(60–80% of the range), and *5 = Very ric*h: the 5th quintile (80–100% of the range).

Data collection tool and procedure

An interviewer-administered structured questionnaire that was adapted from related articles (12–14, 17) to collect relevant information. The questionnaire had five parts: socio-economic and demographic characteristics; CBHI information; individual or household-related factors; CBHI-related factors; and health service use-related factors.

Data was collected by six BSc-trained health professionals using the pre-tested structured questionnaire through face-to-face interviews. Two supervisors who were qualified with a master's degree in public health were recruited. The data collectors and supervisors were trained for 1 day on the objectives of the study, the data collection tool, approach to the interviews, details of interviewing techniques, respect, and maintaining the privacy and confidentiality of the respondents.

Data processing and analysis

After the data collection from each selected household, the data was entered into EPI data version 3.1 and analyzed using SPSS 25 software. Hosmer-Lemeshow goodness-of-fit was used to check the fitness of a multi-variable logistic regression model that had been eventually fitted, the *p*-value was found to be 0.712. Descriptive statistics, including frequencies, cross-tabulation, averages, and percentages, were performed. Binary and multiple logistic regressions were used to identify a significant association between the CBHI membership renewal decision and independent variables. Using multiple logistic regressions, a significant association between the CBHI membership renewal decision and independent variables was identified, with the statistical significance level using 95% CI at $p < 0.05$.

Data quality management

The internal consistency of items for independent variables measured in Likert's scale was checked by Cronbach's alpha. The questionnaire was prepared in English and translated from English to Afan Oromo. Before the actual data collection, pre-testing was done by the data collectors on 28 individuals (5% of the sample size) in Dalle Sadi district, Kellem Wollega Zone, and appropriate modifications were made after analyzing the pre-test results. To ensure data quality, the principal investigators provided training all data collectors and supervisors. All collected data were checked for completeness and consistency by the supervisors every day, and onsite close supervision and technical support were given by supervisors and the principal investigators. During the data collection period, when the household head was unavailable, the data collectors asked the house member who could respond to the interview or when he/she would be available and returned to home in the next day for interview.

Ethical considerations

Ethical clearance (*Ref: WU/RD/526/2014*) was obtained from the Research Ethics Review Committee (*RERC*) at Wollega University. A formal letter that explained the objectives, significance, and expected outcomes of the study was written to Kellem Wollega zonal health department from the Wollega University, Institute of Health Sciences and requested cooperation. Based on a supportive letter from Wollega University, Kellem Wollega zonal health department issued a support letter to the districts Health Office.

All study participants were well informed about the purpose of the study, and informed written consent was secured from the study participants prior to the interview. The study participants' confidentiality was maintained, and no personal identifiers were used in the data collection tools; instead, codes were used in their place. All paper-based and computer-based data were kept in protected and safe locations. The recorded data were not accessed by a third party except the research team, and data sharing will be enacted based on the ethical and legal rules of data sharing.

Results

Socio-demographic and economic characteristics of the households

A total of 540 participants responded to the interview, making the response rate 98%. The mean age of the respondents was 45.14 ± 10.84 years. Majority of the respondents, 494 (91.5%), were males, and 506 (93.7%) of the respondents were married. One third, 174 (32.2%) of the participants were unable to read and write. More than three-fourths, 472 (87.5%) of the study participants were farmers. About 250 (46.3%) of the households had fewer than five members in their household.The wealth status of the households was ranked. As a result, 108 (20%), 107 (19.8%), 109 (20.2%), 111 (20.6%), and 105

TABLE 1 Socio-demographic and economic characteristics of the households in Kellem Wollega Zone, Oromia regional state, Ethiopia 2022.

Variables n = 540	Response category	Frequency (%)	CBHI membership renewal decision	
			Renewed (%)	Dropped (%)
Sex of Households	Male	494 (91.5)	334 (61.9)	160 (29.6)
	Female	46 (8.5)	31 (5.7)	15 (2.8)
Age	18–30	55 (10.2)	33 (6.1)	22 (4.1)
	31–40	147 (27.2)	103 (19.1)	44 (8.1)
	41–50	151 (28)	95 (17.6)	56 (10.4)
	50+	187 (34.6)	134 (24.8)	53 (9.8)
Religion	Protestant	314 (58.1)	210 (38.9)	104 (19.3)
	Orthodox	99 (18.3)	59 (10.9)	40 (7.4)
	Muslim	127 (23.5)	96 (17.8)	31 (5.7)
Ethnic group	Oromo	517 (95.7)	349 (64.6)	168 (31.1)
	Amhara	23 (4.3)	16 (3)	7 (1.3)
Marital status	Married	506 (93.7)	348 (64.4)	158 (29.3)
	Divorced	11 (2)	7 (1.3)	4 (0.7)
	Widowed	19 (3.5)	8 (1.5)	11 (2)
	Single	4 (0.8)	2 (0.4)	2 (0.4)
Family size	<5 members	250 (46.3)	153 (28.3)	97 (18)
	≥5 members	290 (53.7)	212 (39.3)	78 (14.4)
Presence of <5 years children	Yes	412 (76.3)	276 (51.1)	136 (25.2)
	No	128 (23.7)	89 (16.5)	39 (7.2)
Presence of Old age (60+)	Yes	224 (41.5)	162 (30)	62 (11.5)
	No	316 (58.5)	203 (37.6)	113 (20.9)
Presence of Pregnant woman	Yes	226 (41.9)	145 (26.9)	81 (15)
	No	314 (58.1)	220 (40.7)	94 (17.4)
Education status	Unable to read and write	174 (32.2)	94 (17.4)	80 (14.8)
	Only able to read and write	105 (19.4)	68 (12.6)	37 (6.9)
	Primary education	158 (29.3)	117 (21.7)	41 (7.6)
	Secondary education+	103 (19.1)	86 (15.9)	17 (3.1)
Occupation	Farmer	472 (87.5)	324 (60.1)	148 (27.4)
	Merchant	44 (8.1)	24 (4.4)	20 (3.7)
	Daily laborer	24 (4.4)	17 (3.1)	7 (1.3)
Wealth status	Extremely poor	108 (20)	65 (12)	43 (8)
	Poor	107 (19.8)	80 (14.8)	27 (5)
	Middle	109 (20.2)	81 (15)	28 (5.2)
	Rich	111 (20.6)	71 (13.1)	40 (7.4)
	Very rich	105 (19.4)	68 (12.6)	37 (6.8)

(19.4%) were extremely poor, poor, middle level, rich, and very rich, respectively (Table 1).

Sources of information about CBHI scheme

The participants were interviewed about the source of information they heard about CBHI for the first time before they became members. Accordingly, about 344 (63.7%) of them heard about the scheme from officials in public meetings, followed by health professionals in health facilities, which accounted for 164 (30.4%), during CBHI house-to-house awareness creation campaigns, 22 (4.1%), mass media (7.3%), and from neighbors or friends (0.6%).

Health status and health care seeking behavior

The study assessed the health status and health care seeking behavior in the last 12 months among households (Table 2). As a result, three-fourths of the participants' members, 383 (75.2%), were

TABLE 2 Health status and health care seeking behavior among households in Kellem Wollega Zone, Oromia regional state, Ethiopia 2022.

Variables $N = 540$	Response categories	Frequency (%)	CBHI membership renewal decision	
			Renewed (%)	Dropped (%)
Perceived health status	Good	402 (74.4)	280 (51.9)	122 (22.6)
	Poor	138 (25.6)	85 (17.5)	53 (9.8)
Chronic disease in family	Yes	157 (29.1)	90 (16.7)	67 (12.4)
	No	382 (70.9)	275 (50.9)	10 (20)
Ill during last 12 months	Yes	428 (79.3)	288 (53.3)	140 (25.9)
	No	112 (20.7)	77 (14.3)	35 (6.5)
Seeking health care in past 12 months	Yes	405 (75)	258 (47.8)	147 (27.2)
	No	135 (25)	107 (19.8)	28 (5.2)
Frequency of Health facility visit in past 12 months ($N = 405$)	Once	203 (50.1)	133 (32.8)	70 (17.3)
	Twice	135 (33.3)	88 (21.7)	47 (10.6)
	Three times	48 (11.9)	38 (9.4)	10 (2.5)
	Four times and above	19 (4.7)	13 (3.2)	6 (1.5)

free from chronic diseases. The participants also rated their family members' health status. Accordingly, the majority of them 402(74.4%) rated it as good, whereas only 138 (25.6%) rated it poor. About 428 (79.3%) household members have been ill during the last 12 months and 405 (75%) of them have sought medical treatment from the contracted health facilities. Out of 405 household members, half of them, 203(50.1%) visited a contracted health facilities only once, whereas only 19(4.7%) visited the facility more than four times in the last 12 months.

Community-based health insurance membership renewal decision

The decision made by households to renew their CBHI membership has also been evaluated by the study. As a result, the majority of households 365 (67.6%, 95% CI = 63.7–71.5%) decided to renew their membership and did so on an annual basis as per to CBHI scheme membership renewal schedule (Figure 3).

Among the study participants, 450 households (83.3%) were payers, and 90 (16.7%) of them were the poorest, exempted from the scheme's contributions. Almost all of them, 479 (88.7%), had CBHI identification cards. Of those who decided to renew their membership, only 19 (5%) had done so consistently over the past 5 years. Among the 175 households that decided to drop their membership, 153 (87.4%) and 22 (12.6%) of them had stayed in the scheme for one to 3 years and 4 years, respectively. About 24 (4.4%) and 125 (23.1%) of those who renewed and dropped their membership, respectively, had decided not to renew their membership in the next coming year (Table 3).

From a total of 175 (32.4%) who decided for the first time to drop their membership, more than one-third of them, 69(39.5%) made their decision after 2 years of membership, followed by 57 (32.6%), 27 (15.4%) after 1 year, 19 (10.9%) after 4 years, and 3 (1.7%) after 5 years. These households reasoned out their best single reason why they decided to drop their membership, such as the quality of health services being low 84(48%), followed by a lack of awareness about the details of how the CBHI works, 32(18.3%) (Figure 4).

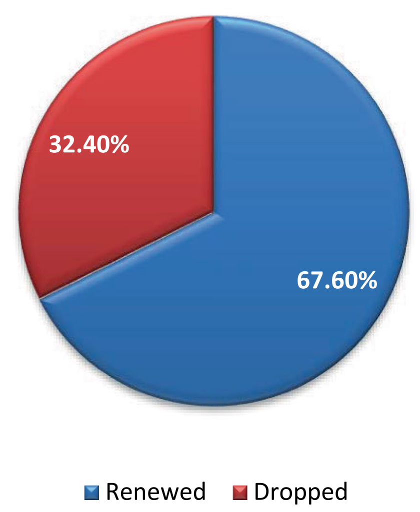


FIGURE 3
CBHI membership renewal decision among rural households in Kellem Wollega, Oromia regional state, Ethiopia, 2022.

More than half of the households 298(55.2%) well understood about CBHI, and the majority of them 222(74.5%) renewed their membership, whereas 242 (or 44.8%) did not understand the scheme well. Among them, 143(59.1%) decided to renew their membership. Among the 316 households (58.5%) who had a favorable attitude toward the CBHI scheme, 231 (73.1%) decided to renew their membership, while 224 (41.5%) had an unfavorable attitude toward the scheme, among whom 134 (59.82%) renewed their membership.

The majority, 344 (63.7%) of the households, did not trust in the CBHI scheme, and 150 (43.6%) of them did not renew their membership, but only 25 (7.9%) of the households that trusted in the CBHI scheme decided to drop their membership and dropped it. More than half, 297 (55%), of the households trusted in the contracted health facilities, and only 33 (11.1%) decided to drop their membership, whereas among those who had no trust in the facilities, 243 (49.5%), with the majority of them, 142 (58.4%),

TABLE 3 Community-based health insurance scheme status among rural households in Kellem Wollega, Oromia regional state, Ethiopia, 2022.

Variables	Response categories	CBHI membership renewal decision		Total (%)
		Renewed (%)	Dropped (%)	
Type of membership	Payer	291	159	450 (83.3)
	Indigent	74	16	90 (16.7)
Having CBHI identification card	Yes	349	130	479 (88.7)
	No	45	16	61 (11.3)
Frequency of membership renewal decision	1 time	33	21	54 (10)
	2 times	84	40	124 (23)
	3 times	156	69	225 (41.7)
	4 times	73	34	107 (19.8)
	≥5 times	19	11	30 (5.5)

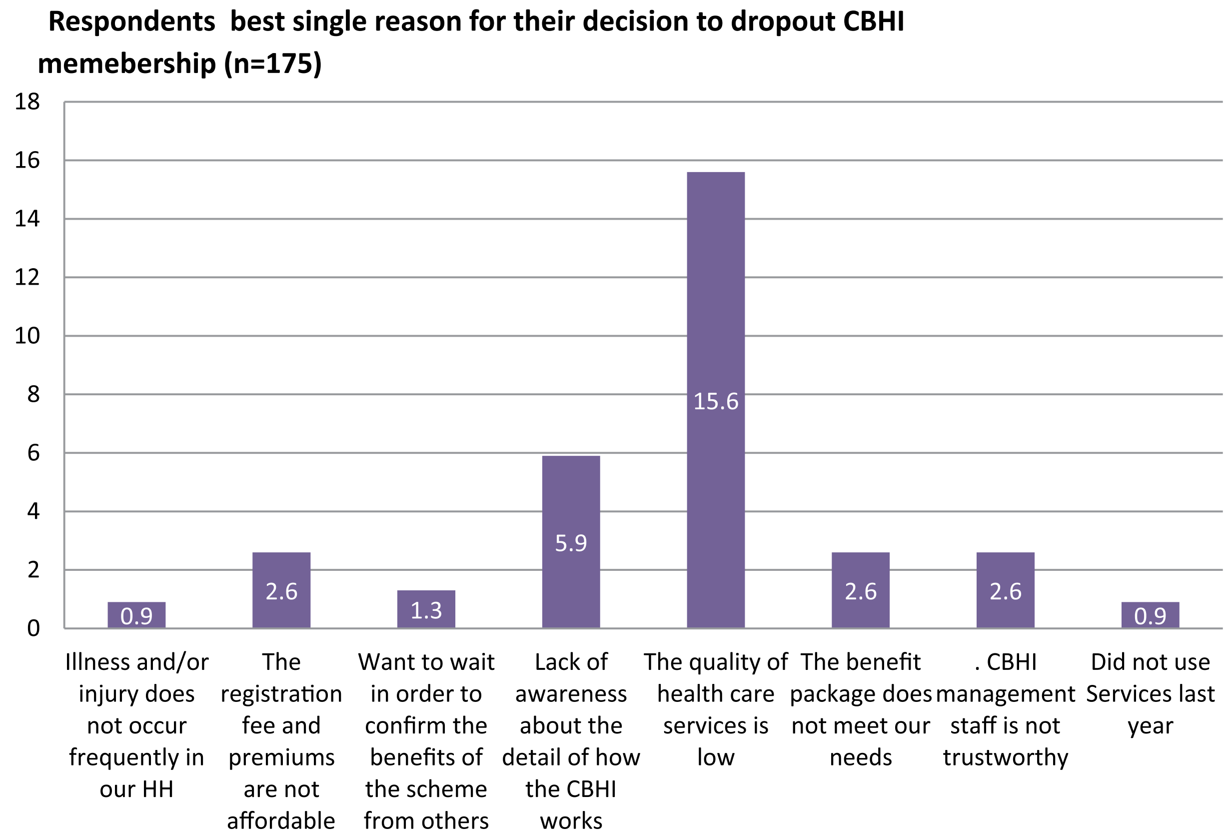


FIGURE 4
The single best reason for the decision made to drop out of the CBHI scheme membership among households in Kellem Wollega zone, Oromia region, Western Ethiopia, in 2022.

decided to drop their membership. More than half the households, 311 (57.6%) could not afford the premium, and 144 (46.3%) of them dropped their membership, whereas only 31 (13.5%) of the households for whom the premium was affordable decided to drop their membership.

About 251 (46.5%) of the households were members for more than 4 years, among whom only 63 (25.1%) decided to drop their membership, whereas 289 (53.5%) were members for 3 years, among whom 112 (30.8%) dropped their membership. More than half of the households, 304(56%) rated the quality of health services provided by contracted health facilities as good, and the majority of them 226 (74.3%) renewed their membership. The three-fourth of households, 324(60%) had the experience of leaving the contracted health facilities without getting treatments; among them, 138 (42.6%) decided to drop their membership (Table 4).

TABLE 4 Factors influencing CBHI membership renewal decision among households in Kellem Wollega zone, Oromia regional state, Ethiopia, 2022.

Variables ($N = 540$)	Response category	Frequency (%)	CBHI membership renewal decision	
			Renewed (%)	Dropped (%)
Level of understanding CBHI	High	298 (55.2)	222 (41.1)	76 (14.1)
	Low	242 (44.8)	143 (26.5)	99 (18.3)
Attitude toward CBHI	Favorable	316 (58.5)	231 (42.8)	85 (15.7)
	Unfavorable	224 (41.5)	134 (24.8)	90 (16.7)
Trust in CBHI scheme	Good	196 (36.3)	171 (31.7)	25 (4.6)
	Poor	344 (63.7)	194 (35.9)	150 (27.8)
Trust in contracted health facilities	Good	297 (55)	264 (48.9)	33 (6.1)
	Poor	243 (45)	101 (18.5)	142 (26.3)
Premium affordability	Affordable	229 (42.2)	198 (36.7)	31 (5.7)
	Unaffordable	311 (57.6)	167 (30.9)	144 (26.7)
Benefit package as expected received	As expected,	407 (75.4)	292 (54.1)	115 (21.3)
	Below expected	133 (24.6)	73 (13.5)	60 (11.1)
CBHI Scheme experience	Good	293 (54.3)	248 (45.9)	45 (8.3)
	Poor	247 (45.7)	117 (21.7)	130 (24.1)
Length of CBHI enrollment	1–3 years	289 (53.5)	117 (32.8)	112 (20.7)
	≥4 years	251 (46.5)	188 (34.8)	63 (11.7)
Perceived quality of health service	Good	304 (56.3)	226 (41.9)	78 (14.4)
	Poor	236 (43.7)	139 (25.7)	97 (18)
Providers' attitude toward CBHI members	Favorable	239 (44.3)	213 (39.4)	26 (4.8)
	Unfavorable	301 (55.7)	152 (28.1)	149 (27.6)
Distance of health facilities in minutes	≤ 30 min	169 (31.3)	113 (20.9)	56 (10.4)
	30–60 min	318 (58.9)	224 (41.5)	94 (17.4)
	≥60 min	53 (9.8)	28 (5.2)	25 (4.6)
Leaving health facilities without getting service	Yes	216 (40)	179 (33.1)	37 (6.9)
	No	324 (60)	186 (34.4)	138 (25.6)

Determinants of CBHI membership renewal decision

In this study, the factors affecting the decision-making process for membership renewal were identified (Table 5). Accordingly, households with fewer than five members were 54% less likely to renew their membership (AOR = 0.46, 95% CI = 0.25–0.86). The education level of households also had a significant influence on decision-making on renewal of membership; as a result, the households whose education level was only being able to read and write were 72% less likely to renew their membership compared to those who attended secondary school or above (AOR = 0.28, 95% CI = 0.12–0.64). On the other hand, households with a lower than middle level of wealth index had a higher likelihood than wealthy households of deciding to renew their membership. As a result, the extremely poor (AOR = 1.71, 95% CI =2.37–12.35), poor (AOR = 5.44, 95% CI = 1.9–32.53), and middle-level (AOR = 9.80, 95% CI = 2.75–34.92) households were more likely to renew their membership compared to the very rich households.

Those households who perceived the annual premium as affordable compared with the expected and promised benefits from the CBHI scheme were four times more likely to decide to renew their membership compared to those who perceived the premium as unaffordable (AOR = 4.34, 95% CI = 2.08–9.04). The households that experienced leaving the contracted health facilities without getting treatments because of the unavailability of diagnosis services and drugs in the facilities in the last 12 months were 74% less likely to renew their membership compared to their counterparts (AOR = 0.26, 95% CI = 0.12–0.55).

The trust among households in contracted health facilities was another significant factor. As a result, those households that trusted in the health facilities were almost six times more likely to renew their membership compared to those that had no trust in the facilities (AOR = 5.81, 95% =2.82–11.94). The households were asked their perceptions of the attitude of health care providers toward the scheme members during health care seeking and health service provision. Accordingly, those households that perceived the health care providers as having a favorable attitude toward the scheme members were eight times more likely to renew their membership, compared to their counterparts (AOR = 8.23, 95% CI = 3.96–19.64).

In addition, those households that perceived the quality of health services provided by the contracted health facilities as good were almost five times more likely to renew their membership compared to those who perceived the quality of health care was poor (AOR = 4.47,

TABLE 5 Determinants of CBHI membership renewal decision among households in Kellem Wollega zone, Oromia regional state, Ethiopia, 2022.

Variables	Response category	Membership renewal decision		Odds ratio, 95% CI	
		Renewed (%)	Dropped (%)	COR	AOR
Sex of households	Male	334 (61.9)	160 (29.6)	1.01 (0.53–1.92)	1.53 (0.51–4.65)
	Female	31(5.7)	15(2.8)	Ref.	Ref.
Family size	<5	153(28.3)	97(18)	0.58 (0.40–0.84)	0.46 (0.25–0.86)*
	≥5	212 (39.3)	78 (14.4)	Ref.	Ref
Old age in family members	Yes	162 (30)	62 (11.5)	1.45 (1.00–2.11)	1.32 (0.69–2.54)
	No	203 (37.6)	113 (20.9)	Ref.	Ref
Under 5 in family members	Yes	276 (51.1)	136 (25.2)	0.89 (0.58–1.37)	0.63(0.29–1.28)
	No	89 (16.5)	39 (7.2)	Ref.	Ref
Education status of households	Unable to read and write	94 (17.4)	80(14.8)	0.23(0.13–0.42)	0.09(0.03–0.25)*
	Only able to read and write	68 (12.6)	37 (6.9)	0.36 (0.19–0.70)	0.28 (0.12–0.64)**
	Primary education	117 (21.7)	41 (7.6)	0.56 (0.30–1.06)	0.40 (0.12–1.27)
	Secondary +	86 (15.9)	17 (3.1)	Ref.	Ref
Wealth status	Extremely poor	65 (12)	43 (8)	0.82 (0.47–1.43)	1.71 (2.37–12.35)**
	Poor	80 (14.8)	27 (5)	1.61 (0.89–2.92)	5.44 (1.9–32.53)*
	Middle	81 (15)	28 (5.2)	1.57 (0.88–2.83)	9.80 (2.75–34.92)**
	Rich	71 (13.1)	40 (7.4)	0.97 (0.55–1.69)	2.35 (0.88–7.05)
	Very rich	68 (12.6)	37 (6.8)	Ref.	Ref.
Understanding CBHI level	High	222 (41.1)	76 (14.1)	2.02 (1.40–2.91)	1.52(0.76–3.04)
	Low	143 (26.5)	99 (18.3)	Ref.	Ref
Attitude to CBHI scheme	Favorable	231 (42.8)	85 (15.7)	1.83 (1.28–2.63)	1.57(0.79–3.09)
	Unfavorable	134 (24.8)	90 (16.7)	Ref.	Ref
Trust in CBHI scheme	Good	171 (31.7)	25 (4.6)	5.29 (3.30–8.47)	1.94 (0.61–6.18)
	Poor	194 (35.9)	150 (27.8)	Ref.	Ref
Premium affordability	Affordable	198 (36.7)	31 (5.7)	5.51 (3.55–8.55)	4.34 (2.08–9.04)***
	Unaffordable	167 (30.9)	144 (26.7)	Ref.	Ref
CBHI Scheme experience	Good	248 (45.9)	45 (8.3)	6.12 (4.09–9.17)	1.75 (0.74–4.15)
	Poor	117 (21.7)	130 (24.1)	Ref.	Ref.
Chronic disease in family	Yes	90(16.7)	67(12.4)	1.90 (1.29–2.79)	0.91 (0.44–1.89)
	No	275(50.9)	10(20)	Ref.	Ref.
Leaving HFs without treatment	Yes	179 (33.1)	37 (6.9)	0.28(0.18–0.42)	0.26(0.12–0.55)***
	No	186 (34.4)	138 (25.6)	Ref.	Ref.
Trust in contracted HFs	Good	264 (48.9)	33 (6.1)	11.25(7.22–17.51)	5.81(2.82–11.94)***
	Poor	101 (18.5)	142 (26.3)	Ref.	Ref.
Providers' attitude toward members	Favorable	213 (39.4)	26 (4.8)	8.03 (5.04–12.79)	8.23 (3.96–19.64)***
	Unfavorable	152 (28.1)	149(27.6)	Ref.	Ref.
Perceived quality of health service	Good	226 (41.9)	78 (14.4)	2.02 (1.40–2.91)	4.47 (2.28–8.85) ***
	Poor	139 (25.7)	97 (18)	Ref.	Ref.
Traveling time to HF	≤ 30 min	226 (41.9)	109 (20.2)	0.99 (0.95–1.02)	0.41 (0.23–1.83)
	˃30 min	139 (25.7)	66 (12.2)	Ref.	Ref.
Perceived family health status	Good	280 (51.9)	122 (22.6)	1.43 (0.96–2.14)	2.29 (0.99–5.23)
	Poor	85 (17.5)	53 (9.8)	Ref.	Ref.
Seeking health care in past 12 months	Yes	258 (47.8)	147 (27.2)	2.18 (1.37–3.46)	3.25 (1.32–7.98)**
	No	107 (19.8)	28 (5.2)	Ref.	Ref.
Length of CBHI enrolment	1–3 years	117 (32.8)	112 (20.7)	1.90 (1.30–2.74)	2.72 (1.45–5.11)
	≥4 years	188 (34.8)	63 (11.7)	Ref.	Ref.

*p-value < 0.05; **p-value < 0.01; ***p-value < 0.001; Ref, reference; CI, Confidence interval; HF, Health Facility; COR, Crude odds ratio; AOR, Adjusted odds ratio.

95% CI = 2.28–8.85). Those households whose family members sought health care from the contracted health facilities in the past 12 months were three times more likely to decide to renew their membership compared to those households that did not (AOR = 3.25, 95% CI = 1.32–7.98).

Discussion

Countries all around the world are aiming to increase the number of people who may join the CBHI program and to keep these people enrolled in it. Yet, the majority of LMICs still have considerable difficulties in retaining membership (18). The Ethiopian CBHI scheme is also facing similar problems, like households' decision to drop their membership. Hence, the study aimed to identify determinants of CBHI scheme membership renewal decision among rural households.

As a result, two-third of the scheme members renewed their membership and decided to continue being members. The results were consistent with those of studies conducted in Ethiopia; Jimma Zone (68.1%) (17) and Dera District (62.8%) (19). However, it was greater than study results from Burkina Faso (45.7%) (20), and lower than the CBHI membership renewal rate in the Gedeo Zone, Southern Ethiopia, which was 82.68% (21), in Ethiopia, 82% of those households who enrolled in the first year renewed their subscriptions during the pilot CBHI scheme and Vietnam (78.9%) (22). This findings discrepancy could have happened due to the study population's socio-demographic and economic characteristics varying during the study period. In addition, the benefit packages provided by the contracted health institutions may vary from country to country in type, volume, and quality of the health services, membership premium load, and health seeking behaviors among the population. These points have been addressed by the current study.

The households with fewer than five family members were less likely to decide to renew their membership than their counterparts; households with fewer than five members were 54% less likely to do so. Similarly, findings from systematic review studies in LMICs (23), the West Gojjam Zone, Ethiopia (24), and Jimma, Ethiopia (17) showed that households with fewer family members had lower probabilities of renewing their CBHI memberships. This might be explained by the fact that getting health care by directly paying from OOP could be more difficult for large households. Hence, they could prefer to be members of the CBHI scheme for longer by renewing their membership.

The study also showed that the level of education significantly influenced the membership renewal decision-making among households, and the households whose education level was only able to read and write were 72% less likely to renew their membership compared with those who attended secondary school and above. This result was consistent with research from Jimma, Ethiopia (17), Sudan, and Bangladesh (25, 26), which found that insurance members with elementary or secondary education or above were more likely to decide to renew their membership than those without a formal education. Similar to this, in India, the study found that household head education affects membership renewal and that secondary education is linked to a 15%-point rise in renewal (27). Another systematic review study in LMICs found that households with higher levels of education were more likely to renew their participation in the plan than their less educated counterparts (15). One of the potential explanations might be that more educated individuals make timely renewal decision and have a better understanding of the benefit packages and operating principles of the CBHI program.

Households whose wealth status was ranked poor or middle-level were almost ten times more likely to decide to renew their membership. It was supported by the study report in Gurage Zone, Ethiopia, which revealed that those households with the highest wealth status were about two times more likely to drop their membership (28). This could be due to the fact that relatively rich households might purchase more goods and services, including health services that are included in the CBHI service package, and might seek medical care as soon as possible from private health care facilities. In contrast to this, the reports from the study conducted in Ghana (12) and Uganda (29) showed that rich households were more likely to decide to renew membership. This disparity could be due to different levels of understanding of the benefits of the CBHI scheme among members, regardless of their wealth status.

Those households who perceived the annual premium as affordable compared with the expected and promised benefits from the CBHI scheme were four times more likely to decide to renew their membership compared to those who perceived the premium as unaffordable. This finding was supported by evidence from the study conducted in Ethiopia (21), which indicated the odds of CBHI scheme membership renewal were about twelve times higher among households for whom the annual premium was affordable compared to their counterparts. The finding was consistent with the study evidence in Rwanda (30) and Ghana (22). This could be explained by the fact that if the scheme contribution was affordable to the members, households with low income or poor wealth status would be able to pay and would be more likely to retain their CBHI scheme membership.

The households that experienced leaving the contracted health facilities without treatment because of the unavailability of diagnosis services and drugs in the facility in the last 12 months were 74% less likely to renew their membership compared to their counterparts. Similarly, the study report in Ethiopia showed that the scheme members who did not get the prescribed care in contracted health facilities were less likely to renew their membership (28), and the study in Bangladesh revealed that the frequent exposure of household members to the contracted health facilities had an association with membership renewal (31). Similarly, the evidence from a meta-analysis in LMICs revealed that when the promised benefit packages are not fulfilled, the members are more likely to drop their membership (23).

The trust among households in contracted health facilities was another significant factor. As a result, those households that trusted in the contracted health facilities were almost six times more likely to renew their membership compared to those that had no trust in the facilities. It was in line with the study findings from Ethiopia (17, 32–34) and Cambodia (35), which revealed that when households trusted in contracted health facilities, they were more likely to renew their membership.

The households were asked their perceptions of the attitudes of health care providers toward the scheme members. Accordingly, those households that perceived the health care provider as having a favorable attitude toward the scheme members were eight times more likely to renew their membership. Similarly, the evidence from the study conducted in Ethiopia (17) showed that when the health care providers' attitude toward the scheme members is unfavorable, the odds of a decision to drop their membership could be significantly higher compared to those with favorable attitudes. A study in Ghana also revealed that 30% of the members decided to leave the scheme because of unfavorable providers' attitudes toward the scheme members (36). This could happen when the demanded health care is provided in a discriminatory manner between the service fee payers and the scheme members when they visit the contracted health facilities.

Those households that perceived the quality of health services provided by the contracted health facilities as good were almost five times more likely to renew their membership compared to their counterparts. This was in line with the study report in Ethiopia, which revealed households who perceived poor health care quality were 12 times more likely to decide to drop their membership (28).

Those households whose family members sought health care from the contracted health facilities in the past 12 months were three times more likely to decide to renew their membership compared to those households that did not. Similarly, the study conducted in Ethiopia showed that the households that had a history of illness and sought medical care were more likely to be enrolled in the CBHI scheme and decide to renew their membership (37), whereas the households that did not experience illness were less likely to renew their membership (28). This could be the case when household members experienced illness during their membership; they might seek and utilize health care from the contracted health facilities compared to those who did not experience illness and may decide to renew their scheme membership.

Implications of the study

The current study indicated that the membership dropout decision was substantial, which might significantly affect the population coverage rate of CBHI and challenge its sustainability. In addition, the study findings implied that households with a larger family size, lower than middle-level wealth status, and above the primary level education of the household heads, the affordability of the scheme premium to renew membership, the availability of the promised benefit packages of health services with good quality in contracted health care facilities, trusting in the contracted health care facilities, good attitude of health care provides towards the scheme members, and health care-seeking behavior when the households' members experience health problems were the significant responsible factors that positively influenced the membership renewal decision among rural households to continue their CBHI scheme membership. As a result, the study findings also assist health planners and decision-makers in developing an appropriate plan and strategy to sustain the CBHI scheme in order to achieve UHC, with a focus on how to maintain membership after enrollment taking into account the identified determinant factors.

Limitations of the study

Despite the fact that the study well addressed the determinants of CBHI scheme membership renewal decision among rural households, it could have a recall and social desirability bias because the respondents were interviewed about the events that occurred in the past 12 months. Furthermore, the current study did not address the potential adverse selection bias that might impact the decision to renew scheme membership.

Conclusion

The overall CBHI membership dropout decision rate among rural households was high, compared to other study findings that could affect the health service provision and utilization. Therefore, the insurance scheme and contracted health facilities should consider and work on family size and wealth status when membership premiums are calculated, the education level of households when creating awareness about the scheme, building trust in the contracted health facilities by providing all promised benefit packages of health services with good quality, and improving the attitude of health care providers towards the scheme members.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by Wollega University Research Ethics Review Committee (RERC). The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

EG, KL, AD, DT, MC, AS, and ML participated in developing the study concept and design of the study. EG contributed to the data analysis, interpretation, report writing, manuscript preparation, and acted as the corresponding author. KL contributed to developing the data collection tools, data collection, and data entry to statistical software. AD, DT, MC, AS, and ML contributed to the data collection tool, data collection supervision, and report writing. All authors contributed to the article and approved the submitted version.

Acknowledgments

Our special thanks go to Wollega University, Kellem Wollega zonal health department, all study participants.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

References

1. WHO (2010). Health system financing. Technical Brief series: Brief No 8. Available at: https://cdn.who.int/media/docs/default-source/health-financing/whr-2010-technical-brief-8.pdf?sfvrsn=1ef5aa64_3

2. United Nations General Assembly. *Resolution a/RES/74/2, political declaration of the high-level meeting on universal health coverage*. New York, NY: United Nations General Assembly (2019).

3. Cotlear D, Nagpal S, Smith O, Tandon A, Cortez R. *Going universal: How 24 countries are implementing universal health coverage reforms from the bottom-up*. Washington, DC: World Bank Group (2014).

4. World Health Organization. *Primary health care on the road to universal health coverage. 2019 Global monitoring report*. Geneva, Switzerland: World Health Organization (2019).

5. Bart C, Maria PW. Declining subscriptions to the Maliando mutual health organisation in Guinea-Conakry (West Africa): what is going wrong? *Soc Sci Med*. (2003) 57:1205–19. doi: 10.1016/S0277-9536(02)00495-1

6. Shifa SH, Shagufta HMA. The role of micro health insurance in providing financial risk protection in developing countries- a systematic review. *BMC Public Health*. (2016) 16:281. doi: 10.1186/s12889-016-2937-9

7. Donfouet HPP, Mahieu P-A. Community-based health insurance and social capital: a review. *Heal Econ Rev*. (2012) 2:5. doi: 10.1186/2191-1991-2-5

8. WHO (2017). Community based health insurance: how can it contribute to progress towards UHC? Policy Brief. Available at: https://www.who.int/publications/i/item/WHO-HIS-HGF-PolicyBrief-17.3

9. Wang H, Pielemeier N. Community-based health insurance: an evolutionary approach to achieving universal coverage in low-income countries. *J Life Sci*. (2012) 6:320–9.

10. Olaniran A, Smith H, Unkels R, Bar-Zeev S, van den Broek N. Who is a community health worker? – a systematic review of definitions. *Glob Health Action*. (2017) 10:1272223. doi: 10.1080/16549716.2017.1272223

11. Moyehodie YA, Fenta SM, Mulugeta SS, Agegn SB, Yismaw E, Biresaw HB, et al. Factors associated with community based health insurance healthcare service utilization of households in South Gondar zone, Amhara, Ethiopia. A community-based cross-sectional study. *Health Serv. Insights*. (2022) 15:1–12. doi: 10.1177/11786329221096065

12. Kusi A, Enemark U, Hansen KS, Asante FA. Refusal to enrol in Ghana's National Health Insurance Scheme: Is affordability the problem? *Int J Equity Health*. (2015) 14:2. doi: 10.1186/s12939-014-0130-2

13. Haile M, Ololo S, Megersa B. Willingness to join community-based health insurance among rural households of Debub Bench District, bench Maji zone, Southwest Ethiopia. *BMC Public Health*. (2014) 14:1–10. doi: 10.1186/1471-2458-14-591

14. Shigute Z, Mebratie AD, Sparrow R, Alemu G. The effect of Ethiopia's community-based health insurance scheme on revenues and quality of care. *Int J Environ Res Public Health*. 17:r8558. doi: 10.3390/ijerph17228558

15. HujSssien M, Azage M. Barriers and facilitators of community-based health insurance policy renewal in low- and middle-income countries: a systematic review. *Clinicoecon Outcomes Res*. (2021) 13:359. doi: 10.2147/CEOR.S306855

16. Kellam Wollega Zonal Health Department. *Annual report of 2021/2022 fiscal year*. Dembi Dollo: Kellam Wollega Zonal Health Department.

17. Eseta WA, Lemma TD, Geta ET. Magnitude and determinants of dropout from community-based health insurance among households in Manna District, Jimma zone, Southwest Ethiopia. *Clin Outcomes Res*. (2020) 12:747–60. doi: 10.2147/CEOR.S284702

18. Gurung GB, Panza A. Predictors of annual membership renewal to increase the sustainability of the Nepal National Health Insurance program: a cross-sectional survey. *PLOS Glob Public Health*. (2022) 2:e0000201. doi: 10.1371/journal.pgph.0000201

19. Ashagrie B, Biks GA, Belew AK. Community-based health insurance membership dropout rate and associated factors in Dera District, Northwest Ethiopia. *Risk Manag Healthc*. (2020) 13:2835–44. doi: 10.2147/RMHP.S277804

20. Dong H, De Allegri M, Gnawali D, Souares A, Sauerborn R. "Drop-out analysis of community-based health insurance membership at Nouna, Burkina Faso," BurkinFaso. *Health Policy Educ*. (2009) 92:174–9. doi: 10.1016/j.healthpol.2009.03.013

21. Kaso AW, Yohanis Y, Debela BG, Hareru HE. Community-based health insurance membership renewal rate and associated factors among households in Gedeo zone, southern Ethiopia. *J Environ Public Health*. (2022) 2022:1–11. doi: 10.1155/2022/8479834

22. Atinga RA, Abiiro GA, Kuganab-Lem RB. Factors influencing the decision to drop out of health insurance enrolment among urban slum dwellers in Ghana. *Tropical Med Int Health*. (2015) 20:312–21. doi: 10.1111/tmi.12433

23. David M, Shahed H, Atanu M, Koehlmoos TLP, John D, Panda PK. What factors affect voluntary uptake of community-based health insurance schemes in low- and middle-income countries? A systematic review and Meta-analysis. *PLoS One*. (2016) 11:1–31. doi: 10.1371/journal.pone.0160479

24. Tsega H, Getu D, Gashaw A. Determinants of community-based health insurance implementation in west Gojjam zone, Northwest Ethiopia: a community based cross sectional study design. *BMC Health Serv Res*. (2019) 19:544. doi: 10.1186/s12913-019-4363-z

25. Herberholz C. Determinants of voluntary national health insurance drop-out in eastern Sudan. *Appl Health Econ Health Policy*. (2016) 15:215–26. doi: 10.1007/s40258-016-0281-y

26. Iqbal M, Chowdhury AH, Mahmood SS, Mia MN, Hanifi SMA, Bhuiya A. Socioeconomic and programmatic determinants of renewal of membership in a voluntary micro health insurance scheme: evidence from Chakaria, Bangladesh. *Glob Health Action*. (2017) 10:1287398. doi: 10.1080/16549716.2017.1287398

27. Panda P, Chakrabort A, Raza W, Bedi AS. Renewing membership in three community-based health insurance schemes in rural India. *Health Policy Plan*. (2016) 31:1433–44. doi: 10.1093/heapol/czw090

28. Zepre K, Yassin F, Tadesse B, Tolossa O, Hailemariam D, Wondimu A, et al. Factors influencing drop-out of households from community-based health insurance membership in rural districts of Gurage zone, southern Ethiopia: community based case-control study. *Front Public Health*. (2022) 10:925309. doi: 10.3389/fpubh.2022.925309

29. Nshakira-Rukundo E, Mussa EC, Nshakira N, Gerber N, von Braun J. Determinants of enrolment and renewing of community-based health insurance in households with under-five children in rural South-Western Uganda. *Int J Health Policy Manag*. (2019) 8:593–606. doi: 10.15171/ijhpm.2019.49

30. Mukangendo M, Nzayirambaho M, Hitimana R, Yamuragiye A. Factors contributing to low adherence to community-based health insurance in rural Nyanza District, southern Rwanda. *J Environ Public Health*. (2018) 2018:1–9. doi: 10.1155/2018/2624591

31. Khan JA, Ahmed S. Impact of educational intervention on willingness-to pay for health insurance: a study of informal sector workers in urban Bangladesh. *Health Econ Rev*. (2013) 3:12. doi: 10.1186/2191-1991-3-12

32. Ololo S, Jirra C, Hailemichael Y, Girma B. Indigenous community insurance (IDDIRS) as an alternative health care financing in Jimma city Southwest Ethiopia. *Ethiop J Health Sci*. (2009) 19:53–60.

33. Namomsa G. Assessing the practices and challenges of community-based health insurance in Ethiopia: the case of Oromia national regional state district of Gimbichu. *Int J Ad Res*. (2019) 7:734–54. doi: 10.21474/IJAR01/9095

34. Asmamawu A. *Community based health insurance in Ethiopia: enrollment, membership renewal, and effects on health service utilization*. Seoul: Seoul National University (2018).

35. Ozawa S, Walker D. Trust in the context of community-based health insurance schemes in Cambodia: villagers' trust in health insurer. *Adv Health Econ Health Serv Res*. (2009) 21:107–32. doi: 10.1108/S0731-2199(2009)0000021008

36. Awudu S. *National health insurance scheme: predictors of card renewal among subscribers in the east Gonja district of Ghana*. Ghana: University of Ghana (2016).

37. Taddesse G, Atnafu DD, Ketemaw A, Alemu Y. Determinants of enrollment decision in the community-based health insurance, north West Ethiopia: a case-control study. *Glob Health*. (2020) 16:4. doi: 10.1186/s12992-019-0535-1

frontiers | Frontiers in Public Health

TYPE Perspective
PUBLISHED 06 March 2024
DOI 10.3389/fpubh.2024.1212439

OPEN ACCESS

EDITED BY
Hai Fang,
Peking University, China

REVIEWED BY
Guvenc Kockaya,
ECONiX Research, Analysis and Consultancy Plc., Türkiye

*CORRESPONDENCE
Simon Eckermann
seckerma@uow.edu.au

RECEIVED 26 April 2023
ACCEPTED 21 February 2024
PUBLISHED 06 March 2024

CITATION
Eckermann S (2024) Aligning opportunity cost and net benefit criteria: the health shadow price.
Front. Public Health 12:1212439.
doi: 10.3389/fpubh.2024.1212439

Aligning opportunity cost and net benefit criteria: the health shadow price

Simon Eckermann*

School of Health and Society, University of Wollongong, Wollongong, NSW, Australia

Given constrained healthcare budgets and many competing demands, public health decision-making requires comparing the expected cost and health outcomes of alternative strategies and associated adoption and financing actions. Opportunity cost (comparing outcomes from the best alternative use of budgets or actions in decision making) and more recently net benefit criteria (relative valuing of effects at a threshold value less costs) have been key concepts and metrics applied toward making such decisions. In an ideal world, opportunity cost and net benefit criteria should be mutually supportive and consistent. However, that requires a threshold value to align net benefit with opportunity cost assessment. This perspective piece shows that using the health shadow price as the ICER threshold aligns net benefit and opportunity cost criteria for joint adoption and financing actions that arise when reimbursing any new strategy or technology under a constrained budget. For an investment strategy with ICER at the health shadow price $Bc = 1/(1/n + 1/d - 1/m)$, net benefit of reimbursing (adopting and financing) that strategy given an incremental cost-effectiveness ration (ICER) of actual displacement, d, in financing, is shown to be equivalent to that of the best alternative actions, the most cost-effective expansion of existing programs (ICER = n) funded by the contraction of the least cost-effective programs (ICER = m). Net benefit is correspondingly positive or negative if it is below or above this threshold. Implications are discussed for creating pathways to optimal public health decision-making with appropriate incentives for efficient displacement as well as for adoption actions and related research.

KEYWORDS

opportunity cost, net benefit, threshold value, health shadow price, budget constrained optimization, allocative efficiency, displacement efficiency

1 Introduction

Optimizing health outcomes from a constrained public health system budget requires decisions about which programs and strategies to support through reimbursement when investing in or allocating budgets and resources. Opportunity cost and net benefit criteria have been key concepts and metrics applied to inform budget-constrained optimal health system decision-making. This review paper introduces opportunity cost (section 2) and net benefit criteria (section 3) and shows how they are aligned using the health shadow price (section 4) as a threshold value for net benefit (section 5). This finding and its implications are discussed in section 6 in relation to creating pathways for optimal resource allocation and investment decisions with joint adoption and financing actions, but also to incentivize research in identifying the best expansion and contraction of programs with constrained budgets.

2 Opportunity cost

Health systems with constrained budgets or resources and unconstrained population health need to make allocative decisions across alternative strategies. Given constrained resources and funding, the opportunity cost of any resource use or reimbursement/investment decision and associated action/s (adoption and financing with reimbursement), is the forgone value of outcomes from the best alternative use or choice and associated set of actions (1–5).

As a result, all constrained healthcare system funding or resource allocation processes face opportunity costs with each reimbursement or investment decision. That is, the value of the best alternative investment or reimbursement choice with adoption and necessary associated financing actions under a constrained budget.

3 Net benefit criteria

The net benefit is a metric that combines the joint consideration of effects and costs (resource use and their prices) to compare the relative value less cost of strategies, decisions, or action/s (6–9). For the simplest case of two strategy comparisons, the incremental net benefit (INB) of a strategy relative to a comparator is:

$$INB = \lambda \Delta E - \Delta C \quad (1)$$

Where λ is the threshold value for effects and ΔE and ΔC are incremental effects and costs. Positive INB implies invest, while 0 or negative INB implies don't invest. Net benefit metrics have a series of advantages over incremental cost-effectiveness ratios (ICERs) (9–17). These include being well ordered when the effect is 0 or changes sign around 0, having an opposite sign consistent with the implications when a strategy is dominated or dominates, and reflecting the degree of any such dominance (9). In addition, additive separability of net benefit (although not ICERs) (10) implies that multiple strategies or multiple domains can be consistently compared relative to any comparator based on maximizing net benefit (NB = λE−C) or equivalently minimizing net loss (NL = λDU + C) under the net benefit correspondence theorem (11–17). DU in the net loss metric simply represents any effect/s (E) in net benefit framed from a disutility perspective (e.g., mortality vs. survival, morbidity vs. no morbidity, QALYs lost vs. QALYs gained, etc.).

4 The health shadow price

Given a fixed or constrained budget, the health shadow price represents the critical or threshold value at which the health outcome from any reimbursement decision (adoption and financing action) equates with the best alternative adoption and financing actions (4, 5). The best alternative adoption and financing actions are to implement the most cost-effective expansion of existing programs (ICER = n, e.g., \$5,000/QALY) funded by reducing the least cost-effective programs (ICER = m, e.g., \$ 1 million/QALY).

Thus, with a constrained budget, for any given investment I with actual displacement (ICER = d, e.g., \$20,000/QALY) the health shadow price (B_C) for any given strategy is found by setting the net health return from reimbursing (adopting and financing) that strategy for any given investment amount I, $I/B_C - I/d$, as equal to that from the best alternative joint adoption and financing actions $I/n - I/m$.

Consequently, solving

$$\frac{I}{B_c} - \frac{I}{d} = \frac{I}{n} - \frac{I}{m}$$

results in:

$$\frac{1}{B_c} = \frac{1}{n} + \frac{1}{d} - \frac{1}{m}$$

or

$$B_c = \left(\frac{1}{n} + \frac{1}{d} - \frac{1}{m}\right)^{-1} \quad (2)$$

The subscript c denotes that the health shadow price (Equation 2), like opportunity cost, corresponds to the economic context of the best alternative actions within a constrained budget (4, 5, 18, 19). Explicitly the context for making budget constrained reimbursement (joint adoption and financing) decisions. That is the context of actual displacement (ICER= d), and best alternative expansion (ICER= n) and contraction (ICER= m) actions.

For example, if n = \$5,000/QALY, d = \$20,000/QALY, and m = \$1,000,000/QALY, then

$$B_c = \frac{1}{\frac{1}{5000} + \frac{1}{20000} - \frac{1}{1000000}} = \frac{1}{0.0002 + 0.00005 - 0.0000001} = \frac{1}{0.0002499} = \$4001.60 / QALY$$

5 Incremental net benefit consistent with opportunity cost

If we conduct an incremental net benefit assessment of an investment or reimbursement amount I relative to the best alternative investment or reimbursement of I (adoption and financing actions) using the health shadow price as a threshold value then from Equation 1 and Equation 2 we have:

$$INB = B_C \Delta E - \Delta C$$

Now for cases of interest where ΔE and ΔC are both positive, i.e., in the NE quadrant, then INB using the health shadow price as a threshold value is only positive where $B_c\Delta E - \Delta C > 0$ and hence $\Delta C/\Delta E < B_c$ or negative where $B_c\Delta E - \Delta C < 0$ and hence $\Delta C/\Delta E > B_c$. QED.

Hence, using the health shadow price, B_c as the threshold value for effects aligns INB with the same decisions as comparing the investment ICER with the health shadow price—which is derived from and represents the opportunity cost of budget-constrained investments.

6 Discussion: implications for optimal research, resource allocation, and investment

In sections 2–5 we have shown that using the health shadow price as the critical threshold value for incremental net benefit appropriately results in equivalent net benefit between:

(1) Any new budget constrained investment (I) in a strategy with ICER equal to the health shadow price funded by displacement (ICER = d) and;
(2) The best alternative health system adoption and financing actions for the same budget constrained investment I.

Furthermore, if the strategy has a lower or higher ICER than this, then its INB is appropriately correspondingly positive or negative.

Importantly this means that for any investment with a constrained budget using the health shadow price as the net benefit threshold value enables net benefit to represent the same rule as opportunity cost.

If the budget was not constrained then investment would only have an adoption action, for which the best alternative action is the most cost-effective expansion of existing programs (ICER = n), which would be the appropriate threshold value. Indeed, this is also the appropriate threshold value for the health shadow price if displacement is efficient ($d = m$), which is then given by:

$$B_c = \left(\frac{1}{n} + \frac{1}{d} - \frac{1}{m}\right)^{-1} = \frac{1}{\frac{1}{n}} = n$$

In response to experiences in the United Kingdom during the 1990 and 2000s where many services were displaced by the mandated use of medications such as Herceptin (20) different ICER thresholds for displaced services were proposed as a threshold value for INB assessment (21–27). Four different displaced service thresholds were proposed:

i The least cost-effective current program, assuming that this is the program that is actually displaced to finance the additional costs of the new technology (22).
ii The least cost-effective program, regardless of whether or not it is displaced (23).
iii The ICER of the services actually displaced to finance that technology regardless of the ICER of that displaced service relative to other services (24–26).
iv The average ICER of historically displaced NHS services (21, 27).

Strictly speaking, these four definitions would only coincide if displacement had been and remained currently efficient ($d = m$). Nevertheless, the health shadow price makes clear the proposed use of d or any displaced service as a threshold in all its guises (18, 19):

i Conflates adoption and financing actions—equates the threshold value in expansion with that in contraction (25).
ii Arises only at a singular point where there is perfect allocative efficiency, but does not provide a pathway to get there.
iii Most importantly, it denies the true opportunity cost of reimbursing (adopting and funding) new technologies—the most cost-effective expansion of existing health system interventions funded by displacement of the least cost-effective interventions.

Sendi et al. (21) advocated the average ICER of displaced services as a second-best alternative threshold value to the shadow price of the budget constraint reflecting the shadow price per unit of effectiveness in the absence of a market. They emphasized that this, like the shadow price, is a function of program size (5, p.82). Later, theoretical arguments or assertions were made for displaced service-related ICERs representing the shadow price of the budget constraint (22–27), explicitly stated in Griffin et al. (25, p.24) as the ICER of actual displaced services, d, with a two-part argument:

i "Identifying marginal programs that would be displaced and quantifying their cost and health outcomes determines the shadow price of the budget constraint" [SIC].
ii "The incremental cost per QALY gained of new treatments are commonly compared to some stated threshold λ, which should in principle represent the inverse of the shadow price of the budget constraint" [SIC].

These two parts were combined to argue that any new treatment should be reimbursed if the incremental health offered by the new treatment option exceeds the health foregone with the displacement of marginal programs (25, p.24).

However, in the context of market failure and allocative inefficiency characteristic of the health care system, displaced service definitions in general, and this two-part argument in particular, conflate shadow price in expansion (maximum unit of effect gained as a result of relaxing a constraint by one unit at the margin) (28), with notions of shadow price in contraction (minimum loss when one unit of a continuous resource is withdrawn) (29). Combined, the two parts misrepresent opportunity cost as the actual loss of displacement when the budget is reduced, rather than the highest value alternative (18). Displaced services do not represent opportunity cost, the highest value alternative. If Griffin et al. (25) had appropriately added "in expansion" in part (ii) to represent opportunity cost, it would be clear that this is different from any notion of the shadow price of the budget constraint "in contraction" in part (ii). The only situation in which shadow prices in expansion and contraction can coincide is at the single point of complete allocative efficiency ($n = m$) and indeed of displacement efficiency ($d = m$) and hence $n = m = d = B_c$.

Empirically, no health system internationally can claim to beat the point of allocative efficiency. Consider the case of the United Kingdom which was ranked in 2014 by the Commonwealth Fund (30) as having the most efficient health system of high income OECD countries. Despite this international standing, the 2013 evidence from Claxton et al. (27) of the ICER for best expansion ($n = 2{,}000$ pounds per QALY), contraction ($m = 2.73$ million pounds per QALY) and displacement ($d = 12{,}713$ pounds per QALY) indicated substantial allocative and displacement inefficiency in practice with $n < d << m$ (19, 31). This resulted in a health shadow price [following Equation (2)] with 2013 United Kingdom evidence (27) of:

$$B_c = \frac{1}{\frac{1}{2000}+\frac{1}{12713}-\frac{1}{2730000}} =$$
$$\frac{1}{0.0005+0.0000787-0.000000366} =$$
$$\frac{1}{0.0005783} = 1,729 \text{ pounds / QALY}$$

Pekarsky (5, p.69-83) shows that in the context of such economic inefficiency and market failure for an input, deriving the health shadow price from existing information about the economic context than from cost benefit analysis following McKean (32) and Mishah and Quah (3). That is, the health shadow price (4, 5) as derived in section 4 above, takes into account observed allocative ($n < m$) and displacement ($d < m$) inefficiencies, rather than any notion of the shadow price of the budget constraint that assumes perfect economic efficiency.

An underlying inappropriate assumption for health care of complete allocative efficiency in the context of market failure can be traced back to the suggested use of shadow price of the budget constraint as a critical ratio for the threshold value by Weinstein and Zeckerhaus (33). They implicitly assumed complete allocative efficiency (and discrete programs) by suggesting a critical ratio of the cost per effect of the last service financed if all services are ranked and allocated up to the budget—the average shadow price.

As Pekarsky (5, p. 83) surmises: "…health economic focus on the shadow price of the budget constraint…can lead to the following catch 22: we cannot find this shadow price until economic efficiency is achieved, and we cannot achieve economic efficiency until this price is found" [*SIC*]. Importantly, the health shadow price (4, 5) creates the appropriate incentives for evidence on the best expansion and contraction of current programs to enable it (18, 19). This meets the imperative to "find a shadow price for health effects that will improve economic efficiency rather than being conditional on economic efficiency" [*SIC*] (5, p. 83). The only point where the health shadow price (4, 5) coincides with the ICER for actual displaced services, *d*, is at the point of complete allocative (and displacement) efficiency; and because $n=m=d=B_c$ only at that singular point. However, using *d* as a threshold value does not provide a pathway to get there, whereas the health shadow price does (18, 19). That is, the coincidence of the shadow price in expansion and contraction at the single point of allocative efficiency does not provide a pathway to get there from any point of allocative inefficiency. Certainly not when using a displaced service ICER threshold such as d, which is only equal to the health shadow price at the single point of complete allocative efficiency. Moreover, considered dynamically over time with allocative inefficiency ($n < m$) if displacement were efficient ($d = m$) then new technologies or strategies priced up to a threshold value of *d* would be next in line to be displaced and would face additional reversal costs not accounted for in ICER calculations as the new technology cycles through. Hence, as highlighted in Eckermann and Pekarsky (18) use of *d* as a threshold with appropriate consideration of reversal costs can easily lead to health outcomes from constrained budgets declining over time, particularly if displacement is efficient.

Now, let us consider if comparison of the reimbursement of an investment were not with the best alternative action/s to reflect opportunity costs, but rather with the second best objective of improving the (short term) net benefit from combined adoption and displacement decisions. Then, with a fixed budget the ICER from adopting new programs could be considered relative to that of actual displaced services (21). However, to the extent that displacement is efficient (*d* approaches m rather than *n*) this creates a straw man for comparing adoption (even without a budget constraint), let alone if joint adoption and financing actions are appropriately considered together with the health shadow price (18).

The alignment of net benefit with opportunity cost for budget-constrained investment or reimbursement (adoption and financing actions) that arises with the use of the health shadow price (B_C) as the ICER threshold value does not occur with *d* (the ICER of displaced services). That is clear noting that generally $B_c \le n \le d \le m$. They only coincide at the single point of complete allocative and displacement efficiency, which no health system internationally satisfies, with $n = m = d = B_C$ at this point alone.

This implies that using a threshold value of *d* for net benefit assessment biases against better use of existing programs or technologies and in favor of pricing new technologies above opportunity cost, given the best alternative reimbursement actions (adoption and financing) that the health shadow price represents.

More generally, in the absence of appropriate incentives created by the health shadow price research decisions are also biased toward evidence for new technologies. On the other hand, there are disincentives for evidence or indeed lack of evidence for unpatented or unpatentable strategies (4, 5, 18, 19). In particular, this would bias against public health strategies such as those for health promotion across the life course (34). Those strategies include community programs that support integrated movement from early childhood to youth, adulthood and older adulthood (35–39); successful ageing (40–44) or rehabilitation and palliative care services (16, 19, 45). The same types of services that were displaced to accommodate mandated Herceptin use in the United Kingdom highlighted in the 2000s (20).

It could be argued that pharmaceutical and device manufacturing companies are only responsible for adoption and should not be penalized for inefficient displacement ($d < m$). However, the reality of a constrained budget is that adoption and financing actions (and associated research) for any reimbursement (investment) decision naturally need to occur together. More generally optimal cycles of joint research, reimbursement and regulatory decision making are required to optimize budget-constrained health system outcomes in any jurisdiction and globally (16, 46). Where research funding is biased in favor of new technologies and against unpatentable technologies or programs (e.g., community programs without vested interests), a pathway to optimization requires public policy incentives for research evidence and better use of existing programs and technologies in adoption and displacement (4, 5, 18, 19). Ideally, processes supporting optimal cycles of research, reimbursement and regulatory decision making (16) that systematically reflect and create an imperative for that pathway.

Consequently use the health shadow price as a threshold value for net benefit assessment is key to creating appropriate incentives for research evidence to support displacement or contraction and for appropriate adoption or expansion actions (4, 5, 18, 19). The use of the health shadow price makes it clear that there are joint adoption and financing actions and associated research requirements for any reimbursement/investment decision with constrained budgets.

7 Conclusion

This paper has shown that incremental net benefit aligns with opportunity cost when the health shadow price (section 4) is used as the threshold value. At this threshold value, section 5 showed that the incremental net benefit criteria (section 3) of an investment are positive (negative) only if the health outcomes from that investment are greater (less) than the best alternative adoption and financing actions (opportunity cost section 2). Hence, using the health shadow price as the threshold value for the incremental net benefit assessment in any jurisdiction makes the same reimbursement decision as opportunity cost (section 5). As the discussion in section 6 highlighted, these findings also allow for optimization in resource allocation and investment decisions and appropriate incentives for research in addition to optimal adoption and financing actions.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

SE conceived and designed the paper and is accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Conflict of interest

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

References

1. Mishan E. *Cost-Benefit Analysis: An Informal Introduction*. London: Allen and Unwin (1971).

2. Birch S, Gafni A. Cost effectiveness/utility analyses: do current decision rules lead us to where we want to be? *J Health Econ*. (1992) 11:279–96. doi: 10.1016/0167-6296(92)90004-K

3. Mishan E, Quah E. *Cost Benefit Analysis. 5th* ed. Abingdon: Routlidge (2007).

4. Pekarsky B (2012). Trusts, constraints and the counterfactual: Reframing the political economy of new drugs. PhD Thesis. University of Adelaide.

5. Pekarsky BAK. *The New Drug Reimbursement Game: A Regulator's Guide to Playing Ad Wining*. London: Springer (2015).

6. Graham DA. Cost-benefit analysis under uncertainty. *Am Econ Rev*. (1981) 1981:715–25.

7. Graham DA. Public expenditure under uncertainty: the net-benefit criteria. *Am Econ Rev*. (1992) 1992:822–46.

8. Stinnett AA, Mullahy J. Net health benefits: a framework for analysis of uncertainty in cost-effectiveness analysis. *Med Dec Making*. (1998) 17:483–9.

9. Willan A, Briggs A. *The Statistical Analysis of Cost-effectiveness Data*. Chichester: Wiley and Sons (2006).

10. Stinnett AA, Paltiel AD. Estimating CE ratios under second-order uncertainty—the mean ratio vs the ratio of means. *Med Decis Mak*. (1997) 17:483–9. doi: 10.1177/0272989X9701700414

11. Eckermann S. (2004). "Hospital performance including quality: creating incentives consistent with evidence-based medicine." PhD Dissertation. UNSW, Sydney. Available at: http://unsworks.unsw.edu.au/vital/access/manager/Repository/unsworks:716

12. Eckermann S, Briggs A, Willan A. Health technology assessment in the cost-disutility plane. *Med Decis Mak*. (2008) 28:172–81. doi: 10.1177/0272989X07312474

13. Eckermann S, Willan A. 2011. Presenting evidence and summary measures to best inform societal decisions when comparing multiple strategies. *PharmacoEconomics*. (2011) 29:563–77. doi: 10.2165/11587100-000000000-00000

14. Eckermann S, Coelli T. Including quality attributes in efficiency measures consistent with net benefit: creating incentives for evidence-based medicine in practice. *Soc Sci Med*. (2013) 76:159–68. doi: 10.1016/j.socscimed.2012.10.020

15. McCaffrey N, Agar M, Harlum J, Karnon J, Currow D, Eckermann S. Better informing decision making with multiple outcomes cost-effectiveness analysis under uncertainty in cost-disutility space. *PLoS One*. (2015, 2015) 10:e0115544. doi: 10.1371/journal.pone.0115544

16. Eckermann S. *Health Economics from Theory to Practice: Optimally Informing Joint Decisions of Research, Reimbursement and Regulation with Health System Budget Constraints and Community Objectives*. London: Springer (2017).

17. Eckermann S, McCaffrey N, Tonmukayakul U, Swann C, Vella S. Multiple effects health economic evaluation of the ahead of the game study for mental health promotion in sporting club communities. *Heal Econ Rev*. (2021) 11:28. doi: 10.1186/s13561-021-00323-1

18. Eckermann S, Pekarsky B. Can the real opportunity cost stand up: displaced services the straw man outside the room. *PharmacoEconomics*. (2014). 32:319–25. doi: 10.1007/s40273-014-0140-3

19. Eckermann S. The health shadow Price and economically meaningful threshold values. Chapter 11. In: E Simon, editor. *Health Economics from Theory to Practice: Optimally Informing Joint Decisions of Research, Reimbursement and Regulation with Health System Budget Constraints and Community Objectives*. Cham, Switzerland: Springer (2017)

20. Barrett A, Riques T, Small M, Smith R. How much will Herceptin really cost? *Br Med J*. (2006) 333:1118–20. doi: 10.1136/bmj.39008.624051.BE

21. Sendi P, Gafni A, Birch S. Opportunity costs and uncertainty in the economic evaluation of health care interventions. *Health Econ*. (2002) 11:23–31. doi: 10.1002/hec.641

22. Culyer AJ, McCabe C, Briggs A, Claxton K, Buxton M, Akehurst R, et al. Searching for a threshold not setting one: the role of the national institute for health and clinical excellence. *J Health Ser Res Policy*. (2007) 12:56–8. doi: 10.1258/135581907779497567

23. McCabe C, Claxton K, Culyer AJ. The NICE cost-effectiveness threshold: what it is and what that means. *PharmacoEconomics*. (2008) 26:733–44. doi: 10.2165/00019053-200826090-00004

24. Claxton K, Buxton M, Culyer A, Walker S, Sculpher M. Value based pricing for NHS drugs: an opportunity not to be missed? *BMJ*. (2008) 336:251–4. doi: 10.1136/bmj.39434.500185.25

25. Griffin S, Claxton K, Sculpher M. Decision analysis for resource allocation in health care. *J Health Ser Res Policy*. (2008) 13:23–30. doi: 10.1258/jhsrp.2008.008017

26. Sculpher M, Claxton K. Real economics needs to reflect real decisions. *PharmacoEconomics*. (2012) 30:133–6. doi: 10.2165/11596660-000000000-00000

27. Claxton K, Martin S, Soares M, Rice N, Spackman E, Hinde S, et al. (2013). Methods for the estimation of the NICE cost effectiveness threshold final report working paper 82 Centre for Health Economics, University of York.

28. Mas-Colell A, Whinston M, Green J. *Macroeconomic Theory*. New York: Oxford University Press (1995).

29. Takayama A. *Analytic Methods in Economics*. Michigan: Harvester Wheatsheaf. Hemel (1994).

30. Davis K, Stremikis K, Squires D, Schoen C (2014). Mirror, Mirror on the wall, 2014 update: how the U.S. health care system compares internationally. Commonwealth Fund pub no. 1755, 2014.

31. Eckermann S. Kinky thresholds revisited: opportunity costs differ in the NE and SW quadrants. *Appl Health Econ Health Policy*. (2015) 13:7–13. doi: 10.1007/s40258-014-0136-3

32. McKean RN. (1972). The use of shadow prices in *Cost Benefit Analysis*. (ed.) Layard R (Hammonsworth: Penguin) 119–139.

33. Weinstein M, Zeckerhauser R. Critical ratios and efficient allocation. *J Public Econ*. (1973) 2:147–57. doi: 10.1016/0047-2727(73)90002-9

34. World Health Organisation (2017). Best buys and other recommended interventions for the prevention and control of noncommunicable diseases updated (2017), appendix 3 of the global action plan.

35. Tremblay MS, Carson V, Chaput JP, Connor Gorber S, Dinh T, Duggan M, et al. Canadian 24-hour movement guidelines for children and youth: an integration of physical activity, sedentary, and sleep. *Appl Physiol Nutr Metab*. (2016) 41:S311–27. doi: 10.1139/apnm-2016-0151

36. Okely A, Ghersi D, Hesketh KD, Santos R, Loughran SP, Cliff DP, et al. A collaborative approach to adopting/adapting guidelines. The Australian 24-hour movement guidelines for the early years: an integration of physical activity, sedentary behaviour, and sleep. *BMC Public Health*. (2017) 17:869. doi: 10.1186/s12889-017-4867-6

37. Ross R, Chaput JP, Giangregorio LM, Janssen I, Saunders TJ, Kho ME, et al. Canadian 24-hour movement guidelines for adults aged 18–64 years and adults aged 65 years or older: an integration of physical activity, sedentary behaviour, and sleep. *Appl Physiol Nutr Metab*. (2020) 45:S57–S102. doi: 10.1139/apnm-2020-0467

38. World Health Organisation. *Guidelines on Physical Activity, Sedentary Behaviour and Sleep for Children Under 5 Years of Age*. Geneva: World Health Organization (2019).

39. Eckermann S, Willan AR, Okely A, Tremblay MS, Coelli T. Robust cross-country comparison of children meeting 24-hr movement guidelines: an odds solution for binary effect efficiency measures. *J Public Health*. (2021) 30:2059–68. doi: 10.1007/s10389-021-01587-x

40. World Health Organization (2002). Active ageing: A policy framework. WHO/NMH/NPH/02.8 Geneva. Available at: https://www.who.int/ageing/publications/active_ageing/en/

41. World Health Organisation. *Global age-friendly cities, a guide*. Geneva: World Health Organization. (2007).

42. Kalache A. *The Longevity Revolution: Creating a society for all ages. Adelaide Thinker in Residence 2012–2013*. Adelaide: Government of South Australia (2013).

43. World Health Organization (2015). World report on ageing and health. Geneva: WHO. Available at: http://apps.who.int/iris/bitstream/10665/186463/1/9789240694811_eng.pdf (Accessed December 2019).

44. Eckermann S. Policy implications and applications across health and aged care reform with baby boomer ageing—from age and dementia friendly communities to palliative care. Chapter 12. In: E Simon, editor. *Health Economics From Theory to Practice: Optimally Informing Joint Decisions of Research, Reimbursement and Regulation with Health System Budget Constraints and Community Objectives*. London: Springer (2017). 279–320.

45. McCaffrey N, Eckermann S. Raise the Bar, not the threshold value: meeting patient preferences for palliative and end-of-life care. *Pharm Econ Open*. (2018) 2:93–5. doi: 10.1007/s41669-017-0039-y

46. Eckermann S. Globally optimal trial design and risk sharing arrangements are key to avoiding opportunity costs of delay and enabling equitable, feasible and effective global vaccine research and implementation in current or future pandemics. *Front Public Health*. (2022) 10:1085319. doi: 10.3389/fpubh.2022.1085319

frontiers | Frontiers in Public Health

TYPE Original Research
PUBLISHED 18 March 2024
DOI 10.3389/fpubh.2024.1333081

Check for updates

OPEN ACCESS

EDITED BY
Hai Fang,
Peking University, China

REVIEWED BY
Eduardo Gutiérrez-Abejón,
Universidad de Valladolid, Spain
Styliani A. Geronikolou,
National and Kapodistrian University of Athens, Greece

*CORRESPONDENCE
Amaya Burgos-Esteban
amaya.burgos@unirioja.es

RECEIVED 04 November 2023
ACCEPTED 16 February 2024
PUBLISHED 18 March 2024

CITATION
Calderón-Moreno J, Delgado-Rodriguez MJ, Juárez-Vela R, Tejada-Garrido CI, de Viñaspre-Hernández RR, Burgos-Esteban A, Sánchez-Conde P, Andreu-Fernández V, Gea-Caballero V, Santos-Sanchez JA, Quintana-Diaz M and Andrés-Esteban EM (2024) Approximation to the economic cost of healthcare for hypertensive patients diagnosed with COVID-19.
Front. Public Health 12:1333081.
doi: 10.3389/fpubh.2024.1333081

Approximation to the economic cost of healthcare for hypertensive patients diagnosed with COVID-19

Jesús Calderón-Moreno[1], María Jesús Delgado-Rodriguez[1], Raúl Juárez-Vela[2,3], Clara Isabel Tejada-Garrido[2], Regina Ruiz de Viñaspre-Hernández[2,3], Amaya Burgos-Esteban[2]*, Pilar Sánchez-Conde[4,5], Vicente Andreu-Fernández[6], Vicente Gea-Caballero[6], Jose Angel Santos-Sanchez[4], Manuel Quintana-Diaz[3,7] and Eva María Andrés-Esteban[1]

[1]Business Economics Department, University of Rey Juan Carlos, Madrid, Spain, [2]Department of Nursing, GRUPAC, University of La Rioja, Logroño, Spain, [3]Research Group Blood Patient Management, IDI-Paz Research Institute, Madrid, Spain, [4]Faculty of Medicine, University of Salamanca, Salamanca, Spain, [5]Anesthesia and Resuscitation Service, University Healthcare Complex, Salamanca, Spain, [6]Faculty of Health Sciences, International University of Valencia, Valencia, Spain, [7]Intensive Care Unit, Hospital La Paz, La Paz, Spain

Introduction: Many researchers have focused their studies on hypertension due to its over-representation among COVID-19 patients. Both retrospective and observational studies conducted close to the Wuhan area have reported that hypertension is the most common comorbidity observed in patients affected by COVID-19.

Objective: Our objective is that patients with arterial hypertension have a worse prognosis in terms of evolution leading to higher costs.

Methods: A retrospective cross-sectional study was conducted. A total of 3,581 patients from La Paz University Hospital (LPUH) during the period between 15 July 2020 and 31 July 2020 were included in this study.

Results: It should be noted that 40.71% of the patients were hypertensive. As expected, hypertension was associated with men, among whom we observed a higher prevalence and a higher age (median age of 77 years (IQI: 65–85) versus 52 years (IQI: 37–64), p-value < 0.001). Hypertensive patients had a higher prevalence of dyspnea (52.14% vs. 47.15%, p-value = 0.004) and altered awareness (14.89% vs. 4.30%, p-value <0.001). The non-parametric Kaplan–Meier curve estimates the survival of patients in the two study groups. We can see how patients with hypertension have a higher associated mortality, with the difference being statistically significant, p-value (log-rank) = 0.004. Only for the appearance of complications during hospitalization, the group of hypertensive patients reached the figure of €1,355,901.71 compared to the total of 421,403.48 € for normotensive patients.

Conclusion: Our study shows the worse clinical evolution of patients with COVID-19 in terms of associated morbidity and mortality. It also shows that the cost of managing patients with hypertension is greater than that of managing normotensive patients.

KEYWORDS

healthcare economics and organizations, economics, hospital, COVID-19, public health administration, cost of illness

Introduction

Many researchers have focused their studies on hypertension due to its over-representation among COVID-19 patients (1). Both retrospective and observational studies conducted close to the Wuhan area have reported that hypertension is the most common comorbidity observed in patients affected by COVID-19, ranging between 15 and 30% (2–4). In one of the largest studies conducted in Wuhan with data collected from 1,099 COVID-19 patients, 165 patients (approximately 15% of the total sample) had high blood pressure (5). The same study also reported that a total of 23.7% of hypertensive patients had higher disease severity than 13.4% of normotensive subjects. However, 35.8% of hypertensive patients experienced worst outcomes in terms of intensive care unit (ICU) admission, mechanical ventilation, or death compared to just 13.7% of normotensive patients (5).

Another study conducted in China, which investigated 138 COVID-19 patients, found a similarly high prevalence of hypertension among the patients (31.2%) (2). The researchers also affirmed that 58.3% of hypertensive patients with COVID-19 infection were admitted to ICU compared to 21.6% of patients with normal blood pressure. Guan et al. studied a cohort of 1,590 patients from 575 hospitals and found that hypertension was independently associated with severe COVID-19 (hazard ratio 1.575; 95% CI: 1.07–2.32). All these findings indicate that hypertensive patients have a higher risk of developing severe outcomes from COVID-19.

These early results were similar to those subsequently found in other countries. Thus, JAMA published data on 1,591 patients admitted to intensive care units in Italy (6). Arterial hypertension (49%) and cardiovascular disease (21%) were the most frequent comorbidities, above other respiratory diseases. The study stratified the cohort by the presence or absence of hypertension and hypertensives finding that patients with arterial hypertension had higher mortality (65% vs. 40%, $p < 0.001$).

The Spanish National Health System (SNS) is based on a Beveridge-type public model (7). It is a decentralized national health system, with competencies transferred to 17 Spanish autonomous communities (regions), under the control of the Ministry of Health. The SNS coverage gradually spread until 100% of citizens were covered in 1989. Currently, care is financed by taxes, and services are accessed by health cards. There are not many studies related to the cost of managing patients infected with the SARS-CoV-2 virus. In Spain, Calderon et al. reported that the cost of managing patients with COVID-19 without hospitalization is €729.79, and the cost of hospitalized patients ranges between €4294.36 and €14440.68, if there is an ICU admission (8).

If we focus on the worse evolution of hypertensive patients, they have a higher incidence of complications, longer hospital stays, or stays in intensive care units than normotensive patients, and all this translates into higher healthcare costs for the management of hypertensive patients when infected with the SARS-CoV-2 virus. Therefore, our working hypothesis is that patients with arterial hypertension have a worse prognosis in terms of evolution leading to higher costs.

Methods

Design

A retrospective cross-sectional study was carried out.

Data collection

Given the avalanche of patients in the emergency department, wards, and the ICU and the lack of knowledge of the disease during the initial months of the pandemic, the Hospital Universitario La Paz created a specific data collection notebook for all those who came to the hospital with clinical manifestations compatible with SARS-CoV-2 virus infection. This database was created by several experts in epidemiology at the hospital with the aim of learning more about the disease known as COVID-19.

Population and sample

A total of 3,581 patients from the La Paz University Hospital (LPUH) during the period between 15 July 2020 and 31 July 2020 were included in this study. The database included sociodemographic data, clinical status, laboratory findings, and clinical management of patients admitted with a respiratory infection caused by SARS-CoV-2 since the outbreak of the current pandemic.

Variables

Patient demographic data were collected prior to admission. Total costs were categorized based on care settings (admission to the hospital ward, admission to the ICU, and length of hospital stay) and the occurrence of most frequent complications (such as respiratory infection, pneumonia, acute respiratory distress syndrome, pneumothorax, pleural effusion, meningitis, convulsions, stroke, heart failure, endocarditis, arrhythmia, cardiac ischemia, cardiac arrest, coagulation problems, anemia, renal failure, pancreatitis, hepatic failure, psychiatric illness, and gastrointestinal bleeding). Additionally, variables associated with chronic health problems (such as smoking, diabetes, hypertension, chronic cardiac diseases, asthma, and chronic bronchitis) were considered. These variables have been linked to complications in COVID-19.

The cost data used were provided by the accounting department of the hospital, which allowed more precise estimates to be made.

TABLE 1 Description of demographic variables in patients with and without arterial hypertension admitted for COVID-19.

Variable	Hypertension		*p*-value
	No	Yes	
N	2,123 (59.29%)	1,458 (40.71%)	
Sex			< 0.001
Male	926 (44.80%)	799 (54.80%)	
Female	1,141 (55.20%)	659 (45.20%)	
Age (median, IQI)	52 (37–64)	77 (65–85)	< 0.001
Healthcare worker	601 (30.23%)	67 (4.83%)	< 0.001
Type overcrowding			< 0.001
Without overcrowding	1941 (94.68%)	1,222 (84.80%)	
Residence	100 (4.88%)	214 (14.85%)	
Hotel	8 (0.39%)	5 (0.35%)	
Prison	1 (0.05%)	0 (0.00%)	
Relationship with positive COVID	333 (17.48%)	221 (16.54%)	0.485
Suspected nosocomial transmission	702 (34.50%)	362 (25.02%)	< 0.001
Functional stage			< 0.001
Dependent for basic activities of daily living	107 (5.35%)	145 (10.48%)	
Semi-dependent for basic activities of daily living	56 (2.80%)	134 (9.68%)	
Independent for basic activities of daily living	1838 (91.85%)	1,105 (79.84%)	

Statistical analysis

Quantitative variables were described using robust statistics, such as median and interquartile interval, whereas for qualitative variables, frequency distribution was used. For the comparison of quantitative variables that were not normally distributed among frailty groups, the Kruskal–Wallis non-parametric H test was used, based on the Shapiro–Wilk test. Finally, the chi-squared test was used to compare qualitative variables.

The survival estimate was assessed using the Kaplan–Meier method comparing the survival curve between the groups with the log-rank test. The multivariate analysis was carried out by means of Cox regression, with the forward conditional method, introducing as independent variables the variables that obtained statistical significance in the bivariate analysis or that could have a clinically plausible implication. The results of the multivariate model were presented as a hazard ratio (95% CI).

The statistical analysis was performed using STATA v16.0, and a *p*-value of 5% was considered statistically significant.

Ethical considerations

The study was conducted in accordance with the principles outlined in the Declaration of Helsinki (2008 update, available on the World Medical Association website).[1] Additionally, it adhered to the standards of good clinical practice as described in the ICH Harmonized Tripartite Guidelines for Good Clinical Practice (2001) and the Guidelines for Good Epidemiological Practice.[2] The study was approved by the Clinical Research Ethics Committee of LPUH, Madrid, with the LPUH code: PI-4155. It was not necessary to provide a formulary of informed consent as the anonymized database was used for data extraction. This study was conducted in accordance with European and Spanish regulations for the protection of personal data (Organic Law 3/2008).

Results

Description of the sample

The patients were stratified according to the diagnosis of hypertension. Table 1 shows the demographic characteristics of these patients. It should be noted that 40.71% of the patients were hypertensive. As expected, hypertension was associated with men, among whom we observed a higher prevalence and a higher median age [median of 77 years (IQI: 65–85) vs. 52 years (IQI: 37–64), *p*-value <0.001].

The clinical presentation of COVID-19 symptomatology was also very different between patients with hypertension and normotensive patients, as shown in the following Table 2. Notably, hypertensive patients exhibited a higher prevalence of dyspnea (52.14% vs. 47.15%, *p*-value = 0.004) and altered awareness (14.89% vs. 4.30%, *p*-value <0.001).

1 http://www.wma.net/e/policy/b3.htm

2 http://www.ieaweb.org/GEP07.html

TABLE 2 Clinical symptomatology at hospital admission.

Symptoms	Hypertension		*p*-value
	No	Yes	
Fever	1,435 (71.68%)	999 (68.90%)	0.077
Headache	525 (26.25%)	141 (9.74%)	< 0.001
General discomfort	819 (40.91%)	603 (41.61%)	0.678
Myalgias	645 (32.30%)	273 (18.85%)	< 0.001
Rhinorrhea	136 (6.81%)	57 (3.94%)	< 0.001
Dysgeusia	345 (17.36%)	102 (7.05%)	< 0.001
Anosmia	355 (17.78%)	87 (6.02%)	< 0.001
Cough	1,275 (63.59%)	814 (56.14%)	< 0.001
Productive cough	258 (12.97%)	235 (16.36%)	0.005
Odynophagia	240 (12.02%)	67 (4.64%)	< 0.001
Thoracic pain	225 (11.26%)	114 (7.87%)	0.001
Chest pain	62 (3.10%)	32 (2.21%)	0.112
Hemoptysis expectoration	23 (1.15%)	17 (1.17%)	0.946
Dyspnea	944 (47.15%)	756 (52.14%)	0.004
Abdominal pain	106 (5.30%)	63 (4.35%)	0.204
Diarrhea	449 (22.43%)	319 (22.00%)	0.766
Nausea	187 (9.35%)	130 (8.98%)	0.714
Vomiting	162 (8.09%)	100 (6.90%)	0.191
Alteration of level awareness	86 (4.30%)	216 (14.89%)	< 0.001
Alteration of level behavior	22 (1.10%)	29 (2.00%)	0.030
Convulsion	2 (0.10%)	3 (0.31%)	0.415

Regarding the complications presented by patients with hypertension, we observed a significant difference in most of them. Acute Respiratory Syndrome by COVID-19, much more present in patients with HT (31.37% vs. 12.00%, p-value <0.001), pneumothorax (6.73% vs. 0.67%, p-value = 0.007), cardiac arrest (15.38% vs. 0.00%, p-value <0.001), acute confusional syndrome (29.81% vs. 4.67%, p-value <0.001), and clotting alteration or sharp failure as shown in Table 3. In addition, hypertensive patients have a higher in-hospital mortality rate than normotensive patients (Tables 4, 5).

Figure 1 shows the non-parametric Kaplan–Meier curve, which estimates the survival of patients in the two study groups. We can see how patients with hypertension have a higher associated mortality, with the difference being statistically significant, p-value (log-rank) = 0.004.

In the Cox regression model, we observed that chronic cardiac disease (HR = 1.70, 95% CI: 1.05–2.75), chronic kidney disease (HR = 2.08, 95% CI: 1.13–3.80), and arterial hypertension (HR = 1.67, 95% CI: 1.07–2.35) were associated with in-hospital mortality.

Finally, to conclude the analysis, we include the cost of managing complications. We have already seen that hypertensive patients have more complications compared to normotensive patients, and this increases the healthcare costs of these patients. Specifically, only for the appearance of complications during hospitalization, the group of hypertensive patients reached the figure of €1,355,901.71 compared to the total of €421,403.48 for normotensive patients. This difference in figures means that the cost of managing the complications observed in hypertensive patients is 3.2 times higher than in normotensive patients. However, there was no significant difference in hospital stay between the two groups.

Discussion

Our data show that the group of hypertensive patients studied are older and more frequently men. These two characteristics, male sex and advanced age, are considered as highly relevant conditions associated with a worse prognosis in the evolution of COVID-19. Furthermore, older age is related to higher incidence of comorbidities other than hypertension, such as diabetes, cardiovascular disease, cerebrovascular disease, or obesity, which also increase susceptibility to infection and worsen disease progression. Consequently, the impact of hypertension on COVID-19 is not well defined. However, findings of some studies suggest that hypertension alone may not increase the risk of infection and complications of COVID-19 including death (9).

Many studies show that the cost of managing hypertensive patients is double that of normotensive patients. Our studies are in line with the findings of Badia et al. (10) and it is important to establish an evaluation of interventions and services aimed at the management of hypertension with special emphasis on complications. Numerous studies, such as the analyses presented in *The Lancet* (11), focus on improvements in detection and treatment with the aim, precisely, of reducing prevalence through early diagnosis, thereby reducing complications, which our study has quantified. For example, obesity is an important aspect to take into account in the development of

TABLE 3 Incidence of complications during hospital stay.

Complications	Hypertension		*p*-value
	No	Yes	
Infections	25 (16.00%)	34 (32.69%)	0.002
Infections with microorganisms determined	14 (9.33%)	25 (24.04%)	0.001
Bacterial pneumonia	6 (4.00%)	13 (12.50%)	0.011
Acute respiratory syndrome	18 (12.00%)	33 (31.73%)	<0.001
Pneumothorax	1 (0.67%)	7 (6.73%)	0.007
Effusion pleural	2 (1.33%)	4 (3.85%)	0.195
Meningitis	0 (0.00%)	3 (2.88%)	0.036
Convulsions	0 (0.00%)	1 (0.96%)	0.229
Stroke	1 (0.67%)	2 (1.92%)	0.362
Congestive cardiac inflation	3 (2.00%)	4 (3.85%)	0.377
Myocarditis	0 (0.00%)	1 (0.96%)	0.229
Pericarditis	1 (0.67%)	0 (0.00%)	0.404
Endocarditis	0 (0.00%)	0 (0.00%)	NA
Arrhythmia	2 (1.33%)	8 (7.69%)	0.010
Cardiac ischemia	1 (0.67%)	1 (0.96%)	0.794
Cardiac arrest	0 (0.00%)	16 (15.38%)	< 0.001
Bacteremia	7 (4.67%)	13 (12.50%)	0.023
Clotting alteration	5 (3.33%)	20 (19.23%)	< 0.001
Anemia subsidiary	4 (2.67%)	6 (5.77%)	0.211
Rhabdomyolysis	2 (1.33%)	3 (2.88%)	0.381
Sharp failure	8 (5.33%)	38 (36.54%)	< 0.001
Pancreatitis	1 (0.67%)	0 (0.00%)	0.404
Hepatic failure	2 (1.33%)	6 (5.77%)	0.047
Acute confusional syndrome	7 (4.67%)	31 (29.81%)	< 0.001
Psychiatric complications	4 (2.67%)	4 (3.85%)	0.597
Adverse reaction drugs	13 (8.67%)	8 (7.69%)	0.782
Severe adverse drug reaction	1 (0.67%)	3 (2.88%)	0.163
Exitus	204 (10.52%)	438 (30.54%)	< 0.001
Hospital stays	11 (9–19)	10 (7–14)	0.296

*Median and interquartile range.

arterial hypertension. Different studies have quantified that, if managed at an aggregate level, the savings in healthcare costs would amount to between €1,859 and €1,926 per person, and the return on investment would be between 3.3 and 7.0%. (12)

However, if we take a global view of hypertension, we know precisely that several studies (13) reflect the comorbidity of patients with hypertension together with other pathologies, such as dyslipidemia, diabetes, ischemic heart disease, and even stroke, which is also reflected in our study when discussing associated comorbidities. Precisely in the field of stroke, hypertension is the main driver of cerebral small vessel disease (CSVD) leading to cognitive impairment and lacunar stroke (14). On the other hand, the COVID-19 pandemic has also highlighted the worse evolution of patients with COVID-19 and the associated costs (8). Precisely, the association between cardiovascular pathology and poor evolution of SARS-CoV-2 infection is striking in terms of costs. With respect to comorbidities and COVID-19 and its associated costs, studies published in different countries (14) show that hypertension, diabetes, cerebrovascular disease, and ischemic heart disease are markedly more frequent in patients who require critical care or die from COVID-19, establishing a causal link between an underlying pathology, such as hypertension, and other factors, such as myocardial dysfunction produced by SARS-CoV-2.

Continuing with myocardial dysfunction, special interest should alert us to the relationship between hypertension and heart failure. It is precisely in the development of left ventricular hypertrophy and consequently heart failure (15) that hypertension is a key factor, and early diagnosis and treatment are necessary. Hypertensive heart disease describes a spectrum of diseases ranging from uncontrolled hypertension to the final development of heart failure, being mainly among others, the triggering event of left ventricular hypertrophy a hypertensive heart disease, something that can be reversible if recognized early and treated

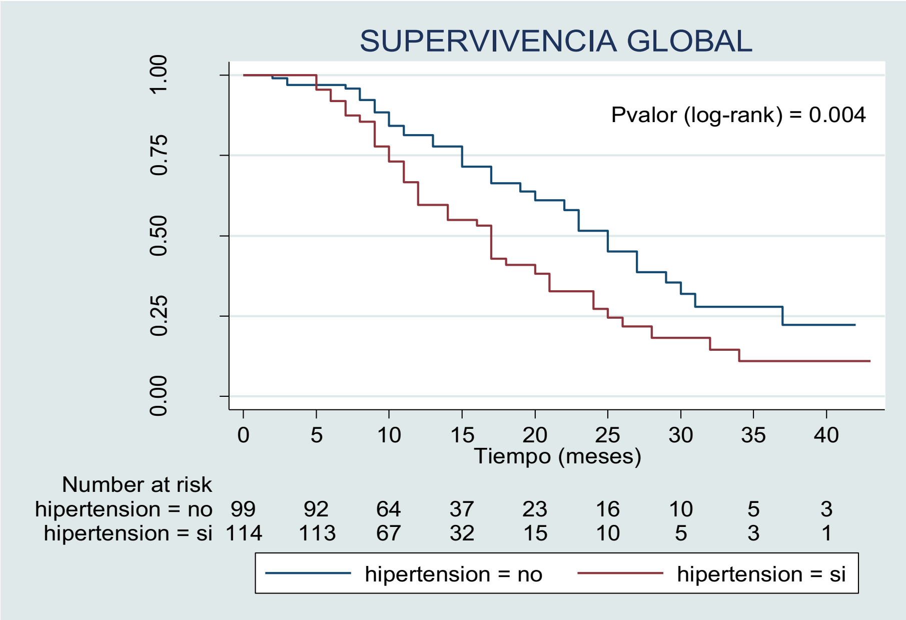


FIGURE 1
Kaplan–Meier estimator.

TABLE 4 Cox regression model to predict COVID-19 mortality.

	HR	*p*-value	CI (95%)	
			Lower	Superior
Chronic heart disease	1.70	0.030	1.05	2.75
Chronic renal disease	2.08	0.018	1.13	3.80
Hypertension	1.67	0.024	1.07	2.62

C – Harrell = 0.632. HR, hazard ratio; CI, confidence interval.

aggressively. Regarding heart failure, a study in the United States (16) found that the mean total cost ± SD was $13,807 ± 24,145, with mean total costs of $15,618 ± 25,264 for patients with 30-day readmission and $11,845 ± 22,710 for patients without readmission. These findings are consistent with our study, which also found both the higher costs associated with hypertension and readmission.

Another aspect to be addressed is the complications that end in fatal consequences. We have already mentioned the relationship between hypertension and stroke, stroke being a major public health problem and a problem that accounts for 10% of all deaths (17) Different studies (18, 19) established that approximately half of the patients analyzed had hypertension.

There are many factors to take into account when discussing hypertension and its associated costs. It has been well established that patients with hypertension have greater associated comorbidities, are admitted to hospital more often, and have higher morbidity and mortality rates.

Limitations

This study has limitations: first, inherent to the type of study, it cannot evaluate cause and effect relationships. Another limitation is that the study was a single-center study mainly due to the imminent need to know the evolution of the disease, and the costs in different autonomous communities or regions may vary. However, as they are public hospitals, the prices are usually subject to the Official State Gazette; therefore, we state that these variations are slight.

Finally, the creation of a specific The Electronic Data Collection Notebook (CRD) for the hospital itself and for this disease in particular means that we cannot compare it with other types of infections such as Influenza.

Conclusion

The results obtained provide evidence that tends to support our initial hypothesis that hypertensive patients admitted for SARS-CoV-2 respiratory infection would have a worse prognosis in terms of outcomes compared to normotensive patients, leading to higher healthcare costs for the hypertensive patient group. Our study shows the worse clinical evolution of patients with COVID-19 in terms of associated morbidity and mortality. It also shows that the cost of managing the complications observed in hypertensive patients is 3.2 times higher than in normotensive patients.

TABLE 5 Costs associated with the management of COVID-19 patients with and without hypertension.

Table of costs per person	Hypertension	
	No	Yes
Infections	65.070,25 €	88.495,54 €
Infections with microorganisms determined	853,86 €	1.524,75 €
Bacterial pneumonia	22.218,00 €	48.139,00 €
MRS	60.557,22 €	111.021,57 €
Pneumothorax	2.649,75 €	18.548,25 €
Effusion pleural	8.108,06 €	16.216,12 €
Meningitis	- €	6.684,00 €
Convulsions	- €	3.057,00 €
Stroke	3.572,34 €	7.144,68 €
Congestive cardiac inflation	8.670,00 €	11.560,00 €
Myocarditis	- €	3.214,00 €
Pericarditis	2.079,00 €	- €
Endocarditis	- €	- €
Arrhythmia	4.906,00 €	19.624,00 €
Cardiac ischemia	2.430,00 €	2.430,00 €
Cardiac arrest	- €	51.040,00 €
Bacteremia	19.299,00 €	35.841,00 €
Coagulation alteration	20.045,00 €	80.180,00 €
Anemia	15.852,00 €	23.778,00 €
Rhabdomyolysis	23.264,00 €	34.896,00 €
Sharp failure	25.384,00 €	120.574,00 €
Pancreatitis	9.807,00 €	- €
Hepatic failure	6.170,00 €	18.510,00 €
Acute confusional syndrome	39.627,00 €	175.491,00 €
Psychiatric compliances	29.536,00 €	29.536,00 €
Adverse reaction drugs	45.500,00 €	28.000,00 €
Severed adverse drug reaction	5.805,00 €	17.415,00 €
Hypertension		402.981,80 €
TOTAL COMPLICATIONS	421.403,48 €	1.355.901,71 €
Cost of hospital stay	7.491,00 €	6.810,00 €
Total patient management	428.894,48 €	1.362.711,71 €
Total handling per person	202,02 €	934,64 €

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by the Clinical Research Ethics Commitee of LPUH, Madrid, with LPUH code: PI-4155. The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation was not required from the participants or the participants' legal guardians/next of kin in accordance with the national legislation and institutional requirements.

Author contributions

JC-M: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Software, Validation, Writing – original draft, Writing – review & editing. MD-R: Investigation, Project administration, Resources, Validation, Visualization, Writing – original draft, Writing – review & editing. RJ-V: Funding acquisition, Methodology, Project administration, Resources, Visualization, Writing – original draft, Writing – review & editing. CT-G: Validation, Visualization, Writing – original draft. RV-H: Funding acquisition, Methodology, Writing – original draft, Writing – review &

editing. AB-E: Funding acquisition, Project administration, Writing – original draft. PS-C: Investigation, Supervision, Validation, Writing – original draft. VA-F: Data curation, Investigation, Validation, Writing – original draft. VG-C: Data curation, Writing – original draft. JS-S: Writing – original draft, Investigation. MQ-D: Project administration, Supervision, Writing – original draft, Writing – review & editing. EA-E: Data curation, Formal analysis, Investigation, Methodology, Project administration, Software, Supervision, Validation, Writing – original draft, Writing – review & editing.

Funding

The author(s) declare that no financial support was received for the research, authorship, and/or publication of this article.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

References

1. Schiffrin EL, Flack JM, Ito S, Muntner P, Webb RC. Hypertension and COVID-19. *Am J Hypertens*. (2020) 33:373–4. doi: 10.1093/ajh/hpaa057

2. Wang D, Hu B, Hu C, Zhu F, Liu X, Zhang J, et al. Clinical characteristics of 138 hospitalized patients with 2019 novel coronavirus–infected pneumonia in Wuhan, China. *JAMA*. (2020) 323:1061–9. doi: 10.1001/jama.2020.1585

3. Zhang J-J, Dong X, Cao Y-Y, Yuan Y-D, Yang Y-B, Yan Y-Q, et al. Clinical characteristics of 140 patients infected with SARS-CoV-2 in Wuhan, China. *Allergy*. (2020) 75:1730–41. doi: 10.1111/all.14238

4. Zhou F, Yu T, Du R, Fan G, Liu Y, Liu Z, et al. Clinical course and risk factors for mortality of adult inpatients with COVID-19 in Wuhan, China: a retrospective cohort study. *Lancet*. (2020) 395:1054–62. doi: 10.1016/S0140-6736(20)30566-3

5. Guan W-J, Ni Z, Hu Y, Liang W, Ou C-Q, He J, et al. Clinical characteristics of coronavirus disease 2019 in China. *N Engl J Med*. (2020) 382:1708–20. doi: 10.1056/NEJMoa2002032

6. Onder G, Rezza G, Brusaferro S. Case-fatality rate and characteristics of patients dying in relation to COVID-19 in Italy. *JAMA*. (2020) 323:1775–6. doi: 10.1001/jama.2020.4683

7. Boscá JE, Doménech R, Ferri J, García JR. Shifts in the beveridge curve in Spain and their macroeconomic effects. *Revista de Economía Aplicada*. (2017) 25:5–27.

8. Calderón-Moreno J, Juárez-Vela R, Delgado-Rodríguez MJ, Quintana-Díaz M, Magallón-Botaya R, Olivan-Blázquez B, et al. Approximation to the consumption of healthcare resources and the economic cost of SARS-CoV-2 patient management: a retrospective study. *Front Public Health*. (2022) 10:751. doi: 10.3389/fpubh.2022.843751

9. Gallo G, Calvez V, Savoia C. Hypertension and COVID-19: current evidence and perspectives. *High Blood Press Cardiovasc Prev*. (2022) 29:115–23. doi: 10.1007/s40292-022-00506-9

10. Badía X, Rovira J, Tresserras R, Trinxet C, Segú JL, Pardell H. The cost of arterial hypertension in Spain. *Med Clin (Barc)*. (1992) 99:769–73.

11. NCD Risk Factor Collaboration (NCD-RisC). Worldwide trends in hypertension prevalence and progress in treatment and control from 1990 to 2019: a pooled analysis of 1201 population-representative studies with 104 million participants. *Lancet*. (2021) 398:957–80. doi: 10.1016/S0140-6736(21)01330-1

12. Drozdz D, Alvarez-Pitti J, Wójcik M, Borghi C, Gabbianelli R, Mazur A, et al. Obesity and Cardiometabolic risk factors: from childhood to adulthood. *Nutrients*. (2021) 13:4176. doi: 10.3390/nu13114176

13. Lee JH, Kim KI, Cho MC. Current status and therapeutic considerations of hypertension in the elderly. *Korean J Intern Med*. (2019) 34:687–95. doi: 10.3904/kjim.2019.196

14. Salazar M, Barochiner J, Espeche W, Ennis I. COVID-19, hipertensión y enfermedad cardiovascular [COVID-19 and its relationship with hypertension and cardiovascular disease]. *Hipertens Riesgo Vasc*. (2020) 37:176–80. doi: 10.1016/j.hipert.2020.06.003

15. Slivnick J, Lampert BC. Hypertension and heart failure. *Heart Fail Clin*. (2019) 15:531–41. doi: 10.1016/j.hfc.2019.06.007

16. Kwok CS, Abramov D, Parwani P, Ghosh RK, Kittleson M, Ahmad FZ, et al. Cost of inpatient heart failure care and 30-day readmissions in the United States. *Int J Cardiol*. (2021) 329:115–22. doi: 10.1016/j.ijcard.2020.12.020

17. Mozaffarian D, Benjamin EJ, Go AS, Arnett DK, Blaha MJ, Cushman M, et al. Heart disease and stroke statistics-2015 update: a report from the American Heart Association. *Circulation*. (2015) 131:e29–e322. doi: 10.1161/CIR.0000000000000152

18. Holloway RG, Benesch CG, Burgin WS, Zentner JB. Prognosis and decision making in severe stroke. *JAMA*. (2005) 294:725–33. doi: 10.1001/jama.294.6.725

19. Roch A, Michelet P, Jullien AC, Thirion X, Bregeon F, Papazian L, et al. Long-term outcome in intensive care unit survivors after mechanical ventilation for intracerebral hemorrhage. *Crit Care Med*. (2003) 31:2651–6. doi: 10.1097/01.CCM.0000094222.57803.B4

frontiers | Frontiers in Public Health

TYPE Original Research
PUBLISHED 10 April 2024
DOI 10.3389/fpubh.2024.1384122

Check for updates

OPEN ACCESS

EDITED BY
Hai Fang,
Peking University, China

REVIEWED BY
Renata Šmit,
Goethe University, Germany
Eduardo Fernandez,
University of Salamanca, Spain

*CORRESPONDENCE
João P. Martins
✉ jom@ess.ipp.pt

RECEIVED 08 February 2024
ACCEPTED 20 March 2024
PUBLISHED 10 April 2024

CITATION
Torres M, Nunes A, Martins JP, Ferreira PL and Pimenta R (2024) Health care expenses impact on the disability-adjusted life years in non-communicable diseases in the European Union.
Front. Public Health 12:1384122.
doi: 10.3389/fpubh.2024.1384122

Health care expenses impact on the disability-adjusted life years in non-communicable diseases in the European Union

Margarida Torres[1], Alcina Nunes[2], João P. Martins[1,3,4]*, Pedro L. Ferreira[4,5] and Rui Pimenta[1,4]

[1]Escola Superior de Saúde, Instituto Politécnico do Porto, Rua Dr. António Bernardino de Almeida, Porto, Portugal, [2]UNIAG, Instituto Politécnico de Bragança, Bragança, Portugal, [3]CEAUL – Centro de Estatística e Aplicações, Faculdade de Ciências, Universidade de Lisboa, Lisbon, Portugal, [4]Centre for Health Studies and Research of University of Coimbra, Centre for Innovative Biomedicine and Biotechnology, Coimbra, Portugal, [5]Faculty of Economics, University of Coimbra, Coimbra, Portugal

Background: Non-communicable diseases are a global health problem. The metric Disability-Adjusted Life Years was developed to measure its impact on health systems. This metric makes it possible to understand a disease's burden, towards defining healthcare policies. This research analysed the effect of healthcare expenditures in the evolution of disability-adjusted life years for non-communicable diseases in the European Union between 2000 and 2019.

Methods: Data were collected for all 27 European Union countries from Global Burden of Disease 2019, Global Health Expenditure, and EUROSTAT databases. Econometric panel data models were used to assess the impact of healthcare expenses on the disability-adjusted life years. Only models with a coefficient of determination equal to or higher than 10% were analysed.

Results: There was a decrease in the non-communicable diseases with the highest disability-adjusted life years: cardiovascular diseases (–2,952 years/10^5 inhabitants) and neoplasms (–618 years/10^5 inhabitants). Health expenditure significantly decreased disability-adjusted life years for all analysed diseases ($p < 0.01$) unless for musculoskeletal disorders. Private health expenditure did not show a significant effect on neurological and musculoskeletal disorders ($p > 0.05$) whereas public health expenditure did not significantly influence skin and subcutaneous diseases ($p > 0.05$).

Conclusion: Health expenditure have proved to be effective in the reduction of several diseases. However, some categories such as musculoskeletal and mental disorders must be a priority for health policies in the future since, despite their low mortality, they can present high morbidity and disability.

KEYWORDS

health expenditure, health policy, disease burden, panel data, chronic diseases, public health expenditure, private health expenditure

Introduction

Burden disease is defined as the difference between a population's current state of health and the optimal state of health, where the whole population achieves a full life without suffering a major illness (1).

There are several methodologies to quantify the burden of disease. However, to be able to compare between countries, the most used measure is the Disability Adjusted Life Years (DALY) which is equal to the sum of years of life lost due to premature death (YLL) and years lived with disability (YLD) (2–4). Thus,

$$DALY = YLL + YLD \quad (1)$$

This work focuses on non-communicable diseases (NCD), known as chronic diseases, which tend to result from a combination of genetic, physiological, environmental, and behavioural factors (5, 6). According to the World Health Organization (WHO), their impact increased from 61% of global deaths in 2000 to 74% in 2019, causing 63% of DALYs in that year (compared to 47% in 2000). In Europe, NCD affects life expectancy and is responsible for 77% of the total disease burden (5, 7). The literature points to a more significant burden of cardiovascular diseases, neoplasms, chronic respiratory diseases (such as Chronic obstructive pulmonary disease and Asthma) and diabetes within NCD, accounting for more than 33 million deaths in 2019 (an increase of 28% compared to the year 2000), with at least 80% of all heart attacks, diabetes and strokes, and 40% of cancers could be prevented by monitoring the main risk factors - tobacco, alcohol, poor diet, physical inactivity and environmental factors (5, 6, 8).

NCDs were included in the WHO agenda for Sustainable Development 2030, with the goal of reducing the probability of death resulting from the four main diseases by one-third, for ages between 30 and 70 years, by 2030 (6). Moreover, the European Commission launched the *Healthier Together—EU Non-Communicable Diseases* initiative as a way of helping European Union (EU) countries to achieve that goal through the identification and implementation of effective policies and actions to reduce the burden of the NCD, which shows the topicality of this topic (7).

The economic consequences of NCDs significantly impact health care and decrease productivity. NCDs are the most significant cause of health expenditure (2).

Global Health Expenditure Database (GHED) is the largest international expense comparison database across almost 190 countries since its inception in 2000 (9). It includes financing source indicators such as current healthcare expenses (CHE), domestic general government health expenditures (GGHE-D), and domestic private expenditures (PVT-D), which include household out-of-pocket payments (OOP) (9). EU health systems vary in organisation and financing as their governance relies mainly on national legislation. However, ensuring universal access and delivering high-quality care at an affordable price for all citizens are recognised as essential societal needs as they are fundamental values and principles within the EU (10).

Therefore, the growing population ageing and the subsequent rise in demand for healthcare services present a significant challenge to the health economy (11, 12). Healthcare expenditures are a significant part of the national budgets of the EU countries. In 2020, it was equivalent to approximately 11% of the gross domestic product (13, 14). As disability becomes a large component of disease burden, it represents a high component of health expenditure and, in addition, there is also a loss of productivity and labour (7, 11).

It becomes crucial to anticipate trends and formulate adequate policies (11, 12). Thus, policymakers need to recognise the significance of DALYs as they reflect the disease burden that healthcare systems must effectively address. This highlights the importance of assessing the effect of these expenses in improving the health of EU citizens (15, 16). Healthcare expenditure is not the sole determinant of health outcomes such as DALYs. However, it plays a significant role in the accessibility, quality, and effectiveness of healthcare services, all of which ultimately influence population health outcomes. Thus, this research has two aims: to analyse the evolution of DALYs in NCDs and the health expenditures in the EU, and to evaluate the effect of health expenditures on the evolution of DALYs in NCDs.

Methods

Databases and variables

A multinational retrospective longitudinal study was performed. Data were collected for all 27 EU countries for the period 2000 to 2019, from 3 databases:

- Global Burden of Disease (GBD) 2019 for YLL and YLD and therefore for DALY, as described by Equation 1, related to communicable, maternal, neonatal and nutritional diseases (CMND), injuries (INJU), NCD and each NCD;
- GHED for health expenditure data;
- EUROSTAT database for population data (17).

Detailed descriptions of the health expenditure variables can be found in Supplementary Table S1.

The collected YLL, YLD and DALY values were adjusted for a standardised age and for both sexes.

Statistical analysis

Data treatment was performed using STATA® (version 14.2) and Microsoft Excel® 365. First, an exploratory data analysis was carried out which included a weighted average of DALY and YLD, and some graphical representations. For a better analysis of expenditures within the private sector, private expenditure (E_{Prv}) was generated by the difference between PVT-D and the out-of-pocket expenditure (E_{OOP}), and, for uniformity in the reading of the results, a logarithmization of the DALYs referring to each NCD was carried out in STATA®.

Secondly, a econometric panel data models were used to assess the impact of healthcare expenses on DALYs, through cross-sections (analysis of between countries in a given year) and chronological sequences (analysis of a country over the years). To avoid collinearity issues, the analysis was performed in two steps: the first step consisted in the analysis of fixed effects (FE) and random effects (RE) models for the DALYs of a NCD for country i at time t ($DALY_{it}$) with the total of health expenditures (E_{Tot}) as the single covariate. The FE model can be described by Equation 2,

$$DALY_{it} = \beta_0 + \beta_1 \times E_{\text{Tot}_{it}} + \mu_i + \varepsilon_{it} \tag{2}$$

Where β_0 is a constant, β_1 is the coefficient of the independent variable, μ_i are the country-specific effects that are assumed constant over time and verify $\sum_i \mu_i = 0$, and ε_{it} are the normal error terms. The RE model is given by Equation 3,

$$DALY_{it} = \beta_0 + \beta_1 \times E_{\text{Tot}_{it}} + \alpha_i + \varepsilon_{it} \tag{3}$$

Where α_i stand for the country-specific effects that are now assumed to be normal random variables with null mean and equal variance, and ϵ_{it} are the normal error terms.

The second step was to consider as explanatory variables all possible combinations between E_{Pub}, E_{Prv} and E_{OOP}. Both FE and RE models were considered.

The option between the FE and RE models was based on the result of the Hausman test for a significance level of 5%. The BIC (Bayesian information criterion) was also used to obtain a parsimonious selection of independent variables (18–21). Only models with an overall coefficient of determination equal to or higher than 10% were analysed (22).

Results

Evolution of DALYs

The evolution of DALYs for NCD, CMND and INJ in the EU from 2000 to 2019 is detailed in Figure 1. The burden of NCDs is significantly higher than the burden of CMND or INJU since the minimum for NCDs (16,800 years per 10^5 inhabitants in 2019) is more than five times greater than the maximum number of injuries (3350.28 years per 10^5 inhabitants in 2018) and about ten times greater than the CMND maximum (1719 years per 10^5 inhabitants in 2009).

Despite the tendency to maintain DALYs, the percentage of these due to YLD has changed. While the CMND and INJU had a decrease in the rate of YLD within the DALYs (50.14 to 38.85% and 49.28 to 37.64%, respectively), the NCDs show an increase in the burden of YLD within DALYs, rising from 41.45 to 54.46% (Figure 2).

When analysing the evolution of DALYs within NCDs (Figure 3), cardiovascular diseases presented the highest DALY values within NCDs. During the period under review, these diseases had a positive evolution with a decrease over time (maximum 5,502 years per 10^5 inhabitants in 2002, and minimum 2,189 years per 10^5 inhabitants in 2019).

Neoplasms were the second most impactful NCD, with recorded values exceeding 4,000 years per 10^5 inhabitants during the initial three years under analysis, and in subsequent years these values consistently remained below that threshold.

Musculoskeletal and mental disorders and other NCDs change their position in terms of rank over time. However, all showed increasing values of DALYs. In 2019, mental disorders were the third NCD, followed by musculoskeletal disorders and other NCDs.

Neurological disorders is the sixth NCD with the most significant effect, with the lowest values in the first three years under analysis. The two highest records are found in the last decade (1,443 years per 10^5 inhabitants in 2012 and 1,438 years per 10^5 inhabitants in 2019), which indicates an upward trend.

Conversely, there has been a notable downward trend in the percentage of YLD (Figure 4) in diabetes and kidney diseases (maximum of 65.10% in 2000 and minimum 47.58% in 2019) and substance use disorders (maximum of 79.12% in 2003 and minimum 52.41% in 2010), while chronic respiratory diseases follow an increase in the percentage of YLD (minimum 41.43% in 2000 and maximum 57.22% in 2019). When analysing the variation in the rate of YLD between 2000 and 2019, these same diseases were the only ones with changes exceeding five percentual points.

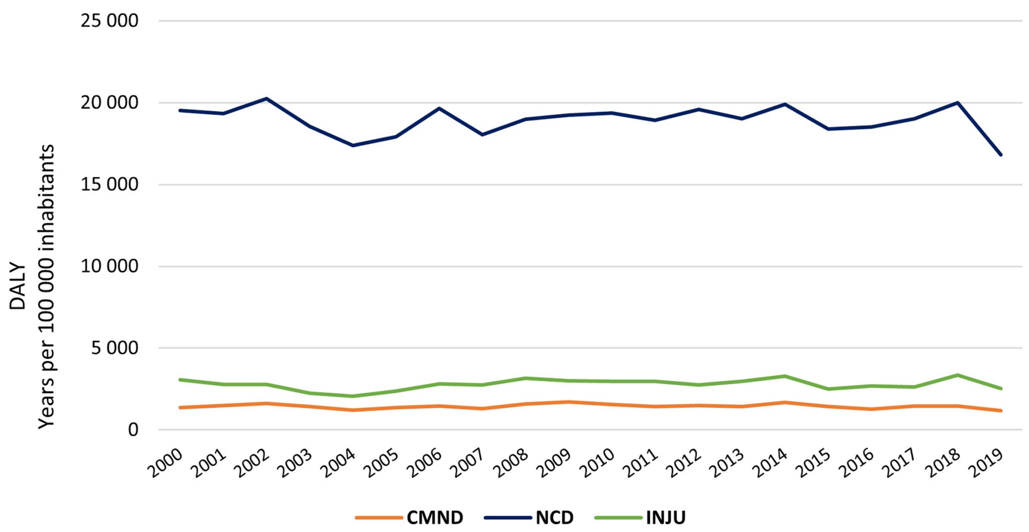


FIGURE 1
Evolution of DALYs for DNC, CMND and INJ in the EU from 2000 to 2019; CMND, communicable, maternal, neonatal and nutritional diseases; NCD, non-communicable diseases; INJU, injuries.

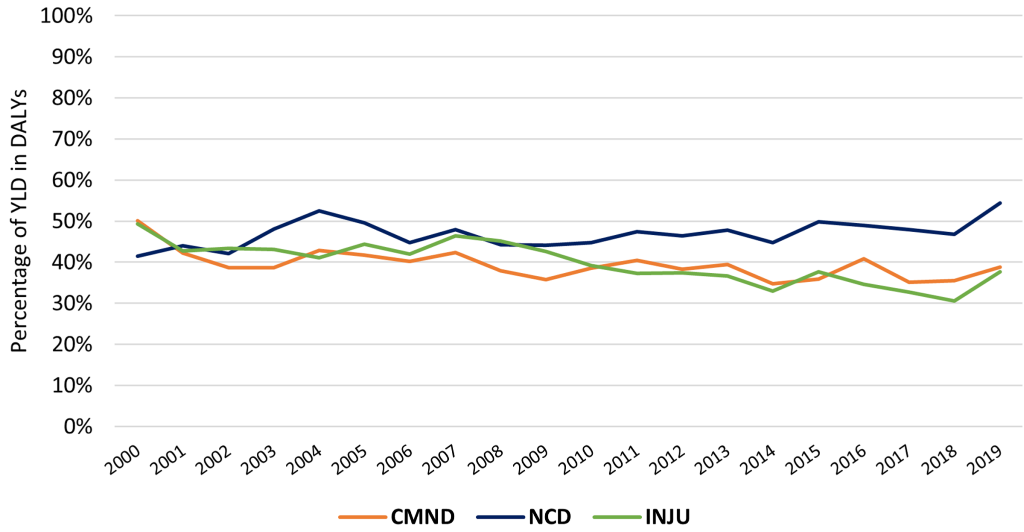


FIGURE 2
Evolution of the YLD percentage in DALYs for DNC, CMND and INJ in the EU from 2000 to 2019; CMND, communicable, maternal, neonatal and nutritional diseases; NCD, non-communicable diseases; INJU, injuries.

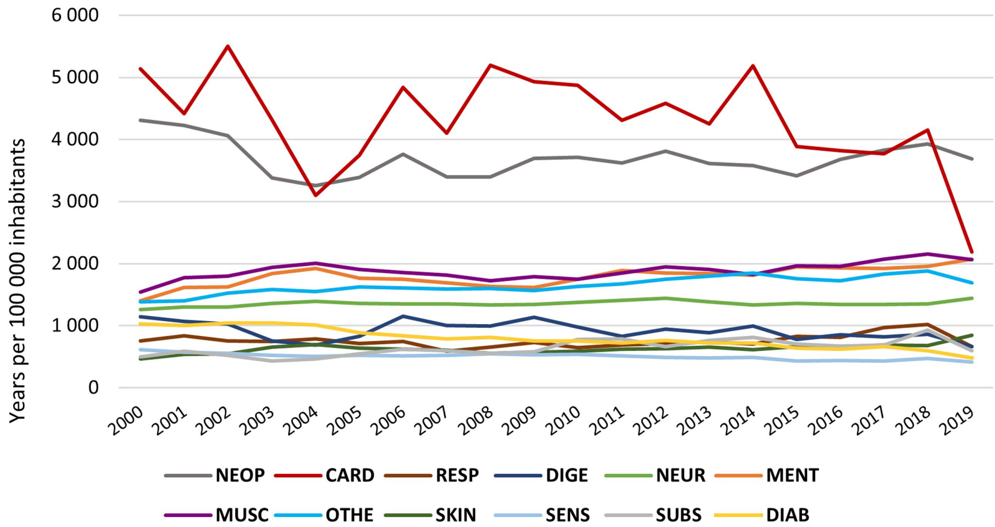


FIGURE 3
DALY's evolution by NCD in the EU from 2000 to 2019; NEO- neoplasm; CARD, cardiovascular disease; Resp., chronic respiratory disease; DIGE, digestive disease; NEUR, neurological disorders; MENT, mental disorders; MUSC, musculoskeletal disorders; OTHE, other non-communicable disease; SKIN, skin and subcutaneous disease; SENS, sense organ disease; SUBS, substance use disorders; DIAB, diabetes and kidney disease.

Health expenditures

The total of health expenditures (E_{Tot}), public and private, has increased since 2000 (6.90% of GDP), reaching the maximum value in 2009 (8.47% of GDP) and remaining above 8.00% until the end of the study period (cf. Figure 5). The maximum expenditure occurred in 2019 in Germany (11.70% of GDP), while the minimum was in 2000 in Romania (4.21% of GDP).

Public expenditure (E_{Pub}) was the E_{Tot} component with the most significant impact on health, its evolution over time was similar to the total growth. Thus, E_{Pub} attained its minimum in 2000 (5.04% of GDP) and its maximum in 2009 (6.18% of GDP), maintaining approximately 6.00% of expenditure afterwards. When examining the data by country (Figure 6), significant variations in values were observed. Sweden, the country with the highest E_{Pub}, presented an expenditure of 9.28% of GDP in 2018 which is three times higher than Cyprus in the same period (2.88% of GDP in 2018).

On the other hand, private sector expenditures (Private expenditure (E_{Prv}) and out-of-pocket expenditure (E_{OOP})), had a similar evolution over time. On average, both types of expenditure reached their minimum recorded at the beginning of the period under study, although the maximum of E_{Prv} occurred in 2019 (0.60% of GDP) and of E_{OOP} in 2014 (1.78% of GDP). By country, the Netherlands had the highest E_{Prv} in 2017 (2.49% of GDP), while for

E_{OOP}, Bulgaria had the highest in 2012 (3.60% of GDP). The countries with the lowest E_{Prv} and E_{OOP} were, respectively, Slovakia in 2004 (0.003% of GDP) and Luxembourg in 2019 (0.52% of GDP).

In short, all health expenditures have an upward trend with stabilisation in the last decade. By analysing the typology of health expenditure (Figure 6), it is possible to observe that Cyprus was the only EU country with an E_{Pub} mean lower than 50% of E_{Tot} (being 46.27% of these expenditures by E_{OOP}), followed by Bulgaria and Latvia with ana E_{OOP} higher than 40%. Most countries have an E_{Prv} and E_{OOP} lower than 30% (17 countries), thus there is a higher expenditure on health by public agencies. E_{OOP} represent more than 50% of non-public expenditure in most countries, with a median of almost 20% of E_{Tot}. France (9.15%), Netherlands (10.16%) and Luxembourg (11.65%) have the lowest percentages of E_{OOP}.

Panel data models

The panel data models were found to model the evolution of the DALYs of each NCD with E_{Tot}, as the only explanatory variables are detailed in Supplementary Table S2. Four of the NCDs presented a low overall r^2 (chronic respiratory disease, substance use disorders, diabetes and kidney disease and other non-communicable disease). Mental disorders despite an overall r^2 of more than 30%, did not present statistically significant for E_{Tot}. As for the other NCDs, all had a significant favourable evolution, except for musculoskeletal disorders, where, according to the fitted model, a 1% increase in E_{Tot} increased DALYs by 0.26%. The evolution was especially favourable in cardiovascular and digestive diseases.

To determine the effect of the expenditures E_{Pub}, E_{Prv} and E_{OOP} on the evolution of the DALYs of each NCD, panel data models were fitted for every combination of the explanatory variables. The most parsimonious model, according to the BIC criteria, was chosen and its parameters are presented in Table 1 (results for diseases with an overall r^2 less than 10% were omitted). Supplementary Table S3 shows the complete results.

Public health expenditure has a significant effect on all NCDs except for skin and subcutaneous diseases. However, in musculoskeletal disorders, the increase in public expenditure does not have a positive impact on DALYs (a 1% increase in E_{Pub} increases its DALYs by 0.32%).

Upon analysing both the private and public sector expenses, it becomes clear that these expenses have a significant impact on NCDs, with cardiovascular diseases showing the coefficients with the greatest improvements for E_{Pub} (10.37%), E_{Prv} (45.32%) and E_{OOP} (18.54%). Comparing the types of expenditure, the impact of the increase in private sector expenditure (E_{Prv} and E_{OOP}), in percentage terms, always showed an expected variation greater than that of E_{Pub}, in all models.

Discussion

Evolution of DALYs

In this study, we assessed trends in DALYs and health expenditure across the 27 EU countries over 20 years (2000–2019), and analysed the effect of health expenditure in the DALYs evolution.

According to GBD 2019 Diseases and Injuries Collaborators (2020), with the increase in the sociodemographic index, there is an inversion of the burden from CMND to NCDs, where the contribution of YLD to DALYs becomes greater. This research also observed that NCDs present a more significant burden for health systems compared to CMND and injuries, as well as the trend of increasing disability, measured by YLD, for these diseases.

Despite the higher burden of NCDs, there was a maintenance of DALYs in the EU over time, through a downward trend in diseases such as cardiovascular and neoplasms and an upward trend for musculoskeletal and mental disorders. Daroudi et al. also observed a maintenance of DALYs for NCDs between 2000 and 2016 (worldwide), while Liu et al. observed a downward trend worldwide in DALYs for musculoskeletal disorders between 1990 and 2019 (23).

The drop of more than 1900 years per 10^5 inhabitants in cardiovascular diseases in 2019 should be carefully analysed since the mean in 2018 is lower than the three lower minimum values found for the same variable over the period analysed. This fall needs further studies and analysis in subsequent years.

Regarding the contribution of the YLD in the evolution of the DALYs, the NCDs have shown different performances. DALYs

TABLE 1 Most parsimonious panel data model for NCD DALYs by E_{Pub}, E_{Prv}, E_{OOP}.

	NEO	CARD	DIGE	NEUR	MUSC	SKIN	SENS
PDM	RE*	FE*	RE*	FE*	FE*	FE*	FE*
E_{Pub}[a]	−2.99%* (−4.03,-1.95)	−10.37%* (−12.70,-8.05)	−4.35%* (−6.00,-2.69)	−0.34%* (−0.51,-0.16)	0.32%* (0.19,0.45)		−0.33%* (−0.47,0.20)
E_{Prv}[a]	−7.14%* (−10.84,3.44)	−45.32%* (−53.75,-36.88)	−23.05%* (−29.01,-17.09)			−0.70%* (−1.01,-0.39)	−1.90%* (−2.40,1.41)
E_{OOP}[a]	−6.25%* (−9.10,3.40)	−18.54%* (−25.14,-11.94)	−7.08%* (−11.70,-2.45)			−0.59%* (−0.82,-0.36)	−0.95%* (−1.34,-0.56)
Overall r^2	13.83%	46.82%	28.32%	18.05%	25.52%	13.31%	29.10%

PDM, Panel data model; E_{Pub}, Public expenditure on health; E_{Prv}, Private health expenditure without out-of-pocket payments; E_{OOP}, Private health expenditure in the form of out-of-pocket payments; RE, random effects model; FE, fixed effects model; NEO, neoplasm; CARD, Cardiovascular disease; DIGE, digestive disease; NEUR, neurological disorders; MUSC, Musculoskeletal disorders; SKIN, skin and subcutaneous disease; SENS, Sense organ disease; *Significant at a 1% level; [a]coefficient obtained in the most parsimonious panel data model according to the BIC criterion; 95% confidence intervals are presented in brackets.

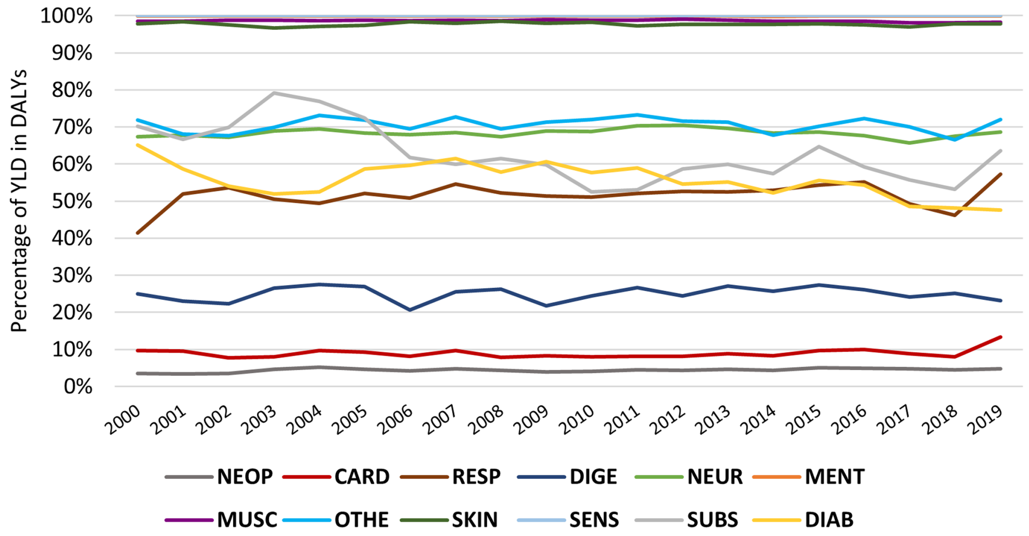


FIGURE 4
Evolution of YLD within DALYs by NCD in the EU from 2000 to 2019; NEO, neoplasm; CARD, cardiovascular disease; Respiratory chronic respiratory disease; DIGE, digestive disease; NEUR, neurological disorders; MENT, mental disorders; MUSC, musculoskeletal disorders; OTHE, other non-communicable disease; SKIN, skin and subcutaneous disease; SENS, sense organ disease; SUBS, substance use disorders; DIAB, diabetes and kidney disease.

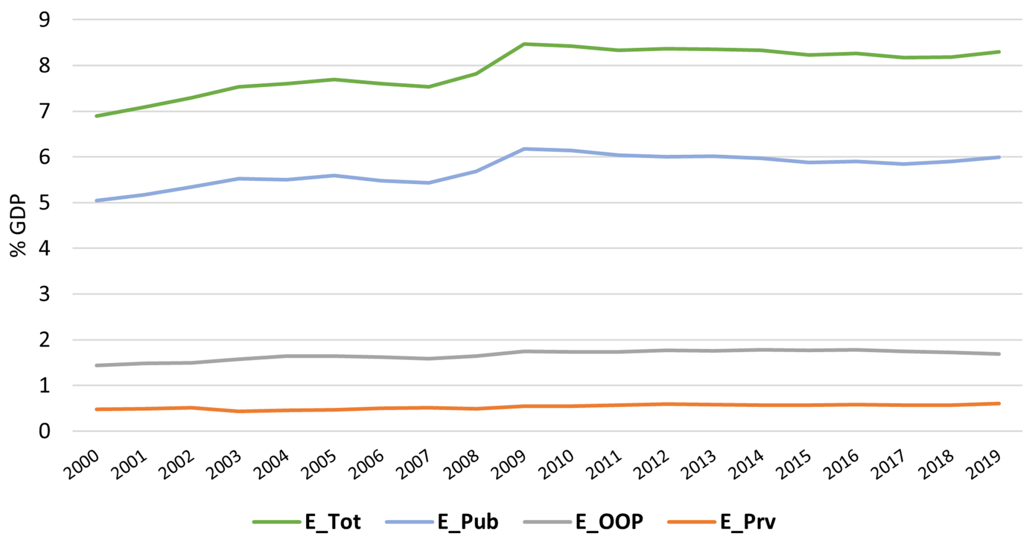


FIGURE 5
Evolution of Health Expenditure in the EU from 2000 to 2019; E_Tot, Total Health Expenditure; E_Pub, Public expenditure on health; E_Prv, Private health expenditure without out-of-pocket payments; E_OOP, Private health expenditure in the form of out-of-pocket payment.

concerning cardiovascular, digestive, and sensory organ diseases decreased, and the YLD percentage remained similar over time. DALYs due to diabetes and kidney disease fell, but the YLL percentage increased. On the other hand, skin and subcutaneous diseases, chronic respiratory diseases, other NCDs and neurological, musculoskeletal and mental disorders had a trajectory of increased DALYs with YLD percentage showing low variation. However, disorders due to substance use increased DALYs and decreased the YLD percentage. Thus, most NCDs maintain the percentage of DALYs components over time, except for diabetes and kidney disease and disorders due to substance use, where there is an increase in premature deaths, and chronic respiratory diseases, with an increase in disability. Moreover, in the study by GBD 2019 Diseases and Injuries Collaborators, worldwide, an increase in YLL for disorders due to substance use was observed, justified by the inadequate prescription of opiates or fentanyl abuse. On the other hand, Kotwas et al., in a study in central Europe, observed an increase in DALYs for type 2 diabetes mellitus with an increase in YLDs (24).

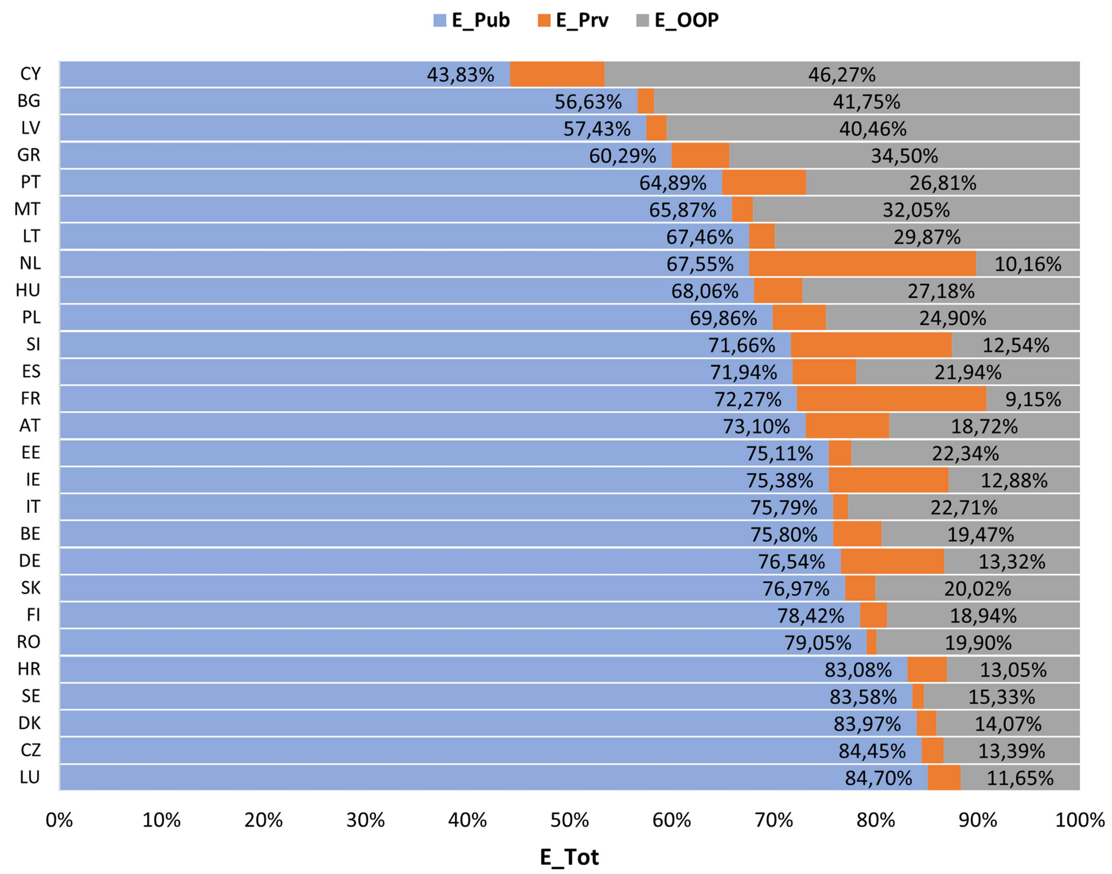


FIGURE 6
Percentage ratio of public, private and OOP expenditures within total health expenditures by country. *E_Pub* - Public expenditure on health; E_Prv, Private health expenditure without out-of-pocket payments; E_OOP, Private health expenditure in the form of out-of-pocket payments; E_Tot, Total health expenditure; Germany (DE), Austria (AT), Belgium (BE), Bulgaria (BG), Czechia (CZ), Cyprus (CY), Croatia (HR), Denmark (DK), Spain (ES), Slovakia (SK), Slovenia (SI), Estonia (EE), Finland (FI), France (FR), Greece (GR), Hungary (HU), Ireland (IE), Italy (IT), Latvia (LV), Lithuania (LT), Luxembourg (LU), Malta (MT), Netherlands (NL), Poland (PL), Portugal (PT), Romania (RO) and Sweden (SE).

Healthcare expenditures policies in the EU

EU adhere to the principle of universal access to healthcare, which is achieved through compulsory funding for the public sector, and there is no country in the EU (and very few worldwide) in which the private sector is the only source of access to health (25). Therefore, in this study, all EU countries financed their health systems through the public and private sectors, where, on average, there was an upward trend in all types of expenditure over time, with E_{Pub} being the ones that most contribute to E_{Tot}, followed by E_{OOP} and E_{Prv}. Note that Cyprus was the only country with a E_{Pub} component below 50%, as in WHO et al., being the value justified by the inability of the Cypriot health system to cover 10% of the population, motivating a significant reform in the health system in 2019 (26).

Thus, public entities were the major funders of health systems in EU countries, reaching over 80% in Croatia, Sweden, Denmark, Czechia and Luxembourg.

Figure 5 shows a sudden increase in health expenditure in 2009. This increase, as described by OECD & European Commission (2020), is due to a contraction in GDP due to the 2008 financial crisis and not to increased funding for health.

Both this study and WHO et al. observed a higher burden with E_{OOP} compared to E_{Prv} , except in France, Slovenia and the Netherlands. These results may be due to its quick access, the provider's choice or better facilities provided by the private system. However, it also shows a deficit in the articulation of health subsystems and the private sector, since E_{OOP} are borne directly by users, withdrawing income or savings from households. In the EU, on average, 1/5 of total health expenditure is paid out-of-pocket, mainly for pharmaceutical, dental and other long-term healthcare services (26).

The effect of health expenditures on DALYs

The NCDs received, until 2019, a residual investment, mainly compared to the expenses in diseases such as AIDS, tuberculosis, malaria and neonatal, child and maternal health (27). However, it is estimated that a 1% increase in per capita health expenditure reduces DALYs for all causes by 0.24%, and in countries with a high development index [as in the 27 EU countries (28)] the decrease in DALYs reaches 0.27% (29). This highlights the importance of analysing the impact of the health expenditure (30) in the DALYs for each category of disease as its potential benefit has been previously reported in other studies (31, 32). Our findings suggest that benefits regarding neoplasms, cardiovascular and digestive diseases are significantly higher than the estimated benefit of 0.27%, for all causes, estimated by Daroudi et al.

Most health expenditures are related to public organisations, reflecting fewer changes in DALYs compared to the private sector. All increases in E_{Prv} and/or E_{OOP} decrease the DALYs of NCDs, while the increase in E_{Pub} always shows less significant improvements compared to the private sector or even the increase in DALYs (as for musculoskeletal disorders). On the other hand, despite E_{OOP}, in most countries, being responsible for more than 50% of expenditures in the private sector, the health outcomes for increasing these expenditures are always lower than the results with increasing E_{Prv}.

Neurological disorders increased DALYs over time, however, only E_{Pub} significantly contributed to the decrease in their impact. Thus, a deeper private sector involvement should be considered in the future. Conversely, skin and subcutaneous diseases presented an increase in their DALYs and its evolution was only influenced by the private sector. A bigger contribution from the public sector would be important to face this increase.

Cardiovascular diseases showed the most significant effect on health systems through DALYs and simultaneously had the most favourable evolution when there was a 1% increase - in any health expenditure type - translating into a decrease in DALYs between 10 and 45%! These results show considerable attention to this pathology, justifying the downward DALY trend over time. Otherwise, musculoskeletal disorders showed the worst increasing trends for the period under study. As for the musculoskeletal, it was the only NCD in which the increase in E_{Tot} and/or E_{Pub} did not show positive results in the health of the population. Mental diseases showed a poor relation between DALYs and expenditures (overall r^2 equal to 1%). This result shows that investment, mainly public, is not responding to the needs of the population since, as advocated by GBD 2019 Diseases and Injuries Collaborators (2020), there is little development of strategies for these diseases, given the low mortality (main focus of health policies at a global level). Singh et al., in southeast Asia, found better results with public expenditure, compared to private expenditure: a 1% increase in public expenditure reduced NCD mortality by 0.6%, while private expenditure increased mortality by 0.15% (33).

Several studies have already addressed the problem of assessing the impact of healthcare expenditure on health outcomes (e.g., mortality rate) (15, 16, 22, 33). However, to our knowledge, this is the first study in which the health outcome of interest are DALYs and it is important to conduct further research in this area.

Limitations

This study had some limitations. Firstly, the study was designed as a second analysis of GBD data, and its limitations have already been published (such as the availability of primary data and the case definition or measurement method). Secondly, only the main categories of diseases within the NCDs were analysed without considering each disease, which may bias the results. Thirdly, only health expenditures were analysed as contributing to the DALYs, and the literature points to a multifactorial impact [risk factors such as poor diet, obesity and high blood (33, 34); socioeconomic and demographic structure of the populations and health inequalities (12)]. This is particularly clear in the cases where models have a very low overall coefficient of determination r^2 (e.g., mental disorders). Finally, the study did not consider the typology of health systems within the EU, relying only on definitions of health expenditure.

Conclusion

The strategic plans implemented in cardiovascular diseases and neoplasms have yielded positive outcomes since the funding invested is associated with a more significant reduction in DALYs, with repercussions in improving the population's health over time. Conversely, musculoskeletal must be a priority for health policies in the future since, despite their low mortality, they present high morbidity and disability, associated with an increasing evolution over time have a significant economic impact on society.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

MT: Writing – original draft. AN: Writing – review & editing. JM: Writing – review & editing. PF: Writing – review & editing. RP: Writing – review & editing.

Funding

The author(s) declare that no financial support was received for the research, authorship, and/or publication of this article.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2024.1384122/full#supplementary-material

References

1. WHO. *Health Promotion Glossary of Terms 2021*. Geneva: World Health Organization (2021).

2. Hunter D, Reddy S. Noncommunicable Diseases. *N Engl J Med*. (2013) 369:1336–43. doi: 10.1056/NEJMra1109345

3. Boutayeb A, Boutayeb S. The Burden of non communicable diseases in developing countries. *Int J Equity Health*. (2005) 4:2. doi: 10.1186/1475-9276-4-2

4. WHO. *WHO methods and data sources for global burden of disease estimates 2000–2019. Global Health Estimates Technical Pape*. Geneva: Department of Data and Analytics (2020).

5. WHO. *World Health Statistics 2023: Monitoring health for the SDGs Sustainable Development Goals*. Geneva: World Health Organization (2023).

6. WHO. Fact sheets. (2022). Noncommunicable diseases. Available from: https://www.who.int/news-room/fact-sheets/detail/noncommunicable-diseases

7. European Commission. *Healthier Together- European Union Non-Communicable Diseases Initiative*. Luxembourg: Publications Office of the European Union (2022).

8. Orhan R, Paric M, Czabanowska K. Lessons learnt from the eu response to ncds: A content analysis on building resilient post-covid health systems. *Healthcare (Switzerland)*. (2021) 9:1–14. doi: 10.3390/healthcare9121659

9. WHO. *Methodology for the updated of the Global Health Expenditure Database 2000-2020*. World Health Organization. (2022).

10. Eurostat. Statistics Explained. (2022) [cited 2023 Jun 3]. Healthcare expenditure statistics. Available from: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Healthcare_expenditure_statistics

11. GBD 2019 Diseases and Injuries Collaborators. Global burden of 369 diseases and injuries in 204 countries and territories, 1990–2019: a systematic analysis for the Global Burden of Disease Study 2019. *Lancet*. (2020) 396:1204–22. doi: 10.1016/S0140-6736(20)30925-9

12. Andrade CAS, Mahrouseh N, Gabrani J, Charalampous P, Cuschieri S, Grad DA, et al. Inequalities in the burden of non-communicable diseases across European countries: a systematic analysis of the Global Burden of Disease 2019 study. *Int J Equity Health*. (2023) 22:140. doi: 10.1186/s12939-023-01958-8

13. Eurostat. (2022). Statistics Explained. Healthcare expenditure statistics. Available from: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Healthcare_expenditure_statistics#Healthcare_expenditure

14. Eurostat. Statistics Explained. (2023). Health care expenditure by function. Available from: https://ec.europa.eu/eurostat/databrowser/view/hlth_sha11_hc/default/table?lang=en

15. Moler-Zapata S, Kreif N, Ochalek J, Mirelman AJ, Nadjib M, Suhrcke M. Estimating the Health Effects of Expansions in Health Expenditure in Indonesia: A Dynamic Panel Data Approach. *Appl Health Econ Health Policy*. (2022) 20:881–91. doi: 10.1007/s40258-022-00752-x

16. Gloria MAJ, Thavorncharoensap M, Chaikledkaew U, Youngkong S, Thakkinstian A, Chaiyakunapruk N, et al. Systematic review of the impact of health care expenditure on health outcome measures: implications for cost-effectiveness thresholds. *Expert Rev Pharmacoecon Outcomes Res*. (2024) 24:203–15. doi: 10.1080/14737167.2023.2296562

17. Eurostat. Demography, population stock and balance. (2023). Available from: https://ec.europa.eu/eurostat/databrowser/explore/all/popul?lang=en&subtheme=demo&display=list&sort=category

18. Neath AA, Cavanaugh JE. The Bayesian information criterion: Background, derivation, and applications. *Wiley Interdiscip Rev Comput Stat*. (2012) 4:199–203. doi: 10.1002/wics.199

19. Baltagi BH. *Econometric Analysis of Panel Data*. *6th* ed. Switzerland: Springer (2021).

20. StataCorp. *STATA Longitudinal-Data/Panel-Data reference manual 17*. *17th* ed. Texas: Stata Press (2021).

21. Marques LD. *Modelos Dinâmicos com Dados em Painel: revisão de literatura*. Porto: Faculdade de Economia do Porto (2000).

22. Rad EH, Vahedi S, Teimourizad A, Esmaeilzadeh F, Hadian M, Pour AT. Comparison of the effects of public and private health expenditures on the health status: A panel data analysis in eastern mediterranean countries. *Int J Health Policy Manag*. (2013) 1:163–7. doi: 10.15171/ijhpm.2013.29

23. Liu S, Wang B, Fan S, Wang Y, Zhan Y, Ye D. Global burden of musculoskeletal disorders and attributable factors in 204 countries and territories: a secondary analysis of the Global Burden of Disease 2019 study. *BMJ Open*. (2022) 12:e062183. doi: 10.1136/bmjopen-2022-062183

24. Kotwas A, Karakiewicz B, Zabielska P, Wieder-Huszla S, Jurczak A. Epidemiological factors for type 2 diabetes mellitus: evidence from the Global Burden of Disease. *Arch Public Health*. (2021) 79:110. doi: 10.1186/s13690-021-00632-1

25. Sagan A, Thomson S. *Voluntary health insurance in Europe: role and regulation*. Copenhagen, Denmark: European Observatory on Health Systems and Policies (2016). Available from: https://pubmed.ncbi.nlm.nih.gov/28825784/

26. OECD, European Commission. Health at a Glance: Europe (2020). State of Health in the EU Cycle [Internet]. Paris: OECD Publishing; 2020. (Health at a Glance: Europe). Available from: https://www.oecd-ilibrary.org/social-issues-migration-health/health-at-a-glance-europe-2020_82129230-en

27. Micah AE, Bhangdia K, Cogswell IE, Lasher D, Lidral-Porter B, Maddison ER, et al. Global investments in pandemic preparedness and COVID-19: development assistance and domestic spending on health between 1990 and 2026. *Lancet Glob Health*. (2023) 11:e385–413. doi: 10.1016/S2214-109X(23)00007-4

28. United Nations Development Programme. Human Development Report 2021/2022. United States: United Nations (2022). Available from: https://www.unilibrary.org/content/books/9789210016407

29. Daroudi R, Akbari Sari A, Nahvijou A, Faramarzi A. Cost per DALY averted in low, middle- and high-income countries: evidence from the global burden of disease study to estimate the cost-effectiveness thresholds. *Cost Effectiveness and Resource Allocation*. (2021) 19:260. doi: 10.1186/s12962-021-00260-0

30. Murray CJL, Frenk J. A framework for assessing the performance of health systems. *Bull World Health Organ*. (2000) 78:717–31.

31. Ciccone DK, Vian T, Maurer L, Bradley EH. Linking governance mechanisms to health outcomes: A review of the literature in low- and middle-income countries. *Soc Sci Med*. (2014) 117:86–95. doi: 10.1016/j.socscimed.2014.07.010

32. Mays GP, Smith SA. Evidence links increases in public health spending to declines in preventable deaths. *Health Aff*. (2011) 30:1585–93. doi: 10.1377/hlthaff.2011.0196

33. Singh S, Bala MM, Kumar N. The dynamics of public and private health expenditure on health outcome in Southeast Asia. *Health Soc Care Community*. (2022) 30:e2549–58. doi: 10.1111/hsc.13698

34. Bikbov B, Perico N, Remuzzi G. Mortality landscape in the Global Burden of Diseases, Injuries and Risk Factors Study. *Eur J Intern Med*. (2014) 25:1–5. doi: 10.1016/j.ejim.2013.09.002

35. Institute for Health Metrics and Evaluation (IHME). WA: IHME. Seattle: University of Washington (2020).

36. WHO. Global Health Expenditure Database. (2021). Available from: https://apps.who.int/nha/database/Select/Indicators/en

frontiers | Frontiers in Public Health

TYPE Systematic Review
PUBLISHED 19 April 2024
DOI 10.3389/fpubh.2024.1390937

Check for updates

OPEN ACCESS

EDITED BY
Hai Fang,
Peking University, China

REVIEWED BY
Alexandre Morais Nunes,
University of Lisbon, Portugal
Eduardo Fernandez,
University of Salamanca, Spain

*CORRESPONDENCE
Ewunetie Mekashaw Bayked
emebirhan7@gmail.com

RECEIVED 24 February 2024
ACCEPTED 20 March 2024
PUBLISHED 19 April 2024

CITATION
Bayked EM, Assfaw AK, Toleha HN, Zewdie S, Biset G, Ibirongbe DO and Kahissay MH (2024) Willingness to pay for National Health Insurance Services and Associated Factors in Africa and Asia: a systematic review and meta-analysis. *Front. Public Health* 12:1390937. doi: 10.3389/fpubh.2024.1390937

Willingness to pay for National Health Insurance Services and Associated Factors in Africa and Asia: a systematic review and meta-analysis

Ewunetie Mekashaw Bayked[1]*, Abebe Kibret Assfaw[2], Husien Nurahmed Toleha[1], Segenet Zewdie[3], Gebeyaw Biset[4], Demilade Olusola Ibirongbe[5] and Mesfin Haile Kahissay[6]

[1]Department of Pharmacy, College of Medicine and Health Sciences (CMHS), Wollo University, Dessie, Ethiopia, [2]Department of Psychology, Institute of Teachers' Education and Behavioral Science, Wollo University, Dessie, Ethiopia, [3]Department of Pharmacy, College of Medicine and Health Science, Injibara University, Injibara, Ethiopia, [4]Department of Pediatrics and Child Health Nursing, College of Medicine and Health Sciences (CMHS), Wollo University, Dessie, Ethiopia, [5]Department of Community Medicine, University of Medical Sciences, Ondo, Nigeria, [6]Department of Pharmaceutics and Social Pharmacy, School of Pharmacy, College of Health Sciences, Addis Ababa University, Addis Ababa, Ethiopia

Background: Universal health coverage (UHC) is crucial for public health, poverty eradication, and economic growth. However, 97% of low- and middle-income countries (LMICs), particularly Africa and Asia, lack it, relying on out-of-pocket (OOP) expenditure. National Health Insurance (NHI) guarantees equity and priorities aligned with medical needs, for which we aimed to determine the pooled willingness to pay (WTP) and its influencing factors from the available literature in Africa and Asia.

Methods: Database searches were conducted on Scopus, HINARI, PubMed, Google Scholar, and Semantic Scholar from March 31 to April 4, 2023. The Joanna Briggs Institute's (JBI's) tools and the "preferred reporting items for systematic reviews and meta-analyses (PRISMA) 2020 statement" were used to evaluate bias and frame the review, respectively. The data were analyzed using Stata 17. To assess heterogeneity, we conducted sensitivity and subgroup analyses, calculated the Luis Furuya-Kanamori (LFK) index, and used a random model to determine the effect estimates (proportions and odds ratios) with a p value less than 0.05 and a 95% CI.

Results: Nineteen studies were included in the review. The pooled WTP on the continents was 66.0% (95% CI, 54.0–77.0%) before outlier studies were not excluded, but increased to 71.0% (95% CI, 68–75%) after excluding them. The factors influencing the WTP were categorized as socio-demographic factors, income and economic issues, information level and sources, illness and illness expenditure, health service factors, factors related to financing schemes, as well as social capital and solidarity. Age has been found to be consistently and negatively related to the WTP for NHI, while income level was an almost consistent positive predictor of it.

Conclusion: The WTP for NHI was moderate, while it was slightly higher in Africa than Asia and was found to be affected by various factors, with age being reported to be consistently and negatively related to it, while an increase in income level was almost a positive determinant of it.

KEYWORDS

health insurance, National Health Insurance, willingness to pay, factor, Africa, Asia

Introduction

Context

Earth, formed 4.6 billion years ago, is divided into seven continents: Asia, Africa, North America, South America, Antarctica, Europe, and Australia (1). Asia is the largest and most populous continent (2). Asia's vast geographical area offers a population advantage, comprising 4.6 billion out of the global population of 7.7 billion (3). The Asian region comprises a diverse array of countries, including some of the world's least and most developed nations (4). The East Asia and Pacific region, with over two billion people, is the most populous globally, home to fast-growing economies and the second-largest number of fragile states after Africa (5).

Healthcare systems in Asia are diverse (6–8), with Japan, Singapore, South Korea, and Taiwan renowned for advanced systems, high care standards, and UHC (9–11). Governments in some Asian countries ensure healthcare access through public funding and provider regulation (12), while other Asian countries face challenges like limited access, inadequate infrastructure, and disparities in healthcare delivery (9). As a result, Asian countries are prioritizing healthcare infrastructure investment, quality access, and addressing non-communicable diseases (13, 14), while promoting collaboration and knowledge-sharing to improve health outcomes (15). Hence, Asia's healthcare systems are undergoing significant transformations and reforms to improve access, quality, and affordability of services for their unique challenges (16, 17).

Africa is the world's second-largest and second-most populous continent, after Asia. It spans approximately 30.3 million km^2, including adjacent islands, accounting for 6.0% of Earth's surface area and 20.0% of its land area. With a 2021 population of 1.4 billion, it comprises about 18.0% of the global human population (18). The majority of the African population, comprising 53.3%, is rural, with a median age of 18.8 years (19), the youngest population worldwide (18).

Healthcare systems in Africa encounter multiple challenges, such as institutional, human resources, financial, technical, and political issues (20). Africa is grappling with a significant number of both communicable and non-communicable diseases (21). The African continent was home to a particularly diverse and deadly set of tropical diseases (20). Cost-effective interventions to prevent disease burden are available, but their coverage is limited by weaknesses in health systems (21).

Background and rationale

The primary objective of an efficient health system is to improve public health (22, 23), which critically requires UHC (22). The concept of UHC was introduced in 2005 with the aim of addressing disparities in access to healthcare services (24). The post-2015 sustainable development agenda proposes UHC as an umbrella health goal, aiming for universal, equitable, and effective delivery of comprehensive health services (25), which is at the heart of contemporary efforts to strengthen health systems (26).

However, financing UHC is a challenging task, requiring countries to consider all revenue sources for healthcare system reform (27). On the other hand, while increased spending can improve health outcomes, improving the efficiency of these expenditures is even more critical (28). Health financing involves the collection of revenue, pooling of risk, and purchasing of goods and services to enhance population health, primarily funded by individuals and households through the tax system (29). Not only revenue collection but also effective healthcare purchasing and proper regulation of healthcare providers are crucial for the sustainability of healthcare financing (30). Health purchasing is the transfer of funds to health providers, either passively or strategically, to deliver services (31).

As mentioned before, one of the targets of the Sustainable Development Goals (SDGs) is the promise to work toward achieving UHC by 2030 (32). UHC not only contributes to achieving SDG 3, good health and wellbeing, but also poverty eradication, work and economic growth, and reduced inequalities, which represent the targets of SDGs 1, 8, and 10, respectively (33). It should shield households from financial risk, especially the poorest who find it difficult to pay for services (34), which include access to high-quality, vital medical care as well as safe, effective, and reasonably priced medicines and vaccinations (32). The World Health Organization (WHO) emphasizes the significance of equitable access to safe and affordable medicines for optimal health, aligning with the SDGs, particularly SDG 3.8, which aims for UHC, and SDG 3.b, which focuses on the accessibility of medicines to address existing treatment gaps (35).

Yet, 2 billion people worldwide have no access to essential medicines (35) and face catastrophic or impoverished health spending (36), and at least 400 million individuals do not have access to essential health services (32), because the most common method of paying for health services globally is OOP spending (37). On average, each nation spends roughly 32.0% of its total health budget on OOP expenses. Due to OOP medical expenses, 150 million individuals each year experience financial catastrophe (32), and 100 million are forced into poverty (32, 38). These individuals reside in developing countries where the health systems are plagued by inefficiency, unequal access, insufficient funding, and substandard services and account for 92.0, 68.0, and 80.0% of the world's annual deaths from communicable diseases, non-communicable conditions, and injuries, respectively (39).

The burden of the lack of UHC is highest in LMICs, particularly in Africa and Asia (Figure 1) (40), where 97.0% of the population is impoverished by OOP health spending (33). In 2023, 75.0% of the 3.1 billion people worldwide without effective UHC are from LMICs in South Asia, Southeast Asia, East Asia, and Sub-Saharan Africa (SSA) (41). For example, by using their household income to access healthcare services, medications, and other products, an estimated 11 million Africans fall into poverty each year (33), which is a concerning issue considering that Asia and Africa together constitute over 75% of the global population (41).

Nevertheless, a system that generates net savings by eliminating profit and waste can be used to address the rapidly rising health expenditures (42), because up to one fifth of health expenditures could be directed towards better use by avoiding waste (43). To ensure equitable access through such a mechanism, health care must be funded, managed, and provided in a way that puts the needs of individuals and communities first (32), which is embedded in national, regional, and international contexts (44). This implies that improving health system performance to attain UHC requires actions at national, regional, and global levels (45). In fact, the dedication to collaborating with the global health community enhances access to quality healthcare and makes UHC a reality for patients, families, and communities worldwide. Together, this effort will lead to healthier communities and stronger economies (46).

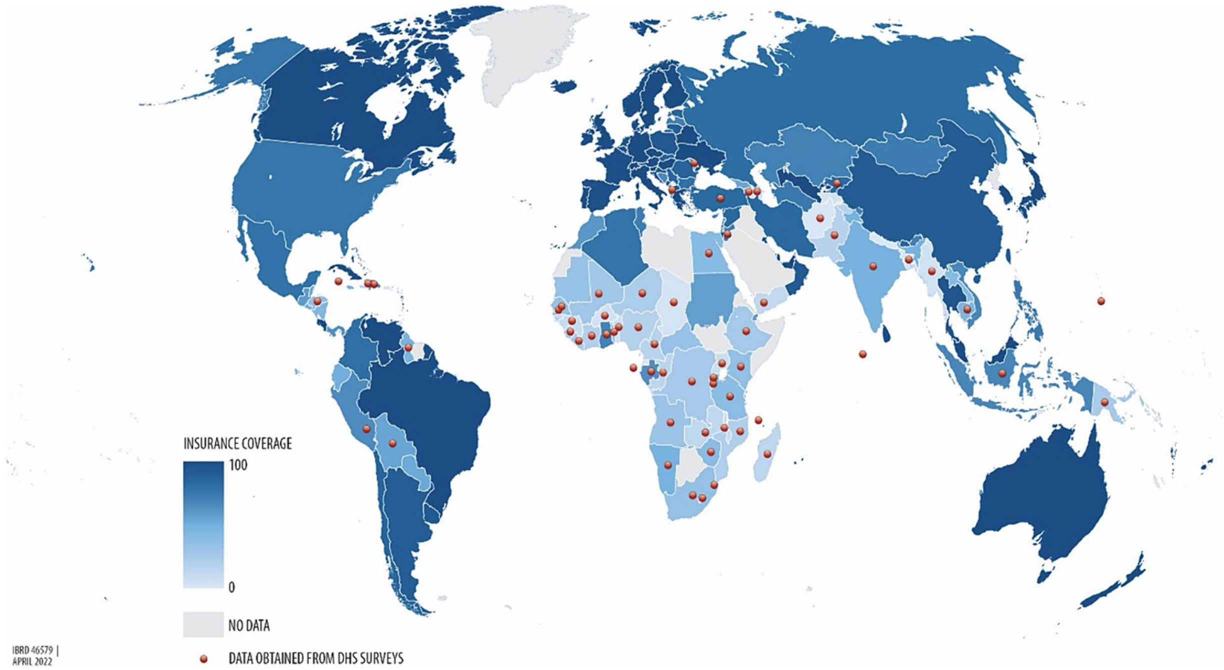


FIGURE 1
Percentage of health insurance coverage across the world, from the lowest UHC (light blue) to the highest UHC (dark blue) (40).

Accordingly, to overcome the challenge to achieve UHC, the two regions, Africa and Asia, have recognized the importance of collaboration among governments, civil society, and the private sector. Consequently, they have started working together to use a global south perspective. Kenya and Egypt, for instance, are looking for guidance on free basic healthcare through health insurance from Thailand and Japan, respectively (33), which is, undoubtedly, the most significant sort of insurance (47).

Insurance is a contract where the subscriber pays the insurer on a regular basis in exchange for the assurance of indemnification against specific risks. The specific risks covered by health insurance are the financial burden of the treatments required following an illness or injury (48). There are several reasons to introduce health insurance, including the removal of financial barriers to healthcare access, providing financial protection against high medical costs, and negotiating better-quality healthcare with providers (49), which dictate that the way of funding health services is a crucial aspect of UHC (50). As a result, health policymakers must prioritize selecting the appropriate financing mechanisms for health services to achieve broader health policy goals, as this decision impacts both providers and consumers, particularly in low-income countries (LICs) where service usage rates across income groups are a significant issue (51).

Though there are various healthcare financing mechanisms to choose from, national, social, private, and community-based health insurance programs are the four main categories of health insurance programs (52, 53), dictating that health insurance programs can be privately or publicly run, cover various population subgroups, and provide different premium costs and benefit packages. The two primary types of government health insurance programs are NHI and Social Health Insurance (SHI), which are based on the Beveridge and Bismarck healthcare systems, respectively. Health insurance programs in many nations include components from both of these models, and the design varies across countries. However, in the majority of government health insurance schemes, enrollment, contributions, and payments are managed by a fully or partially independent government body (52).

Public health insurance models provide benefits through either a national health insurance fund, a national social security fund, or branches of the central government (54). NHI, as a public health insurance scheme, is thus provided by the federal government through general taxation (55), usually with mandatory coverage for all citizens (56). It is a single-payer scheme that covers all citizens and residents, with eligibility based on citizenship and residency status (57), indicating that it is the best option to ensure equity, fairness, and priorities aligned with medical needs. This strategy improves public health by providing universal access to desirable care with treatment options tailored to the patient's needs (42).

Therefore, as health care is a human right and requires system-wide changes in financing to achieve UHC (58), a public, single-payer system is the best, most efficient, and most equitable health-care system. This is because, through partnerships with provider organizations and the use of taxes for everyone, single-payer systems enable people to serve as their own insurers. The best care to satisfy needs is then selected by the consumer, with minimal or no OOP expenses. That is, patients are partners in their care, obtaining diagnosis, treatment, and prevention services without financial restrictions (42). Hence, it is important to bear in mind that a nation's financial resources primarily originate from its population, with the exception of external aid and natural resources (56).

Thus, NHI is funded through income-based premiums (59). The premium is the cost of insurance coverage, which is typically paid monthly or yearly (52). This cost of a health insurance plan is a key factor in its viability, which is determined by the members' WTP (60), i.e., a stated preference that involves assigning a monetary value to the benefits of health-related goods or services (61). However, LICs face constraints in raising revenue to finance health and health insurance, as government tax revenues are only 15% of gross domestic product (GDP), compared to over 20% in higher-income countries (HICs) (56), and the tax structure is often regressive (62).

The WTP is the utmost amount of money that an individual is WTP for a service or product (52). It is a proxy measure of cost–benefit trade-offs in health insurance (63) and is one of two popular approaches for estimating the monetary value of health benefits, the other being the Human Capital (HC) approach (64). WTP is a widely-used concept in the health sector to guide policy decisions (65). The assessment of WTP can be conducted through evaluating historical healthcare utilization and expenditure data or by employing a contingent valuation (CV) approach (66), which is a survey methodology to assess the benefit or worth of a program to individuals (67). When employing the CV method to determine WTP, two general elements should be included: a hypothetical scenario and a bidding vehicle. The goal of the hypothetical scenario is to give the respondents a detailed explanation of the good or service they are being asked to pay for. Bids can be obtained in a number of ways, including open-ended or closed-ended questions, a bidding game, or a payment card (64).

Estimating the WTP is the best way to assess the expected income of health insurance schemes. This estimate is required to ensure that the cost of benefit packages does not surpass available resources to minimize the risk of bankruptcy. WTP data are, therefore, crucial for informing the design of tailored benefit packages for consumers, particularly groups or communities (68). Cross-country studies are decisive in assessing such data and the impacts of common elements of reforms adopted by many countries, as they provide a comprehensive understanding of which reforms have been successful or not (22). Thus, this systematic review and meta-analysis aimed to determine the pooled WTP for NHI and its influencing factors from the available literature in Africa and Asia. Accordingly, the main question to be answered by the review, using the CoCoPop Framework—Condition (WTP for NHI), Context (Africa and Asia), and Population (African and Asian households)—was: What proportion of households were willing to pay for NHI in Africa and Asia?

Methods

Registration and protocol

The protocol for this review was registered on PROSPERO, accessible at https://www.crd.york.ac.uk/prospero/display_record.php?ID=CRD42023411411. We used the PRISMA 2020 Statement as a frame for the review (69) (Supplementary file S1). However, to pictorially present the screening process of the studies, because of its ease and clarity, we used the PRISMA 2009 flow diagram (70), while we sufficiently discussed the screening process in words in line with the PRISMA 2020 flow diagram.

Eligibility criteria

All original and published cross-sectional studies that report the prevalence of WTP for NHI and/or factors influencing it were deemed eligible for the systematic review. We considered all English-language studies conducted in both community and institutional settings on WTP for NHI in Africa and Asia. The selection of studies was also based on several parameters including outcome variables, study population, year of the study, regional context, sample size, and response rate.

Information sources and search strategy

Database searches were conducted on Scopus, HINARI, PubMed, Google Scholar, and Semantic Scholar from March 31 to April 4, 2023 (Supplementary file S2). Manual searches were performed on PubMed and HINARI. Conversely, Scopus, Google Scholar, and Semantic Scholar were searched using the "Publish or Perish" database searching tool, version 8 (71).

Selection process

After excluding duplicate studies using Zotero reference manager version 6, two reviewers, EMB and HNT, independently screened the remaining studies. The selection process was meticulously conducted by these researchers. Initially, articles were refined based on their title and abstract; subsequently, a full-text revision was performed independently and then collaboratively until a consensus was reached. In cases of disagreement, a third reviewer was consulted for resolution.

Data collection process and data items

A Microsoft Excel 2019 spreadsheet was utilized for data extraction. The outcome variables - population (study units), year of study, context, sample size, response rate, and proportions - were extracted using this spreadsheet. Two independent reviewers, EMB and HNT, extracted the data, compared their findings and reached a consensus. In cases where agreement could not be reached, a third reviewer was invited to help achieve consensus. Additionally, we reached out to the authors of the study to gather any missing information. The primary outcome of this systematic review and meta-analysis was the WTP for NHI. An additional outcome was the factors influencing the WTP for NHI.

Study risk of bias assessment

Two reviewers, EMB and HNT, independently assessed the risk of bias in the included studies using JBI tools. The assessment focused on several criteria: inclusion in the sample, descriptions of study subjects and settings, validity and reliability of measurements, confounding factors and strategies to address them, and appropriateness of the outcome measure. The JBI's tool with eight criteria was used to evaluate the risk of bias within the articles. Scores of 7 or higher were classified as low risk, 5–6 as medium risk, and 4 or lower as high risk. Studies identified as low and medium risk were included in the review. All inconsistencies were addressed through discussion and, if necessary, the involvement of a third reviewer.

Effect measures and synthesis methods

For the qualitative synthesis, thematic strategies were utilized to categorically conceptualize the outcome variables. Preliminary effect

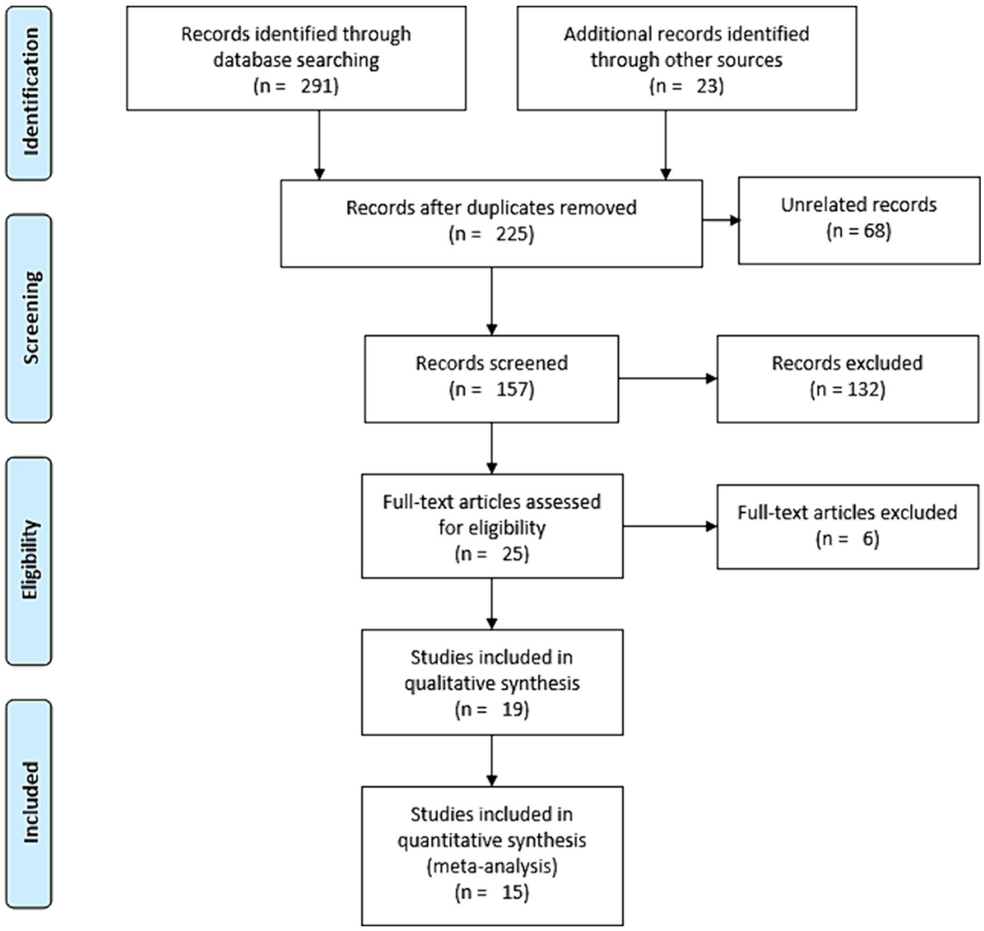


FIGURE 2
Schematic description of the screening processes for literature, 2023.

measures were then calculated for the quantitative synthesis based on the qualitative synthesis using a Microsoft Excel 2019 spreadsheet. STATA 17 was employed to determine the effect estimates (proportions and odds ratios—ORs) of the WTP for NHI. Sub-group analyses were subsequently conducted to compare these effect estimates across studies focusing on the outcome variable. The overall level of statistical significance was set at a *p*-value less than 0.05 with a 95% confidence interval (CI).

Reporting bias and certainty assessment

The study authors were contacted to obtain missing or incomplete data. Studies with incomplete data were excluded from the analysis. Heterogeneity between studies was assessed using the I^2 statistic. The influence of each study on the overall meta-analysis was measured using percentages of weights, and subgroup analysis comparing the WTP for NHI in Asia and Africa was conducted. A sensitivity analysis was also conducted to determine the outlier studies.

Moreover, Doi plots were used to examine potential inter-study bias, also known as publication bias, which helps to calculate asymmetry using the LFK index (72). The Doi plot, which is a folded normal quantile (z-score) versus effect plot, replaces the conventional scatter (funnel) plot of precision versus effect. It provides a quick overview of study symmetry and heterogeneity when combined with the Galbraith plot (73). The visual examination involves observing the dots representing specific studies and their arrangement (74). In addition, the plots comprise the LFK index and *p*-value of Egger's test (73). The LFK index is used to identify and measure the asymmetry of study effects (75). The closer the LFK index value is to zero, the greater the symmetry in the Doi plot. Values of the LFK index that fall outside the range of −1 to +1 suggest asymmetry, indicative of publication bias (76).

Results

Study selection

We conducted a comprehensive search of Google Scholar ($n = 200$), HINARI ($n = 50$), Scopus ($n = 19$), and PubMed ($n = 22$) from March 31 to April 4, 2023. An additional 23 records were identified through other sources, resulting in a total of 314 resources (Figure 2). After eliminating duplicates, we were left with 225 articles. Out of these, we screened 157 papers for relevance and discarded 68. Subsequently, 25 studies were chosen based on title and abstract evaluation. After a full-text evaluation, six studies were excluded due to reasons such as language other than

TABLE 1 Characteristics of the included studies ($n = 19$), 2023.

Study ID	Design	Country	Continent	Year	SS	RR	Outcome
Nurlia (2021) (83)	Cross-sectional	Indonesia	Asia	2020	200	200	WTP
Oyekale (2012) (84)	Cross-sectional	Nigeria	Africa	2007	212	208	WTP
Omonira and Oyekale (2012) (85)	Cross-sectional	Nigeria	Africa	2006	122	120	WTP
Noor et al. (2019) (86)	Cross-sectional	Malaysia	Asia	2014	915	774	WTP
Oktora and Pujiyanto (2018) (87)	Cross-sectional	Indonesia	Asia	-	166	158	WTP
Omotowo et al. (2016) (88)	Cross-sectional	Nigeria	Africa	-	400	400	WTP
Al-Hanawi et al. (2018) (89)	Cross-sectional	Saudi Arabia	Asia	2015	1,250	1,187	WTP
Alharbi (2022) (90)	Cross-sectional	Saudi Arabia	Asia	2021	475	475	WTP
Njie et al. (2023) (91)	Cross-sectional	Gambia	Africa	2020	780	717	WTP
Basaza et al. (2017) (92)	Cross-sectional	South Sudan	Africa	2015	422	381	WTP
Hasan and Rahman (2022) (93)	Cross-sectional	Malaysia	Asia	2020	1,388	1,208	WTP
Agyei-Baffour et al. (2022) (94)	Cross-sectional	Sierra Leone	Africa	-	1,185	1,185	WTP
Tan (2022) (95)	Cross-sectional	Malaysia	Asia	2019	489	462	WTP
Ramadhan et al. (2015) (96)	Cross-sectional	Indonesia	Asia	2013	210	210	WTP
Oga et al. (2019) (97)	Cross-sectional	Côte d'Ivoire	Africa	2017	450	450	WTP
Oyekale and Adeyeye (2012) (98)	Cross-sectional	Nigeria	Africa	2008	110	110	WTP
Puurbalanta et al. (2020) (99)	Cross-sectional	Ghana	Africa	-	335	335	WTP
Dartanto et al. (2016) (100)	Cross-sectional	Indonesia	Asia	-	400	400	WTP
Nugraheni et al. (2022) (101)	Cross-sectional	Indonesia	Asia	2021	1,211	1,203	WTP
Total					10,720	10,183	WTP

RR, response rate; SS, sample size.

English (77), high risk of bias (78–81), and inaccessibility of the full text (82). In conclusion, 19 resources were identified for inclusion, out of which 15 were deemed suitable for the quantitative meta-analysis.

Study characteristics

Ten of the studies included in the systematic review were conducted in Asia, and nine were conducted in Africa. The Asian studies took place in Indonesia ($n = 5$), Malaysia ($n = 3$), and Saudi Arabia ($n = 2$). The African studies were carried out in Nigeria ($n = 4$), Gambia, South Sudan, Sierra Leone, Côte d'Ivoire, and Ghana. Each study was evaluated based on its design, context, year of study, sample size, non-response and response rates, and primary outcome. The individual characteristics of each study are summarized in Table 1.

Risk of bias in the included studies

The risk of bias in the included studies was evaluated using JBI's critical appraisal tool. Subsequently, studies with low and medium risk were incorporated into the review. As depicted in (Figure 3), the average risk of bias across the studies was 6.0 (75%).

Results of synthesis

Qualitative synthesis

As shown in Table 1, the sample population for all included studies (n = 19) comprised 10,720 individuals, with a response rate of 95.0%, equating to 10,183 respondents. The WTP for NHI was found to be significantly affected by various factors, which were categorized into seven themes as follows:

1. Socio-demographic factors: family size (83–85, 89, 92, 93, 100, 101), age (84, 86, 87, 90, 94, 95, 99), marital status (85, 86, 95), gender (85, 86, 88–91, 94, 95, 97, 100, 101), area of residence (86, 89, 90, 94), and education level (83, 89–91, 94, 95, 98, 99, 101).
2. Income and economic issues: level of income (83, 85–87, 89, 91, 92, 94, 99–101), extent of government taxation (85), and employment status (88, 95, 99, 101).
3. Information level and information sources: awareness about the scheme (84, 92, 94, 98), knowledge regarding the scheme (87, 95), perceptions about financing healthcare (89, 95), insurance literacy, and access to the internet (100).
4. Illness and illness expenditure: illness condition and illness experiences (84, 86, 89, 93, 95, 98, 101), and previous healthcare expenditure (100).
5. Health service factors: availability of hospitals (100), type or ownership of usual healthcare provider (90), level of health facility to get treatment, in-patient or outpatient service (101), and quality of healthcare services (89, 90).
6. Factors related to financing schemes: scheme trust and preference (84), impression of paying much more (85), having alternative health insurance (86, 89, 92, 95), and class or level of health insurance plan (101).
7. Social capital and solidarity: religious affiliation (92), level of empowerment, group and network connection, and social cohesion and inclusion (93).

As demonstrated in Table 2, the included studies reported varying results concerning the relationship between the associated variables

10.3389/fpubh.2024.1390937

Study ID	Clear sampling criteria	Participants and setting	Measurement of exposure	Objective and/or question	Identification of confounding factors	Strategies to deal with confounding factors	Measurement of outcome	Appropriate statistical analysis	Score	Risk
Nurlia, 2021	?	+	+	+	?	?	+	+	5/8	Medium
Oyekale, 2012	+	+	+	+	-	-	+	+	6/8	Medium
Omonira, 2012	+	+	+	+	-	-	+	?	5/8	Medium
Noor, 2019	+	+	+	+	+	+	+	+	8/8	Low
Oktora, 2018	+	+	+	+	?	-	+	+	6/8	Medium
Omotowo, 2016	+	+	?	+	-	-	+	+	5/8	Medium
Al-Hanawi, 2018	+	+	+	+	-	-	+	+	6/8	Medium
Alharbi, 2022	+	+	+	+	?	?	+	+	6/8	Medium
Njie, 2023	+	+	+	+	-	-	+	+	6/8	Medium
Basaza, 2017	+	+	+	+	-	-	+	?	5/8	Medium
Hasan, 2022	?	+	+	+	+	+	+	+	7/8	Low
Agyei-Baffour, 2022	+	+	+	+	?	-	+	+	6/8	Medium
Tan, 2022	+	+	+	+	-	-	+	+	6/8	Medium
Ramadhan, 2015	+	+	?	+	-	-	+	+	5/8	Medium
Oga, 2019	+	+	+	+	-	-	+	+	6/8	Medium
Oyekale, 2012	+	+	?	+	-	-	+	+	5/8	Medium
Puurbalanta, 2020	+	+	+	+	-	-	+	+	6/8	Medium
Dartanto, 2016	+	+	+	+	?	?	+	+	6/8	Medium
Nugraheni, 2022	+	+	+	+	+	+	+	+	8/8	Low
								Average	**6/8**	**Medium**

Green = Low risk of bias, Red = High risk of bias, and Yellow = Unclear risk of bias

FIGURE 3
Summary of the risk of bias assessment of the included studies (n=19), 2023.

and the WTP for NHI. Despite these inconsistencies, some studies have found consistent outcomes. Specifically, the relationship of household age and marital status with WTP for the scheme has shown a negative relationship, meaning that the WTP decreases as age and married household heads increase.

Quantitative synthesis

Proportional estimation of the willingness to pay

From all the included studies, 15 records with a total of 9,497 participants were included in the quantitative synthesis (Table 3). Six of the eight included studies for the meta-analysis from Asia were conducted in Indonesia ($n=3$) and Malaysia ($n=3$), and the rest were conducted in Saudi Arabia ($n=2$), while those from Africa were conducted in Nigeria ($n=2$), Gambia, Sierra Leone, Côte d'Ivoire, and Ghana. Most of the participants (62.3%) were from Asia, and the rest (37.7%) were from Africa.

The combined (average) WTP for NHI in Africa and Asia was determined to be 66.0% (95% CI: 54.0–77.0%). The highest WTP for NHI was reported in Gambia at 94.0% (95% CI: 92–96%), while the lowest was reported in Indonesia at 18.0% (95% CI: 13–23%). The overall heterogeneity between studies was considerably high (102),

TABLE 2 Direction of the relationship between the associated factors and the WTP for NHI.

Themes (variables)	Direction of relationship with the WTP for NHI		
	Positive (+)	Negative (–)	Inconclusive
1 *Socio-demographic factors*			
1.1 Family size	(83, 85, 92, 101)	(84, 89, 93)	(100)
1.2 Household head's age	–	(84, 86, 87, 90, 94, 95, 99)	–
1.3 Married participants	–	(85, 86, 95)	–
1.4 Male gender	(88, 89, 91, 97, 100)	(85, 86, 90, 94, 95, 101)	–
1.5 Place of residence (urban)	(89)	(86, 94)	(90)
1.6 Education level	(83, 89, 94, 95, 98)	–	(90, 91, 99, 101)
2 *Income and economic issues*			
2.1 Income level	(86, 87, 89, 94, 99–101)	(83)	(85, 91, 92)
2.2 Government taxation	–	(85)	–
2.3 Formal employment	(88, 95, 99)	(101)	–
3 *Information level and information sources*			
3.1 Awareness about NHI	(84, 92, 94)	(98)	–
3.2 Knowledge regarding NHI	(87)	(95)	–
3.3 Perception of financing healthcare	(95)	(89)	–
3.4 Insurance literacy	(100)	–	–
3.5 Internet access	(100)	–	–
4 *Illness and illness expenditure*			
4.1 Illness experience	(86, 93, 98).	(84, 89, 95, 101)	–
4.2 Previous healthcare expenditure	(100)	–	–
5 *Health service factors*			
5.1 Hospital availability at district level	(100)	–	–
5.2 Healthcare provider type (public hospital)	(101)	(90)	–
5.3 Service utilization (inpatient)	(101)	–	–
5.4 Health service quality	(89, 90)	–	–
6 *Factors related to financing schemes*			
6.1 Scheme trust and preference	(84)	–	–
6.2 Impression of paying more	–	(85)	–
6.3 Level of health insurance plan (class 1)	(101)	–	–
6.4 Having alternative health insurance	(95)	(86, 89, 92)	–
7 *Social capital and solidarity*			
7.1 Religious affiliation	–	–	(92)
7.2 Level of empowerment	(93)	-	–
7.3 Group and network connection	–	(93)	–
7.4 Social capital cohesion and inclusion	–	(93)	–

with an I^2 value of 99.51%. So, a random-effects model was used to calculate the pooled WTP for NHI (103). To identify the source of heterogeneity, as shown in Figure 4, we conducted a subgroup analysis based on continent, which showed significant difference between the subgroups ($p = 0.039$). According to the subgroup analysis, the WTP for NHI in Africa and Asia, respectively, was 77.0% (95% CI: 63–91%) and 56.0% (95% CI, 41–70%). The studies conducted in Sierra Leone and Gambia reported the lowest and highest WTP for the scheme in Africa, at 49.0% (95% CI, 46.0–52.0%) and 94.0% (95% CI, 92.0–96.0%), respectively. In Asia, the lowest and highest WTP for NHI were found in Indonesia and Malaysia, with rates of 18.0% (95% CI, 13–23%) and 77.0% (95% CI, 74.0–79.0%), respectively.

When the outliers were excluded, the difference between the subgroups was not found to be significant ($p = 0.680$), but still, the overall result showed that there was considerable heterogeneity between studies, with an I^2 value of 83.82%, which was significant ($p < 0.01$). After removing the outliers, the WTP for NHI in Africa decreased from 77.0% (95% CI: 63–91%) to 73.0% (95% CI: 65.0–80.0%). Conversely, the WTP for the scheme in Asia increased from 56.0% (95% CI: 41–70%) to 71.0% (95% CI: 66–75%). The combined

TABLE 3 The frequency of the WTP for NHI in Africa and Asia (n = 15), 2023.

Study ID	Participants	Events (WTP)	Country	Continent
Al-Hanawi et al. (2018) (89)	1,187	826	Saudi Arabia	Asia
Alharbi (2022) (90)	475	299	Saudi Arabia	Asia
Hasan and Rahman (2022) (93)	1,208	401	Malaysia	Asia
Tan et al. (2022) (95)	462	344	Malaysia	Asia
Noor et al. (2019) (86)	774	593	Malaysia	Asia
Ramadhan et al. (2015) (96)	210	37	Indonesia	Asia
Dartanto et al. (2016) (100)	400	280	Indonesia	Asia
Nugraheni et al. (2022) (101)	1,203	496	Indonesia	Asia
Omotowo et al. (2016) (88)	400	356	Nigeria	Africa
Njie et al. (2023) (91)	717	677	Gambia	Africa
Basaza et al. (2017) (92)	381	258	South Sudan	Africa
Agyei-Baffour et al. (2022) (94)	1,185	581	Sierra Leone	Africa
Oga et al. (2019) (97)	450	350	Côte d'Ivoire	Africa
Oyekale et al. (2012) (98)	110	79	Nigeria	Africa
Puurbalanta et al. (2020) (99)	335	295	Ghana	Africa
Total	9,497	5,872	All	Both

WTP for the scheme also rose from 66.0% (95% CI: 54.0–77.0%) to 71.0% (95% CI: 68–75%; Figure 5). Consequently, the difference in the WTP levels for the scheme between the two continents narrowed. Yet, Africa's WTP was higher than that of Asia.

Factors influencing the willingness to pay

Eight of the included studies reported binary outcomes regarding the influence of gender, previous illness, residence, alternative health insurance, awareness of the scheme, and the type of ownership of health facilities on the WTP for NHI. With respect to gender, two studies were from Africa and four were from Asia. About previous illness (five studies), type of ownership of facilities (two studies), and owning alternative health insurance (three studies), all studies were from Asia. Three studies, two from Asia and the other from Africa, reported about residence. Similarly, two studies, one in Africa and the other from Asia, reported awareness of the WTP for NHI. Since there was considerable heterogeneity (102) between studies and groups, we employed the DerSimonian and Laird (DL) method, which is recognized as the simplest and most widely used approach for applying the random effects model in metanalysis (104).

As demonstrated in Figure 6, the pooled estimate showed no difference between males and females concerning the WTP for NHI (OR = 0.99, 95% CI: 0.75–1.23) in Africa (Nigeria and Sierra Leone) and Asia (Saudi Arabia, Indonesia, and Malaysia). Male participants in Africa were 1.08 times more likely to pay than female individuals (OR = 1.08, 95% CI: 0.21–1.96), while in Asia, male participants were 3.0% less likely to pay for the scheme compared to female participants (OR = 0.97, 95% CI: 0.73–1.21), indicating that gender had no significant influence on WTP for NHI.

Regarding illness, as in the case of gender, the combined result showed that there was no significant difference between households with illness and those without (OR = 1.01, 95% CI: 0.43–1.60) in terms of likelihood to pay for NHI in Asia (Saudi Arabia, Indonesia, and Malaysia). This indicated that having a previous illness did not significantly influence the WTP for NHI (Figure 7).

Concerning place of residence, the pooled estimate showed that participants living in urban areas were 1.03 times (OR = 1.03, 95% CI: 0.09–1.98) more likely to pay for the NHI scheme than those living in rural areas in Africa (Sierra Leone) and Asia (Saudi Arabia and Malaysia); however, the relationship was not significant (Figure 8). Participants living in urban areas of Africa (Sierra Leone) were 31.0% less likely to pay for the scheme compared to their rural counterparts (OR = 0.69, 95% CI: 0.62–0.76). In Asia (Saudi Arabia and Malaysia), urban residents were 1.20 times more likely to pay for the scheme (OR = 1.20, 95% CI: −0.65-3.06) than those living in rural areas.

The other important factor was the type of ownership of a health facility in accessing healthcare. As portrayed in Figure 9, the estimate in Asia (Saudi Arabia and Indonesia) showed that those who used healthcare services at public health facilities were 1.68 times more likely (OR = 1.68, 95% CI: −0.76-4.12) to pay for NHI compared to participants who did not use services at public health facilities, indicating that the type of ownership of the health facility had no significant influence on the WTP for NHI.

In Asia (Saudi Arabia and Malaysia), there was no significant difference between participants who owned PHI and those who did not (OR = 1.02, 95% CI: 0.65–1.39) to pay for NHI. However, the association between ownership of having alternative health insurance and WTP for NHI was not significant (Figure 10).

Though the strength of association was not significant, the combined result of two studies from Africa (Sierra Leone) and Asia (Malaysia) showed that participants with good awareness about the scheme were 4.26 times more likely to pay for it (OR = 4.26, 95% CI: −1.17–9.69) than those with poor awareness. However, in both individual studies or sub-groups, awareness had a significant relationship with the WTP for NHI (Figure 11). In Asia, individuals with good awareness were 1.52 more likely (OR = 0.66, 95% CI: 0.49–0.83) to pay for NHI compared to those with poor awareness. Similarly, in Africa, those with good awareness were 7.06 times more likely (OR = 7.06, 95% CI: 5.89–8.23) to pay for it than their counterparts with poor awareness.

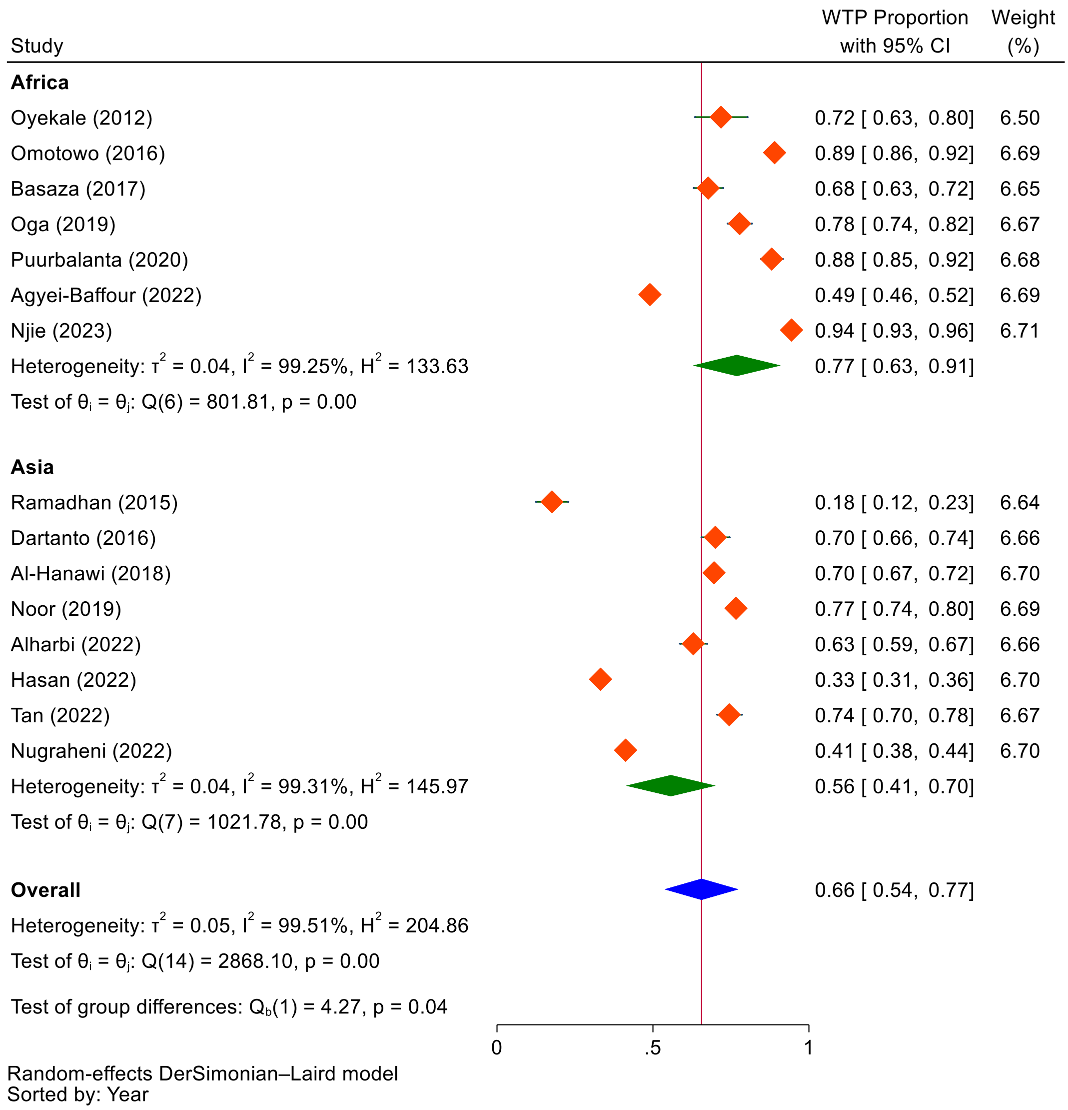


FIGURE 4
The forest plot showing the proportions of the WTP for NHI in Africa and Asia prior to excluding outliers (*n* = 15), 2023.

Reporting bias and certainty of evidence

The I^2 statistic was used to measure between-study heterogeneity, which showed that the overall I^2 value was greater than 50% (99.51%). To control the influence of each study on the combined result, measured as percentages of weights, a random-effects model was used to calculate the pooled WTP for NHI. To identify the source of heterogeneity, we conducted a test for the subgroup difference based on continents, which was significant ($p = 0.039$). To determine if there was publication bias between studies (asymmetry or the effect of small studies), we drew a Doi plot (Figure 12) that provided an LFK index 1.72 and showed minor asymmetry.

A sensitivity analysis was also conducted to identify outlier studies. Accordingly, seven studies were found to be outliers (88, 91, 93, 94, 96, 99, 101), and the pooled estimate (effect size) was influenced by the inclusion and exclusion of these studies. Nevertheless, as shown in Figure 13, when we adjusted for outliers using a random effects model, all of the included studies (n = 15) were found not to be outliers. Therefore, we combined the data using a random effects model without excluding any outliers. Yet, the WTP for NHI was higher in Africa compared to Asia.

Discussion

Due to the diverse preferences of individuals, the WTP might be a very subjective measure of their intention to use health insurance. As a result, it might be affected by a variety of broad issues, like the nature of the healthcare market, information asymmetry, the psychosocial inclinations of individuals, the contexts in individual nations, the culture of a specific or defined community, health service valuation techniques or perceptions of peoples, the development level of countries, political dynamics and health policy, disease distribution and frequency, the quality of healthcare services, health system structure and taxation, reimbursement mechanisms, and the type of benefit packages to be covered, among others. The differences in the health systems of individual countries are perhaps the most crucial

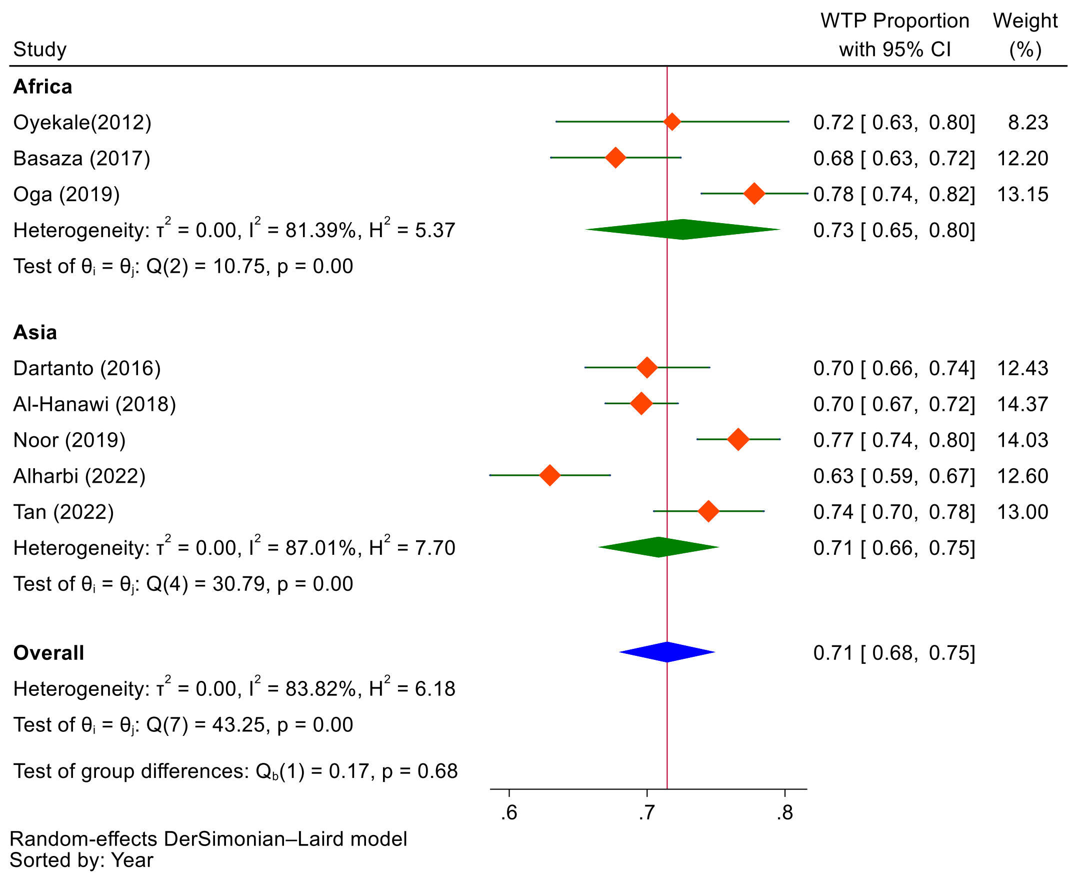


FIGURE 5
The forest plot showing the proportions of the subgroup analysis of the WTP for NHI in Africa and Asia after excluding outliers (*n* = 8), 2023.

factors, as they shape the overall healthcare environment and are thus central to our well-being and livelihood. Should they collapse or experience disruption, it would impact the entire healthcare market and the overall sustainability of our economy (105). On the other hand, health insurance is not universally available in all developing countries, and the most cost-efficient approach to promoting health is unclear, which is a central policy concern in health economics (106). Furthermore, health insurance coverage varies greatly among different countries (107). Therefore, our discussion was not merely dependent on the specific results of this systematic review and meta-analysis; rather, we tried to deeply debate, compare, contrast, and comprehend various issues and evidence while being within the scope and context of our review and its findings.

Prevalence of the willingness to pay

This systematic review and meta-analysis found that the pooled WTP for NHI in Africa and Asia was 71.0% (95% CI: 68–75%). Though the difference was not significant ($p = 0.680$), the WTP for the scheme in Africa (73.0, 95% CI: 65.0–80.0%) was higher than that in Asia (71.0, 95% CI: 66–75%). This is comparable to the findings of a primary study conducted in St. Vincent and the Grenadines, a Caribbean country, which reported that the WTP for NHI was 72.3% (108). From this evidence, one can easily extrapolate that the mean of the three percentages (73.0% in Africa, 71.0% in Asia, and 72.0% in Latin America) was 72.0%, which was approximately equivalent to the pooled WTP data mentioned above. This, in turn, indicates that the WTP for the scheme across the three continents was noteworthy, with minimal differences. Despite this appreciable WTP for NHI, the UHC on these continents, particularly in Africa and Asia, is still the lowest, and access to essential health services remains at a worrying level (109).

Chen et al. (110) noted that attaining UHC is difficult due to various factors globally and on these continents. Primarily, LMICs lack the funds required for UHC (110). As a result, OOP payments remained the single most common healthcare financing option in LICs, which can create a health protection gap (HPG) (111), a shortfall in finances to fund health expenditures (38). HPG is the portion of uninsured losses in total losses, or it is the sum of financially stressful OOP expenditures and the estimated cost of non-treatment due to unaffordability (111). In areas with weak financial protection, HPG, or catastrophic spending, is primarily driven by OOP payments (112). For instance, in SSA, the pooled annual incidence of catastrophic health expenditure (CHE) was 16.5%, with countries in central SSA having the highest incidence while those in southern SSA had the lowest (113). Additionally, health insurance coverage is both insufficient and unbalanced (110). These two reasons dictate that development partners should align financial and technical assistance with national health priorities, establish accountability mechanisms for resource efficiency, and strengthen national health accounts to

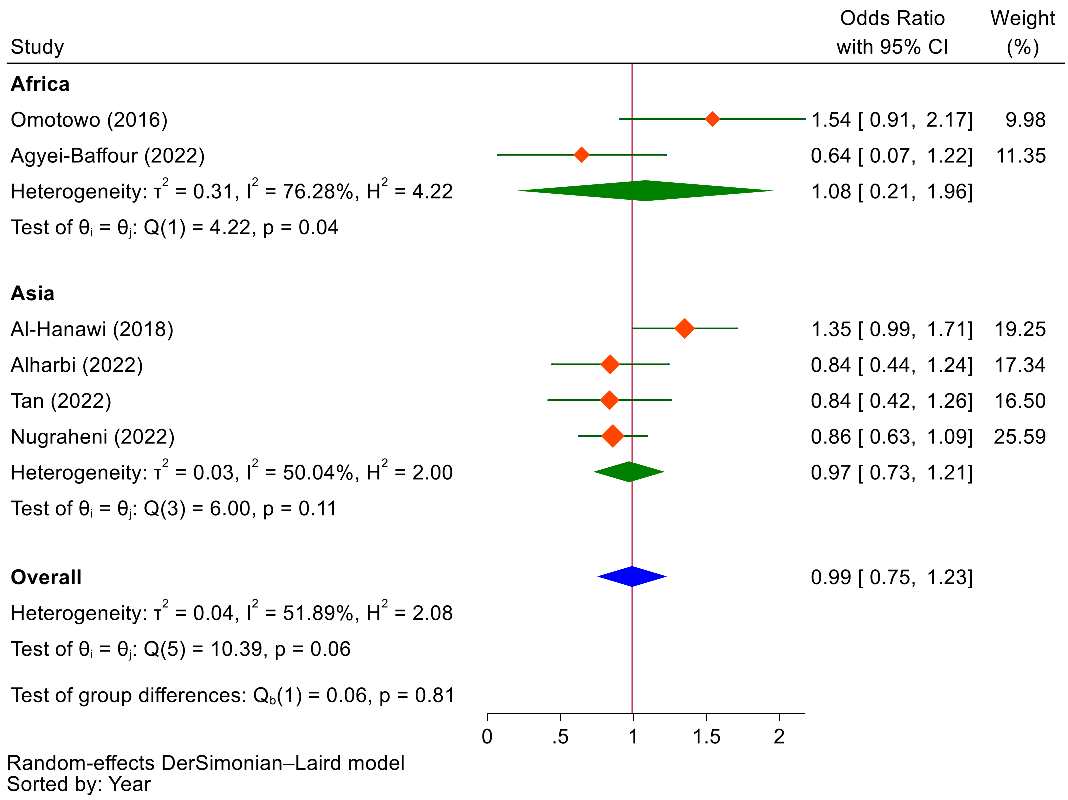


FIGURE 6
The strength of the relationship between gender and the WTP for NHI in Africa and Asia.

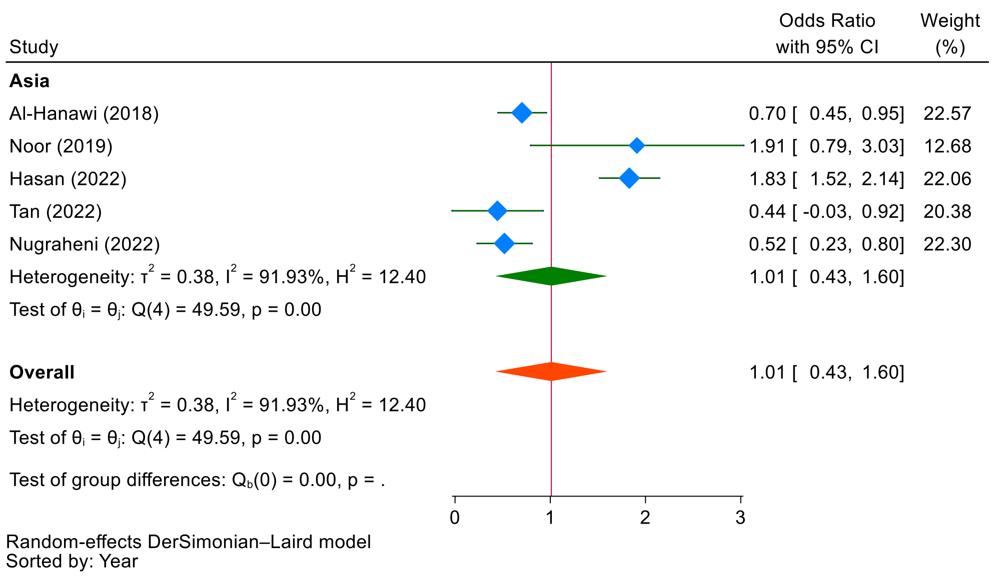


FIGURE 7
The strength of the relationship between experiencing illness and the WTP for NHI in Asia.

monitor allocations and expenditures, as health financing is a global responsibility that requires solidarity and collective effort (114).

However, without controlling for outliers, the combined WTP for the scheme was 66.0% (95% CI: 54.0–77.0%), 77.0% (95% CI: 63–91%) in Africa, and 56.0% (95% CI: 41–70%) in Asia, which indicated a significant difference in the WTP for the scheme between the two continents ($p = 0.039$). In both scenarios, with and without outlier studies, the review indicated that the WTP for the scheme was higher in Africa than in Asia, which might be due to the heterogeneity in health insurance preference between the two

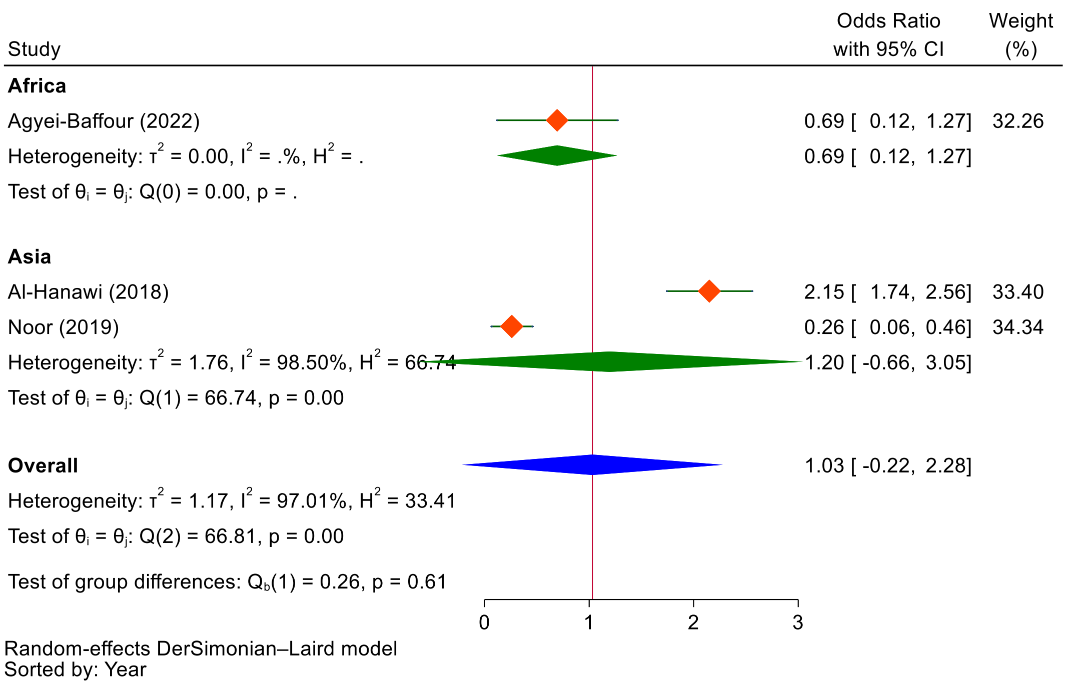


FIGURE 8
The strength of the relationship between residence and the WTP for NHI in Africa and Asia.

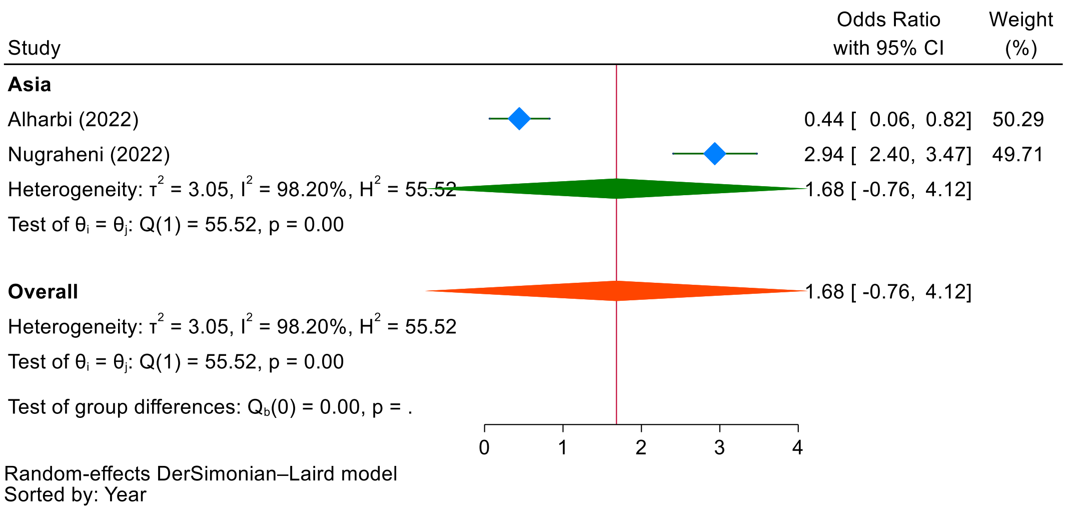


FIGURE 9
The strength of the relationship between the type of health facilities to access health services and the WTP for NHI in Asia.

continents' populations, as reported by a study in Australia (115). The lower WTP for NHI in Asia might be attributable to the fact that the included studies for meta-analysis were from only three countries, as opposed to six nations in Africa. This slight lower WTP for the scheme in Asia contrasted with the evidence that consumers bear a disproportionate share of healthcare costs as OOP expenses due to inadequate UHC and the middle class's demand for high-quality care, which in turn is expected to significantly increase their demand for health insurance (116). In Africa, even higher aggregate proportions of WTP for health insurance were reported. For instance, a cross-sectional study in seven East and West African communities revealed a 78.8% WTP for health insurance, exceeding the results of our review (60).

In fact, several African countries have recently made significant progress in extending UHC (117), as highlighted by the Africa Health Strategy 2016–2030, which aimed to strengthen national health systems as a crucial step towards achieving UHC (114). However, the rate of UHC varies significantly among countries (117). Cashin et al. (118) state that SSA is increasingly adopting public contributory health insurance for UHC, with eight countries having NHI systems and seven more considering or enacting laws. Gabon, Ghana, and Rwanda have notably extended NHI to cover large population

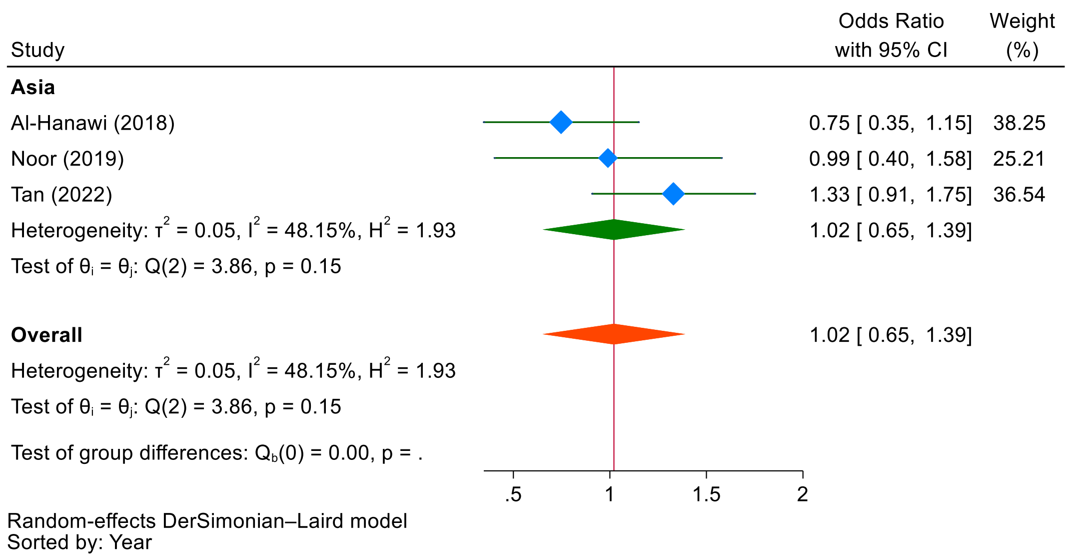


FIGURE 10
The strength of the relationship between alternative health insurance ownership and the WTP for NHI in Asia.

FIGURE 11
The strength of the relationship between the awareness level of participants about the scheme and the WTP for NHI in Africa and Asia.

segments, demonstrating that clear goals, equity-focused designs, strong political will, and ongoing adaptation are key to facilitating UHC through NHI (118). To that end, the WHO is collaborating with the African Union and the Africa Centers for Disease Control (CDC) to establish the African Medicines Agency (AMA). This important regulatory authority aims to improve access to medicines in Africa, where many nations struggle with pharmaceutical regulation. A vital part of this effort is guaranteeing a reliable supply of safe, effective, and high-quality medicines across the continent (119).

Nonetheless, due to the inherent drawbacks of WTP studies, it cannot necessarily be said that the demand for health insurance is higher in Africa than in Asia (120). For instance, even in Asia, an original study conducted in Indonesia reported that the ability to pay (ATP) was greater than the WTP (121). Another original study conducted in the same country showed that about 57.6% of the participants were able to pay for NHI, but only 17.4% of them were willing to pay the required premium (96). This indicates that an individual's WTP may not align with their ability to pay (ATP), despite WTP being directly related to household income or the ATP (122). This in turn might be due to the fact that an ATP approach assumes all resources are available for healthcare, while a capacity to pay (CTP) approach considers some resources for basic needs. The CTP for healthcare is defined as a household's consumption minus a standard amount for basic needs, known as the poverty line or basic needs line (123).

Accordingly, ATP could be a more accurate predictor of enrollment, continuity, and sustainability than WTP (122), whereas, since it is the level of contribution that would prevent an individual from falling below the poverty line, CTP could be a better indicator of the WTP (set premium amount). As a result, placing all participants together in a single pool and mandating contributions based on their CTP instead of individual or average pool risk can enable cross-subsidization and, depending on the extent of pooled resources, greatly improve financial protection for all members (124). Moreover,

10.3389/fpubh.2024.1390937

governments should not rely solely on household premiums as a primary source of financing but should enhance their fiscal capacity through alternative means to support an equitable healthcare system (125). This is because resilient and equitable health systems with strong population coverage are crucial for preparing for health emergencies and ensuring equity, the right to health, and justice for all people (126).

The other reason that the WTP might not be as accurate as ATP and CTP is that the responses can be biased because respondents either want to please the interviewer, indicating a high WTP, or they aim to ensure the intervention is offered at a low cost, reflecting a low WTP (127); consequently, what people say they are willing to pay may not correspond to what they actually would pay (120). The former bias is termed social desirability bias (SDB), which is a pervasive measurement challenge, particularly in the social sciences and survey research (128). This bias can increase the WTP by approximately 23–29% if surveys are administered through face-to-face interviews (129). It is more common in collectivist cultures, which tend to engage more in deception and socially desirable responses (128). That is because collectivistic cultures prioritize social harmony over personal goals, promoting forbearance and enduring adversity as coping mechanisms to maintain positive social relations (130).

Inversely, this social cohesion can have invisible benefits and can serve as a strategic tool in community-based healthcare interventions. Evidence shows that collectivistic individuals are more likely to adhere to public health interventions than their less collectivistic counterparts (131), with collectivistic leadership interventions have shown positive

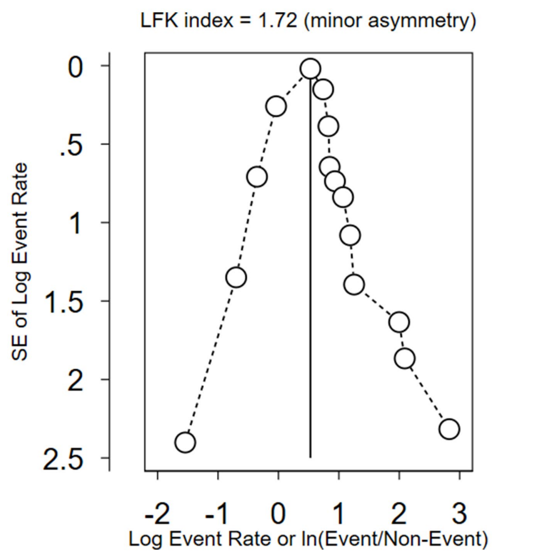


FIGURE 12
A Doi plot to assess publication bias between the included studies.

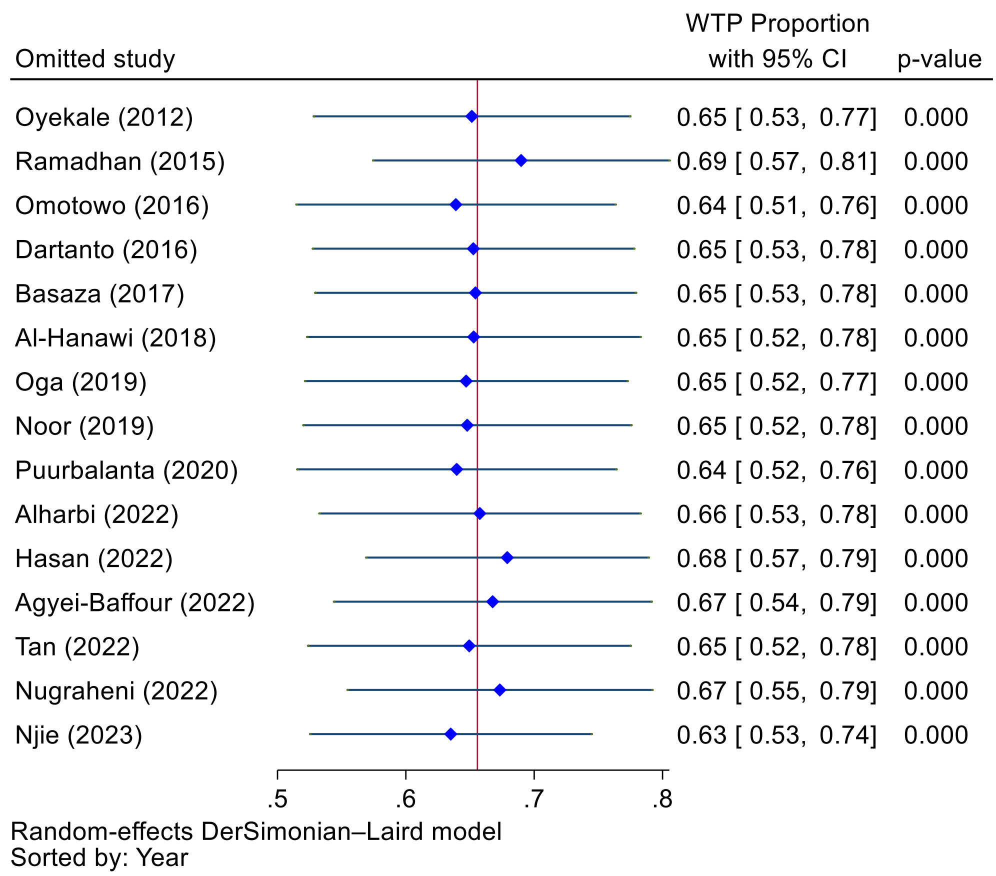


FIGURE 13
A sensitivity analysis to identify outlier studies from the included studies using the random effects model.

results (132). Hence, because healthcare spending is a critical expense for most nations and their citizens to ensure they stay healthy and receive proper care (133), and collectivism is common in the traditional societies (Asia, Latin America, and Africa) than in Western Europe, North America, and Australia (134), healthcare leaders in Africa and Asia may consider collective leadership as a strategy to achieve UHC through NHI.

Though our finding showed a higher WTP for NHI in Africa, the population generally exhibits low satisfaction levels with their healthcare systems compared to other regions globally. This persists despite significant investments from international donors and African governments, as the healthcare sector continues to struggle with issues such as limited access, corruption, infrastructural deficiencies, and medication and personnel shortages (135). On the contrary, beside the health workforce, the implementation of comprehensive NHI itself requires human resources, all of which contribute to the promotion of noble goals for everyone's well-being (136). The primary challenge caused by funding shortages in many African countries is that their health financing systems' strategies and mechanisms are problematic. In nearly half of these nations, household OOP payments make up 40% or more of total health expenditure, representing the least equitable method of healthcare funding (137). For instance, the health insurance coverage in the SSA is limited and favors the wealthy (138). This indicated that the majority of health care funding in SSA comes from direct OOP payments, predominantly from lower-income households (139). Donor funding is another common source of finance (139). As a result, less than half of Africa's population (48%) has access to necessary healthcare, with the quality of services being substandard. Every year, 97 million Africans, or 8.2% of the population, face CHE, and these OOP costs drive 15 million people into poverty annually (119).

In contrast to the slightly lower WTP for NHI than Africa, estimates for Asian people were the lowest globally for delaying or foregoing care due to cost (4%) (140), because Asian individuals possess the lowest rate of being uninsured (141). Though UHC is thought to be a system that offers coverage to a vast majority of the population, the exact percentage required for it to be considered universal is debated. Some experts argue that coverage must extend to 99% of citizens and residents, whereas others believe a 90% threshold is sufficient (140). On the other hand, progress varies by country. Indonesia has advanced in health service coverage and financing, yet faces implementation challenges. Ghana's health funding has decreased, with under 50% achievement in the UHC service coverage index. India still contends with high OOP expenses and low public health financing. Kenya still faces challenges in using public financing to enhance coverage for the informal sector, while South Africa has made little progress in strategic purchasing (142).

The disparity in population coverage could stem from the fact that many African countries adopt CBHI, characterized by fragmented coverage, whereas Asian countries prioritize SHI, which is typically more integrated (143). This demonstrates that the fragmentation and inequity caused by targeting specific population groups with various prepayment mechanisms can be addressed by harmonizing these schemes early on. Thus, it is advisable to implement strong public accountability and participation when formulating the UHC strategy (144) through equitable NHI schemes (139). In fact, most countries now prefer mixed NHI systems, learning from past experiences. These systems are not primarily funded by contributions but rather by significant tax-financed subsidies, resulting in a blend of contribution payments and government revenues. NHI schemes are thought to improve equity and reduce barriers to access in LMICs through two features: pooling, whereby financial risk is spread across the population, and pre-payment, the collection of financial resources in anticipation of service use rather than out-of-pocket payments when health care is consumed. Accordingly, a growing number of LMICs are considering rolling out NHI schemes (145).

However, there are various challenges with the implementation of NHI schemes in LMICs. Friebel et al. (145) identified several obstacles to implementing SHI or NHI programs in LMICs. Firstly, LMICs often have limited fiscal capacity compared to wealthier nations. Secondly, countries with smaller workforces may struggle to generate adequate funds for UHC. Lastly, the administrative expenses of NHI plans and the costs associated with collecting contributions are frequently overlooked (145). According to a systematic review by Lim et al. (146), the health financing challenges in Southeast Asian countries for UHC are unsustainable revenue-raising methods, fragmented health insurance schemes, a mismatch between insurance benefits and the needs of the population, political and legislative apathy, unmanageable and swiftly escalating healthcare costs, and unethical behaviors (146). A study by Oleribe et al. (147) reported that inadequate human resources, insufficient budgetary allocation to health, and poor leadership and management are key challenges facing healthcare systems in Africa on the path to UHC through health insurance (147). According to a qualitative study in Nepal, the major bottlenecks for the implementation of the NHI program included difficulty enrolling insurees, non-competitive selection of health providers, and failure to act as a prudent purchaser, leading to high dropout rates and low coverage of poor households, potentially jeopardizing the program's sustainability if these problems persist (148).

Factors influencing the willingness to pay

The factors affecting the WTP for NHI were thematically identified as demographic variables, income and economic issues, information level and information sources, illness and illness expenditure, health service factors, factors related to financing schemes, and social network and social solidarity. According to systematic reviews conducted in the context of LMICs on the uptake of CBHI, these factors not only affect the WTP for health insurance but also its uptake (149, 150). Another piece of evidence also showed that the choice of health insurance is influenced by a variety of factors, which can be broadly categorized into personal, economic, and external factors. Personal factors include age, health status, and income, as well as awareness, financial security, lifestyle, and risk cover. Economic factors encompass income and the cost of insurance packages, while external factors involve awareness, company-related information, risk, promotion, tax benefits, and advertising. Additionally, personality traits and clients' preferences play a role in their choice of health insurance, often driven by social and behavioral factors (151). A systematic review of the WTP for SHI in Ethiopia also found that sociodemographic factors, health status, health service-related factors, awareness, perception, and scheme-related factors were significant determinants of the WTP (152).

Socio-demographic factors

Under this theme, the WTP for NHI was found to be influenced by family size, age, marital status, gender, area of residence, and level of education. Accordingly, some studies have reported that WTP for the scheme increased with family size (83, 85, 92, 101), while others have found a negative relationship between household size and WTP for the scheme (84, 89, 93). Other reviews and original studies conducted worldwide have also shown inconsistent findings regarding the relationship between family size and the WTP for NHI. For instance, a systematic review of WTP for health insurance in LMICs showed that an increase in family size was consistently correlated with higher WTP (125), while another systematic review on the uptake of health insurance in Zambia found that families with more children were less likely to contribute sustainably to health services (153). The inverse relationship between family size and the WTP for NHI may be attributed to the fact that larger families could reduce the likelihood of affording premiums (84). Or, in some countries, an extra contribution is required for each increase in family size, which may dissuade household heads from paying more (92).

This systematic review found that age was a consistent negative predictor of WTP for NHI (84, 86, 87, 90, 94, 95, 99); that is, WTP for the NHI scheme consistently decreased with increasing age. This dictates that the slightly higher WTP for NHI in Africa may be due to the continent's youngest population, with 70% of SSA under 30 years old (154). Similarly, original studies in Germany (155), St. Vincent and the Grenadines (108), Malaysia (156), Ghana (157), and Vietnam (158), as well as systematic reviews in LMICs (125, 159), showed that the WTP for health insurance and membership was positively associated with younger age groups. However, some other original studies, such as the one conducted in Indonesia among non-salaried participants (160), Ghana (161), and in LMICs (Europe and the Eastern Mediterranean, Latin America and the Caribbean, Southeast Asia and the Western Pacific, and SSA) (162), found that older people were more likely to have health insurance and a lower probability of dropping out compared to younger adults (163). The findings of this review contradict the common belief that seniors, due to chronic illnesses or pre-existing conditions, face higher health risks and thus require increased utilization of health insurance plans (164), resulting in higher premiums than those paid by younger individuals, leading to adverse selection (165, 166). The possible reason could be that OOP payments for healthcare, which are common among older adults, significantly affect disposable income (167), which could be attributed to the inability of health insurance to provide equitable access due to limited service benefits and restricted use of services within schemes (168). Another reason may be that as people age, their supplemental income sources decrease, rendering them unable to afford the premium (169). Consequently, older individuals may have a reduced capacity to pay for necessary healthcare (170), which results in their exclusion from quality health services (171), indicating that inequity may arise in the provision of healthcare (172). Nevertheless, proactively addressing priorities can lead to the development of strategies that promote better health and equitable, goal-directed care for older adults (173).

Regarding the influence of marital status on the WTP for NHI, married households were less likely to pay compared to their single or unmarried counterparts (85, 86, 95). A study in SSA also revealed that married women's health insurance coverage is only 21.3%, with the highest and lowest coverage in Ghana (66.7%) and Burkina Faso (0.5%). This might be because women with household decision-making autonomy had higher odds of health insurance enrollment compared to those without such autonomy (174). Oppositely, a study in China found that marriage positively impacts participation in commercial health insurance, suggesting that married residents are more likely to invest in such insurance (175).

The reports on the influence of gender on WTP for NHI from the included studies were inconsistent, akin to those concerning family size. The pooled odds ratio (OR = 0.99, 95% CI: 0.75–1.23) also showed no difference between males and females in the WTP for NHI. Some studies indicated that households headed by females had a higher likelihood of WTP for NHI (85, 86, 90, 94), whereas other studies found that males were more inclined to pay (91, 97, 100, 101), which was similar to an original study in Burkina Faso showing that men were more willing to pay to join health insurance than women (176).

The report on the included studies concerning the influence of place of residence on WTP for NHI was inconsistent, similar to that of family size and gender, as evidenced by the pooled odds ratio (OR = 1.03, 95% CI: 0.09–1.98). Some of the included studies showed that the WTP for the scheme was negatively related to urban residence (86, 94), while some studies showed the reverse (89), and the other one found an inconclusive finding (90). In another study, health insurance coverage is generally higher in urban areas (177).

The other important sociodemographic variable affecting the WTP for NHI was level of education, in that in most of the included studies, participants who have higher education attainment were more likely to pay for the scheme (83, 89, 94, 95, 98), while in some of them, its influence was found to be inconclusive (90, 91, 101). Similar studies in Malaysia also showed that a higher education level was associated with a higher demand (156) and a higher WTP (125) for health insurance. Another study also found that more educated people were more likely to have health insurance (162), indicating that educational interventions can increase demand for health insurance schemes (178).

Income and economic issues

Factors such as income level, government taxation extent, employment status, and occupation type were categorized under this theme. Most of the included studies (86, 87, 89, 94, 99–101) showed that the WTP for NHI was higher among those with a higher income; the interest to pay for NHI was found to be increased with the household's income level. Other studies also found that higher income was one of the most positive factors influencing the WTP for health insurance (179–181). In fact, the *per capita* level of healthcare expenditure is closely linked to the level of *per capita* income (182), because households with high incomes are more likely to be able to contribute to or pay for health insurance (183), indicating that the wealthy are more likely to be insured in most countries (177). Health insurance schemes in LMICs, despite government efforts, are often not reaching underserved populations and primarily supporting better-off groups (184). However, the health insurance system should ensure healthcare costs are proportional to households' ability to pay, protect the poor from financial shocks, and improve service accessibility for the poor (185). But it is possible for governments to effectively reach marginalized and vulnerable populations in LMICs by implementing supportive regulatory, policy, and administrative provisions (186). That is because, though trade-offs are inevitable, there are opportunities to simultaneously improve access, affordability, and equity (187).

Regarding employment status, the studies' reports were not consistent. Some studies found that those families with a formally employed head were more likely to pay (88, 95, 99), while others reported the opposite (101). In general, employment status can significantly influence an individual's WTP for health insurance, as higher-income individuals are more likely to afford premiums. This can be evidenced by a study conducted in Ghana, which showed that as income increases or the number of unemployed household members decreases, people are willing to pay higher health insurance premiums (188).

Information level and information sources

Awareness about the scheme, knowledge regarding the scheme, and perceptions about financing healthcare, insurance literacy, and access to the internet were classified under this theme. These variables serve as motivational factors to encourage individuals to adhere to health insurance contribution payments (189). On the other hand, lack of access to information is a significant contributor to the inequality in health insurance subscriptions (190). Our review revealed that awareness level (84, 92, 94), good knowledge (87) and perception (95), insurance literacy, and access to the internet (100) were positively related to the WTP for NHI. However, some studies reported that level of awareness (98), good knowledge (95), and good perception (89) were negatively related to the WTP for the scheme. Though it was not significant, from the pooled ORs of two of the included studies, households with awareness of the scheme were 4.26 times more likely to pay for it (OR = 4.26, 95% CI: 1.17–9.69) than those without awareness. In support of our finding, a study conducted in Uganda revealed that awareness plays a crucial role in determining the demand for health insurance (191). Another study also showed that media exposure significantly contributed to the pro-rich distribution of health insurance coverage (182). However, few studies showed that, for instance, in Nigeria, awareness of health insurance was low (192).

Illness and illness expenditure

Illness condition, illness experiences, and previous healthcare expenditure were important variables determining the WTP for NHI. In some of the included studies (84, 89, 95, 101), illness experience was negatively related to the WTP for NHI, while in others (86, 93, 98), it was positively related. The pooled OR from five of the included studies also revealed that illness experience did not significantly influence the WTP for NHI (OR = 1.01, 95% CI: 0.43–1.60). According to a study in Vietnam, decision-making regarding healthcare expenditure hinges heavily on an individual's health status and their certainty about the future (193).

Experience of previous healthcare expenditure for healthcare services (inpatient and outpatient) was positively related to the WTP for NHI (100). This might be due to the fact that past high healthcare expenses have increased awareness of financial risks, leading to an increased WTP for health insurance and a reminder of potential medical care needs. However, a cross-sectional study among seven communities in East and West Africa showed that previous spending on healthcare was found to decrease the likelihood of being willing to pay for a health insurance scheme (60), which could be associated with poor quality health services.

Health service factors

These factors included the availability of hospitals, type of usual healthcare provider, place of treatment, inpatient and/or outpatient service, and quality of healthcare services. Hospital availability at district level (100), healthcare provider type (public hospital) and health service utilization (inpatient) (101), and health service quality (89, 90) were found to be positively related to the WTP for NHI. The pooled OR from two of the included studies showed that those who used healthcare services at public health facilities were 1.68 times more likely (OR = 1.68, 95% CI: −0.76-4.12) to pay for NHI compared to participants who did not use services at public health facilities, though it was not significant.

Another review also emphasized the importance of preserving health services' equitability, affordability, and quality as crucial features (194). However, the lack of access to and unaffordable healthcare remain significant challenges faced by households worldwide (195), particularly in Africa, which faces numerous challenges in accessing medicines (196). For instance, in Egypt, governmental health expenditure accounts for one-third of total health expenditure, with OOP expenditure accounting for over 60.0% and the Ministry of Finance contributing 37.0% (197), which disproportionately burdens the poor (198). This showed that equity in financing health systems is hindered by direct payments, inadequate insurance coverage, and insufficient tax exemptions (199). Yet, NHI can improve health service accessibility and financial protection, especially for low-income individuals (200). This is because increased health insurance coverage generally leads to an increase in access to healthcare facilities (201) and can effectively manage service disparities if standardized benefit packages are implemented (202).

The UHC Coalition and WHO have incorporated quality as the fourth dimension of UHC (203), because it can significantly enhance the likelihood of achieving desired health outcomes (204). On the other hand, poor-quality services hinder UHC (205). Quality of care is therefore crucial for UHC and can be achieved through good leadership, robust planning, and intelligent investment in all settings (206). This implies that a comprehensive healthcare system should meet local needs, prioritize high-quality primary care, and involve individuals and communities in service design, delivery, assessment, and improvement (205). As a result, a well-designed national quality policy is crucial for countries to enhance health service access and outcomes, as quality is a multifaceted concept requiring strategic interventions (207). Unless, health insurance may improve structural quality but not quality measures, service delivery efficiency, or equitable benefit distribution (208).

Factors related to financing schemes

Factors related to financing schemes, such as trust in the scheme, insurance preference, having alternative health insurance, the impression of paying, and the type of health insurance plan, can greatly affect the WTP for NHI. Scheme trust and preference (84), level of health insurance plan (101), and having alternative health insurance (95) were found to influence the WTP for NHI positively, while the impression of paying more (85) and having alternative health insurance (86, 89, 92) were found to influence it negatively. Another study also found that enrolling in another health insurance scheme reduced the WTP for the scheme (60). However, the pooled OR from three of the included studies indicated that there was no significant difference between participants who owned alternative health insurance and those who did not (OR = 1.02, 95% CI: 0.65–1.39) to pay for NHI.

Another review also found that scheme trust, low and flexible contribution rates, benefit packages, government subsidies, and the quality of scheme administration significantly influence enrolment and contributions (183). The findings of our review differ from those of a Ugandan study, which revealed that patients without microfinance schemes are 76% less likely to enroll in a NHI scheme (209). In any way, the sub-Saharan and southeast Asian regions face challenges in health insurance development, including demand, supply, and regulatory aspects (210, 211). There are also unfavorable attitudes towards health insurance coverage even in developed countries, with 60% of Americans believing the federal government is responsible for ensuring UHC (212).

Social capital and solidarity

The review found that level of empowerment was found to be positively linked with the WTP for NHI, while group and network connection and social capital cohesion and inclusion were negatively linked with it (93). Another study reported that demand for health insurance is affected by social networks (213), while a study in Nigeria identified cultural and religious norms and poor social infrastructure as common barriers to adopting the NHI (214).

Policy and practical implications

The combination of social insurance and taxes in healthcare financing systems in LMICs is known to be effective when supported by political commitment and family-based membership, contributing to rapid population coverage and leading to UHC. Effective healthcare purchasing and provider regulation are also crucial for sustainability (30), as successful universal healthcare schemes follow standard country-wide rules, combining decentralized financial management with centralized oversight and risk pooling (117). Based on the review results, it is strongly recommended to consider economic factors, particularly income levels and age stratification, in the design characteristics of the scheme and implementation strategies. Since all successful schemes offer free health coverage for the poorest segments (117), considering these factors in designing, implementing, monitoring, and evaluating is highly recommended to minimize adverse selection when determining eligibility for indigent services among poor families.

Limitations

The data was pooled despite the high heterogeneity between the reports of the included studies. We could not be able to calculate and pool the exact amount of the WTP in monetary value due to the differences in the exchange rates between the countries. As a result, we only pooled the percentage of participants who were found to be willing to pay. Additionally, since the included studies were few in number, the result could not necessarily be generalizable to all other countries on the continents other than the countries from which the studies were included.

Directions for future research

Since the WTP for a health intervention before any actual health adversity or experience is highly influenced by an individual's feelings and intentions, comprehensive exploratory studies regarding the perceptions and sociocultural beliefs of NHI in Africa and Asia may be important. It might also be important to conduct actuarial analyses to measure the success of NHI implementation, which may help evaluate the effectiveness of the scheme and revise the design and implementation strategies.

Conclusion

The WTP for NHI in Africa and Asia was moderate, while it was slightly higher in Africa than Asia. The factors affecting it were thematically identified as demographic variables, income and economic issues, information level and information sources, illness and illness expenditure, health service factors, factors related to financing schemes, and social network and social solidarity. Age was found to be consistently and negatively related to the WTP for NHI, while higher income level was almost consistently and positively related to it, which might in turn indicate that income level might decrease with increased age due to a decrease in economic productivity.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

EMB: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. AKA: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. HNT: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. SZ: Resources, Supervision, Validation, Visualization, Writing – review & editing. GB: Resources, Supervision, Validation, Visualization, Writing – review & editing. DOI: Resources, Supervision, Validation, Visualization, Writing – review & editing. MHK: Resources, Supervision, Validation, Visualization, Writing – review & editing.

Funding

The author(s) declare that no financial support was received for the research, authorship, and/or publication of this article.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2024.1390937/full#supplementary-material

References

1. Devarakonda M. *The World's Largest Continent Makes Up 60% of the Global Population. Here's Which It Is.* New York, United States: Gannett Satellite Information Network (2023).

2. Ropelato J. *Top 7 Largest Continents in the World.* Utah, United States: WhiteClouds (2023).

3. Rosenberg M. *Ranking the 7 Continents by Size and Population* ThoughtCo (2020).

4. Mundy L, Trowman R, Kearney B. Overcoming the barriers to achieving universal health Care in the Asian Region. *Int J Technol Assess Health Care*. New York, United States: Dotdash Meredith. (2018) 34:352–9. doi: 10.1017/S0266462318000417

5. Coady D., Clements B.J., Gupta S., *Health financing Systems in East Asia and the Pacific: Early Successes and Current Challenges, the Economics of Public Health Care Reform in Advanced and Emerging Economies*. Washington, DC: International Monetary Fund (2012). pp. 133–155.

6. Tham TY, Tran TL, Prueksaritanond S, Isidro JS, Setia S, Welluppillai V. Integrated health care systems in Asia: an urgent necessity. *Clin Interv Aging*. (2018) 13:2527–38. doi: 10.2147/CIA.S185048

7. Chongsuvivatwong V, Phua KH, Yap MT, Pocock NS, Hashim JH, Chhem R, et al. Health and health-care systems in Southeast Asia: diversity and transitions. *Lancet*. (2011) 377:429–37. doi: 10.1016/S0140-6736(10)61507-3

8. Gauld R, Ikegami N, Barr MD, Chiang T-L, Gould D, Kwon S. Advanced Asia's health systems in comparison. *Health Policy*. (2006) 79:325–36. doi: 10.1016/j.healthpol.2006.01.009

9. Wagstaff A. Health systems in East Asia: what can developing countries learn from Japan and the Asian tigers? *Health Econ*. (2007) 16:441–56. doi: 10.1002/hec.1180

10. Zhang X, Oyama T. Investigating the health care delivery system in Japan and reviewing the local public hospital reform. *RMHP*. (2016) 9:21–32. doi: 10.2147/RMHP.S93285

11. Hong K, Laude AMC, Huibin A. Towards a comparative analysis of health systems reforms in the Asia-Pacific region. Asia Pacific. *J Public Health*. (2002) 14:9–16. doi: 10.1177/101053950201400104

12. Yeoh E-K, Johnston C, Chau PYK, Kiang N, Tin P, Tang J. Governance functions to accelerate Progress toward universal health coverage (UHC) in the Asia-Pacific region. *Health Syst Reform*. (2019) 5:48–58. doi: 10.1080/23288604.2018.1543521

13. Caussy D. U. Than sein, East Asia and Pacific states, health systems of In: SR Quah, editor. *International Encyclopedia of Public Health*. *2nd* ed. Oxford: Academic Press (2017). 387–95.

14. Hays R, Pong LT, Leopando Z. Primary care in the Asia-Pacific region: challenges and solutions. *Asia Pac Fam Med*. (2012) 11:8. doi: 10.1186/1447-056X-11-8

15. Van Minh H, Pocock NS, Chaiyakunapruk N, Chhorvann C, Duc HA, Hanvoravongchai P, et al. Progress toward universal health coverage in ASEAN. *Glob Health Action*. (2014) 7:25856. doi: 10.3402/gha.v7.25856

16. Lin V, Leung G, Carter B. Asia-Pacific countries moving toward universal health coverage. *Health Syst Reform*. (2019) 5:1–6. doi: 10.1080/23288604.2018.1543537

17. Tulchinsky TH, Varavikova EA, Cohen MJ. Chapter 13 - national health systems In: TH Tulchinsky, EA Varavikova and MJ Cohen, editors. *The New Public Health*. *4th* ed. San Diego: Academic Press (2023). 875–986.

18. Elwakil R, Ocama P, Kayamba V, Fouad Y, Ojo O. Editorial: global excellence in gastroenterology: Africa. *Front Med (Lausanne)*. (2022) 9:1121276. doi: 10.3389/fmed.2022.1121276

19. Worldometer. *Population of Africa.* Dover, United States: Worldometer (2024).

20. Atta IA, Duah HO. Better or worse? Despite Progress, many Africans still finds it difficult in accessing health care: a comparative analysis of eight African countries. *J Health Med Inform*. (2018) 9:299. doi: 10.4172/2157-7420.1000299

21. Kirigia JM, Barry SP. Health challenges in Africa and the way forward. *Int Arch Med*. (2008) 1:27. doi: 10.1186/1755-7682-1-27

22. Gupta S. The challenge of health care reform in advanced and emerging economies In: *The Economics of Public Health Care Reform in Advanced and Emerging Economies*. Eds. B. Clements, D. Coady and S. Gupta Washington, DC: International Monetary Fund (2012). 3–21.

23. Coady D, Clements BJ, Gupta S, Coady D, Clements BJ, Gupta S. *The Economics of Public Health Care Reform in Advanced and Emerging Economies* Washington, DC: International Monetary Fund (2012).

24. Wagle K. *Universal Health Coverage (UHC): Dimensions, Guiding Principles and Advantages!!* San Francisco, United States: Public Health Notes, WordPress (2018).

25. Vega J, Frenz P. Integrating social determinants of health in the universal health coverage monitoring framework. *Rev Panam Salud Publica*. (2013) 34:468–72.

26. World Health Organization. *Making Fair Choices on the Path to Universal Health Coverage: Final Report of the WHO Consultative Group on Equity and Universal Health Coverage*. Geneva, Switzerland: World Health Organization (2014).

27. Yazbeck AS, Savedoff WD, Hsiao WC, Kutzin J, Soucat A, Tandon A, et al. The case against labor-tax-financed social health insurance for Low- and Low-middle-income countries. *Health Aff*. (2020) 39:892–7. doi: 10.1377/hlthaff.2019.00874

28. Coady D. Public health care spending: past trends In: *The Economics of Public Health Care Reform in Advanced and Emerging Economies*. Eds. B. Clements, D. Coady and S. Gupta Washington, DC: International Monetary Fund (2012). 23–36.

29. Addis Ababa University. *University of Gondar, and Jimma University, Module 6: Health Care Financing, Jhpiego and Its Licensors.* Milton Keynes, England: The Open University (2014).

30. Kwon S. Thirty years of national health insurance in South Korea: lessons for achieving universal health care coverage. *Health Policy Plan*. (2009) 24:63–71. doi: 10.1093/heapol/czn037

31. Gatome-Munyua A, Sieleunou I, Sory O, Cashin C. Why is strategic purchasing critical for universal health coverage in sub-Saharan Africa? *Health Syst Reform*. (2022) 8:e2051795. doi: 10.1080/23288604.2022.2051795

32. World Health Organization. *Universal Health Coverage, World Health Organization | African Region*. Geneva, Switzerland: World Health Organization (2021).

33. Dimitrova D, Akinola S. *How Africa and Asia Are Joining Forces on Universal Healthcare.* Davos, Switzerland: World Economic Forum, Holtzbrinck Publishing Group (2019).

34. Beattie A, Yates R, Noble D. *Accelerating Progress Towards Universal Health Coverage for Women and Children in South Asia*. Kathmandu, Nepal: East Asia and the Pacific, UNICEF Regional Office South Asia (2016). 68 p.

35. Chattu VK, Singh B, Pattanshetty S, Reddy S. Access to medicines through global health diplomacy. *Health Promot Perspect*. (2023) 13:40–6. doi: 10.34172/hpp.2023.05

36. World Health Organization. *Universal Health Coverage (UHC)*. Geneva, Switzerland: World Health Organization (2023).

37. Savedoff W., *Tax-Based Financing for Health Systems: Options and Experiences*, Geneva, Switzerland, World Health Organization, (2004), pp. 1–22.

38. Swiss Re Institute. *The Health Protection Gap in Asia: A modelled Exposure of USD 1.8 Trillion*. Zürich, Switzerland: Swiss Re Institute (2018). 21 p.

39. Escobar M.-L., Griffin C.C., Shaw R.P., *Why and How Are We Studying Health Insurance in the Developing World? The Impact of Health Insurance in Low- and Middle-Income Countries*, The Brookings Institution, Washington, DC, (2010), pp. 1–12.

40. Das J, Do Q-T. *The Prices in the Crises.* Washington, D.C: Centre for Economic Policy Research (CEPR) (2023).

41. Kodali PB. Achieving universal health coverage in Low- and middle-income countries: challenges for policy post-pandemic and beyond. *Risk Manag Healthc Policy*. (2023) 16:607–21. doi: 10.2147/rmhp.S366759

42. A. American Public Health. *Adopting A Single-Payer Health System.* Washington, DC: American Public Health Association (2021).

43. World Health Organization. *Access to Medicines and Vaccines Report by the Director-General, Seventy-Second World Health Assembly*. Geneva, Switzerland: World Health Organization (2019). 8 p.

44. Bigdeli M, Jacobs B, Tomson G, Laing R, Ghaffar A, Dujardin B, et al. Access to medicines from a health system perspective. *Health Policy Plan*. (2012) 28:692–704. doi: 10.1093/heapol/czs108

45. World Health Organization. *Healthy Systems for Universal Health Coverage – A Joint Vision for Healthy Lives, World Health Organization and International Bank for Reconstruction and Development*. Geneva, Switzerland: The World Bank (2017).

46. Shah M. *Universal Health Coverage: Collaboration to Achieve Health for All, Organisation for Economic Co-operation and Development (OECD)*. France: Paris Cedex (2023).

47. Mint L. 5 Different Types of Insurance Policies & Coverage that You Need. *MintLife Blog*. Oakland, California: Credit Karma (2020).

48. D'Ambrosio C, Ghislandi S. Health insurance: economic and risk aspects In: JD Wright, editor. *International Encyclopedia of the Social and Behavioral Sciences. 2nd* ed. Oxford: Elsevier (2015). 640–5.

49. Devadasan N, Goswamy SP. *Framework for Developing Health Insurance Programmes*. Government of India, New Delhi, India: Ministry of Health and Family Welfare (2007).

50. Cherry AL, Baltag V, Dillon ME. *International Handbook on Adolescent Health and Development*. Switzerland: The Public Health Response. Springer Internatioanl Publishing (2017).

51. Jowett M. *Theoretical Insights Into the Development of Health Insurance in Low-Income Countries*. Centre for Health Economics: University of York (2004). 31 p.

52. USAID. *Health Insurance, Financing Roadmap, Health Policy Plus*. Washington, DC: USAID (2021).

53. Bayked EM, Toleha HN, Kebede SZ, Workneh BD, Kahissay MH. The impact of community-based health insurance on universal health coverage in Ethiopia: a systematic review and meta-analysis. *Glob Health Action*. (2023) 16:2189764. doi: 10.1080/16549716.2023.2189764

54. Ly MS, Bassoum O, Faye A. Universal health insurance in Africa: a narrative review of the literature on institutional models. *BMJ Glob Health*. (2022) 7:e008219. doi: 10.1136/bmjgh-2021-008219

55. Insuranceopedia. *National Health Insurance*. Edmonton, Canada: Insuranceopedia (2018).

56. Wang H., Switlick K., Ortiz C., Zurita B., Connor C., *Design Element 2. Choice of Financing Mechanisms, Africa Health Insurance Handbook—How to Make It Work, Health Systems 20/20 Project*, Abt Associates Inc., Washington, DC, (2010), pp. 13–20.

57. USAID. *Health Insurance, Health Policy Plus*. Washington, DC: USAID (2021).

58. Berkhout E, Oostingh H. *Health Insurance in Low-Income Countries: Where Is The Evidence that It Works?* Nairobi, Kenya: Oxfam International (2008). 29 p.

59. Wen H-C, Lee L-H, Valvi N, Dixon BE. Health information exchange in Taiwan: multiple layers to facilitate broad access and use of data for clinical and population health In: BE Dixon, editor. *Health Information Exchange: Navigating and Managing a Network of Health Information Systems*. Cambridge, Massachusetts: Academic Press (2023). 621–45.

60. Bolarinwa OA, Ameh S, Ochimana C, Oluwasanu AO, Samson O, Mohamed SF, et al. Willingness and ability to pay for healthcare insurance: a cross-sectional study of seven communities in east and West Africa (SevenCEWA). *PLoS Glob Public Health*. (2021) 1:e0000057. doi: 10.1371/journal.pgph.0000057

61. Abbas SM, Usmani A, Imran M. Willingness to pay and its role in health economics. *J. Bahria Univ. Med. Dent. Coll.* (2019) 9:62–6. doi: 10.51985/JBUMDC2018120

62. Preker AS, Langenbrunner J, Jakab M. Rich-poor differences in health care financing, social reinsurance: a new approach to sustainable community health financing. *Int. Bank Reconstr. Dev.* (2002):21–36.

63. Nzowa PG, Nandonde FA, Seimu SML. Mediation effect of trust on willingness to pay for health insurance among co-operative members in Tanzania. *Fut Bus J*. (2023) 9:18. doi: 10.1186/s43093-023-00198-0

64. Rascati K.L., *Cost-Benefit Bnalysis, Essentials of Pharmacoeconomics*, Lippincott Williams & Wilkins, A Wolters Kluwer Business Philadelphia, PA, (2014), pp. 103–130.

65. Russell S, Fox-Rushby J, Arhin D. Willingness and ability to pay for health care: a selection of methods and issues. *Health Policy Plan*. (1995) 10:94–101. doi: 10.1093/heapol/10.1.94

66. Brenzel L., Newbrander W., *Linking ability and Willingness to Contribute to Microinsurance, Social Reinsurance: A New Approach to Sustainable Community Health Financing*, Geneva, Switzerland: The International Bank for Reconstruction and Development/The World Bank and the International Labour Organisation, (2002), pp. 293–302.

67. McGhan WF. Pharmacoeconomics In: D Troy, editor. *Remington: The Science and Practice of Pharmacy*. Philadelphia, United States: Lippincott Williams & Wilkins (2005). 2070–81.

68. Dror D.M., *Willingness to Pay for Health Insurance, Financing Micro Health Insurance*, World Scientific, New Delhi, India, (2018), pp. 113–116.

69. Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *BMJ*. (2021) 372:n71. doi: 10.1136/bmj.n71

70. Moher D, Liberati A, Tetzlaff J, Altman DG. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *PLoS Med*. (2009) 6:e1000097. doi: 10.1371/journal.pmed.1000097

71. Adams D. *Publish or Perish on Microsoft Windows*. St. Albans, United Kingdom: Tarma Software Research Ltd. (2016).

72. Lu J-W, Huang Y-W, Chen T-L. *2.4. Data Synthesis and Statistical Analysis*. California, USA: Bio-Protocol LLC (2023).

73. Xu C, Furuya-Kanamori L, Doi SAR. *DOIPLOT: Stata Module for Visualization of Asymmetry and Heterogeneity in Meta-Analysis*. Statistical Software Components: MA, USA (2021). S459011 p.

74. Shamim MA. Real-life implications of prevalence meta-analyses? Doi plots and prediction intervals are the answer. *Lancet Microbe*. (2023) 4:e490. doi: 10.1016/S2666-5247(23)00096-4

75. Furuya-Kanamori L, Barendregt JJ, Doi SAR. A new improved graphical and quantitative method for detecting bias in meta-analysis. *Int J Evid Based Healthc*. (2018) 16:195–203. doi: 10.1097/xeb.0000000000000141

76. Furuya-Kanamori L, Doi SA. *LFK: Stata Module to Compute LFK Index and Doi Plot for Detection of Publication Bias in Meta-Analysis*. MA, USA: Statistical Software Components (2020). S458762 p.

77. Apriani M, Zulkarnaian M, Idris H. Analysis of willingness to pay contributions in the membership of the National Health Insurance in regency of Banyuasin. *PREPOTIF Jurnal Kesehatan Masyarakat*. (2021) 5:484–95. doi: 10.31004/prepotif.v5i2.1733

78. Edoh D, Brenya A. A community-based feasibility study of National Health Insurance Scheme in Ghana. *Afr J Health Sci*. (2002) 9:41–50. doi: 10.4314/ajhs.v9i1.30754

79. Mulenga K., Booysen F., *Inequalities in Willingness to Pay for Zambia's National Social Health Insurance Scheme*, Research Square. (2022). doi: 10.21203/rs.3.rs-2250957/v1

80. Lang H-C, Lai M-S. Willingness to pay to sustain and expand National Health Insurance services in Taiwan. *BMC Health Serv Res*. (2008) 8:261. doi: 10.1186/1472-6963-8-261

81. Aji B, Masfiah S, Harwanti S, Ulfah N. Factors affecting willingness to pay for National Health Insurance Program among informal Workers in Indonesia. *Jurnal Info Kesehatan*. (2023) 21:107–15. doi: 10.31965/infokes.Vol21.Iss1.940

82. Mansur R., Subroto A., Using Tree-Based Algorithm to Predict Informal Workers' Willingness to Pay National Health Insurance after Tele-Collection, 2022 10th International Conference on Information and Communication Technology (ICoICT), (2022), pp. 23–28.

83. Nurlia NA, Murti B, Tamtomo DG. Factors correlated with willingness and compliance to pay National Health Insurance Premium in Jember regency. *J Health Policy Manage*. (2021) 6:35–47. doi: 10.26911/thejhpm.2021.06.01.04

84. Oyekale AS. Factors influencing households' willingness to pay for National Health Insurance Scheme (NHIS) in Osun state. *Nigeria Stud Ethno Med*. (2012) 6:167–72. doi: 10.1080/09735070.2012.11886435

85. Omonira OF, Oyekale A. Households' willingness to pay (WTP) for the National Health Insurance Scheme (NHIS): the case of Ojo Local Government Area of Lagos state. *Nigeria Life Sci J*. (2012) 9:3873–7.

86. Noor AA, Saperi S, Aljunid SM. The Malaysian community's acceptance and willingness to pay for a National Health Financing Scheme. *Public Health*. (2019) 175:129–37. doi: 10.1016/j.puhe.2019.07.008

87. Oktora R, Pujiyanto. Willingness to pay for National Health Insurance among Motorcycle Taxi Driver in Depok City, Indonesia. KnE. *Life Sci*. (2018) 4:190–200. doi: 10.18502/kls.v4i1.1381

88. Omotowo IB, Ezeoke UE, Obi IE, Uzochukwu BSC, Agunwa CC, Eke CB, et al. Household perceptions, willingness to pay, benefit package preferences, health system readiness for National Health Insurance Scheme in southern Nigeria. *Health*. (2016) 8:1630–44. doi: 10.4236/health.2016.814159

89. Al-Hanawi MK, Vaidya K, Alsharqi O, Onwujekwe O. Investigating the willingness to pay for a contributory National Health Insurance Scheme in Saudi Arabia: a cross-sectional stated preference approach. *Appl Health Econ Health Policy*. (2018) 16:259–71. doi: 10.1007/s40258-017-0366-2

90. Alharbi A. Willingness to pay for a National Health Insurance (NHI) in Saudi Arabia: a cross-sectional study. *BMC Public Health*. (2022) 22:951. doi: 10.1186/s12889-022-13353-z

91. Njie H, Wangen KR, Chola L, Gopinathan U, Mdala I, Sundby JS, et al. Willingness to pay for a National Health Insurance Scheme in the Gambia: a contingent valuation study. *Health Policy Plan*. (2023) 38:61–73. doi: 10.1093/heapol/czac089

92. Basaza R, Alier PK, Kirabira P, Ogubi D, Lako RLL. Willingness to pay for National Health Insurance Fund among public servants in Juba City, South Sudan: a contingent evaluation. *Int J Equity Health*. (2017) 16:158. doi: 10.1186/s12939-017-0650-7

93. Hasan H, Rahman MM. Willingness to pay for the National Health Insurance Scheme: a cross-sectional study in Sarawak, Malaysia. Bangladesh journal of. *Med Sci*. (2022) 21:577–89. doi: 10.3329/bjms.v21i3.59571

94. Agyei-Baffour P, Jimmy AI, Twum P, Larbie D, Boateng KA, Duah IK, et al. Socio-demographic predictors of willingness to pay for premium of National Health Insurance: a cross-sectional survey of six districts in Sierra Leone. *Int J Health Policy Manag*. (2022) 11:1451–8. doi: 10.34172/ijhpm.2021.50

95. Tan RTH, Abdul Rasid SZ, Wan Ismail WK, Tobechan J, Tan ETY, Yusof AN, et al. Willingness to pay for National Health Insurance: a contingent valuation study among patients visiting public hospitals in Melaka, Malaysia. *Appl Health Econ Health Policy*. (2022) 20:255–67. doi: 10.1007/s40258-021-00691-z

96. Ramadhan AA, Rahmadi AR, Djuhaeni H. Ability and willingness to pay premium in the framework of National Health Insurance System. *Althea Med J*. (2015) 2:635. doi: 10.15850/amj.v2n4.635

97. Oga ASS, Attia-konan AR, Vehi F, Kouame J, Koffi K. Diabetic and cardiovascular patients' willingness to pay for upcoming national health insurance scheme in Côte d'Ivoire. *Health Econ Rev*. (2019) 9:8. doi: 10.1186/s13561-019-0225-y

98. Oyekale A, Adeyeye A. Rural households' awareness and willingness to pay for national health insurance scheme (NHIS) in Ilesha West Local Government Area, Osun State Nigeria: a recursive bivariate probit approach. *Life Sci J*. (2012) 9:2086–93.

99. Puurbalanta R, Adjei M, Afosaa V. Ghana's National Health Insurance Scheme: an ordinal Probit valuation of willingness to pay higher premiums for improved services. *Am J Theor Appl Stat*. (2020) 9:57. doi: 10.11648/j.ajtas.20200903.15

100. Dartanto T, Rezki JF, Pramono W, Siregar CH, Bintara U, Bintara H. Participation of informal sector Workers in Indonesia's National Health Insurance System. *J Southeast Asian Econ*. (2016) 33:317–42. doi: 10.1355/ae33-3c

101. Nugraheni DA, Satibi S, Kristina SA, Puspandari DA. Factors associated with willingness to pay for cost-sharing under universal health coverage scheme in Yogyakarta, Indonesia: a cross-sectional survey. *Int J Environ Res Public Health*. (2022) 19:15017. doi: 10.3390/ijerph192215017

102. Siebert M., *Heterogeneity: What Is It and Why Does It Matter? Students 4 Best Evidence*, London, United Kingdom: Cochrane. (2018).

103. Cantley N., *Tutorial: How To Read a Forest Plot, Students 4 Best Evidence*, London, United Kingdom: Cochrane. (2016).

104. Jackson D, Bowden J, Baker R. How does the DerSimonian and Laird procedure for random effects meta-analysis compare with its more efficient but harder to compute counterparts? *J Stat Plan Infer*. (2010) 140:961–70. doi: 10.1016/j.jspi.2009.09.017

105. StudySmarter. *Market Failure In Healthcare*. Germany: StudySmarter, StudySmarter GmbH, Munich (2023).

106. Cutler DM, Zeckhauser RJ. The anatomy of health insurance In: AJ Culyer and JP Newhouse, editors. *Handbook of Health Economics*. Amsterdam, Netherlands: Elsevier (2000). 563–643.

107. Odipo E. The path to universal health coverage in five African and Asian countries: examining the association between insurance status and health-care use. *Lancet Glob Health*. (2024) 12:e123–33. doi: 10.1016/S2214-109X(23)00510-7

108. Adams R, Chou Y-J, Pu C. Willingness to participate and pay for a proposed national health insurance in St. Vincent and the grenadines: a cross-sectional contingent valuation approach. *BMC Health Serv Res*. (2015) 15:148. doi: 10.1186/s12913-015-0806-3

109. Institute of Tropical Medicine. *Achieving Universal Health Coverage by 2030: The Health Financing and Social Protection Challenges*. Antwerp, Belgium: Institute of Tropical Medicine (2023).

110. Chen S, Cao Z, Wang Z, Wang C. The challenging road to universal health coverage. *Lancet Glob Health*. (2023) 11:e1490–1. doi: 10.1016/S2214-109X(23)00373-X

111. The Geneva Association. *Healthcare in Emerging Markets: Exploring the Protection Gaps*. The Geneva Association: Geneva, Switzerland (2019). 42 p.

112. Thomson S., Cylus J., Evetovits T., *New Numbers for Europe: Financial Hardship, Can People Afford to Pay for Health Care? New evidence on financial protection in Europe*, World Health Organization, Geneva, Switzerland, (2019), pp. 29–48.

113. Eze P, Lawani LO, Agu UJ, Acharya Y. Catastrophic health expenditure in sub-Saharan Africa: systematic review and meta-analysis. *Bull World Health Organ*. (2022) 100:337–351j. doi: 10.2471/blt.21.287673

114. Union African, *Africa Health Strategy 2016–2030*, African Union, Addis Ababa, Ethiopia, (2016), pp. 18–19.

115. Buchmueller TC, Fiebig DG, Jones G, Savage E. Preference heterogeneity and selection in private health insurance: the case of Australia. *J Health Econ*. (2013) 32:757–67. doi: 10.1016/j.jhealeco.2013.05.001

116. Gräwert AB, Becker M, Takabe Y, Bishop A, Fu S. *Capturing the Health Insurance Opportunity in Asia*. Boston, Massachusetts: Boston Consulting Group (2023).

117. Schwettmann J. *Towards Universal Health Coverage: The Cases of Benin*. Côte d'Ivoire: Ethiopia, Kenya, Senegal and Zambia, Labour and Social Justice (2022). 30 p.

118. Cashin C, Dossou J-P. Can National Health Insurance Pave the way to universal health coverage in sub-Saharan Africa? *Health Systems Reform*. (2021) 7:e2006122. doi: 10.1080/23288604.2021.2006122

119. Cullinan K. *Universal Health Coverage: Only Half of Africans Have Access to Health Care*. Geneva, Switzerland: Health Policy Watch (2021).

120. Sutton SS. Pharmacoeconomics In: *McGraw-Hill's NAPLEX Review Guide*. New York, United States: McGraw-Hill Education (2021). 16.

121. Intiasari AD, Aji B, Masfiah S, Trisnantoro L, Hendrartini J. A study of ability to pay and willingness to pay of National Health Insurance Voluntary Participant in rural area. *ATMPH*. eds. S. Scott Sutton McGraw-Hill Companies. (2019) 22:174–82. doi: 10.36295/ASRO.2019.221124

122. Dror D.M., Preker A.S., *Introduction, Social Reinsurance: A New Approach to Sustainable Community Health Financing*, The International Bank for Reconstruction and Development/The World Bank and the International Labour Organisation, Geneva, Switzerland. (2002), pp. 1–17.

123. Thomson S., Cylus J., Evetovits T., *Policy-Relevant Measurement with a Focus on Equity, Can People Afford to Pay for Health Care? New Evidence on Financial Protection in Europe*, World Health Organization, Geneva, Switzerland, (2019), pp. 11–27.

124. Gottret P., Schieber G., *Collecting Revenue, Pooling Risk, and Purchasing Services Health Financing Revisited: A Practioner's Guide*, The International Bank for Reconstruction and Development/The World Bank, Washington, USA, (2006), pp. 45–72.

125. Nosratnejad S, Rashidian A, Dror DM. Systematic review of willingness to pay for health Insurance in Low and Middle Income Countries. *PLoS One*. (2016) 11:e0157470. doi: 10.1371/journal.pone.0157470

126. Barron GC, Koonin J, Akselrod S, Fogstad H, Karema C, Ditiu L, et al. Universal health coverage is a matter of equity, rights, and justice. *Lancet Glob Health*. (2023) 11:e1335–6. doi: 10.1016/S2214-109X(23)00317-0

127. Systems for Improved Access to Pharmaceuticals Services. *Applying Principles of Pharmacoeconomics to Improve Medical Product Selection and Use in Low- and Middle-Income Countries: Trainer's Guide*. SIAPS, Arlington, USA: USAID (2017).

128. Nurumov K, Hernández-Torrano D, Mhamed AAS, Ospanova U. Measuring social desirability in collectivist countries: a psychometric study in a representative sample from Kazakhstan. *Front Psychol*. (2022) 13:822931. doi: 10.3389/fpsyg.2022.822931

129. Leggett CG, Kleckner NS, Boyle KJ, Duffield JW, Mitchell RC. Social desirability Bias in contingent valuation surveys administered through in-person interviews. *Land Econ*. (2003) 79:561–75. doi: 10.2307/3147300

130. Pharr JR, Dodge Francis C, Terry C, Clark MC. Culture, caregiving, and health: exploring the influence of culture on family caregiver experiences. ISRN. *Public Health*. (2014) 2014:689826:1–8. doi: 10.1155/2014/689826

131. Leong S, Eom K, Ishii K, Aichberger MC, Fetz K, Müller TS, et al. Individual costs and community benefits: collectivism and individuals' compliance with public health interventions. *PLoS One*. (2022) 17:e0275388. doi: 10.1371/journal.pone.0275388

132. De Brún A, O'Donovan R, McAuliffe E. Interventions to develop collectivistic leadership in healthcare settings: a systematic review. *BMC Health Serv Res*. (2019) 19:72. doi: 10.1186/s12913-019-3883-x

133. T.I. Team. *What Country Spends the Most on Healthcare?* New York, USA: Investopedia (2021).

134. Triandis HC. Collectivism: cultural concerns In: NJ Smelser and PB Baltes, editors. *International Encyclopedia of the Social & Behavioral Sciences*. Oxford: Pergamon (2001). 2227–32.

135. Signé L., *Strategies for Effective Health Care for Africa in the Fourth Industrial Revolution: Bridging the Gap between the Promise and Delivery*. Cape Town, South Africa: Africa Growth Initiative. (2021).

136. Adyas A. The Indonesian strategy to achieve universal health coverage through National Health Insurance System: challenges in human resources. *Natl Public Health J*. (2021) 16:221–7. doi: 10.21109/kesmas.v16i4.5440

137. World Health Organization. *State of Health Financing in the African Region*. Geneva, Switzerland: World Health Organization (2013). 25 p.

138. Edwine B, Jacob K, Peter N, Nirmala R. Examining the level and inequality in health insurance coverage in 36 sub-Saharan African countries. *BMJ Glob Health*. (2021) 6:e004712. doi: 10.1136/bmjgh-2020-004712

139. Ifeagwu SC, Yang JC, Parkes-Ratanshi R, Brayne C. Health financing for universal health coverage in sub-Saharan Africa: a systematic review. *Glob Health Res Policy*. (2021) 6:8. doi: 10.1186/s41256-021-00190-7

140. Cronin J. *Countries with Free or Universal Healthcare*. Hingham, USA: International Citizens Insurance (2023).

141. Tolbert J, Drake P, Damico A. *Key Facts about the Uninsured Population*. Washington, DC: KFF (2022).

142. Atim C, Bhushan I, Blecher M, Gandham R, Rajan V, Davén J, et al. Health financing reforms for universal health coverage in five emerging economies. *J Glob Health*. (2021) 11:16005. doi: 10.7189/jogh.11.16005

143. Spaan E, Mathijssen J, Tromp N, McBain F, ten Have A, Baltussen R. The impact of health insurance in Africa and Asia: a systematic review. *Bull World Health Organ*. (2012) 90:685–92. doi: 10.2471/blt.12.102301

144. Tangcharoensathien V, Patcharanarumol W, Panichkriangkrai W, Sommanustweechai A. Policy choices for progressive realization of universal health coverage; comment on "ethical perspective: five unacceptable trade-offs on the path to

universal health coverage". *Int J Health Policy Manag*. (2017) 6:107–10. doi: 10.15171/ijhpm.2016.99

145. Friebel R, Josephson E, Forman R, Calza S. *Challenges of Social Health Insurance in Low- and Lower-Middle Income Countries: Balancing Limited Budgets and Pressure to Provide Universal Health Coverage*. Washington, USA: Center for Global Development (2020).

146. Lim MY, Kamaruzaman HF, Wu O, Geue C. Health financing challenges in southeast Asian countries for universal health coverage: a systematic review. *Arch Public Health*. (2023) 81:148. doi: 10.1186/s13690-023-01159-3

147. Oleribe OO, Momoh J, Uzochukwu BSC, Mbofana F, Adebiyi A, Barbera T, et al. Identifying key challenges facing healthcare systems in Africa and potential solutions. *Int J Gen Med*. (2019) 12:395–403. doi: 10.2147/IJGM.S223882

148. Gurung GB, Panza A. Implementation bottlenecks of the National Health Insurance program in Nepal: paving the path towards universal health coverage: a qualitative study. *Int J Health Plann Manag*. (2022) 37:171–88. doi: 10.1002/hpm.3301

149. Adebayo EF, Uthman OA, Wiysonge CS, Stern EA. A systematic review of factors that affect uptake of community-based health insurance in low-income and middle-income countries. *BMC Health Serv Res*. (2015) 15:543. doi: 10.1186/s12913-015-1179-3

150. Bayked EM, Kahissay MH, Workneh BD. Factors affecting the uptake of community-based health insurance in Ethiopia: a systematic review. *Int J Sci Rep*. (2021) 7:459–67. doi: 10.18203/issn.2454-2156.IntJSciRep20213261

151. PubGenius. *Factors Influencing in Choosing Health Insurance? SciSpace - Question*. Seattle, USA: PubGenius Inc (2023).

152. Bayked EM, Toleha HN, Chekole BB, Workneh BD, Kahissay MH. Willingness to pay for social health insurance in Ethiopia: a systematic review and meta-analysis. *Front Public Health*. (2023) 11:1089019. doi: 10.3389/fpubh.2023.1089019

153. Chamileke N. A systematic review of factors affecting uptake of health Insurance in the Informal Sector in Lusaka Province. *Zambia TIJPH*. (2020) 8:68–74. doi: 10.21522/TIJPH.2013.08.01.Art008

154. Mulikita JJ. *Young People's Potential, the Key to Africa's Sustainable Development*. Washington, D.C.: United Nations (2024).

155. Hajek A, Enzenbach C, Stengler K, Glaesmer H, Hinz A, Röhr S, et al. Determinants of willingness to pay for health Insurance in Germany—Results of the population-based health study of the Leipzig research Centre for Civilization Diseases (LIFE-adult-study). *Front Public Health*. (2020) 8:456. doi: 10.3389/fpubh.2020.00456

156. Ellyana Mohamad S, Abd GSR, Nurcholisah F. Systematic review of factors influencing the demand for medical and health insurance in Malaysia. *Int J Public Health Res*. (2020) 10:1242–50.

157. Badu E, Agyei-Baffour P, Ofori Acheampong I, Preprah Opoku M, Addai-Donkor K. Households sociodemographic profile as predictors of health insurance uptake and service utilization: a cross-sectional study in a municipality of Ghana. Advances. *Public Health*. (2018) 2018:1–13. doi: 10.1155/2018/7814206

158. Lofgren C, Thanh NX, Chuc NTK, Emmelin A, Lindholm L. People's willingness to pay for health insurance in rural Vietnam. *Cost Effect Resour Allocat*. (2008) 6:16. doi: 10.1186/1478-7547-6-16

159. Wang T, Wang W, Liang J, Nuo M, Wen Q, Wei W, et al. Identifying major impact factors affecting the continuance intention of mHealth: a systematic review and multi-subgroup meta-analysis. *NPJ Digit Med*. (2022) 5:145–13. doi: 10.1038/s41746-022-00692-9

160. Istiqomah N, Mafruhah I. Determinants of payment compliance of the national health insurance among non-salaried participants. *Corporate Bus Strategy Rev*. (2023) 4:54–61. doi: 10.22495/cbsrv4i4art6

161. Sarkodie AO. Effect of the National Health Insurance Scheme on healthcare utilization and out-of-pocket payment: evidence from GLSS 7. *Humanit Soc Sci Commun*. (2021) 8:293. doi: 10.1057/s41599-021-00984-7

162. Chen S, Geldsetzer P, Chen Q, Moshabela M, Jiao L, Ogbuoji O, et al. Health insurance coverage in Low- and middle-income countries remains far from the goal of universal coverage. *Health Aff*. (2022) 41:1142–52. doi: 10.1377/hlthaff.2021.00951

163. Van der Wielen N, Falkingham J, Channon AA. Determinants of National Health Insurance enrolment in Ghana across the life course: are the results consistent between surveys? *Int J Equity Health*. (2018) 17:49. doi: 10.1186/s12939-018-0760-x

164. Mao W, Zhang Y, Xu L, Miao Z, Dong D, Tang S. Does health insurance impact health service utilization among older adults in urban China? A nationwide cross-sectional study. *BMC Health Serv Res*. (2020) 20:630. doi: 10.1186/s12913-020-05489-8

165. Li J. *Effects of Age and Income on Individual Health Insurance Premiums* Undergraduate Economic Review 7 (2011) 1–20.

166. Sengupta R, Rooj D. The effect of health insurance on hospitalization: identification of adverse selection, moral hazard and the vulnerable population in the Indian healthcare market. *World Dev*. (2019) 122:110–29. doi: 10.1016/j.worlddev.2019.05.012

167. Scheil-Adlung X, Bonan J. Gaps in social protection for health care and long-term care in Europe: are the elderly faced with financial ruin? *Int Soc Secur Rev*. (2013) 66:25–48. doi: 10.1111/issr.12001

168. Amani PJ, Hurtig A-K, Frumence G, Kiwara AD, Goicolea I, San Sebastiån M. Health insurance and health system (un) responsiveness: a qualitative study with elderly in rural Tanzania. *BMC Health Serv Res*. (2021) 21:1140. doi: 10.1186/s12913-021-07144-2

169. Amilaku EM, Fentaye FW, Mekonen AM, Bayked EM. Willingness to pay for social health insurance among public civil servants: a cross-sectional study in Dessie City Administration, North-East Ethiopia. *Front Public Health*. (2022) 10:920502. doi: 10.3389/fpubh.2022.920502

170. Morgan AK, Adei D, Agyemang-Duah W, Mensah AA. An integrative review on individual determinants of enrolment in National Health Insurance Scheme among older adults in Ghana. *BMC Primary Care*. (2022) 23:190. doi: 10.1186/s12875-022-01797-6

171. Ruano AL, Rodríguez D, Rossi PG, Maceira D. Understanding inequities in health and health systems in Latin America and the Caribbean: a thematic series. *Int J Equity Health*. (2021) 20:94. doi: 10.1186/s12939-021-01426-1

172. Van Hees SGM, O'Fallon T, Hofker M, Dekker M, Polack S, Banks LM, et al. Leaving no one behind? Social inclusion of health insurance in low- and middle-income countries: a systematic review. *Int J Equity Health*. (2019) 18:134. doi: 10.1186/s12939-019-1040-0

173. Fulmer T, Reuben DB, Auerbach J, Fick DM, Galambos C, Johnson KS. Actualizing better health and health care for older adults. *Health Aff*. (2021) 40:219–25. doi: 10.1377/hlthaff.2020.01470

174. Zegeye B, Idriss-Wheeler D, Ahinkorah BO, Ameyaw EK, Seidu A-A, Adjei NK, et al. Association between women's household decision-making autonomy and health insurance enrollment in sub-Saharan Africa. *BMC Public Health*. (2023) 23:610. doi: 10.1186/s12889-023-15434-z

175. Xiao W. Effects of marital status on household commercial health insurance participation behavior. *J Interdisc Math*. (2018) 21:397–407. doi: 10.1080/09720502.2017.1420569

176. Dong H, Kouyate B, Snow R, Mugisha F, Sauerborn R. Gender's effect on willingness-to-pay for community-based insurance in Burkina Faso. *Health Policy*. (2003) 64:153–62. doi: 10.1016/s0168-8510(02)00144-6

177. Bachmann MO. Would national health insurance it prove equity and efficiency of health care in South Africa? Lessons from Asia and Latin America. *S Afr Med J*. (1994) 84:153–7.

178. Khan JAM, Ahmed S. Impact of educational intervention on willingness-to-pay for health insurance: a study of informal sector workers in urban Bangladesh. *Health Econ Rev*. (2013) 3:12. doi: 10.1186/2191-1991-3-12

179. Mustikasari VD, Malasari AN, Rochmah TN, Sugiarto K. The effect of willingness to pay on customer preferences for health insurance membership: a systematic review. *Jurnal Aisyah*. (2023) 8:2052. doi: 10.30604/jika.v8i3.2052

180. Panda A, Lambert P, Surminski S. *Insurance and Financial Services Across Developing Countries: An Empirical Study of Coverage and Demand*. London, United Kingdom: Grantham Research Institute on Climate Change and the Environment (2020).

181. Javan-Noughabi J, Kavosi Z, Faramarzi A, Khammarnia M. Identification determinant factors on willingness to pay for health services in Iran. *Health Econ Rev*. (2017) 7:40. doi: 10.1186/s13561-017-0179-x

182. Rannan-Eliya R.P., *Extending Social Health Protection in the Asia Pacific Region: Progress and Challenges*, International Labour Organization, New Delhi, India, (2008), pp. 9–20.

183. Miti JJ, Perkio M, Metteri A, Atkins S. Factors associated with willingness to pay for health insurance and pension scheme among informal economy workers in low- and middle-income countries: a systematic review. *Int J Soc Econ*. (2020) 48:17–37. doi: 10.1108/IJSE-03-2020-0165

184. Osei Afriyie D, Krasniq B, Hooley B, Tediosi F, Fink G. Equity in health insurance schemes enrollment in low and middle-income countries: a systematic review and meta-analysis. *Int J Equity Health*. (2022) 21:21. doi: 10.1186/s12939-021-01608-x

185. Bennett S., Gilson L., *Health Financing: Designing and Implementing Pro-Poor Policies*. Pretoria, South Africa: Human Sciences Research Council. (2001).

186. Shah A, Lemma S, Tao C, Wong J. The role of health policy and Systems in the Uptake of community-based health insurance schemes in Low- and middle-income countries: a narrative review. *Health Serv Insights*. (2023) 16:11786329231172675. doi: 10.1177/11786329231172675

187. Shrank WH, DeParle N-A, Gottlieb S, Jain SH, Orszag P, Powers BW, et al. Health costs and financing: challenges and strategies for a new administration. *Health Aff*. (2021) 40:235–42. doi: 10.1377/hlthaff.2020.01560

188. Asenso-Okyere WK, Osei-Akoto I, Anum A, Appiah EN. Willingness to pay for health insurance in a developing economy. A pilot study of the informal sector of Ghana using contingent valuation. *Health Policy*. (1997) 42:223–37. doi: 10.1016/S0168-8510(97)00069-9

189. Trisnasari O, Laosee CR, Janmaimool P. Assessing the determinants of compliance with contribution payments to the National Health Insurance Scheme among informal Workers in Indonesia. *Int J Environ Res Public Health*. (2023) 20:7130. doi: 10.3390/ijerph20237130

190. Atakorah YB, Arthur E, Osei-Fosu AK, Novignon J. Economic inequalities in health insurance subscription renewal: evidence from Ghana's National Health Insurance Scheme. *Soc Sci Med*. (2023) 341:116514. doi: 10.1016/j.socscimed.2023.116514

191. Mpuuga D, Yawe BL, Muwanga J. Determinants of demand for health Insurance in Uganda: an analysis of utilisation and willingness to pay. *Tanzanian Econ Rev*. (2020) 10:1–22. doi: 10.56279/ter.v10i1.53

192. Akwaowo CD, Umoh I, Udo AA, Motilewa OO, Dan E, Akpan N, et al. Willingness to join social health insurance and community-based health insurance among rural residents in Akwa Ibom state, Nigeria. *Ibom Med J*. (2023) 16:207–17. doi: 10.61386/imj.v16i2.320

193. Vuong Q-H, Ho T-M, Nguyen H-K, Vuong T-T. Healthcare consumers' sensitivity to costs: a reflection on behavioural economics from an emerging market. *Palgrave Commun*. (2018) 4:70. doi: 10.1057/s41599-018-0127-3

194. Noor Aizuddin A, Sulong S, Aljunid SM. Factors influencing willingness to pay for healthcare. *BMC Public Health*. (2012) 12:A37. doi: 10.1186/1471-2458-12-S2-A37

195. Nwanaji-Enwerem O, Bain P, Marks Z, Nwanaji-Enwerem P, Staton CA, Olufadeji A, et al. Patient satisfaction with the Nigerian National Health Insurance Scheme two decades since establishment: a systematic review and recommendations for improvement. *Afr J Prim Health Care Fam Med*. (2022) 14:e1–e10. doi: 10.4102/phcfm.v14i1.3003

196. Adebisi YA, Nwogu IB, Alaran AJ, Badmos AO, Bamgboye AO, Rufai BO, et al. Revisiting the issue of access to medicines in Africa: challenges and recommendations. Public health. *Challenges*. (2022) 1:e9. doi: 10.1002/puh2.9

197. Fasseeh A, ElEzbawy B, Adly W, ElShahawy R, George M, Abaza S, et al. Healthcare financing in Egypt: a systematic literature review. *J Egypt Public Health Assoc*. (2022) 97:1. doi: 10.1186/s42506-021-00089-8

198. Ahmed Y, Ramadan R, Sakr MF. Equity of health-care financing: a progressivity analysis for Egypt. *J Hum Appl Soc Sci*. (2020) 3:3–24. doi: 10.1108/JHASS-08-2019-0040

199. Rostampour M, Nosratnejad S. A systematic review of equity in healthcare financing in Low- and middle-income countries. *Value Health Reg Issues*. (2020) 21:133–40. doi: 10.1016/j.vhri.2019.10.001

200. Bodhisane S, Pongpanich S. The impact of National Health Insurance upon accessibility of health services and financial protection from catastrophic health expenditure: a case study of Savannakhet province, the Lao People's Democratic Republic. *Health Res Policy Syst*. (2019) 17:99. doi: 10.1186/s12961-019-0493-3

201. Erlangga D, Suhrcke M, Ali S, Bloor K. The impact of public health insurance on health care utilisation, financial protection and health status in low- and middle-income countries: a systematic review. *PLoS One*. (2019) 14:e0219731. doi: 10.1371/journal.pone.0219731

202. Debie A, Khatri RB, Assefa Y. Contributions and challenges of healthcare financing towards universal health coverage in Ethiopia: a narrative evidence synthesis. *BMC Health Serv Res*. (2022) 22:866. doi: 10.1186/s12913-022-08151-7

203. Barker P. *Making Universal Health Coverage Whole: Adding Quality as the Fourth Dimension*. Orlando, USA: Institute for Healthcare Improvement (2016).

204. World Health Organization, OECD, and International Bank for Reconstruction and Development/the World Bank, *Global State of Health Care Quality, Delivering Quality Health Services: A Global Imperative for Universal Health Coverage*, Geneva, Switzerland: World Health Organization, OECD, and International Bank for Reconstruction and Development/The World Bank, (2018), pp. 27–38.

205. World Health Organization, OECD, and International Bank for Reconstruction and Development/the World Bank, *Building Quality Into the Foundations of Health Systems, Delivering Quality Health Services: A Global Imperative for Universal Health Coverage*, Geneva, Switzerland: World Health Organization, OECD, and International Bank for Reconstruction and Development/The World Bank, (2018), pp. 41–56.

206. World Health Organization, OECD, and International Bank for Reconstruction and Development/the World Bank, *Background: Striving for Quality in Health Care Services, Delivering Quality Health Services: A Global Imperative for Universal Health Coverage*, World Health Organization, OECD, and International Bank for Reconstruction and Development/The World Bank, (2018), pp. 15–22.

207. World Health Organization, OECD, and International Bank for Reconstruction and Development/the World Bank, *Understanding Levers to Improve Quality, Delivering Quality Health Services: A Global Imperative for Universal Health Coverage*, World Health Organization, OECD, and International Bank for Reconstruction and Development/The World Bank, Geneva, Switzerland. (2018), pp. 57–71.

208. Osei Afriyie D, Masiye F, Tediosi F, Fink G. Purchasing for high-quality care using National Health Insurance: evidence from Zambia. *Health Policy Plan*. (2023) 38:681–8. doi: 10.1093/heapol/czad022

209. Kangwagye P, Bright LW, Atukunda G, Basaza R, Bajunirwe F. Utilization of health insurance by patients with diabetes or hypertension in urban hospitals in Mbarara, Uganda. *PLoS Global Public Health*. (2023) 3:e0000501. doi: 10.1371/journal.pgph.0000501

210. Kellett J, Dhaliwal M. *Can Insurance and Telemedicine Revolutionize Healthcare in Africa?* NY, USA: United Nations Development Programme (2022).

211. Palas JU, Ashraf M, Ray PK. Financing universal health coverage: a systematic review. *Int Technol Manage Rev*. (2017) 6:133–48. doi: 10.2991/itmr.2017.6.4.2

212. Kiley J. *60% in US Say Health Care Coverage is Government's Responsibility.* Washington, DC: Pew Research Center (2018).

213. Oraro T, Ngube N, Atohmbom GY, Srivastava S, Wyss K. The influence of gender and household headship on voluntary health insurance: the case of north-West Cameroon. *Health Policy Plan*. (2018) 33:163–70. doi: 10.1093/heapol/czx152

214. Ewulum K, Abiodun OP, Ogunniyi AO, Ajani OF, Yashim AN, Tomori MO, et al. Enrollees' knowledge, satisfaction, and barriers to uptake of National Health Insurance Scheme in north-Central Nigeria. *MGM J Med Sci*. (2022) 9:89–96. doi: 10.4103/mgmj.mgmj_79_21

Frontiers in Public Health

TYPE Original Research
PUBLISHED 10 May 2024
DOI 10.3389/fpubh.2024.1364973

Check for updates

OPEN ACCESS

EDITED BY
Hai Fang,
Peking University, China

REVIEWED BY
Amin Torabipour,
Ahvaz Jundishapur University of Medical Sciences, Iran
Ricardo De Moraes E. Soares,
Instituto Politecnico de Setubal (IPS), Portugal

*CORRESPONDENCE
Wei Xu
✉ xuwei21@mails.tsinghua.edu.cn
Wei Lu
✉ hy0205044@hainmc.edu.cn

RECEIVED 03 January 2024
ACCEPTED 16 April 2024
PUBLISHED 10 May 2024

CITATION
Ye Y, Evans R, Huang X, Xu W and Lu W (2024) Technical efficiency and its convergence among village clinics in rural China: evidence from Shanxi Province.
Front. Public Health 12:1364973.
doi: 10.3389/fpubh.2024.1364973

Technical efficiency and its convergence among village clinics in rural China: evidence from Shanxi Province

Yun Ye[1], Richard Evans[2], Xiaojun Huang[1], Wei Xu[3]* and Wei Lu[1]*

[1]School of Management, Hainan Medical University, Haikou, Hainan, China, [2]Faculty of Computer Science, Dalhousie University, Halifax, NS, Canada, [3]PBC School of Finance, Tsinghua University, Beijing, China

Introduction: Village clinics (VCs) are the foundation of the three-tiered health service system in China, delivering basic and routine outpatient services to citizens in rural China. VC technical efficiency and its convergence play a critical role in policy decisions regarding the distribution of health service resources in rural China.

Methods: This study measured VC technical efficiency (using the slacks-based measure model), its convergence (using the convergence model), and the factors that influence the convergence in Shanxi Province, China. Data were obtained from the *Shanxi Rural Health Institute 2014–2018 Health Statistics Report*, which involved 3,543 VCs.

Results: The results showed that VC technical efficiency was low and differed by region. There was no α convergence in VC technical efficiency, but evidence of β convergence was found in Shanxi. The main factors that influence convergence were the building area of each VC (BA), proportion of government subsidies (PGS), and ratio of total expenditure to total income of each VC (RTETI).

Conclusion: The government should increase investments in VCs and improve VC technical efficiency. Meanwhile, the government should be aware of and take measures to curb the inequity in VC technical efficiency among different regions and take suitable measures to curb this disparity.

KEYWORDS

village clinics, technical efficiency, convergence, PGS, BA, RTETI

1 Introduction

China's three-tiered rural health service system comprises three types of primary healthcare institutions (PHCIs): village clinics (VCs), township health centers, and county hospitals. VCs serve as the foundation of the three-tiered health service system, delivering basic and routine outpatient services to local villagers and undertaking important responsibilities for citizens residing in rural areas (1). According to the statistics of the National Health Commission of the People's Republic of China (2), the number of visits to VCs was >1.3 billion in 2021, accounting for >31% of visits to PHCIs.

VC technical efficiency represents VCs' ability to transform health inputs into outputs. Since China's healthcare reform in 2009, the Chinese government has increased health resource investments in rural areas to provide high-quality healthcare for rural citizens, including improving VC technical efficiency (3). However, due to differences in economic development, VC technical efficiency considerably varies among regions (4). This disparity in the efficiency levels of VCs indicates an imbalanced distribution of health resources among VCs (5). Policymakers need to understand the VC technical efficiency level and assess whether there has been progress in reducing the inequity of VC technical efficiency in rural areas over time.

The convergence of VC technical efficiency can be used to assess the changing tendency of inequity of resource allocation applied to the healthcare field (6–8). Undoubtedly, the convergence of VC technical efficiency plays a critical role in health resource distribution for policymakers in China. First, if VC technical efficiency is found to converge to a steady-state level, policymakers can formulate a comprehensive medical and health resource policy that is applicable across the field. Conversely, if convergence is not achieved, a set of distinct policies can be formulated to ensure convergence. Second, establishing health resource policies that help VC technical efficiency converge to a steady-state level improves not only health resource allocation equity but also health resource utilization efficiency in China's rural areas. In addition, it is crucial for the government to understand how to intervene in the convergence in order to implement precise measures to narrow the VC technical efficiency differences between rural areas in China.

For the abovementioned purposes, this study measured VC technical efficiency, the convergence of VC technical efficiency, and the factors that affect convergence. Overall, this study answered the following critical questions: (1) What is the level of VC technical efficiency in rural areas of China? (2) Is VC technical efficiency converging? and (3) What factors influence the convergence of VC technical efficiency?

The structure of the article is as follows. Section 2 provides an overview of the relevant research literature. Section 3 introduces the methods in detail. Section 4 presents the research results. Section 5 reports the discussion. Section 6 presents the conclusion and limitations of the study.

2 Literature review

An increasing number of studies have been conducted on the efficiency of rural health institutions (9–13). The efficiency of rural health institutions in China is garnering increased research attention, with the majority focusing on hospitals in counties and towns. For instance, Zhong et al. estimated the efficiency of PHCIs and its influencing factors across 86 counties in Hunan Province. They found that, although the quantity of health resources in PHCIs in Hunan Province has increased significantly, PHCIs remain inefficient in most counties (14). Similarly, Zheng et al. analyzed the efficiency of China's rural township-level medical service systems during 2013–2017 and found that 11 out of 27 provinces were inefficient and 10 out of 27 provinces had lower efficiency than the average scores (4). Similarly, Zhang et al. measured the efficiency and productivity of primary healthcare resource allocation in China and found that >80% of the provinces had inefficient PHCIs and the productivity of the PHCIs declined by 0.6% from 2012 to 2016 (15).

Although several studies have explored VCs, they mainly focused on VC medical waste management and VC utilization and its determinants. For instance, Gao et al. analyzed VC medical waste management based on survey data and found that the average rate of medical waste generation in the sampled VCs was ∼0.65 kg/day or 0.17 kg/patient/day, and the total quantity of medical waste generated was noteworthy (16). Chen et al. estimated that the probability that individuals sought care at VCs when ill decreased by 44% between 2011 and 2018, whereas the utilization of outpatient services in county hospitals increased by 56% and patient self-treatment increased by 20% (1). Bark et al. found that VC utilization can be explained by economic status and walking time to VCs (17).

Convergence was initially used to analyze economic growth and gaps among countries or regions (18, 19), and later, it was used by a small number of studies to analyze factors related to healthcare systems. Gächter et al. analyzed the convergence of age-standardized mortality (as an indicator of health status) and found evidence of absolute and conditional β-convergence but no α-convergence (20). Traoré examined the convergence of public health expenditure among sub-Saharan African countries and found no evidence of convergence (21). Zhang et al. assessed the convergence of China's regional government health expenditure and found evidence of α convergence and β convergence (8). Shen et al. analyzed the convergence of healthcare resource supply in the Yangtze River Delta region in China and revealed that it increased significantly and converged rapidly (22). Kasman et al. investigated whether convergence existed in technical efficiency and productivity levels of the healthcare systems of 26 EU members and an EU candidate country; they found evidence of both α convergence and β convergence (23).

The literature review indicates that studies generally focus only on assessing the efficiency of hospitals in counties and towns. The issue of convergence has been examined mostly in the context of health expenditures and health outcomes. Unlike the existing literature, this study conducted a convergence analysis to identify convergence of technical efficiency among VCs and determined the factors that affect convergence. This finding provides a basis to optimize the dynamic management of rural health resources to promote rational health resource allocation.

3 Methods

3.1 Study area and data collection

Shanxi Province, located in central China, has a population of 34.81 million and had a gross domestic product per capita of RMB¥73,675 in 2022 (24). Shanxi has 26,355 VCs, ranking 7th among 31 provinces/municipalities in China in terms of the number of VCs. These VCs provide medical services to 12.73 million rural residents in Shanxi (36.6% of the population) every year (2).

Data were collected from the Shanxi Rural Health Institute 2014–2018 Health Statistics Report (25), and 3,543 VCs were analyzed (13.44% of VCs in Shanxi). These VCs were selected from 100 counties (including prefecture-level cities and municipal districts) in 11 cities of Shanxi (Figure 1).

3.2 Technical efficiency analysis

Data envelopment analysis (DEA), which can be used to measure VC technical efficiency, has been widely used in previous research (26–33). However, conventional radial DEA models, such as the Constant Returns to Scale Ratio Model (CCR model) proposed by Charnes, Cooper, and Rhodes) and Variable Returns

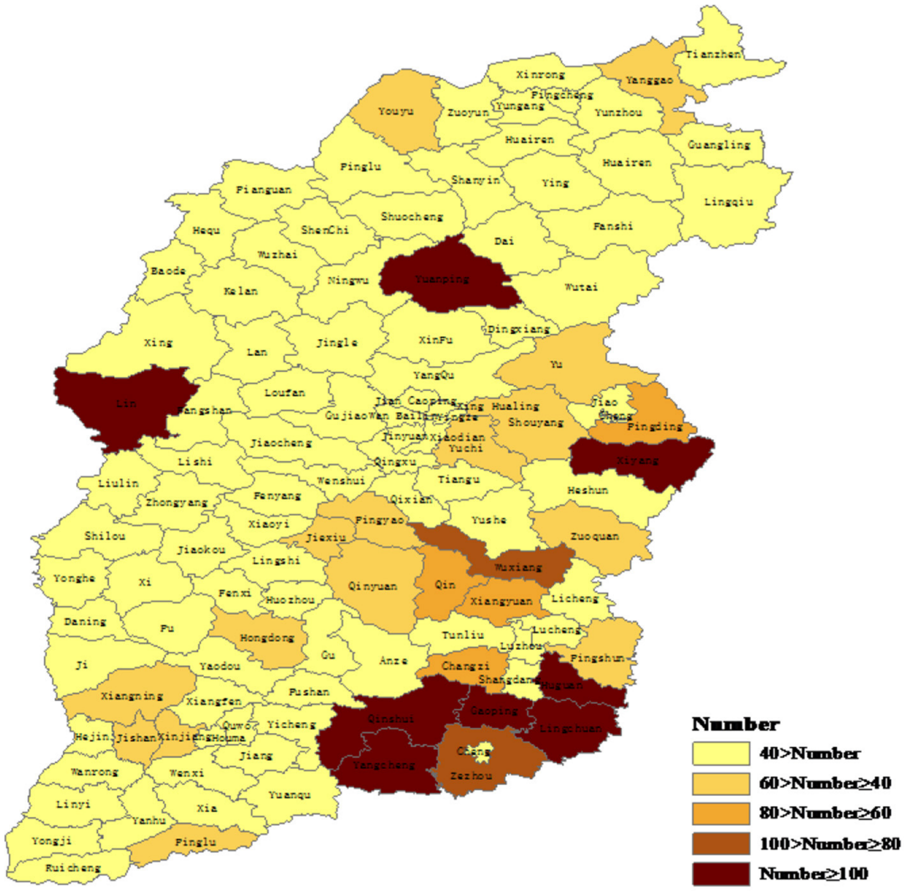


FIGURE 1
Number of village clinics (VCs) sampled in each county of Shanxi Province.

to Scale Model (BCC model) proposed by Banker, Charnes, and Cooper), only include the proportion of all inputs or outputs reduced or increased. When measuring an institution's efficiency, the effect of slack variables is not considered, which may result in the deviation of the efficiency estimate from the ground truth. Tone proposed a slacks-based measure (SBM) model (as a function of the farthest distance to the efficiency frontier) that solved the problem of radial DEA models not including slack variables (34, 35). The present study adopted the following SBM model (Equation 1):

$$\text{To objective function : min}\rho = \frac{1 - \frac{1}{m}\sum_{i=1}^{m}\frac{s_i^-}{x_{ik}}}{1 + \frac{1}{q}\sum_{r=1}^{q}\frac{s_r^+}{y_{rk}}} \quad (1)$$

$$\text{Constraints :} x_k = x\lambda + s^-,\ y_k = y\lambda - s^+, \lambda, s^-, s^+ \geq 0 \quad (2)$$

where m and q are inputs and outputs, respectively, of each VC, x_{ik} *and* y_{rk} are the *ith* input and the *rth* output, respectively, of the VC, s^- and s^+ are the slack variables of the *ith* input and *rth* output, respectively, and s_i^-/x_{ik} and s_i^+/x_{ik} are the inefficiencies of the *ith* input and *rth* output, respectively. Regarding the constraints (Equation 2), x_k and y_k are the input and output, respectively, of the *kth* VC, λ is the adjustment matrix, $x\lambda$ and $y\lambda$ are the input and output, respectively, of the frontier production line, s^- *and* s^+ are the slack variables of the input and output, respectively, and ρ lies between 0 and 1. If $\rho = 1$, the VC is highly effective and located at the efficiency frontier, and each slack is 0. If is close to 0, the VC is inefficient.

Unlike town and county hospitals, VCs mainly provide rural citizens with general diagnosis and treatment, along with referrals for common diseases. Therefore, VC input and output indicators are considerably different from those of county and town hospitals. We selected input and output variables based on the input and output variables in the literature (36–38), combined with the characteristics of VCs. The input variables were the number of rural doctors, the number of rural doctors who underwent technical training, the quantity of medical equipment, and drug expenditure (Table 1). The output variables were the number of patients who visited and income from essential drugs (Table 1). The number of rural doctors who underwent technical training was chosen as an input variable because the increased training can improve doctors' medical service capabilities and promote their efficiency. *Management Measures of VCs (Trial Implementation)*, issued by the National Health Commission of the People's Republic of China, clearly proposed to establish a VC training system and encourage doctors employed in VCs to receive further medical education (39).

TABLE 1 Input and output variables of a technical efficiency measurement model.

Category	Variable	Definition	Unit
Inputs	Number of rural doctors	Number of rural doctors employed in each VC	Person
	Number of rural doctors who underwent technician training	Number of rural doctors that participated in the technician training program organized by the government in each VC	Person
	Quantity of medical equipment	Total quantity of examination beds, refrigerators, Chinese medicine cabinets, western medicine cabinets, disposal tables, computers, and other medical equipment in each VC.	/
	Drug expenditure	Expenditure of each VC on drugs listed in the National Essential Medicines List	Yuan
Outputs	Number of patients who visited	Number of patients who visited each VC	Person
	Income from essential drugs	Income obtained by each VC from the sale of drugs listed in the National Essential Medicines List	Yuan

3.3 Convergence analysis

Convergence analysis is used to identify whether there is inequity of VC technical efficiency among different VCs and the factors that affect the convergence. There are two types of convergence analysis: α convergence and β convergence (40).

3.3.1 α convergence

α convergence refers to the process whereby the VC technical efficiency changes over time. α convergence (Equation 3) was calculated based on the coefficient of variation (CV) of VC technical efficiency, as follows (41).

$$CV = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(TE_i - \bar{TE_i})^2} \tag{3}$$

where TE_i is the technical efficiency of the *ith* VC, and n is the total number of VCs.

If CV decreases over time, the efficiency exhibits α convergence, that is, the disparity in technical efficiency among VCs narrows. By contrast, if CV increases over time, the disparity in technical efficiency among VCs expands.

3.3.2 β convergence

β convergence can be divided into absolute β convergence and conditional β convergence. Absolute β convergence indicates that the lower the initial VC technical efficiency, the higher the average annual growth rate of the efficiency of that VC. Therefore, with the passage of time, the inefficient VCs will gradually reach the same level as the more efficient VCs, resulting in the convergence of the efficiency of VCs to a steady-state level. Conditional β convergence considers the effect of other factors on the average annual growth rate of efficiency. Absolute β convergence (Equation 4) and conditional β convergence (Equation 5) were calculated as follows (42):

$$\ln\frac{TE_{i,t+1}}{TE_{i,t}} = \alpha + \beta \ln TE_{i,t} + \varepsilon_{i,t} \tag{4}$$

$$\ln\frac{TE_{i,t+1}}{TE_{i,t}} = \alpha + \beta \ln TE_{i,t} + \gamma X_{i,t} + \varepsilon_{i,t}, \tag{5}$$

where $TE_{i,t+1}$ and $TE_{i,t}$ are the technical efficiencies of the ith VC in the periods $t+1$ and t, respectively, $\ln(TE_{i,t+1}/TE_{i,t})$ is the average annual growth rate of technical efficiency of the *ith* VC, $X_{i,t}$ are other variables that affect $\ln(TE_{i,t+1}/TE_{i,t})$, and are the error terms.

A significant and negative β coefficient indicates that the average annual growth rate of the technical efficiency is negatively correlated with the efficiency score in the base period, signifying a "catch-up effect" among VCs. In other words, the VCs with a low initial technical efficiency score have a higher growth rate, and the technical efficiency of all VCs will eventually approach the steady-state level. By contrast, a significant and positive β coefficient indicates a widening disparity in technical efficiency among VCs.

In the conditional β convergence model, the following variables that affect the average annual growth rate of the technical efficiency were considered: the number of people served (PS), building area (BA), proportion of government subsidies (PGS), and ratio of total expenditure to total income (RTETI; Table 2) (43).

4 Results

4.1 VC technical efficiency

Figure 2 shows the VC technical efficiency scores in Shanxi Province during 2014–2018. VC technical efficiency generally showed a fluctuating downward trend, from 0.4196 in 2014 to 0.3764 in 2018. The average scores during 2014–2018 were 0.4196, 0.4423, 0.4304, 0.4325, and 0.3764, respectively, and 57.8% of VCs had efficiency lower than the average score in 2018. In addition, most of the VCs were inefficient (scores < 1), with 3,424 (96.6%), 3,414 (96.4%), 3,432 (96.9%), 3,418 (96.8%), and 3,435 (97.0%) inefficient VCs in 2014–2018, respectively.

TABLE 2 Influencing variables used in convergence analysis of village clinics (VCs).

Variable	Definition	Unit
Number of people served (PS)	Number of people served by each VC	Person
Building area (BA)	Building area of each VC	Sm^2
Proportion of government subsidies (PGS)	Subsidies from the government as a proportion of the total income in each VC	%
Ratio of total expenditure to total income (RTETI)	Total expenditure of each VC divided by the total income of each VC	%

As for the technical efficiency of VCs of different regions, the average scores of the southern, central, and northern regions were 0.4376, 0.4176, and 0.3584, respectively. The southern region had the highest average score during 2014–2018, while the northern region had the lowest average score, indicating the largest technical efficiency disparity between the southern and northern regions (0.0792). VC technical efficiency in the southern, central, and northern regions also showed a fluctuating downward trend, from 0.4336, 0.4161, and 0.3722, respectively, in 2014 to 0.3970, 0.3732, and 0.3036, respectively, in 2018. The northern region exhibited the largest decline (18.42%).

4.2 Convergence analyses

4.2.1 α convergence

The convergence analysis depicted in Figure 3 demonstrated that the CVs of the VC technical efficiency were 0.2080, 0.2203, 0.2149, 0.2181, and 0.2142 for 2014–2018, respectively. For Shanxi VCs, the CVs exhibited an upward trend from 2014 to 2018, indicating an overall divergence trend. However, the trend was unstable; the CV increased from 2014 to 2015, decreased from 2015 to 2016, increased slightly from 2016 to 2017, and finally decreased from 2017 to 2018.

CVs in the southern and central regions exhibited an overall upward trend from 2014 to 2018, whereas those in the northern region exhibited an overall upward trend from 2014 to 2017 with a slight decline in 2018. These trends indicate the general divergence of VC technical efficiency in these three regions. However, the degree of divergence differed among regions, with the southern and central regions showing a greater degree of divergence than the northern region.

4.2.2 β convergence

A fixed-effect model was adopted for β convergence analysis because the result of Hausman test showed that the statistics for the VCs in Shanxi and the three regions (i.e., southern, central, and northern) were all significant at the 1% level.

Table 3 displays the absolute and conditional β convergence coefficients. β convergence coefficients of the VCs in Shanxi and the three regions were negative and significant, indicating the existence of absolute β convergence of VC technical efficiency, that is, the average annual growth rate of efficiency was negatively correlated with the efficiency score in the base period. This finding suggests that the underdeveloped regions (with a low initial technical efficiency) were catching up with the advanced regions, gradually narrowing the efficiency gap between VCs among the regions. The VC technical efficiency in Shanxi (from the provincial perspective) and that in the three regions (from the regional perspective) tended to converge to a steady-state level.

Control variables were added to the model to assess the conditional β convergence. The coefficients of VC technical efficiency in Shanxi and the three regions remained negative and significant at the 1% level, indicating a significant conditional convergence in these regions.

4.2.3 Factors affecting convergence

In Shanxi, the southern region, and the central region, compared to the coefficient of VC technical efficiency in the absolute β convergence analysis, the absolute value of the coefficient of VC technical efficiency in the conditional β convergence analysis increased (albeit it remained negative), demonstrating that the efficiency disparity among VCs narrowed when controlling for influencing factors. The results of the factors that affect the convergence of VC technical efficiency are presented in Table 3.

First, the PS coefficient was not significant in Shanxi or any of the three regions, indicating that PS had no significant effect on the convergence of VC technical efficiency in these areas. Second, the BA coefficient was positive and significant in Shanxi, the southern region, and the central region at the 1% level, indicating that increased BA lowers the convergence of VC technical efficiency in Shanxi, the southern region, and the central region. By contrast, BA had no significant effect on the convergence of VC technical efficiency in the northern region. Third, the PGS coefficient was negative and significant at the 1% level in Shanxi and the southern, central, and northern regions, indicating that government subsidies accelerate the convergence of VC technical efficiency. Finally, the RTETI coefficient was negative and significant at the 1% level in Shanxi, the southern region, and the central region, indicating that the higher the proportion of total expenditure out of the total income of a VC, the higher the convergence of VC technical efficiency.

4.3 Endogeneity problem

Endogeneity may be an issue because of the causality between the response variable $\ln(TE_{i,t+1}/TE_{i,t})$ (the average annual growth rate of VC technical efficiency) and the explanatory variable $\ln TE_{i,t}$ (VC technical efficiency in period t). The main reason is that VC technical efficiency can affect the average annual growth rate, which in turn can affect VC technical efficiency. To resolve the endogeneity problem, lagged values of the endogenous variables

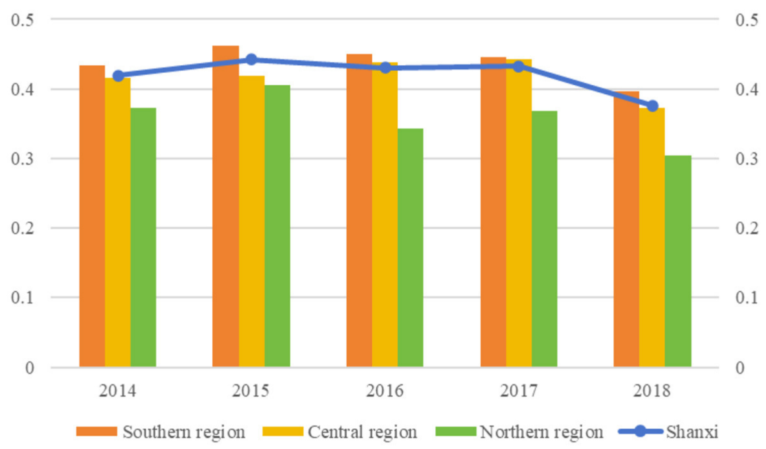


FIGURE 2
Village clinic (VC) technical efficiency scores in Shanxi from 2014 to 2018.

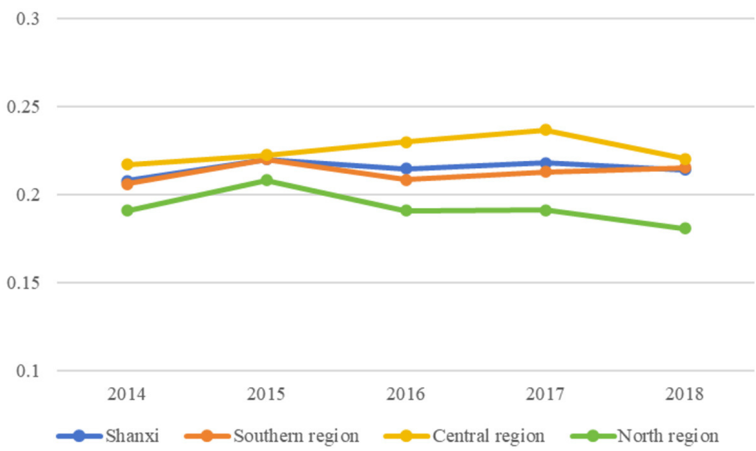


FIGURE 3
α convergence of village clinic (VC) technical efficiency in Shanxi from 2014 to 2018.

($\ln TE_{i,t}$) were used as instruments (44), and a two-stage least-square approach was employed (45). In addition, because the explanatory variable ($\ln TE_{i,t}$) was the lag term of the response variable [], the generalized method of moments (GMM) was further used for estimation (46). The results shown in Table 4 indicate that the estimated results are robust to endogeneity problems.

5 Discussion

Since China's new healthcare reform in 2009, the Chinese government has increased investments on health resources for the primary healthcare system in rural areas, including VCs (47). Policymakers must gain a comprehensive understanding of the level of VC technical efficiency in rural areas of China, whether the inequity of VC technical efficiency has diminished over time, and about methods to reduce the disparity of VC efficiency between regions. These insights help in improving the distribution of health resources and health resource utilization efficiency in rural China.

The result of technical efficiency measurement on VCs indicated that VC technical efficiency was low, exhibiting a fluctuating downward trend over time, and there were obvious differences in VC technical efficiency among regions in rural China. These results are supported by Zheng et al. (4), who demonstrated that most provinces of China had inefficient rural medical service systems in 2013–2017 and more than one-third of provinces had lower efficiency scores than the average scores. The low VC technical efficiency can be strongly attributed to the decline in the number of rural doctors and insufficient drug resources. According to the *China Health Statistics Yearbook 2022*, the number of rural doctors decreased from 1,031,828 in 2010 to only 690,561 in 2021, and there have been mass resignations of rural doctors (48). In addition, the decrease in drug expenditure is significantly related to the limited variety of essential medicines because of the Zero-Markup Policy, as reported by Chen et al. (1). As a result, patients prefer to go to higher-level hospitals (49), causing an insufficient number of patients visiting VCs, which leads to poor VC technical efficiency.

TABLE 3 β convergence (absolute and conditional) of village clinic (VC) technical efficiency and the influencing factors.

	Shanxi		Southern region		Central region		Northern region	
	Absoluteβ convergence	Conditional β convergence	Absolute β convergence	Conditional β convergence	Absolute β convergence	Conditional β convergence	Absolute β convergence	Conditional β convergence
$TE_{i,t}$	−0.9823***	−0.9829***	−0.9778***	−0.9800***	−0.9296***	−0.9322***	−1.0846***	−1.0821***
	(0.0132)	(0.0127)	(0.0184)	(0.0181)	(0.0240)	(0.0216)	(0.0268)	(0.0264)
PS		−0.0013		0.0035		−0.0039		−0.0002
		(0.0044)		(0.0088)		(0.0060)		(0.0084)
BA		0.0564***		0.0556***		0.0776***		−0.0529
		(0.0138)		(0.0204)		(0.0228)		(0.0324)
PGS		−0.2553***		−0.2054***		−0.4308***		−0.2221***
		(0.0573)		(0.0672)		(0.0240)		(0.0387)
RTETI		−0.0314***		−0.0255***		−0.0666***		−0.0160
		(0.0085)		(0.0092)		(0.0253)		(0.0158)
Individual fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.5020	0.5398	0.5029	0.5333	0.4698	0.4026	0.5765	0.5944
N	14,172	14,172	8,300	8,300	3,688	3,688	2,184	2,184
Hausman test	4,595.22***	4,647.55***	2,767.46***	2,750.43***	1,041.42**	1,112.94***	1,285.58**	726.57***

***$p < 0.01$, **$p < 0.05$.

10.3389/fpubh.2024.1364973

TABLE 4 Endogeneity test of β convergence analyses.

	Absolut β convergence			Conditional β convergence		
	2SLS	Different GMM	System GMM	2SLS	Different GMM	System GMM
$TE_{i,t}$	−0.9176***	−0.8644***	−0.8586***	−0.8690***	−0.7709***	−0.8107***
	(0.0378)	(0.0532)	(0.0514)	(0.0369)	(0.0423)	(0.2132)
PS				−0.0041	−0.0020	−0.0006
				(0.0054)	(0.0052)	(0.0142)
BA				0.0308*	0.1548*	0.0990***
				(0.0167)	(0.0907)	(0.0380)
PGS				−0.2116***	−0.3120***	−0.2902***
				(0.0098)	(0.0835)	(0.1048)
RTETI				−0.0153***	−0.3384***	−0.1546***
				(0.0043)	(0.1176)	(0.0586)
LM	764.227***			759.496***		
Wald F	856.372			849.833		
AR(1) (p-value)		0.000	0.000		0.000	0.002
AR(2) (p-value)		0.371	0.326		0.093	0.543
Hansen test (p-value)		0.733	0.167		0.570	0.109

$^{***}p < 0.01$, $^{*}p < 0.1$.

This study used convergence analysis models to evaluate the inequity of VC technical efficiency over time. The analysis results of the convergence of VC technical efficiency provided empirical evidence for the absence of α convergence of VC technical efficiency and the occurrence of β convergence in Shanxi and the southern, central, and northern regions over the sample period (convergence coefficients were negative and significant). Jing et al. (50) reached similar conclusions. In this study, the absolute α convergence results suggested that, without intervention, VC technical efficiency in different regions tends to diverge over time. By contrast, the β convergence results indicated that, when the characteristics of different regions are considered and policy guidance is strengthened, VC technical efficiency in different regions tends to converge. This indicates decrease in the disparity in VC efficiency, signifying the catch-up phenomenon. More importantly, the results of the conditional β convergence analysis demonstrated that catch-up can be improved if factors such as BA, PGS, and internal revenue and expenditure management (based on their relative advantages) of low-efficiency VCs are optimized. This finding is of great significance to the equity of medical services and the rationality of medical resource allocation in rural areas.

In addition, the results of conditional β convergence showed that the main factors that affect convergence were BA, PGS, and RTETI. (1) Increased BA slowed down the convergence of VC technical efficiency in Shanxi, the southern region, and the central region, whereas there was no such effect in the northern region. The coefficient of BA indicated that the average annual growth rate of the efficiency was positively correlated with the level of BA in the base period; the larger the level of BA in the base period, the higher the average annual growth rate of the efficiency. The BA of high-efficiency VCs was larger than that of low-efficiency VCs (51). With the increase in BA, the high-efficiency VCs exhibited a higher average annual growth rate, thus exacerbating the efficiency inequity among VCs. (2) Increased PGS accelerated the convergence of VC technical efficiency and narrowed the disparity in VC technical efficiency. The coefficient of PGS showed that the average annual growth rate of the efficiency was negatively correlated with the level of PGS in the base period, implying that VCs with low PGS in the base period had a higher average annual growth rate. Government subsidies include subsidies for personnel funding, housing, equipment, and implementation of the essential drugs system. High-efficiency VCs receive more PGS in rural China (52). Furthermore, with the increase in PSG, high-efficiency VCs exhibit a low average annual growth rate, whereas low-efficiency VCs exhibit a high average annual growth rate, thus narrowing the efficiency disparity among VCs. A similar result was reported in a previous study (53), which indicated that government health subsidies were progressive and contributed to the narrowing of the gap between poor and rich regions in China. (3) Similarly, increased RTETI narrowed the disparity in VC technical efficiency. The coefficient of RTETI indicated that the average annual growth rate of efficiency was negatively correlated with the level of RTETI in the base period. This implies that VCs with a smaller RTETI in the base period had a higher average annual growth rate than VCs with a large RTETI. As the expenditure of most VCs arises from local government subsidies (54), high-efficiency VCs can receive more subsidies than low-efficiency VCs, leading to a smalle RTETI of low-efficiency VCs. Therefore, government investments can improve the efficiency of low-efficiency VCs more than that of high-efficiency VCs, thus accelerating the convergence and thereby narrowing the disparity in efficiency between high- and low-efficiency VCs (55).

6 Conclusion and limitations

6.1 Conclusion

This study analyzed the technical efficiency of VCs and its convergence using an efficiency measurement model (SBM) and a convergence model using data from the Shanxi Rural Health Institute 2014–2018 Health Statistics Report. The main conclusions of this study are as follows. First, the VC efficiency from the SBM was low and exhibited obvious differences among regions in rural China. Second there was no α convergence in the VC efficiency, but β convergence occurred in Shanxi and the southern, central, and northern regions over the sample period. Third, the main factors that affect convergence were BA, PGS, and RTETI.

Based on the results, the following policy implications are proposed. First, the government should increase investments in VCs and improve VC technical efficiency by increasing support for rural doctors, including establishing effective promotion mechanisms and providing a higher and more reasonable income (56); improving the Zero-Markup Policy for essential drugs; and increasing drug allocation in VCs (49, 57). Second, the government should be aware of and take measures to curb the inequity in VC technical efficiency among different regions and take suitable measures to curb this disparity. For example, in the southern and central regions, the government should exert moderate control of the scale of VCs, increase government subsidies for VCs, guide VCs to optimize their revenue and expenditure management, and increase PGS regarding low-efficient VCs' expenditure.

6.2 Limitations

This study has the following limitations. First, the selection of variables in the VC technical efficiency measurement model and convergence model needs to be improved. Research on VCs is limited, affecting the selection of variables in this study. Future research should focus on using more suitable variables to evaluate VC technical efficiency and convergence. Second, challenges in collecting data over an extended period exist due to factors such as lack of data, statistical data lags, and the impact of the COVID-19 pandemic. The evaluation of VC technical efficiency was restricted to 2014–2018; therefore, future research should extend the research period.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding authors.

Author contributions

YY: Conceptualization, Data curation, Formal analysis, Investigation, Writing—original draft. RE: Conceptualization, Formal analysis, Writing—original draft. XH: Conceptualization, Data curation, Formal analysis, Methodology, Writing—original draft. WX: Conceptualization, Data curation, Formal analysis, Writing—original draft. WL: Conceptualization, Data curation, Formal analysis, Writing—original draft, Writing—review & editing.

Funding

The author(s) declare that financial support was received for the research, authorship, and/or publication of this article. This study was funded by the National Natural Science Foundation of China (No. 72204069), the Hainan Natural Science Foundation of China (No. 821RC578), the Research Fund of Hainan Medical University (Nos. HYPY2020025 and RZ2300006014), and the Hainan Province Clinical Medical Center (No. QWYH202175).

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

References

1. Chen Y, Sylvia S, Wu P, Yi H. Explaining the declining utilization of village clinics in rural China over time: a decomposition approach. *Soc Sci Med*. (2022) 301:114978. doi: 10.1016/j.socscimed.2022.114978

2. National Health Commission of the People's Republic of China. *China Health Statistical Yearbook*. Beijing: Peking Union Medical College Press (2022).

3. Li X, Krumholz HM, Yip W, Cheng KK, De Maeseneer J, Meng Q, et al. Quality of primary health care in China: challenges and recommendations. *Lancet*. (2020) 395:1802–12. doi: 10.1016/S0140-6736(20)30122-7

4. Zheng D, Gong J, Zhang C. Efficiency of medical service systems in the rural areas of Mainland China: a comparative study from 2013 to 2017. *Public Health*. (2019) 171:139–47. doi: 10.1016/j.puhe.2019.04.003

5. Liu W, Liu Y, Twum P, Li SX. National equity of health resource allocation in China: data from 2009 to 2013. *Int J Equity Health*. (2016) 15:68. doi: 10.1186/s12939-016-0357-1

6. Wang Z. The convergence of health care expenditure in the US States. *Health Econ*. (2009) 18:55–70. doi: 10.1002/hec.1343

7. Happich M, Von Lengerke T. Convergence of life expectancy in the European Union: a Markov approach. *Appl Econ Lett*. (2007) 14:175–8. doi: 10.1080/13504850500425261

8. Zhang G, Zhang L, Wu S, Xia X, Lu L. The convergence of Chinese county government health expenditures: capitation and contribution. *BMC Health Serv Res*. (2016) 16:408. doi: 10.1186/s12913-016-1635-8

9. Kontodimopoulos N, Nanos P, Niakas D. Balancing efficiency of health services and equity of access in remote areas in Greece. *Health Policy*. (2006) 76:49–57. doi: 10.1016/j.healthpol.2005.04.006

10. Hernndez AR, Sebastian MS. Assessing the technical efficiency of health posts in rural Guatemala: a data envelopment analysis. *Glob Health Act.* (2014) 7:1–9. doi: 10.3402/gha.v7.23190

11. Oikonomou N, Tountas Y, Mariolis A, Souliotis K, Athanasakis K, Kyriopoulos J. Measuring the efficiency of the Greek rural primary health care using a restricted DEA model: the case of southern and western Greece. *Health Care Manag Sci*. (2016) 19:313–25. doi: 10.1007/s10729-015-9324-4

12. Kirigia JM, Sambo LG, Renner A, Alemu W, Seasa S, Bah Y. Technical efficiency of primary health units in Kailahun and Kenema districts of Sierra Leone. *Int Arch Med.* (2011) 4:15–15. doi: 10.1186/1755-7682-4-15

13. Marschall P, Flessa S. Efficiency of primary care in rural Burkina Faso. A two-stage DEA analysis. *Health Econ Rev*. (2011) 1:5. doi: 10.1186/2191-1991-1-5

14. Zhong K, Chen L, Cheng S, Chen H, Long F. The efficiency of primary health care institutions in the counties of Hunan province, China: data from 2009 to 2017. *Int J Environ Res Publ Health.* (2020) 17:1781. doi: 10.3390/ijerph17051781

15. Zhang Y, Wang Q, Jiang T, Wang J. Equity and efficiency of primary health care resource allocation in mainland China. *Int J Eq Health*. (2018) 17:140. doi: 10.1186/s12939-018-0851-8

16. Gao Q, Liu K, Song S, Li J, Nie J, Shi Y, et al. Medical waste management of village clinics in rural China. *J Publ Health*. (2022) 30:1197–204. doi: 10.1007/s10389-020-01399-5

17. Baker JB, Liu L. The determinants of primary health care utilization: a comparison of three rural clinics in southern Honduras. *GeoJournal.* (2006) 66:295–310. doi: 10.1007/s10708-006-9001-8

18. Barro RJ. Convergence. *J Polit Econ*. (1992) 100:22–51. doi: 10.1086/261816

19. Grossman GM, Helpman E. Endogenous innovation in the theory of growth. *J Econ Perspect*. (1994) 8:23–44. doi: 10.1257/jep.8.1.23

20. Gächter M, Theurl E. Health status convergence at the local level: empirical evidence from Austria. *Int J Eq Health*. (2011) 10:34. doi: 10.1186/1475-9276-10-34

21. Traoré O. Convergence in public health expenditure across the Sub-Saharan African countries: does club convergence matter? *Health Econ Rev*. (2021) 11:21. doi: 10.1186/s13561-021-00316-0

22. Shen Y, Sun Z. Estimating the spatial correlation and convergence of China's healthcare resources allocation: evidence from the Yangtze River Delta Region. *Archiv Publ Health*. (2022) 80:207. doi: 10.1186/s13690-022-00958-4

23. Kasman S, Kasman A, Gökalp G. Efficiency and productivity convergence in health care systems: evidence from EU member countries. *METU Stud Dev*. (2019) 46:227–50. doi: 10.60165/metusd.v46i2.1026

24. Shanxi Provincial Bureau of Statistics. *Shanxi Statistical Yearbook*. Beijing: China Statistics Press (2023).

25. Health Commission of Shanxi Province. *National Health Statistics Network Direct Reporting System*. Available online at: http://218.26.86.114:8001/irpt/esmain/portal/loginportal.do?portalid$=$DLnew (accessed August 8, 2007).

26. Sherman HD. Hospital efficiency measurement and evaluation: empirical test of a new technique. *Med Care.* (1984) 10:922–38. doi: 10.1097/00005650-198410000-00005

27. Gözde Y. Health efficiency measurement in Turkey by using data envelopment analysis: a systematic review. *Ankara Saglik Bilimleri Dergisi*. (2017) 62:49–69. doi: 10.1501/Asbd_0000000062

28. Kim J, Kim H, Leem B, Yoon J. Analyzing the national medical service efficiency of OECD countries using DEA and malmquist productivity index. *Acta Biomater.* (2012) 37:197–207. doi: 10.7737/JKORMS.2012.37.4.125

29. Nasiripour AA, Mehrolhasani MH. The efficiency of the head offices of Medical-Services Insurance Organization in Iran using AP-DEA: 2009. *J Health Admin.* (2011) 46:39–46.

30. Matos R, Ferreira DC, Pedro I. Economic analysis of Portuguese public hospitals through the construction of quality, efficiency, access, and financial related composite indicators. *Soc Indic Res.* (2021) 157:361–92. doi: 10.1007/s11205-021-02650-6

31. Ferreira D, Marques R. Public-private partnerships in health care services: do they outperform public hospitals regarding quality and access? Evidence from Portugal. *Socio-Econ Plan Sci.* (2021) 73:1–15. doi: 10.1016/j.seps.2020.100798

32. Ferreira D, Nunes A, Marques R. Operational efficiency vs. clinical safety, care appropriateness, timeliness, and access to health care. *J Product Anal.* (2020) 53:355–75. doi: 10.1007/s11123-020-00578-6

33. Ferreira D, Nunes A. Technical efficiency of Portuguese public hospitals: a comparative analysis across the five regions of Portugal. *Int J Health Plan Manag.* (2018) 34:411–22. doi: 10.1002/hpm.2658

34. Tone K. A slacks-based measure of efficiency in data envelopment analysis. *Eur J Oper Res.* (2001) 130:498–509. doi: 10.1016/S0377-2217(99)00407-5

35. Mei K, Kou R, Bi Y, Liu Y, Huang J, Li W. A study of primary health care service efficiency and its spatial correlation in China. *BMC Health Serv Res*. (2023) 23:247. doi: 10.1186/s12913-023-09197-x

36. Pelone F, Kringos DS, Romaniello A, Archibugi M, Salsiri C, Ricciardi W. Primary care efficiency measurement using data envelopment analysis: a systematic review. *J Med Syst.* (2015) 39:156. doi: 10.1007/s10916-014-0156-4

37. Cantor VJM, Poh KL. Integrated analysis of healthcare efficiency: a systematic review. *J Med Syst*. (2018) 42:1. doi: 10.1007/s10916-017-0848-7

38. Kohl S, Schoenfelder J, Fugener A, Brunner JO. The use of Data Envelopment Analysis (DEA) in healthcare with a focus on hospitals. *Health Care Manag Sci*. (2019) 22:245–86. doi: 10.1007/s10729-018-9436-8

39. NHC. *Management Measures of Village Clinics (Trial Implementation)*. Available online at: https://www.gov.cn/gongbao/content/2014/content_2765488.htm (accessed June 3, 2014).

40. Sala-I-Martin X. The classical approach to convergence analysis. *Econ J*. (1996) 106:1019–36. doi: 10.2307/2235375

41. Dalgaard C, Vastrup J. On the measurement of σ-convergence. *Econ Lett.* (2001) 70:283–7. doi: 10.1016/S0165-1765(00)00368-2

42. Barro RJ, Salaimartin X. Economic growth and convergence across the United States. In: *NBER Working Papers*. Cambridge, MA: National Bureau of Economic Research (1990).

43. Mohammadpour S, Javan-Noughabi J, Vafaee Najar A, Zangeneh M, Yousefi S, Nouhi M, et al. Factors affecting the technical efciency of rural primary health care centers in Hamadan, Iran: data envelopment analysis and Tobit regression. *Cost Effect Resour Allocat*. (2020) 18:53. doi: 10.1186/s12962-020-00249-1

44. Bellemare MF, Masaki T, Pepinsky TB. Lagged explanatory variables and the estimation of causal effect. *J Polit*. (2017) 79:949–63. doi: 10.1086/690946

45. Semykina A, Wooldridge JM. Estimating panel data models in the presence of endogeneity and selection. *J Econ*. (2010) 157:375–80. doi: 10.1016/j.jeconom.2010.03.039

46. Ullah S, Akhtar P, Zaefarian G. Dealing with endogeneity bias: the generalized method of moments (GMM) for panel data. *Indus Market Manage*. (2018) 71:69–78. doi: 10.1016/j.indmarman.2017.11.010

47. Li X, Lu J, Hu S, Cheng KK, De Maeseneer J, Meng Q, et al. The primary health-care system in China. *Lancet*. (2017) 12:2584–94. doi: 10.1016/S0140-6736(17)33109-4

48. Chen Zhongmin YW, Haiyi J. Formation mechanism of the turnover intention of rural doctors under essential medicine system based on grounded theory. *Chin Gen Pract.* (2015) 18:3036. doi: 10.3969/j.issn.1007-9572.2015.25.008

49. Zhou Z, Su Y, Campbell B, Zhou Z, Gao J, Yu Q, et al. The financial impact of the "zero-markup policy for essential drugs" on patients in county hospitals in western rural China. *PLoS ONE*. (2015) 10:1–17. doi: 10.1371/journal.pone.0121630

50. Jing D, Zixuan Z, Lin Y, Yunyu H. Analysis of regional differences and convergence of medical resource efficiency in rural China. *Chin Health Serv Manag.* (2023) 40:616–21.

51. Benhai Y, Yingqiao G, Dongfeng Z. Evaluation of service efficiency of grassroots medical and health institutions based on three-stage DEA. *Chin Hosp*. (2024) 28:37–42. doi: 10.19660/j.issn.1671-0592.2024.1.09

52. Yang Y, Hengpeng Z, Yulind W. Effects of public subsidies on hospital management in China. *Econ Res J*. (2023) 3:155–71.

53. Qin W, Xu L, Li J, Sun L, Ding G, Shao H, et al. Estimating benefit equity of government health subsidy in healthcare Services in Shandong Province, China: a cross-sectional study. *Int J Eq Health*. (2018) 17:61. doi: 10.1186/s12939-018-0775-3

54. Zhiyong L, Wenxue J, Qiang Y, Fei L, Luyang H, Shanquan C, et al. Influences of essential medicine system on revenue-expenditure structure in primary medical institutions: empirical study in Shanghai, Chongqing and Sichuan. *Chin Health Econ*. (2014) 38:21–3. doi: 10.7664/CHE20140105

55. Xiaoyi Z, Xiao L, Jinshun Z, Sheng W, Zhansheng L, Zhikai Y, et al. Income and expenditure level and structure of primary health service institutions in Weifang City from 2019 to 2021. *Chin Health Resour*. (2023) 26:197–202. doi: 10.13688/j.cnki.chr.2023.220904

56. Zhang X, Bian L, Bai X, Kong D, Liu L, Chen Q, et al. The influence of job satisfaction, resilience and work engagement on turnover intention among village doctors in China: a cross-sectional study. *BMC Health Serv Res*. (2020) 20:283. doi: 10.1186/s12913-020-05154-0

57. Liu WY, Hsu CH, Liu TJ, Chen PE, Zheng B, Chien CW, et al. Systematic review of the effect of a zero-markup policy for essential drugs on healthcare costs and utilization in China, 2015–2021. *Front Med*. (2021) 8:618046. doi: 10.3389/fmed.2021.618046

Frontiers | Frontiers in Public Health
TYPE Original Research
PUBLISHED 20 May 2024
DOI 10.3389/fpubh.2024.1394688

Check for updates

OPEN ACCESS

EDITED BY
Hai Fang,
Peking University, China

REVIEWED BY
Eduardo Fernandez,
University of Salamanca, Spain
Yuegang Song,
Henan Normal University, China

*CORRESPONDENCE
Zheng Zang
✉ zangzheng@suda.edu.cn

RECEIVED 01 March 2024
ACCEPTED 03 May 2024
PUBLISHED 20 May 2024

CITATION
Yang J, Li Z, Zhang J and Zang Z (2024) The impact of basic pension for urban and rural residents on the subjective well-being of the older adult in Chinese rural areas.
Front. Public Health 12:1394688.
doi: 10.3389/fpubh.2024.1394688

The impact of basic pension for urban and rural residents on the subjective well-being of the older adult in Chinese rural areas

Jianhai Yang[1], Ziying Li[1], Jiexin Zhang[1] and Zheng Zang[2]*

[1]School of Economics, Beijing Technology and Business University, Beijing, China, [2]School of Marxism, Soochow University, Suzhou, China

Introduction: As an important component of the social security system, basic pension insurance for urban and rural residents is expected to improve the quality of life of rural older adult people and make their lives better and happier. This article mainly studies the relationship between the basic pension for urban and rural residents and the subjective well-being of older adult people in rural China.

Methods: This paper uses data from the China Health and Retirement Longitudinal Study (CHARLS) for the years 2018 and 2020. It selected samples of rural older adult people aged 60 and above, ultimately obtaining 9,310 samples. The impact of the basic pension for urban and rural residents on the subjective well-being of rural older adult people was estimated by constructing Ordinary Least Squares (OLS) estimation methods and ordered logistic regression models. The robustness of the results was verified by changing the regression methods, and the samples were divided into different groups for heterogeneity analysis according to three different standards.

Results: The results show that the basic pension for urban and rural residents significantly improves the life satisfaction of rural older adult, reduces their degrees of depression, and thereby enhances their subjective well-being. The impact of the basic pension for urban and rural residents is more significant for older adult individuals in areas with a higher gender ratio, those suffering from chronic diseases, and those in the eastern regions of the country. Further verification indicates that the basic pension for urban and rural residents enhances the subjective well-being of the rural older adult by improving their health status and reducing their labor supply.

Discussion: Most of the existing research on basic pension insurance for urban and rural residents and subjective well-being has been conducted from the perspective of whether individuals are enrolled in the pension scheme or whether they received a pension. However, there are few studies analyzing from the perspective of the amount of pension benefits received by residents. The results of this study help to enrich the research perspective on the basic pension insurance system for urban and rural residents in China and expand the understanding of the impact and value of the basic pension for urban and rural residents.

KEYWORDS

basic pension insurance for urban and rural residents, basic pension, older adult in rural areas, subjective well-being, degree of depression

1 Introduction and literature review

With the increasing degree of population aging, how to deal with the older adult care issue has become a focus of attention in China. In rural China, the older adult care for most older adult people is still primarily based on family care (1), but the development and changes in society, along with changes in family structure, have continuously increased the burden of family care (2), limiting the function of family care. Therefore, to better guarantee the older adult care life of rural residents, China implemented the New Rural Pension Insurance System in 2009 and merged it with the Urban Resident Pension Insurance into the Urban and Rural Residents Pension Insurance System in 2014, to serve as a supplement to the family care of urban and rural residents.

After the implementation of the basic pension insurance system for urban and rural residents, many domestic scholars have evaluated the impact of this policy on the living conditions and welfare levels of the older adult in rural areas and their families. Some studies indicate that basic pension insurance for urban and rural residents indeed improves the income level of the older adult in rural areas (3), promotes consumption (4), and reduces older adult poverty (5). However, most scholars focus only on the economic welfare aspect, and only a few scholars pay attention to its subjective welfare effects. Existing research points out that participation in basic pension insurance for urban and rural residents can significantly enhance the subjective well-being of the older adult in rural areas. Specifically, on the one hand, the basic pension insurance for urban and rural residents provides an economic source for the older adult, reduces expected risks, and decreases their uncertainty about the future, thereby enhancing well-being (6); on the other hand, by playing a role in income redistribution (7), the basic pension insurance for urban and rural residents alleviates the negative impact of income disparities on well-being, thus enhancing happiness (8). Therefore, studying the relationship between the basic pension for urban and rural residents and the subjective well-being of the older adult in rural areas is of great significance for improving the quality of older adult care for rural residents.

Subjective well-being is the emotional and cognitive overall evaluation of one's life quality based on subjective experiences of current life (9). By assessing subjective well-being, it is possible to understand the effects of public policy implementation and whether there is an increase in public satisfaction (10). Variables of subjective well-being include broad measures of overall life satisfaction, as well as satisfaction in narrower areas such as household income (11). A review of previous studies finds that explorations into the factors affecting older adult subjective well-being mainly focus on individual characteristics and social characteristics (12). Looking at the factors of individual characteristics, the impact of gender on subjective well-being has not reached a consistent conclusion (13, 14), a study in South Africa found that women rise first and then fall, while men do the opposite (15). There is a U-shaped relationship between age and subjective well-being, and subjective well-being tends to decrease with age before increasing (13, 16). Variables such as health status, education level, and the number of children have a positive correlation with subjective well-being (17–20). In terms of social characteristics, securing an income level can improve the welfare of the older adult (21), and the relationship between income level and subjective well-being is an inverted U-shape, where subjective well-being increases with income to a maximum point and then declines (22, 23). Variables such as unemployment and environmental issues have a negative impact on well-being (24–26), while factors like social relationships are positively correlated with well-being (27).

Moreover, some studies both domestically and internationally have shown that there exists a significant positive relationship between pension systems and the subjective well-being of the older adult (28–31), with pensions providing a reliable source of income for the older adult, reducing the insecurity felt about pensions due to individual resource and economic condition differences, thereby enhancing subjective well-being (32). The level of pension income affects the subjective well-being of the older adult (33), and a generous pension can significantly improve the subjective well-being of the older adult and reduce the incidence of diagnosed depression (34). For the older adult in rural China, pensions have a significant impact on their level of well-being (35), with basic pension insurance for urban and rural residents being one of their main sources of pension income. By the end of 2022, the number of participants in the basic pension insurance for urban and rural residents had reached 549.52 million, essentially achieving full coverage for rural residents. From this, it can be seen that the subjective welfare effects produced by the basic pension insurance for urban and rural residents have a certain impact on the subjective well-being of the older adult.

Although the basic pension insurance system for urban and rural residents has been implemented for over a decade, its level of protection remains very limited, with the actual pension replacement rate far below the target level (36), unable to provide the older adult with sufficient pension security. Looking at the actual operation of the system, due to the weak payment ability of most older adult people in rural areas or their complete lack of ability to pay, the pensions they receive is mainly based on basic pension. Furthermore, the basic pension for urban and rural residents also faces issues such as low benefit levels and slow increase rates, which have not yet achieved the goal of "ensuring basic needs" (37, 38). In this context, it is necessary to increase the level of basic pensions for urban and rural residents to ensure the basic living of the older adult in rural areas, alleviate the burden of family care, and enhance the subjective well-being of the older adult.

In summary, current research has proven that participation in basic pension insurance for urban and rural residents can significantly enhance the subjective well-being of the older adult (39, 40). However, existing studies on the basic pension insurance for urban and rural residents and the subjective well-being of rural older adult people have mostly focused on whether they participate or receive pensions, without much discussion on the relationship between the level of basic pensions and happiness. Therefore, this paper utilizes microdata from the China Health and Retirement Longitudinal Study (CHARLS) for the years 2018 and 2020, constructs OLS and ordered logistic regression models, explores the impact of the basic pension for urban and rural residents on the subjective well-being of rural older adult people, and conducts a mechanism analysis, which is of certain practical significance.

This paper focuses on answering the following three questions: What is the impact of the basic pension for urban and rural residents on the subjective well-being of the rural older adult? How do these effects differ among the older adult of different genders, income levels, and regions? How does the basic pension for urban and rural residents affect the well-being of the older adult? The paper will make contributions in the following two areas: (1) By combining the amount of the basic pension for urban and rural residents with micro data to explore the impact of the basic pension on subjective well-being, and further analyzing the heterogeneity of the impact; (2) Using the mediating effect method to test the impact mechanism of the subjective welfare effect of the basic pension for urban and rural residents.

2 Materials and methods

2.1 Conceptual framework

The primary focus of this paper is the impact of basic pension for urban and rural residents on the subjective well-being of the older adult in rural areas. The outcome variables selected for this study are the degree of depression and life satisfaction. Since life satisfaction is a discrete variable and also a categorical variable, ordered logistic regression is used for estimation. The model is constructed as follows:

$$Happiness_i = \alpha_0 + \alpha_1 Pension_i + \alpha_2 X_i + \varepsilon_i \quad (1)$$

In Equation (1), $Happiness_i$ represents the life satisfaction of sample *i*; α_0 represents the constant term; Pensioni is the level of basic pension received by sample *i*, represented by the ratio of the local basic pension level to the minimum wage income; X_i represents the impact of control variables on subjective well-being for sample *i*, with control variables including individual characteristic variables, number of children, social relationships, and family income; μ_i is the random disturbance term.

Given that the degree of depression is a discrete variable, Ordinary Least Squares (OLS) regression is we used for estimation. The model is constructed as follows:

$$Depression_i = \beta_0 + \beta_1 Pension_i + \beta_2 Z_i + \varepsilon_i \quad (2)$$

In Equation (2), $Depression_i$ represents the degree of depression of sample *i*;

β_0 represents the constant term; $Pension_i$ is the level of basic pension received by sample *i*, represented by the ratio of the local basic pension level to the minimum wage income; Z_i represents the impact of control variables on subjective well-being for sample *i*, with control variables including individual characteristic variables, number of children, social relationships, and family income; ε_i is the random disturbance term.

2.2 Data

The data used in this study comes from the 2018 and 2020 panel data of the China Health and Retirement Longitudinal Study (CHARLS). The CHARLS project led by the National School of Development at Peking University, aims to collect a set of high-quality microdata to promote interdisciplinary research on aging issues. The national baseline survey of CHARLS began in 2011, and since then, the sample has been followed up and updated every 2–3 years, with new samples added to maintain its relevance. This dataset targets households and individuals aged 45 and above, covering 150 county-level units, 450 village-level units, and approximately 17,000 individuals from 10,000 households. CHARLS data extensively cover the demographic background of respondents, work, retirement and pension status, health condition, medical security, detailed family income, expenditure, asset status, etc., which is an important data source for sociology, economics, demography, and other fields. To study the impact of basic urban and rural pensions on the subjective well-being of the older adult in rural areas, this paper selected samples of rural older adult people aged 60 and above, ultimately obtaining a sample size of 9,310.

2.3 Explained variables

Table 1 shows the variable description. In this paper, the degree of depression and life satisfaction are used as indicators to measure the subjective well-being of the rural older adult (6, 40–43). The degree of depression is calculated based on responses to questions from the short depression scale (CES-D) in the CHARLS questionnaire. The CES-D scale is one of the best screening tools for depressive symptoms in the older adult, known for its high reliability and validity. The depression scale consisted of 10 questions related to the feelings and behaviors of the respondents in the previous week, with each question having the same set of responses: rarely or none of the time, some or a little of the time, occasionally or a moderate amount of time, and most of the time. Answers are assigned scores from 0 to 3; for questions about positive emotions, scores are assigned inversely from 3 to 0. The scores of the 10 questions are then summed and averaged to represent the degree of depression, with higher scores indicating more severe depression (6). Additionally, this paper selects life satisfaction as a positive measure of subjective well-being. The corresponding question in the CHARLS database is "Are you satisfied with your life?" Responses are scored from 1 to 5, corresponding to the options: not satisfied at all, not very satisfied, somewhat satisfied, very satisfied, and completely satisfied, with higher values indicating greater satisfaction.

2.4 Explaining variables

This paper selects the basic pension for urban and rural residents received monthly by the sample individuals to investigate its impact on the subjective well-being of the older adult in rural areas. The data on the basic pensions for urban and rural residents in 2018 and 2020 were organized and matched with the CHARLS micro-database by province. The level of basic pension for urban and rural residents is the core explanatory variable of this paper. Due to the significant differences in the basic pension levels among some provinces, this paper uses the ratio of the basic pension for urban and rural residents to the minimum wage income to represent it.

2.5 Control variables

Referencing existing studies, this article includes individual characteristic variables, number of children, family income, and social relationships as control variables. The individual characteristic variables encompass age, gender, education level, marital status, chronic disease status, and personal income. The subjective well-being of the older adult is the result of the value judgment and subjective feelings of the older adult individuals on their living conditions according to their own wishes and expectations. Generally speaking, age, gender (44), education level, marital status, and other factors will have a positive impact on subjective well-being, but well-being does

TABLE 1 Variable description.

Variable properties	Variable	Variable description
Explained variables	Degree of depression	The scores for the 10 questions in the depression scale were summed and then averaged.
	Life satisfaction	Not satisfied at all = 1; Not very satisfied = 2; Somewhat satisfied = 3; Very satisfied = 4; Extremely satisfied = 5.
Explaining variables	Basic pension for urban and rural residents	Ratio of basic pension and minimum wage income for urban and rural residents.
Control variables	Age	The age of the respondent at the time of the survey.
	Gender	Male = 1; Female = 0.
	Education level	Junior high school and below =1; junior high school and above = 2.
	Marital status	With a spouse = 1; without a spouse = 0.
	Chronic disease status	Yes = 1; No = 0.
	Number of children	The number of children the respondent has.
	Personal income	The logarithm of the total wage income and transfer payment income of the respondent in the past year
	Family income	The logarithm of the respondent's family income in the past year, including income from product sales, self-employment or private income, and public transfer payment income.
	Social relationship	Whether the respondent engaged in social activities in the past month: Yes = 1; No = 0.
Mediating variables	Health condition	Respondent's self-rated health condition: Very bad = 1; Bad = 2; Fair = 3; Good = 4; Very good = 5
	Intergenerational support	The logarithm of the total financial support provided by children to their parents, including cash and in-kind.
	Labor supply	The number of working hours per week that the respondent worked in self-employment, employment, and as a helper in family business activities in the past year.

not necessarily increase simultaneously when income increases (45). The number of children is also an important factor that affect the subjective well-being of the older adult in rural areas, and the number of children has a significant impact on the subjective well-being of the older adult (46, 47). Children can accompany and take care of the older adult, providing spiritual comfort and support to the older adult, so parents with children have higher subjective well-being (48). From the perspective of social relations, Chinese society is a typical relationship-oriented society, "relationship" occupies an important position in the social and economic activities of residents, and plays a very important role. Compared with urban residents, rural residents pay more attention to the harmonious relationship between their neighbors. Studies have shown that social interaction has a positive impact on subjective well-being (49, 50), and the more harmonious the relationship between friends, the higher the well-being (51). Therefore, this article uses the question from the survey, "Have you engaged in the following social activities in the past month?" as a proxy variable for the respondents' social relationships.

2.6 Mediating variables

Studies have shown that participation in basic pension insurance for urban and rural residents and the New Rural Pension (NRP) insurance can effectively improve the health condition of rural older adult people (52, 53), and rural older adult people have a certain degree of worry about pension issues, which is an important indicator of the quality of life for rural residents from the spiritual level, and pension income can reduce the degree of worry about the future pension, thereby improving the mental health of rural older adult people. The relationship between health conditions and subjective well-being is bidirectional. Older adult people with diseases such as coronary heart disease and chronic lung disease tend to have higher depression and impaired well-being (54). Therefore, personal health condition has a significant positive impact on subjective well-being (55), and the higher the self-rated health, the stronger the subjective well-being (56). Therefore, this article selects the self-rated health condition from the questionnaire responses to represent the physical health condition of the older adult, aiming to explore whether the basic pension for urban and rural residents affects the subjective well-being of rural older adult people through health conditions.

Additionally, considering the influence of subjective factors when respondents conduct self-rated of their health, this article also selects intergenerational support and labor supply as mediating variables. Basic pension insurance for urban and rural residents and family pension are the two primary methods of providing for the rural older adult in China, among which family pension includes intergenerational support from children to their parents. Intergenerational support refers to the financial support of children to their parents. As a son or daughter, he or she has an obligation to care for his or her parents, which includes taking care of their daily lives (57) and providing financial support, and receiving the basic pension for urban and rural residents will have a certain impact on intergenerational support. According to research, participation in pension insurance significantly increases the intergenerational economic support received by the older adult (58), and older adult people who receive support from their children have significantly higher subjective well-being than those who do not receive such support (59). Intergenerational economic support can further promote the well-being effect of pension insurance (60). Existing research proves that pension income can reduce the labor supply of the older adult to some extent (3, 60, 61). As a non-labor income, basic pension for urban and rural residents can enable the older adult to obtain more opportunities for free distribution of labor and leisure, and leisure time can allow people to meet their psychological needs such as relaxation and self-improvement and can enable rural older adult people to increase their participation in life and reduce the negative impact of aging. Since the sum of labor and leisure time is constant, when they choose to obtain leisure time, they must reduce a certain amount of labor supply. The reduction in labor participation time and the increase in leisure participation time significantly promote the subjective well-being of rural older adult people (62).

3 Results

3.1 Descriptive statistical

Table 2 reports the descriptive statistics for the variables used in this study.

In terms of degrees of depression, the average depression index for rural older adult in 2018 and 2020 was 0.955 points, close to the critical value of 1 point for depressive symptoms. If the older adult samples are grouped according to a depression index cutoff of 1 point, then 43.4% of the rural older adult with a depression index of 1 point and above show symptoms of mental depression. The average life satisfaction score for rural older adult is 3.288, indicating that overall, they are "relatively satisfied" with their lives. The basic pension indicator for urban and rural residents is the ratio of the basic pension for urban and rural residents to the minimum wage income. The average level of basic pension for urban and rural residents in the sample overall is 0.0683, the minimum value in the sample is 0.0516, and the maximum value is 0.444. The mean value is closer to the minimum value in the sample, reflecting that the current basic pension for urban and rural residents in China is still at a low level, with only a few regions having basic pension levels much higher than the minimum standard.

3.2 The estimation results of the impact of rural and urban residents' basic pension on the subjective well-being of rural older adult

Table 3 presents the OLS regression estimates for the impact of basic pension levels on the degrees of depression among the older adult in rural areas and the ordered logit regression estimates for life satisfaction. Column (1) shows the univariate OLS regression results, indicating a significant negative impact of basic pension levels on the degrees of depression among rural older adult, indicating that higher levels of basic pensions are associated with lower degrees of depression and higher subjective well-being. After adding control variables into the regression, the results in column (2) still show a significant negative effect of basic pension levels on depression. Similarly, column (3) presents the univariate ordered logit regression results for the impact of basic pension levels on life satisfaction, revealing a significant positive effect, meaning that higher basic pension levels are associated with higher life satisfaction and greater subjective well-being among rural older adult. After the introduction of control variables, the results in column (4) remain significant. These findings indicate that basic pension levels have a significant positive impact on the subjective well-being of the older adult in rural areas, regardless of whether the measure is a positive or negative indicator of subjective well-being. Most of the older adult living in rural China do not have neither fixed jobs nor stable incomes. With the growth of age, their working ability

TABLE 2 Descriptive statistics and description of variables.

Variable properties	Variable	Observations	Mean	Standard deviation	Minimum value	Maximum value
Explained Variables	Degree of depression	9,310	0.955	0.671	0	3
	Life satisfaction	9,310	3.288	0.791	1	5
Explaining Variables	Basic pension for urban and rural residents	9,310	0.0683	0.0163	0.0516	0.444
Control variables	Age	9,310	67.36	5.554	60	108
	Gender	9,310	0.508	0.500	0	1
	Education level	9,310	1.202	0.402	1	2
	Marital status	9,310	0.824	0.381	0	1
	Chronic disease status	9,310	0.420	0.494	0	1
	Number of children	9,310	3.098	1.441	0	13
	Personal income	9,296	6.444	3.039	0	12.49
	Family income	9,163	5.789	3.649	0	14.45
	Social relationship	9,309	0.439	0.496	0	1
Mediating variables	Health condition	9,307	2.967	1.036	1	5
	Intergenerational support	9,310	7.079	2.864	0	13.06
	Labor supply	9,310	26.60	31.96	0	320

TABLE 3 Basic pension level and subjective well-being of rural older adult.

	Degrees of depression	Degrees of depression	Life satisfaction	Life satisfaction
	(1)	(2)	(3)	(4)
Basic pension for urban and rural residents	−2.224*** (0.426)	−1.727*** (0.416)	4.206*** (1.219)	3.652*** (1.228)
Age		−0.004*** (0.001)		0.020*** (0.004)
Gender		−0.194*** (0.014)		−0.005 (0.042)
Education level		−0.140*** (0.018)		−0.158*** (0.052)
Marital status		−0.165*** (0.018)		0.078 (0.056)
Chronic disease status		0.165*** (0.014)		−0.224*** (0.041)
Number of children		0.027*** (0.005)		−0.011 (0.016)
Personal income		−0.016*** (0.002)		0.027*** (0.007)
Family income		0.007*** (0.002)		−0.002 (0.006)
Social relationship		−0.069*** (0.014)		0.089** (0.040)
Sample size	9,310	9,148	9,310	9,148
R^2	0.003	0.084	0.001	0.005

*, **, and *** indicate significance level at 1%, 5%, and10%, respectively. Standard errors in brackets.

gradually declines, and their means of obtaining income gradually decrease. However, the basic pension income of urban and rural residents, although not high in amount, alleviates the pressure of insufficient economic sources for the older adult in rural areas. Through this pension, the consumption expenditure of durable goods and the expenditure of medical care can be improved effectively, so as to improve the quality of life of the rural older adult and improve their life satisfaction. In addition, continuous and stable access to pensions will also make the rural older adult feel the stability of life and the security of the future, thus increasing their subjective sense of well-being.

In column (2), regarding the estimation results for control variables, all included control variables show a significant correlation with the subjective well-being of the older adult in rural areas. Age, gender, level of education, having a spouse, personal income, and social relationships all have a significant positive effect on the subjective well-being of rural older adult. Age is significant at the 1% level, indicating that older rural older adult experience lower degrees of depression and higher levels of subjective well-being. The possible explanation is that with the increase of age, the life pressure of the rural older adult is gradually alleviated, and they have more time to pay attention to their own feelings and needs, so they have better psychological state and higher level of subjective well-being; the level of subjective well-being in male groups is higher than that in female groups; rural older adult with higher education levels have a higher level of well-being, possibly because different educational background will have different degrees of impact on individual income and social status; rural older adult with spouses have higher levels of subjective well-being than those without spouses. The reason for this could be that rural older adult with spouses can receive emotional support and care from their spouses, thereby reducing depression and enhancing well-being; the higher the level of personal income, the higher the level of well-being, and high-income levels can bring good material living conditions, and bring economic security and stability, which can reduce the economic pressure and improve the level of well-being; rural older adult social activities can significantly increase the level of subjective well-being, and social interaction activities can help strengthen emotional communication, provide spiritual support and emotional satisfaction for the rural older adult, reduce the degree of mental depression, and enhance the sense of pleasure and happiness.

Having chronic diseases, the number of children, and family income have a significant negative impact on the subjective well-being of rural older adult. The subjective well-being level of the rural older adult with chronic diseases is lower than that of the rural older adult without chronic diseases. Chronic diseases bring both mental and physical burdens to the rural older adult. Most of the people with chronic diseases need long-term medication or treatment, and the expenditure on medical expenses will bring economic pressure to the older adult, which may make them feel anxious and uneasy, increase the probability of falling into health poverty, and thus reduce the level of subjective well-being; the more the number of children, the lower the subjective well-being, which may be due to the fact that the children cannot go home often for migrant work, lack of communication with their parents, or the family relationship is not harmonious, so the increase in the number of children will reduce the subjective well-being of the older adult in the rural areas. From the perspective of income, a higher personal income level can enhance the level of well-being, whereas a higher family income level tends to reduce well-being. This paradoxical effect may suggest that while personal income contributes directly to an individual's sense of security and ability to fulfill personal desires, higher household income could potentially lead to increased responsibilities, expectations, or stress within the family context, thereby negatively affecting the individual's subjective well-being.

3.3 Robustness check

3.3.1 Replacement regression model

Poisson regression is a generalized linear model. Poisson regression assumes that the conditional distribution of the explained

TABLE 4 Poisson regression results.

	Degrees of depression	Degrees of depression
	(1)	(2)
Basic pension for urban and rural residents	−2.661*** (0.535)	−2.074*** (0.484)
Age		−0.004*** (0.001)
Gender		−0.204*** (0.015)
Education level		−0.165*** (0.020)
Marital status		−0.159*** (0.018)
Chronic disease status		0.171*** (0.014)
Number of children		0.027*** (0.005)
Personal income		−0.017*** (0.002)
Family income		0.008*** (0.002)
Social relationship		−0.072*** (0.014)
Constant	0.135*** (0.037)	0.748*** (0.110)
Sample size	9,310	9,148
R^2	0.001	0.018

Standard errors in parentheses $^*p<0.1$, $^{**}p<0.05$, and $^{***}p<0.01$.

TABLE 5 Regression results replacing the explained variable.

	孤独感	孤独感
	(1)	(2)
Basic pension for urban and rural residents	−4.917*** (1.509)	−4.150*** (1.547)
Age		−0.006 (0.005)
Gender		−0.202*** (0.047)
Education level		−0.164*** (0.060)
Marital status		−1.104*** (0.056)
Chronic disease status		0.338*** (0.045)
Number of children		0.038** (0.017)
Personal income		−0.045*** (0.007)
Family income		0.014** (0.006)
Social relationship		−0.127*** (0.045)
Sample size	9,310	9,148
R^2	0.001	0.033

Standard errors in parentheses $^*p<0.1$, $^{**}p<0.05$, and $^{***}p<0.01$.

variable is the Poisson distribution, and predicts the expected value of the explained variable by introducing the explaining variable. Considering that different regression models may affect the results of hypothesis testing, this study further uses Poisson regression model to regress the data (63) to verify the impact of the basic pension of urban and rural residents on the subjective well-being of the rural older adult in China. Table 4 presents the results of the Poisson regression. The stability of the regression coefficient and the regression results in Table 4 show a high consistency with those in Table 3. Both before and after the inclusion of control variables, the level of basic pension has a significant negative impact on the degrees of depression among the older adult in rural areas. That is, in areas with higher basic pension levels, the degrees of depression among rural older adult are lower, and their subjective well-being is higher. This confirms the robustness of the research conclusions stated above.

3.3.2 Replacing the explained variable

The method of replacing the explained variables is to use alternative variables that are highly correlated with the original variables but have different data sources or different calculation methods and re-run the regression analysis to test the robustness of the regression results.

With the migration of rural labor force, the miniaturization and decentralization of rural family structure, and the lack of older adult care have brought many psychological and emotional problems to the older adult, and a large number of rural older adult have been attacked by loneliness. Research has found that loneliness and life satisfaction in the older adult are significantly negatively correlated. Higher levels of loneliness tend to lead to a variety of negative emotional experiences, which in turn reduce levels of life satisfaction (64). If the basic pension for urban and rural residents can reduce the loneliness of the older adult, it will reduce the negative emotions of the rural older adult, and thus enhance the subjective well-being of the rural older adult. Therefore, this article uses the "loneliness" variable as a proxy variable for the subjective well-being of the rural older adult to regress. According to the question "I feel lonely" in the 2018 and 2020 CHARLS questionnaires, the questionnaires classify loneliness as a quadratic variable: "Rarely or not at all (<1 day)," "not much (1–2 days)," "sometimes or half of the time (3–4 days)," "most of the time (5–7 days)," and re-assigned a score of 1–4, with higher scores indicating stronger feelings of loneliness. In this way, it is investigated whether the basic pension for urban and rural residents will similarly affect the loneliness of the rural older adult, thus confirming the robustness of the research results. Table 5 reports the regression results focusing on loneliness, and columns (1) and (2) adopt the ordered logistic estimation method. The regression results show that the basic pension for urban and rural residents has a significant negative impact on the loneliness of rural older adult. The results using loneliness as the explained variable are similar to the empirical results of depression degree, indicating that the above analysis results are relatively robust. It further explains that the basic pension can provide spiritual comfort and support to the rural older adult, reduce their loneliness, and enhance their level of subjective well-being.

3.4 Heterogeneity analysis

The above analysis results show the impact of the basic pension for urban and rural residents on the subjective well-being of the rural older adult. However, this impact is based on the sample model analysis and does not take into account the differences between the gender, health condition, and regions of the rural older adult.

Since the differences between male and female in mental sensitivity may affect the cognitive experience and emotional circuit of subjective well-being, grouping the samples according to gender ratio can reflect the difference in the impact of the basic pension for urban and rural residents on the subjective well-being of male and female; The payment of basic pension for urban and rural residents can produce health effects. For older adult people without chronic diseases, sustained and stable basic pension income can reduce individual depression, while the older adult with chronic diseases face medical expenses, so they have a higher dependence on basic pension and greater life security brought by basic pension, thus improving their subjective well-being. They are grouped according to whether they suffer from chronic diseases to explore the different impacts of basic pension on rural older adult with different health conditions; Under China's unique dual economic structure, there is still a big gap in the level of economic development among different regions, and there are differences in social system, development situation, external environment, and other aspects in different regions. Therefore, under different constraints, the acceptance and expectation of the basic pension policy for urban and rural residents in different regions are different. Therefore, the differences in the subjective well-being of the rural older adult in different regions can be reflected by the grouping of eastern, central, and western regions. Therefore, grouping according to the eastern, central, and western regions can reflect the differences in subjective well-being among rural older adult in different regions.

Therefore, this article conducts group regression on the entire sample from three perspectives: gender ratio of rural older adult, whether they suffer from chronic diseases, and eastern, central and western regions, to examine the heterogeneous impact of basic pension for urban and rural residents on the subjective well-being of rural older adult. The specific results are shown in Table 6.

The estimation results indicate that, from the perspective of gender ratio grouping, the impact of basic pension is greater in provinces with a relatively higher gender ratio, in terms of the absolute value of the coefficient. The gender ratio is the proportion of males to females within a province, with a higher ratio indicating a higher proportion of males in the sample of that province. Therefore, the impact of the basic pension on the subjective well-being of males is greater than females. This might be because men typically bear the responsibility of being the primary source of income in the family, thereby facing greater psychological stress. Consequently, basic pension income can alleviate some of the burden on the male population to a certain extent, enhancing their subjective well-being.

From the perspective of whether individuals have chronic diseases, the level of basic pension for urban and rural residents has a significantly positive effect on the subjective well-being of both groups of samples, with significance at the 1% level. The gap in significance between the two groups is not large, but the absolute value of the regression coefficient for the sample with chronic diseases is slightly higher than that for the sample without chronic diseases. The reason is that for rural older adult people suffering from chronic diseases, the income from the basic pension for urban and rural residents can offset part of their medical expenses, thereby reducing their living burden and improving their subjective well-being.

TABLE 6 Heterogeneity analysis of basic pension levels and degrees of depression among rural older adult.

Variable	Degrees of depression						
	Gender ratio		Chronic disease status		Region		
	(1) High category	(2) Low category	(3) Suffering from chronic diseases	(4) Not suffering from chronic diseases	(5) Eastern region	(6) Central region	(7) Western Region
Basic pension for urban and rural residents	−2.336*** (0.704)	−1.279** (0.518)	−2.064*** (0.621)	−1.426** (0.564)	−1.956*** (0.526)	14.252*** (1.895)	4.273*** (0.976)
Age	−0.006*** (0.002)	−0.003 (0.002)	−0.004* (0.002)	−0.004*** (0.002)	−0.006*** (0.002)	−0.000 (0.003)	−0.005* (0.003)
Gender	−0.170*** (0.020)	−0.213*** (0.020)	−0.243*** (0.023)	−0.160*** (0.018)	−0.171*** (0.022)	−0.198*** (0.025)	−0.230*** (0.026)
Education level	−0.095*** (0.025)	−0.185*** (0.025)	−0.122*** (0.029)	−0.152*** (0.022)	−0.118*** (0.027)	−0.098*** (0.029)	−0.167*** (0.037)
Marital status	−0.187*** (0.027)	−0.145*** (0.025)	−0.155*** (0.029)	−0.172*** (0.024)	−0.174*** (0.030)	−0.194*** (0.031)	−0.078** (0.034)
Chronic disease status	0.160*** (0.020)	0.166*** (0.019)	0.000 (.)	0.000 (.)	0.150*** (0.022)	0.192*** (0.023)	0.138*** (0.025)
Number of children	0.038*** (0.008)	0.018*** (0.007)	0.025*** (0.008)	0.029*** (0.007)	0.015* (0.009)	0.023** (0.010)	0.008 (0.009)
Personal income	−0.016*** (0.003)	−0.016*** (0.003)	−0.017*** (0.004)	−0.016*** (0.003)	−0.019*** (0.003)	−0.019*** (0.004)	−0.006 (0.004)
Family income	0.009*** (0.003)	0.005** (0.003)	0.011*** (0.003)	0.005** (0.002)	0.005* (0.003)	0.004 (0.003)	−0.005 (0.004)
Social relationship	−0.074*** (0.020)	−0.063*** (0.019)	−0.095*** (0.022)	−0.049*** (0.017)	−0.049** (0.021)	−0.076*** (0.023)	−0.057** (0.026)
Sample size	4,437	4,711	3,845	5,303	3,320	2,964	2,864
R^2	0.079	0.090	0.073	0.064	0.083	0.108	0.069

Looking at the regional grouping, the level of basic pension for urban and rural residents has a significant negative impact on the degrees of depression of rural older adult in the eastern region, and is significant at the 1% significance level, indicating that the basic pension for urban and rural residents can improve the level of subjective well-being among rural older adult in the eastern region. The possible explanation is that the economy in the eastern region is generally more developed, the social security system is relatively complete, the level of basic pension benefits is relatively high, and residents have high incomes, and thus the pressure of contribution is small, and the rural older adult in this region are more likely to improve their quality of life, reduce the level of depression, and enhance their subjective well-being through the basic pension. In addition, the regression results show that the level of basic pension has a significant positive effect on the depression degree of rural older adult in the central and western regions, indicating that the basic pension suppresses the subjective well-being of rural older adult in the central and western regions. The possible reason is that the level of economic development in the central and western regions lags behind, and the living standards of the rural older adult are poorer. Basic pension can improve their living standards to a certain extent, but the lower level of pension benefits is not enough to meet their living needs, which may lead to an increase in the degree of depression. The impact of the pension level on the eastern and central regions is more significant than that on the western region, probably because of the development level and cultural differences between regions. The eastern region is more economically developed, cultural exchanges are more active, and the ideology of the rural older adult is more open, and the impact of the pension level is more significant. However, the rural older adult in the western region have relatively conservative ideas and basic pension levels have relatively little impact on them. Among these three sample groups, the absolute value of the regression coefficient for the central region is the largest. The possible reason is the difference in the basic pension levels among regions, which is indeed the case, with the basic pension level in the eastern region being significantly higher than in the central and western regions.

3.5 Mechanism of influence

This study employs the mediation effect method to test whether the basic pension affects the subjective well-being of the rural older adult through three factors: health condition, intergenerational support, and labor supply. The mediation effect model studies how the independent variables affect the dependent variable by analyzing the path of the independent variables on the dependent variable. In empirical analysis, the commonly used approach for the mediation effect test is the stepwise regression method (65–68), which is to determine whether the mediation effect exists or not by multiple regressions, based on the significance of the regression coefficients. The mediation effect model used in this article is constructed as follows:

$$Depression_i = \theta_1 + cPension_i + \gamma CV_i + \varepsilon_i \tag{3}$$

$$M_i = \theta_2 + aPension_i + \gamma CV_i + \varepsilon_i \tag{4}$$

$$Depression_i = \theta_3 + c'Pension_i + bM_i + \gamma CV_i + \varepsilon_i \tag{5}$$

In Equations (3–5), a, b, c, c' are regression coefficients, $Depression_i$ representing the degree of depression of the explained variable; $Pension_i$ representing the basic pension level of the explaining variable; M_i representing mediating variable, including health condition, intergenerational support and labor supply; CV_i and are control variables. According to the mediation effect test process of previous studies, the first step is to test whether the influence coefficient c of the basic pension level on the depression degree of rural older adult is significant, and the second step is to test whether the influence coefficient a of the basic pension level on the mediating variable is significant. If the two coefficients are significant, then test whether coefficient b is significant. If it is significant, it indicates that there is a mediating effect. If one of a and c is not significant, use the Bootstrap method to test $H_0 : ab = 0$. If it is significant, there is a mediating effect. If it is not significant, there is no mediating effect. Table 7 presents the analysis of the mechanism through which the level of basic pension influences the degrees of depression among rural older adult individuals.

Columns (2, 3, 6, 7) show that the coefficients have passed the tests, indicating that health conditions and labor supply have mediating effects in the impact of basic pension on the degrees of depression of rural older adult individuals; whereas column (4) shows that the coefficient for intergenerational support is not significant and does not pass the Bootstrap test, indicating the absence of a mediating effect of intergenerational support. This study empirically tests and verifies the mediating roles of health status and labor supply.

Based on the above analysis, it is evident that due to the older adult being reluctant to increase the burden of their children or the relative backwardness of rural medical resources, most older adult individuals do not seek treatment immediately after falling ill. However, rural older adult individuals use their basic pension for medical expenses, thereby improving their health condition and enhancing their subjective well-being. Moreover, for most rural older adult individuals, if there is no income from the basic pension, who would need to engage in more labor to earn income to sustain their lives in old age. A fixed basic pension income can provide some material security for the older adult, reduce their psychological burden, and release them from heavy labor activities, thereby enhancing their subjective well-being.

4 Discussion

In recent years, with the development of China's economy and the improvement of people's living standards, residents' demands for quality of life have shifted from material aspects such as income and consumption to a greater emphasis on spiritual well-being. Research has found that individuals are able to explicitly evaluate their happiness in terms of overall well-being, meaning, and psychological richness (69). This paper constructs OLS and ordered logistic models and uses data from the 2018 and 2020 China Health and Retirement Longitudinal Study to perform regression analysis, estimating the impact of the basic pension for urban and rural residents on the subjective well-being of the rural older adult. The regression results show that the basic pension for urban and rural residents significantly enhances the level of subjective well-being among the rural older adult. Further evidence indicates that

TABLE 7 Analysis of the impact mechanism of basic pension level on the degrees of depression.

Variable	Degrees of depression	Health condition		Intergenerational support		Labor supply	
		Health condition	Degrees of depression	Financial support	Degrees of depression	Working hours	Degrees of depression
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Basic pension for urban and rural residents	−1.727*** (0.416)	2.973*** (0.646)	−1.056*** (0.390)	2.674 (1.773)	−1.697*** (0.416)	−89.837*** (19.373)	−1.786*** (0.416)
Health condition			−0.225*** (0.006)				
Financial support					−0.011*** (0.002)		
Working hours							−0.001*** (0.000)
Control variables	Control	Control	Control	Control	Control	Control	Control
Sample size	9,148	9,145	9,145	9,148	9,148	9,148	9,148
R^2	0.084	0.072	0.195	0.088	0.086	0.124	0.084

Financial support refers to the logarithm of financial support from children to their parents.

the impact of the basic pension on the subjective well-being of men is greater than that of women. The basic pension has a significant positive impact on the subjective well-being of the rural older adult with chronic diseases. The level of the basic pension has a significant negative impact on the depression levels of the rural older adult in the eastern regions. The analysis of the mechanism of impact based on the mediating effect method shows that health conditions and labor duration play an important role in the process of the impact of basic pension for urban and rural residents on subjective well-being. Improving health conditions and reducing labor supply can enhance the subjective well-being of the rural older adult.

Based on the findings of this study, the policy implications of this paper are as follows:

On the one hand, enhance the level of basic pension benefits for urban and rural residents based on policy goals. Due to the differences in economic development level and fiscal subsidy capacity among different regions, the development of basic pension insurance for urban and rural residents in different regions is not balanced, especially the basic pension in central and western regions is generally low, which is not only the reason of system design, but also the result of local financial capacity. Therefore, it is recommended that the central government increase financial subsidies, improve basic pension benefits for urban and rural residents, meet the basic living needs of the rural older adult, and effectively improve the subjective feelings of the rural older adult.

On the other hand, the basic pension should be optimized and upgraded to a non-contributory pension in terms of system practice. Academic research has proven that pensions obtained through social security have a strong positive impact on personal happiness (70). For the rural older adult, due to the lack of pension accumulation during employment, the most effective and direct way is to obtain a "non-contributory pension" with inclusive nature. The basic pension for urban and rural residents is very similar to the non-contributory pension, which is a kind of "non-contributory pension" in a sense. Because the basic pension for urban and rural residents does not have any accumulation of funds, it is completely from fiscal transfer payments, and has nothing to do with personal contributions, which reflects the non-contributory and welfare nature of the system. Some studies indicate that non-contributory pension schemes targeting the poor population in developing countries can improve the welfare of the poor older adult (71), and non-contributory social pensions can effectively reduce the incidence of older adult poverty and extreme poverty, playing a positive role in poverty reduction (72). Therefore, optimizing and upgrading the basic pension for urban and rural residents into a non-contributory pension can more effectively solve the problem of low basic pension benefits, rapidly expand the coverage of pension insurance, and eliminate poverty in the older adult.

Finally, it needs to be discussed that the relevant welfare policies of the basic pension insurance for urban and rural residents should be tilted toward vulnerable groups such as rural female and left-behind older adult people. Although the implementation of the policy of focusing on the key groups will face many difficulties in practice and will greatly increase administrative cost, the policy effect is obvious. The regression results indicate that the improvement of income level can significantly improve the well-being of rural female older adult and left-behind older adult. Therefore, the government can provide multi-level protection for this low-income group in the form of strengthening local responsibilities. For example, in addition to the basic pension provided by the central government, a certain number of pension subsidies provided by the local government can be added, so as to compensate the income gap of vulnerable groups in society and improve the well-being of vulnerable older adult groups.

This study has several limitations. Firstly, the research data used only consists of two periods of panel data, which only explores the relationship between the current basic pension for urban and rural residents and the subjective well-being of rural older adult. However, the level of the basic pension for urban and rural residents may be adjusted in later periods. Therefore, the relationship between the basic pension level for urban and rural residents in the same region and the well-being of rural older adult requires further exploration. Secondly, although the article controls for some variables during the empirical process, subjective well-being is influenced by a variety of factors, and there may still be issues with the selection of indicators not being comprehensive enough.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Ethics statement

Ethical approval was not required for the study involving humans in accordance with the local legislation and institutional requirements. Written informed consent to participate in this study was not required from the participants or the participants' legal guardians/next of kin in accordance with the national legislation and the institutional requirements.

Author contributions

JY: Writing – original draft, Conceptualization, Formal analysis, Methodology. ZL: Software, Writing – original draft. JZ: Data curation, Writing – original draft. ZZ: Funding acquisition, Project administration, Supervision, Writing – review & editing.

Funding

The author(s) declare that financial support was received for the research, authorship, and/or publication of this article. This work was supported by the Chinese Ministry of Education of Humanities and Social Science Project (Grant Number 19YJCZH235), the Foundation of Tang Scholar, the Major Projects of China's Ministry of Education's Key Research Center for Humanities and Social Sciences (Grant Number 23JJD720003), the National Social Science Foundation of China (Grant Number 22FSHB012), and the Jiangsu Social Science Foundation of China (Grant Number 22HQB38).

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

References

1. Mu G. Reform and prospect of traditional pension plan for the aged in China. *J Renmin Univ Chin*. (2000) 5:39–44.

2. Shu F. From family supporting to social pension: a study on the changes of rural old-age Care in the Past 70 years in new China. *Zhejiang Soc Sci*. (2019) 6:83–91. doi: 10.14167/j.zjss.2019.06.009

3. Zhang C, Giles J, Zhao Y. A policy evaluation of China's new rural pension Programme: income, poverty, expenditure, subjective well-being and labour supply. *Chin Econ Q*. (2014) 14:203–30. doi: 10.13821/j.cnki.ceq.2015.01.012

4. He H, Li X. Evaluation of the impact of the new rural social pension insurance policy on rural residents' consumption. *J Jiangxi Univ Fin Economics*. (2020) 3:61–72. doi: 10.13676/j.cnki.cn36-1224/f.2020.03.006

5. Zhu H. Assessing the poverty reduction effect of the urban and rural resident pension: from the perspective of multidimensional poverty. *Soc Sci Beijing*. (2017) 9:112–9. doi: 10.13262/j.bjsshkxy.bjshkx.170912

6. He Y, Zhou Q. A study on the effect of Chinese new rural pension program on rural subjective well-being. *Insur Stud*. (2016) 3:106–17. doi: 10.13497/j.cnki.is.2016.03.010

7. Wang Y, Long Y, Jiang C, Xu Q. Research on social security income redistribution effect in China. *Econ Res J*. (2016) 2:4–15.

8. Ma H, Xi H. Income gap, social insurance and improvement of residents' happiness. *Soc Sec Stud*. (2020) 1:86–98. doi: 10.3969/j.issn.1674-4802.2020.01.009

9. Diener E, Ryan K. Subjective well-being: a general overview. *S Afr J Psychol*. (2009) 39:391–406. doi: 10.1177/008124630903900402

10. Pak TY. Social protection for happiness? The impact of social pension reform on subjective well-being of the Korean older adult. *J Policy Model*. (2020) 42:349–66. doi: 10.1016/j.jpolmod.2019.12.001

11. Chen Y, Tan Y (2017). Income and subjective well-being: evidence from Singapore's first national non-contributory pension. CREA Working Paper.

12. Zhong C, Yue X. Does economic growth improve human happiness? A review of the influencing factors of SWB. *Nankai Econ Stud*. (2020) 4:24–45. doi: 10.14116/j.nkes.2020.04.002

13. Blanchflower DG, Oswald AJ. Well-being over time in Britain and the USA. *J Public Econ*. (2004) 88:1359–86. doi: 10.1016/S0047-2727(02)00168-8

14. Deaton A, Stone AA. Understanding context effects for a measure of life evaluation: how responses matter. *Oxf Econ Pap*. (2016) 68:861–70. doi: 10.1093/oep/gpw022

15. Schatz E, Gómez-Olivé X, Ralston M, Menken J, Tollman S. The impact of pensions on health and wellbeing in rural South Africa: does gender matter? *Soc Sci Med*. (2012) 75:1864–73. doi: 10.1016/j.socscimed.2012.07.004

16. Horley J, Lavery JJ. Subjective well-being and age. *Soc Indic Res*. (1995) 34:275–82. doi: 10.1007/BF01079200

17. MacKerron G. Happiness economics from 35 000 feet. *J Econ Surv*. (2012) 26:705–35. doi: 10.1111/j.1467-6419.2010.00672.x

18. Cetre S, Clark AE, Senik C. Happy people have children: choice and self-selection into parenthood. *Eur J Popul*. (2016) 32:445–73. doi: 10.1007/s10680-016-9389-x

19. Mendiratta A, Jain A, Malhotra K. Resilience and life satisfaction: predictors of well-being in pensioners and non-pensioners. *Int J Ind Psychól*. (2022) 10:446–52. doi: 10.25215/1002.045

20. Bonsang E, Klein TJ. Retirement and subjective well-being. *J Econ Behav Organ*. (2012) 83:311–29. doi: 10.1016/j.jebo.2012.06.002

21. Baker M, Gruber J, Milligan KS (2009). Retirement income security and well-being in Canada. NBER Working Paper No.14667.

22. Etinzock MN, Kollamparambil U. Subjective well-being impact of old age pension in South Africa: a difference in difference analysis across the gender divide. *S Afr J Econ Manag Sci*. (2019) 22:1–12. doi: 10.4102/sajems.v22i1.2996

23. Etinzock MN (2018). Happiness and the older adult: a subjective wellbeing impact of social grants in South Africa. University of the Witwatersrand, Faculty of Law, Commerce and Management, School of Economics and Finance. Available at: https://wiredspace.wits.ac.za/server/api/core/bitstreams/1c73eb96-9772-4a1b-aa36-bbec86f6072e/content

24. Luo C. Urban-rural divide, employment, and subjective well-being. *Chin Econ Q*. (2006) 2:817–40.

25. He L, Pan C. Uncover the "Easterlin paradox" of China: income gap, inequality of opportunity and happiness. *Manag World*. (2011) 8:11–22. doi: 10.19744/j.cnki.11-1235/f.2011.08.003

26. Yang J, Zhang Y. Pricing air pollution: an analysis based on happiness data. *J World Econ*. (2014) 12:162–88. doi: 10.19985/j.cnki.cassjwe.2014.12.009

27. Lamu AN, Olsen JA. The relative importance of health, income and social relations for subjective well-being: an integrative analysis. *Soc Sci Med*. (2016) 152:176–85. doi: 10.1016/j.socscimed.2016.01.046

28. Liu Y. Empirical study on the happiness effect of social security systems: a perspective based on medical insurance and pension insurance. *J Commer Econ*. (2015) 6:92–4. doi: 10.3969/j.issn.1002-5863.2015.06.036

29. Deng D, Yang J. Pension insurance, consumption inequality and subjective happiness of rural elderly: an empirical analysis using the China household financial survey data. *Chin J Popul Sci*. (2019) 4:43–55.

30. Bando R, Galiani S, Gertler P (2017). The effects of noncontributory pensions on material and subjective well-being. IDB Working Paper Series No. IDB-WP-840.

31. Lloyd-Sherlock P, Barrientos A, Moller V, Saboia J. Pensions, poverty and wellbeing in later life: comparative research from South Africa and Brazil. *J Aging Stud*. (2012) 26:243–52. doi: 10.1016/j.jaging.2012.02.003

32. Olivera J, Ponomarenko V. Pension insecurity and wellbeing in Europe. *J Soc Policy*. (2017) 46:517–42. doi: 10.1017/S0047279416000787

33. Shao C, Li W. Pension level, subjective wellbeing, and preference of care model among elderly people: an empirical study based on structural equation modeling. *Front Public Health*. (2023) 11:1104556. doi: 10.3389/FPUBH.2023.1104556

34. Danzer AM, Danzer N (2016). Pension generosity and mental wellbeing: The effect of eradicating poverty at old-age. Paper presented at Demographischer Wandel-session: pensions and labor market outcomes conference, No. G05-V1, Germany.

35. Han J, Zhang X, Meng Y. The impact of old-age pensions on the happiness level of elderly people–evidence from China. *Ageing Soc*. (2022) 42:1079–99. doi: 10.1017/S0144686X20001452

36. Li HSchool B, University F. Review and evaluation on rural-urban residents social pension insurance: based on replacement rate of basic pension insurance. *Popul Econ*. (2015) 5:91–9. doi: 10.3969/j.issn.1000-4149.2015.05.010

37. Xu T, Wei Y. Adjustment mechanism and calculation of basic pension benefits of urban and rural Residents' pension insurance under the background of rural revitalization. *J Fujian Norm Univ*. (2021) 6:98–109. doi: 10.12046/j.issn.1000-5285.2021.06.010

38. Wang Z. The target treatment and level of measurement about basic pension of urban and rural residents: take six provinces in the east, middle and west of China as an example. *Statist Inform Forum*. (2020) 11:93–102. doi: 10.3969/j.issn.1007-3116.2020.11.011

39. Zhao Y, Zhou J. Does new rural social endowment insurance improve the happiness of middle aged and elderly people: an empirical study based on China family panel studies data. *Chin Econ Stud*. (2021) 6:105–22. doi: 10.19365/j.issn1000-4181.2021.06.08

40. Zheng X, Fang X. The social pension scheme and the subjective well-being of the elderly in rural China. *J Financ Econ*. (2018) 9:80–94. doi: 10.16538/j.cnki.jfe.2018.09.005

41. Ni Z, Li Q. Does old-age security enhance residents' subjective well-being? *Mod Econ Res*. (2021) 10:31–40. doi: 10.13891/j.cnki.mer.2021.10.005

42. Chen F, Liu J, Liu X. The influencing mechanism of 'new rural social pension policy'on subjective well-being of the elderly in rural China. *Res Fin Econ Issues*. (2020) 1:111–20. doi: 10.19654/j.cnki.cjwtyj.2020.01.013

43. Alzua ML, Cantet MN, Dammert AC, Olajide D (2023). The wellbeing effects of an old age pension: experimental evidence for Ekiti state in Nigeria. Documento de Trabajo Nro 322.

44. Alesina AF, Di Tella R, Macculloch R. Inequality and happiness: are Europeans and Americans different? *Soc Sci Electron Publish*. (2004) 88:2009–42. doi: 10.2139/ssrn.293781

45. Easterlin RA, McVey LA, Switek M, Sawangfa O, Zweig JS. The happiness-income paradox revisited. *Proc Natl Acad Sci USA*. (2010) 107:22463–8. doi: 10.1073/pnas.1015962107

46. Yu X, Chen Y, Qu X, Huang X. Related factors on subjective well-being in the elderly. *Chin Ment Health J*. (2016) 6:427–34. doi: 10.3969/j.issn.1000-6729.2016.06.006

47. Gao Y, Yang Q. The current situation and main influencing factors of the happiness level of elderly people receiving home-based care. *Chin J Gerontol*. (2020) 17:3771–3. doi: 10.3969/j.issn.1005-9202.2020.17.057

48. Stutzer A, Frey BS. Does marriage make people happy, or do happy people get married? *J Socio Econ*. (2004) 35:326–47. doi: 10.2139/ssrn.375960

49. Aslam A, Corrado L (2007). No man is an island, the inter-personal determinants of regional well-being in Europe. Cambridge Working Papers in Economics 0717.

50. Portela M, Neira I, Salinas-Jiménez MDM. Social capital and subjective wellbeing inEurope: a new approach on social capital. *Soc Indic Res*. (2013) 114:493–511. doi: 10.1007/s11205-012-0158-x

51. Knight J, Gunatilaka R. Does economic growth raise happiness in China? *Oxf Dev Stud*. (2011) 39:1–24. doi: 10.1080/13600818.2010.551006

52. Kuang M, He F. Study on the impact of the 'new rural social pension policy' on the health of the rural elderly population and the optimization of elderly care services. *Rural Economy*. (2018) 10:84–90.

53. Wu Y, Hu J, Nie J. Study on the impact mechanism of the basic pension Insurance for Urban and Rural Residents on the health performance of the rural elderly. *Soc Secur Stud*. (2021) 6:10–22. doi: 10.3969/j.issn.1674-4802.2021.06.002

54. Steptoe A, Deaton A, Stone A. Subjective wellbeing, health and ageing. *Lancet*. (2015) 385:640–8. doi: 10.1016/S0140-6736(13)61489-0

55. Huang Y, Li Y, Clark WAV. Family connections and subjective wellbeing in transitional China. *J Happiness Stud*. (2024) 25:33. doi: 10.1007/s10902-024-00744-9

56. Wang S. Analysis and evaluation of the structure of subjective well-being of Chinese residents——an empirical study based on CGSS2013 data. *Mod Econ Sci*. (2018) 3:66–74.

57. Zang Z. The care types choice in filial culture: a cross-sectional study of disabled elderly in China. *Front Public Health*. (2022) 10:954035. doi: 10.3389/fpubh.2022.954035

58. Liu P, Sun L. The impact of endowment Insurance for Urban and Rural Residents on intergenerational economic support: research based on the mediating effect model. *J Yunnan Fin Trade Instit*. (2020) 12:3–18. doi: 10.16537/j.cnki.jynufe.000649

59. Wang J, Xu Q. Living arrangement, intergenerational support, and the subject well-being of the olders in China. *J Soc Econ Dev*. (2020) 7:193–208.

60. Sun Z, Zhao Q, Zhao Y. Does the "new-type pension insurance for rural residents" really reduce the labor participation of the rural elderly? A study based on cross-sectional data of two periods of CHARLS. *Commer Res*. (2020) 10:117–26. doi: 10.13902/j.cnki.syyj.2020.10.012

61. Zhao M, Wang X, Li Z. The effect of pension on labor participation of the young old in China. *Popul Res*. (2022) 4:69–83.

62. Nie J, Wu Y. Happiness from work or leisure? An empirical study of the influence of "no leisure/retirement" on rural Elderly's sense of happiness. *Jiang Han Acad*. (2021) 5:60–71. doi: 10.16388/j.cnki.cn42-1843/c.2021.05.006

63. Zhao Y, Zhao Y, Yuan X, Zhou R. How knowledge contributor characteristics andreputation affect user payment decision in paid q&a? An empirical analysis firom theperspective of tust theoryJ. *Electron Commer Res Appl*. (2018) 31:1–11. doi: 10.1016/j.elerap.2018.07.001

64. Mellor D, Stokes M, Firth L, Hayashi Y, Cummins R. Need for belonging, relationship satisfaction, loneliness, and life satisfaction. *Pers Individ Differ*. (2008) 45:213–8. doi: 10.1016/j.paid.2008.03.020

65. Baron RM, Kenny DA. The moderator-mediator variable distinction in social psychological research: conceptual, strategic, and statistical considerations. *J Pers Soc Psychol*. (1986) 51:1173–82. doi: 10.1037/0022-3514.51.6.1173

66. Judd CM, Kenny DA. Process analysis: estimating mediation in treatment evaluations. *Eval Rev*. (1981) 5:602–19. doi: 10.1177/0193841X8100500502

67. Wen Z, Zhang L, Hou J, Liu H. Testing and application of the mediating effects. *Acta Psychol Sin*. (2004) 15:227–32. doi: 10.1007/BF02911031

68. Wen Z, Ye B. Analyses of mediating effects: the development of methods and models. *Adv Psychol Sci*. (2014) 22:731–45. doi: 10.3724/SP.J.1042.2014.00731

69. Dahlen M, Thorbjornsen H. Individuals' assessments of their own wellbeing, subjective welfare, and good life: four exploratory studies. *Int J Environ Res Public Health*. (2022) 19:19. doi: 10.3390/ijerph191911919

70. Kapteyn A, Lee J, Zamarro G (2013). Does Retirement Induced through Social Security Pension Eligibility Influence Subjective Well-being? A Cross-Country Comparison. Working Papers wp301, University of Michigan, Michigan Retirement Research Center.

71. Galiani S, Gertler P, Bando R. Non-contributory pensions. *NBER Work Paper*. (2014) 38:47–58. doi: 10.1016/j.labeco.2015.11.003

72. Salinas-Rodríguez A, Torres-Pereda MDP, Manrique-Espinoza B, Moreno-Tamayo K, Téllez-Rojo Solís MM. Impact of the non-contributory social pension program 70 y más on older adults' mental well-being. *PLoS One*. (2014) 9:1–10. doi: 10.1371/journal.pone.0113085

frontiers | Frontiers in Public Health

TYPE Original Research
PUBLISHED 22 May 2024
DOI 10.3389/fpubh.2024.1358730

Check for updates

OPEN ACCESS

EDITED BY
Hai Fang,
Peking University, China

REVIEWED BY
Milena Lopreite,
University of Calabria, Italy
Deepak Kumar Behera,
RMIT University Vietnam, Vietnam

*CORRESPONDENCE
Di Zhang
✉ zhangdi@hafu.edu.cn

RECEIVED 20 December 2023
ACCEPTED 03 May 2024
PUBLISHED 22 May 2024

CITATION
Zhang D (2024) Eco-friendly revenues for healthcare: assessing the relationship between green taxation, public health expenditures, and life expectancy in China. *Front. Public Health* 12:1358730.
doi: 10.3389/fpubh.2024.1358730

Eco-friendly revenues for healthcare: assessing the relationship between green taxation, public health expenditures, and life expectancy in China

Di Zhang*

School of Finance and Taxation, Henan Finance University, Zhengzhou, Henan, China

Introduction: The synergy of green taxation, public health expenditures, and life expectancy emerges as a compelling narrative in the intricate symphony of environmental responsibility and public well-being. Therefore, this study examine the impact of green taxation on life expectancy and the moderating role of public health expenditure on the said nexus, particularly in the context of China, an emerging economy.

Methods: Statistical data is collected from the National Bureau of Statistics of China to empirically examine the proposed relationships. The dataset contains provincial data across years.

Results: Using fixed-effect and system GMM regression models alongwith control variables, the results found a positive and statistically significant influence of green taxation on life expectancy. Moreover, public health expenditures have a positive and statistically significant partial moderating impact on the direct relationship.

Discussion: These findings suggest that the higher cost of pollution encourages individuals and businesses to shift to less environmentally harmful alternatives, subsequently improving public health. Moreover, government investment in the health sector increases the availability and accessibility of health facilities; thus, the positive impact of green taxation on public health gets more pronounced. The findings significantly contribute to the fields of environmental and health economics and provide a new avenue of research for the academic community and policymakers.

KEYWORDS

green taxation, public health expenditures, life expectancy, health economic, green economics

1 Introduction

The nexus between environmental policy and public health and its collective influence on human well-being has emerged as a prominent concern in today's globalized and environmentally challenged world (1, 2). The use of environmental/green taxes as a prominent policy instrument has gained significant attention due to its potential to effectively tackle environmental degradation and encourage sustainable practices (3). Moreover, sufficient funding for public health expenditures could be an important factor in improving health outcomes and community well-being (4, 5). Therefore, the purpose of this study is to explore how life expectancy can be enhanced through green taxation and how public health expenditure can moderate the said life expectancy and green taxation nexus.

Green taxes are somehow a deliberate approach designed to motivate sustainable behavior and address the harmful effects of environmental consequences (6). This phenomenon indicates a growing global awareness of the detrimental effects of pollution and the reduction of natural resources (7). The purpose of these taxes is to create a framework for addressing environmental concerns that affect public health by internalizing external costs and providing incentives for environmentally responsible behavior (8, 9). Climate change, air and water pollution, and resource shortages all have long-lasting effects on the quality of life (10, 11); therefore, it's important to understand how environmental taxes affect the welfare of societies.

Assessing life expectancy is a crucial component in evaluating the overall impact of environmental policy and public health spending (12, 13), making it a vital tool for defining the overall well-being and prosperity of a particular community (14, 15). Such a phenomenon can better describe the complex interaction of various factors that influence the overall welfare of individuals. These factors include the environment, individual lifestyle choices, aging, and the availability and accessibility of healthcare services (16, 17). Therefore, a study that investigates the relationship between green taxes and life expectancy can provide important insights regarding the effectiveness of environmental policies in improving public health outcomes.

Furthermore, it is vital to recognize the significance of public health expenditure, which links to the allocation of financial resources by the government toward healthcare services/infrastructure (18, 19). The moderating variable holds the capability to either increase or decrease the impact of green taxation on life expectancy. The negative health consequences resulting from environmental damage can be mitigated by providing adequate funding to the public health system (20–22). Consequently, this situation improves the efficacy of green taxes in attaining their planned objectives. It is crucial for efficient policymaking and resource optimization to understand how public health expenditures impact the nexus between green taxation and life expectancy (23, 24).

The main purpose of this research is to examine the impact of green taxation on life expectancy and the moderating role of public health expenditures, particularly within the context of China's dynamic and rapidly growing economy. Thus, this study helps to address a critical gap in the literature. Through comprehensive analysis and the application of rigorous econometric testing, we aim to clarify the said nexus and offer new insights to policymakers for the design and delivery of an efficient public health policy. Moreover, the findings of this study encourage the development of policies to boost environmental sustainability and improve public health. Furthermore, these outcomes have relevance for individuals, societies, and organizations that are committed to advancing a more impartial and prosperous future for global societies.

This study focuses on the Chinese economy, where fast industrialization and urbanization have caused several environmental and health concerns; thus, examining green taxation, public health expenditures, and life expectancy is necessary (2). Green taxation encourages sustainable behaviors and reduces industrial pollution. Whereas, public health expenditures also need to be examined to assess the healthcare system for a growing population facing severe environmental risks (25). Policymakers can understand the complex relationships between environmental policies, the healthcare sector, and longevity by analyzing the link proposed in this study.

The rest of the paper is organized as follows: section 2 discusses the literature. Section 3 explains the background of the study. Section 4 entails the methodology to testify to the hypotheses of the study. Section 5 documents the empirical analysis and discussion. Lastly, Section 6 concludes the findings and provided policy implications, limitations, and future research directions.

2 Literature review

We are living in a time when the world is facing numerous health and environmental challenges. Therefore, fields like public health and environmental policy have gained significant attention. Several studies have been conducted to explore how life expectancy can be improved, and many determinants have also been investigated. Table 1 summarizes the recent literature on the topic.

3 Background of the study

Green taxation and life expectancy have gained significant attention, particularly in the domains of environmental policy and public health. Governments use green taxation or eco-taxation as a policy tool to limit the activities that harm the environment by imposing taxes on such activities (25, 35, 36). These costs and regulations are enacted to discourage undesirable actions and reward those who are environmentally responsible (37). While the fundamental aim of green taxation is to protect the environment and promote sustainability, it can potentially impact public health and, particularly, life expectancy (38).

The baseline hypothesis of this study is that green taxation can have a significant positive influence on life expectancy. Such a narrative is also based on the premise that increasing the cost of pollution will encourage individuals and businesses to switch to less harmful alternatives (39, 40). This has the potential to improve public health and even extend people's lifespans by curtailing pollution levels and encouraging environmentally responsible lifestyles (38).

However, there are several components and limitations to the aforementioned connection, all of which are influenced by a series of interdependent circumstances. The relationship between green taxation and life expectancy can be better understood with the help of economic dynamics (41). Sustainable practices can be encouraged through the use of taxation policies, and these policies also have favorable financial outcomes (42). These financial benefits may help reduce environmental damage and subsequently yield various health benefits, including longevity.

The relationship between green taxes and life expectancy also involves changes in people's habits and ways of living (8). Individuals and businesses can be motivated to adjust their activities, particularly in the presence of a dynamic economic framework, such as through the use of green taxes (43). These behavioral changes could lead to healthier and more sustainable practices that promote greener lifestyles and enhance life expectancy.

Moreover, regional differences regarding green taxation policies are also important (44). Taxes are mostly diverse based on jurisdictions because of differences in policies and economic conditions. Therefore, it can be assumed that there are geographical differences in life expectancy, revealing potential variations in the effects of environmental taxes (45). Thus, we can hypothesize that:

TABLE 1 Literature review.

References	Findings
Wang and Tang (26)	The study examined the impact of air pollution and environmental levies on individual well-being and life expectancy. Using the CSS (China Social Survey) and addressing endogeneity problems, researchers discovered that air pollution can affect citizens' well-being and that green taxes can not only increase residents' well-being but also reduce the negative impact of air pollution on their well-being.
Arltová and Kot (27)	The authors researched the relationship between green taxation and environmental quality in OECD nations, and their findings showed that more taxation leads to improved quality, which ultimately enhances wellbeing and life expectancy.
Soku et al. (28)	The findings discovered that green taxes reduce carbon emissions and, as a result, improve lives and overall life expectancy.
Zhang et al. (5)	The research shows that environmental and green taxes could promote health outcomes and subsequently enhance life expectancy.
Wang et al. (29)	The authors discovered that green taxes significantly reduce environmentally destructive activities and, hence, improve life expectancy in BRICS countries.
Anwar et al. (30)	The study evaluated the impact of health spending on life expectancy in OECD countries. The findings discovered that health spending has a positive impact on life expectancy in the examined countries.
Awoyemi et al. (31)	This study investigated the effect of government health spending on life expectancy and death rates in Nigeria. According to the study, increased government health spending increases life expectancy and lowers the death rate.
Ahmad et al. (32)	The researchers discussed the impact of health spending on life expectancy in South Asian countries, as well as the function of health spending in moderating the relationship between industrialization, income disparity, and life expectancy. The findings demonstrated that health spending had a considerable impact on life expectancy in Southeast Asian countries.
Zhang et al. (5)	This study explored the nexus between environment-related governance, public health spending, and economic growth. The findings suggested that higher pollution can significantly reduce health and economic growth. Moreover, green or environmental taxes could improve health and life expectancy.
Lopreite et al. (16)	By conducting a bibliographic analysis, the authors explored that an increase in health spending is required to meet the aging requirement and access to healthcare services.
Lopreite and Zhu (15)	The authors examined the relationships between aging, life expectancy, health expenditure, and economic growth. The study compared the US and China, and the findings suggested that effective policies (economic, social, and health) are needed to improve the quality of life and achieve sustainable growth.
Behera and Dash (33)	The authors examined the impact of health expenditures on achieving healthcare goals in Southeast Asian countries. The results enlightened that health expenditure has a positive impact on the improvement in life expectancy.
Behera and Dash (34)	The paper studied the impact of macro-level fiscal policies on health financing in lower-middle-income countries. The findings suggested a positive impact of tax revenue on public health expenditures in the sample countries.
Lopreite and Mauro (22)	The study investigated the relationship between demographic changes and health expenditures, and the results found that expenditures on health have a more pronounced impact on aging as compared to life expectancy, particularly in Italy.

H1: Environmental taxation may have a positive impact on life expectancy.

Research focusing on the complex nexus between green taxation and life expectancy has to incorporate the moderating role of public health expenditure to clearly understand the underlying mechanism of this association. Investing in public health could adjust the results of green taxation policies (46), which in turn affects life expectancy (47). Therefore, understanding this complex relationship is of considerable importance in today's environmentally challenged societies.

It can be hypothesized that green taxation can increase life expectancy and that higher levels of public health expenditure can act as a moderator, enhancing these positive outcomes. Green taxation is established on the idea that it can improve public health by decreasing public exposure to dangerous pollutants and urging them to adopt more environmentally friendly practices (48, 49). However, the extent to which these advantages can be realized is determined by public health expenditures (50).

The term public health expenditure refers to the total amount of money spent on healthcare in the form of taxes and other government-level funds (51, 52). When it comes to addressing the health needs of a population, these resources are important, and they can be particularly useful in decreasing the adverse effects of environmental factors (53). It can also be expected that increases in public health expenditures will improve health care, lower its costs, and expand its accessibility (54, 55). Therefore, when public health facilities are easily accessible, the favorable economic impacts of green taxation on public health, such as lower healthcare expenditures and greater productivity, can get even more pronounced (56).

Public health budgets and the effects of green taxation on individual behavior are also closely linked (23, 57). Environmental taxation policies encourage eco-friendly behaviors, and a rise in public health expenditures can help finance the preventative measures, e.g., public awareness campaigns and health education (58, 59). By providing knowledge and resources for better living, public health programs may encourage individuals to adopt environmentally responsible behaviors (60, 61). This may result in healthier behavioral changes, which in turn can extend longevity.

Understanding the moderating role of public health expenditure may also require considering the regional differences regarding public health expenditure. The extent to which environmental taxation laws affect life expectancy can be influenced by how much funding is allocated to public health in certain regions or countries (62). Promoting public health and eventually contributing to longer and healthier lives, therefore, we can hypothesize that:

> H2: Public health expenditures may have a positive moderating effect on the relationship between green taxation and life expectancy.

4 Methodology

4.1 Source

We use province-level data collected from the China Statistical Year Book published by the National Bureau of Statistics of China (NBS). The China Statistical Yearbook is a compilation of data that offers a complete picture of the country, provinces, and autonomous regions, Every year, the China Statistical Yearbook is published in September. Therefore, in this study, we only collect data until 2022 because the statistics for 2023 will be published in September 2024 (63). The data compiled by the NBS, which is renowned for its reliability, consistency, and accuracy, forms the basis of strategic decision-making and evidence-based policy-making. It offers an extensive range of economic, social, and demographic indicators. The final dataset consists of a diverse range of variables for 30 provinces and 19 years. Table 2 shows the list of provinces used to collect data from NBS.

4.2 Data

We use life expectancy as a dependent variable in this study. Life expectancy is a statistical measure that estimates the average number of years a person can expect to live. In China, such direct data is only calculated through census, which is conducted every 10 years. Therefore, we are unable to use this measure due to the unavailability of consistent data across the year. By considering such limitations, we use an indirect proxy to calculate life expectancy, i.e., the probability of dying. Previous studies, e.g., Roffia et al. (64) and Maiolo et al. (65), also used this proxy to measure life expectancy.

$$e_0 = \frac{1}{\mu_0}$$

Whereas,

$$e_0 = Life\ Expectancy$$

$$\mu_0 = Central\ Death\ Rate$$

The independent variable in this study is green taxation. Literature has provided various measuring tactics to calculate green taxation, e.g., environmental performance indicators, energy consumption, shifts in economic activities, etc. However, contrary to the said indicators, we follow the study of Fang et al. (66) and use environmental protection taxes as a proxy for green finance.

We employ public health expenditures as a moderating variable. Many different methods of measuring have been presented in the literature to calculate the said variable. These methods include government spending on hospitals, doctors, paramedics, etc. On the other hand, in contrast to the aforementioned indications, we adhere to the research conducted by Chipunza and Nhamo (56) and use total governmental health expenditures.

The following are the key control variables that are used to investigate the relationship between green taxation, public health expenditures, and life expectancy.

- Gross regional product: Province-level GRP
- Employment level: Total number of employed persons in the province
- Inflation: Consumer price index (CPI) in the province
- Individual income: *Per capita* income in the province
- Natural disasters: Total affected population in the province by natural disasters
- Population aging: Old age dependency ratio

4.3 Model

By considering the nature of the dataset and testing the aforementioned research hypotheses, we construct two empirical models. The first empirical model (1) quantifies the direct impact of green taxation on life expectancy. Similarly, our second empirical model (2) estimates the moderating relationship of public health expenditure on the nexus between green taxation and life expectancy.

$$Life\ Expectancy_{kt} = \beta_0 + \beta_1 Green\ Taxation_{kt} + \sum_{j=1}^{05} \beta_j\ Control\ Variables_{kt} + e_{kt} \quad (1)$$

$$Life\ Expectancy_{kt} = \beta_0 + \beta_1 Green\ Taxation_{kt} + \beta_2 Public\ Health\ \exp_{kt} + \beta_3 \left(Green\ Taxation_{kt}\ X\ Public\ Health\ \exp_{kt}\right) + \sum_{j=1}^{05} \beta_j\ Control\ Variables_{kt} + e_{kt} \quad (2)$$

The aforementioned Equations (1) and (2) represent regression models where the dependent variable is $Life\ Expectancy_{kt}$ and the independent variable is $Green\ Taxation_{ik}$. However, in Equation (2), particularly, we have a moderating variable that is constructed through an interactive term, i.e., $Green\ Taxation_{kt}\ X\ Public\ Health\ \exp_{kt}$. Lastly, in both the empirical models, we have $Control\ Variables_{kt}$ e.g., gross regional product, employment level, inflation, individual income, natural disasters, and population aging. In these contexts, k denotes individual provinces, and t denotes time. β_0 is an intercept term representing the expected value of life expectancy when all other variables become zero. e is an error term, representing the difference between the observed value of life expectancy and the value predicted by the models. It captures the effects of unobserved factors and random variation.

5 Empirical analysis and discussion

Table 3 presents the descriptive statistics (total number of observations, mean value, standard deviation, minimum and maximum values) of all the variables used in this study. This table summarizes the variables for better understanding. Particularly, the variable of life expectancy represents a mean value of 0.1494 with a standard deviation of 0.0262. Green taxation and public health expenditures have average values of 6.4134 and 6.3920, respectively, and their standard deviations are 7.2447 and 0.9895, respectively. The different control variables show the average value of gross regional productivity (10.0610), employment level (6.0083), inflation (4.6250), individual income (10.3283), natural disasters (5.2040), and population aging (3.2749). The standard deviations of the said indicators are gross regional productivity (0.9666), employment level (0.8637), inflation (0.0072), individual income (0.3282), natural disasters (1.6181), and population aging (2.4981).

The correlation coefficients of the variables are measured and explained in Table 4. The results demonstrate that the variables used for the analysis did not have any multicollinearity issues.

We incorporate the ordinary least square regression technique as a baseline tool To quantify the relationship between green taxation and life expectancy. However, as reported in Table 5, the results are statistically insignificant and misleading. One of the reasons for such deceptive results is the issue of unobserved heterogeneity.

Similar to the aforementioned prevailing statistical concern, i.e., the heterogeneity issue, the results documented in Table 6 to estimate the moderating influence of public health expenditure on the nexus between life expectancy and green taxation are ambiguous and need future investigation.

To address the presence of heterogeneity in both empirical models, we use the fixed effect regression technique. Panel data, which collects observations over multiple periods and for multiple entities, makes fixed effect models particularly useful. Moreover, for selection between fixed effect and random effect regression, we use the Hausman test. According to the results stated in Table 7, the *p*-value of chi-square is significant; therefore, we can reject the null hypothesis and choose an alternate hypothesis, i.e., a fixed effects model is preferred. Moreover, the regression results show a positive and statistically significant impact of green taxation on life expectancy. These results verify our first hypothesis and are in line with the previous study of Tenytska and Palienko (67). These results suggest that environmental taxation escalates the cost of environmental damage, which eventually encourages individuals and businesses to switch to less harmful alternatives. Such a protective approach will help advance longevity.

TABLE 2 List of provinces.

Beijing	Jilin	Anhui	Hubei	Chongqing
Tianjin	Heilongjiang	Fujian	Hunan	Sichuan
Hebei	Shanghai	Jiangxi	Guangdong	Guizhou
Shanxi	Jiangsu	Shandong	Guangxi	Yunnan
Inner Mongolia	Zhejiang	Henan	Hainan	Xinjiang
Liaoning	Shaanxi	Gansu	Qinghai	Ningxia

TABLE 3 Descriptive statistics.

Variable	Observations	Mean	SD	Min	Max
Life expectancy	570	0.1494	0.0262	0.1094	0.2247
Green taxation	570	6.4134	7.2447	0.1430	40.9608
Public health expenditures	570	6.3920	0.9895	4.5246	14.9536
Gross regional productivity	570	10.0610	0.9666	7.3450	11.7685
Employment level	570	6.0083	0.8637	3.6082	7.6549
Inflation	570	4.6250	0.0072	4.6062	4.6415
Individual income	570	10.3283	0.3282	9.7577	11.2849
Natural disasters	570	5.2040	1.6181	−0.6931	7.8035
Population aging	570	3.2749	2.4981	0.0175	10.6400

TABLE 4 Correlation.

	LE	GT	PHE	GRP	EMP	INF	II	ND	PA
LE	1.000								
GT	0.155	1.000							
PHE	0.064	0.304	1.000						
GRP	0.177	0.483	0.603	1.000					
EMP	0.113	0.444	0.597	0.677	1.000				
INF	−0.082	0.091	0.003	0.049	0.102	1.000			
II	0.164	0.201	0.457	0.504	0.462	−0.091	1.000		
ND	−0.397	0.105	0.049	0.346	0.356	0.136	−0.453	1.000	
PA	0.102	0.037	0.008	−0.073	−0.024	−0.021	−0.023	0.108	1.000

LE, life expectancy; GT, green taxation; PHE, public health expenditures; GRP, gross regional product; EMP, employment level; INF, inflation; II, individual income; ND, natural disaster; PA, population aging.

TABLE 5 Base line regression (hypothesis—1).

Dependent variable = life expectancy	Model—1	
	Ordinary least square (OLS)	
	Province-year panel dataset	
	Coefficients	t-stats
Green taxation	−0.0012	(−0.75)
Gross regional productivity	−0.0356	(−9.00)***
Employment level	0.0367	(9.93)***
Inflation	0.0013	(2.57)***
Individual income	0.0221	(5.20)***
Natural disasters	−0.0021	(−2.50)***
Population aging	0.0005	(1.48)
Constant	−0.0483	(−0.74)
Number of observations	570	
F-Stats	30.50	
Prob. > F	0.000	
R-squared	0.2753	
Adj. R-squared	0.2662	

***$p < 0.01$.

TABLE 6 Base line regression (hypothesis—2).

Dependent variable = life expectancy Moderating variable = public health expenditures	Model—2	
	Ordinary least square (OLS)	
	Province-year panel dataset	
	Coefficients	t-stats
Green taxation	0.0024	(1.57)
Public heath expenditure	0.0034	(1.02)
Green taxation × public heath expenditure	−0.0002	(−1.67)*
Gross regional productivity	0.0384	(7.78)***
Employment level	0.0369	(9.51)***
Inflation	0.0013	(2.59)***
Individual income	0.0211	(4.62)***
Natural disasters	−0.0024	(2.73)***
Population aging	0.0005	(1.54)
Constant	−0.0490	(−0.74)
Number of observations	570	
F-Stats	24.16	
Prob. > F	0.0000	
R-squared	0.2797	
Adj. R-squared	0.2681	

***$p < 0.01$, *$p < 0.10$.

Likewise, to test our second hypothesis (i.e., public health spending moderates the link between green taxes and life expectancy), we again run the Hausman test, and based on the significance p-value, we choose the fixed effect moderation model. Furthermore, the technique also helps us deal with the problem of heterogeneity. The

TABLE 7 Advanced regression (hypothesis—1).

Dependent variable = life expectancy	Model—1	
	Fixed effect	
	Province-year panel dataset	
	Coefficients	t-stats
Green taxation	0.0026	(2.47)***
Gross regional productivity	0.0227	(4.52)***
Employment level	0.0356	(8.41)***
Inflation	0.0005	(1.61)*
Individual income	0.0019	(2.72)***
Natural disasters	−0.0421	(7.69)***
Population aging	0.0031	(2.04)***
Constant	0.0815	(1.98)**
Number of observations	570	
Number of groups	30	
F-Stats	46.91	
Prob. > F	0.000	
R-sq. (within)	0.3812	
R-sq. (between)	0.0773	
R-sq. (overall)	0.0240	
Hausman test		
Chi^2	54.05	
Prob. > Chi^2	0.0000	

***$p < 0.01$, **$p < 0.05$, *$p < 0.10$.

results listed in Table 8 show that green taxation, public health expenditures, and the interacting terms of both variables all have a positive and statistically significant impact on life expectancy. These outcomes support our narrative and confirm the partial moderating impact of public health expenditures. Moreover, these results provide a significant understanding that environmental taxation increases life expectancy and that higher levels of public health expenditure can operate as moderators, enhancing these positive outcomes. Increases in public health expenditures will eventually improve health care outcomes, lower its associated costs, and improve the availability of public health facilities. Thus, the accessibility of public healthcare reinforces the economic benefits of green taxation for an improved life expectancy.

Although fixed-effect regression models are efficient at controlling for heterogeneity, endogeneity is a valid concern, particularly in the context of a panel dataset. Therefore, we used the system GMM method to control for the panel-specific endogeneity problems that may be present in the aforementioned models. Moreover, for the validation of GMM models, we have also used the Sargan test for over-identifying restrictions. The Sargan test's p-value suggests that our over-identified restrictions in the models are valid. The empirical results reported in Table 9 suggest a positive impact of green taxation on life expectancy. Similarly, the findings also verify the positive partial moderation of public health on the nexus between green taxation and life expectancy (Table 10). Hence, our baseline results remains unchanged.

TABLE 8 Advanced regression (hypothesis—2).

Dependent variable = life expectancy Moderating variable = public health expenditures	Model—2	
	Fixed effect—moderation	
	Province-year panel dataset	
	Coefficients	t-stats
Green taxation	0.0017	(2.48)***
Public health expenditures	0.0284	(7.84)***
Green taxation × public health expenditures	0.0002	(1.63)*
Gross regional productivity	0.0042	(0.68)
Employment level	0.0319	(7.73)***
Inflation	−0.0522	(−9.29)***
Individual income	0.0005	(1.79)*
Natural disasters	−0.0007	(−1.11)
Population aging	0.0013	(2.62)***
Constant	0.2378	(5.39)***
Number of observations	570	
Number of groups	30	
F-Stats	48.05	
Prob. > F	0.0000	
R-sq. (within)	0.4489	
R-sq. (between)	0.1231	
R-sq. (overall)	0.0303	
Hausman test		
Chi^2	158.06	
Prob. > Chi^2	0.0000	

***$p < 0.01$, *$p < 0.10$.

TABLE 9 Advanced regression (hypothesis—1).

Dependent variable = life expectancy	Model—1	
	System GMM	
	Province-year panel dataset	
	Coefficients	t-stats
Green taxation	0.0071	(2.52)***
Gross regional productivity	0.0395	(8.52)***
Employment level	0.0344	(5.62)***
Inflation	−0.0005	(−1.66)*
Individual income	0.0257	(4.43)***
Natural disasters	−0.0012	(−0.95)
Population aging	0.0007	(3.95)***
Constant	0.0109	(0.25)
Number of observations	570	
Number of groups	30	
Wald chi^2	162.04	
Prob. > chi^2	0.000	
Sargan test (*p*-value)	0.204	

***$p < 0.01$, *$p < 0.10$.

TABLE 10 Advanced regression (hypothesis—2).

Dependent variable = life expectancy Moderating variable = public health expenditures	Model—2	
	System GMM—moderation	
	Province-year panel dataset	
	Coefficients	t-stats
Green taxation	0.0078	(1.70)*
Public health expenditures	0.0138	(2.29)***
Green taxation × public health expenditures	0.0009	(1.76)*
Gross regional productivity	0.0429	(3.56)***
Employment level	0.0329	(3.36)***
Inflation	−0.0012	(−3.69)***
Individual income	0.0149	(1.42)
Natural disasters	−0.0039	(−2.02)**
Population aging	0.0007	(1.77)*
Constant	0.0164	(0.19)
Number of observations	570	
Number of groups	30	
Wald chi^2	104.84	
Prob. > chi^2	0.000	
Sargan test (*p*-value)	0.999	

***$p < 0.01$, **$p < 0.05$, *$p < 0.10$.

Green or environmental taxation is an effective approach that provides benefits for sustainable practices, reduces environmentally harmful activities, and thus enhances life expectancy. One apparent benefit of green taxation is its ability to reduce pollution. High taxes on harmful practices, such as the ignition of fossil fuels, have the potential to decrease emissions and foster air quality. Improved air quality is associated with fewer cases of respiratory disease and cardiovascular issues, both of which add years to a person's life expectancy (49).

Moreover, green taxation has the potential to encourage investment, particularly in the renewable energy and health sectors. By increasing the cost of fossil fuels, competent authorities provide benefits to businesses and individuals who switch to cleaner energy alternatives. Additionally, to reduce emissions, the implementation of sustainable alternatives such as solar power and electric vehicles (EVs) contributes to better health consequences. These sustainable alternatives frequently generate employment opportunities and foster economic growth, thus facilitating enhanced healthcare accessibility and improved quality of life, both of which contribute to an extended lifespan.

Green taxation could also help to enhance life expectancy by addressing environmental challenges, such as climate change. Such a reduction in carbon emissions and encouraging healthier practices could subsequently contribute to reducing global warming, improving food security, diminishing climate-related health threats, and decreasing extreme weather conditions. Mostly, the application of green taxation aids a variety of objectives: it endorses sustainable technology, reduces pollution, and mitigates environmental hazards;

therefore, it contributes to the long-term progress of well-being and prosperity.

The moderating role of public health expenditure, particularly in the context of the positive relationship between green taxation and life expectancy, is significant. The implementation of green taxation policies has the potential to encourage sustainable practices and reduce pollution, thereby positively affecting public health and extending life expectancy. Governmental investment in the public health sector could significantly improve the efficiency of the said measures. We can further boost the benefits of environmental taxation, disease control, and health elevation by allocating additional reserves toward public health. These steps could lead to greener environments and healthier lifestyles.

In countries with resilient healthcare systems, higher health expenditures can ensure that the population receives needed healthcare services. This can aid in early diagnosis and improve health issues, thereby extending life expectancy. Furthermore, allocating funds to public health can address health disparities and target deprived communities, thus tackling the social aspects that influence health outcomes. Ensuring fair distribution of the benefits of green taxation is crucial. To summarize, green taxation has the potential to improve life expectancy. However, the level of public health expenditure influences the extent to which this occurs. This guarantees the optimization and equitable distribution of the benefits of green taxation to those most in need, leading to significant and equitable increases in life expectancy (62).

6 Conclusion

This study aims to explore the impact of green taxation on life expectancy in China. Moreover, we also examine the moderating role of public health expenditures in influencing the proposed association. As the second largest world economy, Chinese economy is one of the most vibrant and emerging economies globally. To explore the said narrative, yearly provincial data was obtained from the National Bureau of Statistics—China. By employing robust econometric approaches such as fixed effect and system GMM regression estimates along with diverse control variables, the finding of the study provides significant supportive evidence toward the research hypotheses and testifies that green taxation enhances life expectancy in the context of China. Moreover, public health expenditures exhibits a favorable influence and partially moderate the said relationship. These results are robust even by choosing different proxies of public health expenditures.

This study significantly contributes to the ongoing discussion in the fields of environmental and public health economics by offering valuable insights for both academic researchers and policymakers. By specifically examining the impact of green taxation on life expectancy and considering the moderating role of public health expenditures, particularly within the context of China's dynamic and rapidly growing economy, this research addresses a critical gap in the literature. Academic researchers can benefit from the findings by deepening their understanding of the nexus between green taxation, public health expenditures, and life expectancy and fostering further exploration in the said fields.

The policy implications of this study propose the importance of implementing green taxation to enhance life expectancy and the role of public health expenditure in strengthening the relationship between green taxation and life expectancy. For policymakers, this study offers fresh insights and directions for the development of sustainable environmental and public health policies. The positive association between green taxation and life expectancy, linked with the moderating effect of public health expenditures. Hence this research provides a base for formulating strategies that balance economic growth with environmental sustainability and advancement in public health.

Although this study has significantly contributed to exploring the relationship between green taxation, public health expenditures, and life expectancy in China, there are certain limitations as well. First, we use provincial data across years, which cannot observe the variations within cities and regions. Moreover, this paper focuses on China, which limits its generalizability to other countries with different cultures and institutions. Future studies could address these limitations by including longitudinal data (cross-countries) and extending the analysis to global settings. Overall, addressing these limitations and exploring the proposed research directions may help to develop a more detailed understanding of the interplay between environmental policies, healthcare expenditures, and life expectancy.

Data availability statement

Publicly available datasets were analyzed in this study. This data can be found at: https://data.stats.gov.cn/english.

Author contributions

DZ: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing.

Funding

The author(s) declare financial support was received for the research, authorship, and/or publication of this article. This work was supported by the General project of humanities and social science research in colleges and universities in Henan Province (No. 2024-ZDJH-308) and Research Start-up Fund of Henan Finance University (No. 2023BS016).

Conflict of interest

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

References

1. Burnett A, Pain K. Linking environmental and human health in English urban development decision-making: the human health literacy of environmental policy. *Built Environ*. (2023) 49:187–206.

2. Popescu I-M, Baditoiu LM, Reddy SR, Nalla A, Popovici ED, Margan M-M, et al. Environmental factors influencing the dynamics and evolution of COVID-19: a systematic review on the study of short-term ozone exposure. *Healthcare*. (2023) 11:2670. doi: 10.3390/healthcare11192670

3. Li N, Gu Z, Albasher G, Alsultan N, Fatemah A. Nexus of financial management, blockchain, and natural resources: comparing the impact on environmental sustainability and resource productivity. *Resour Policy*. (2023) 83:103730. doi: 10.1016/j.resourpol.2023.103730

4. Saleem S. Power, politics, and public health: understanding the role of healthcare expenditure in shaping health outcomes in Pakistan for policy enhancement. *Politica*. (2023) 2:58–72. doi: 10.5281/zenodo.8127367

5. Zhang Z, Ma C, Wang A. Environmental governance, public health expenditure, and economic growth: analysis in an OLG model. *Int J Environ Res Public Health*. (2023) 20:3033. doi: 10.3390/ijerph20043033

6. Ni L, Ahmad SF, Alshammari TO, Liang H, Alsanie G, Irshad M, et al. The role of environmental regulation and green human capital towards sustainable development: the mediating role of green innovation and industry upgradation. *J Clean Prod*. (2023) 421:138497. doi: 10.1016/j.jclepro.2023.138497

7. She W, Mabrouk F. Impact of natural resources and globalization on green economic recovery: role of FDI and green innovations in BRICS economies. *Resour Policy*. (2023) 82:103479. doi: 10.1016/j.resourpol.2023.103479

8. Li J, Irfan M, Samad S, Ali B, Zhang Y, Badulescu D, et al. The relationship between energy consumption, CO_2 emissions, economic growth, and health indicators. *Int J Environ Res Public Health*. (2023) 20:2325. doi: 10.3390/ijerph20032325

9. Yao C, Xi B. Does environmental protection tax improve green total factor productivity? Experimental evidence from China. *Environ Sci Pollut Res*. (2023) 30:105353–73. doi: 10.1007/s11356-023-29739-4

10. Muruganandam M, Rajamanickam S, Sivarethinamohan S, Reddy MK, Velusamy P, Gomathi R, et al. Impact of climate change and anthropogenic activities on aquatic ecosystem–a review. *Environ Res*. (2023) 238:117233. doi: 10.1016/j.envres.2023.117233

11. Onwudiwe NN. Review on climate change impacts on air quality in Nigeria In: *Climate change impacts on Nigeria: environment and sustainable development*. Environment and Sustainable Development (2023). 217–32.

12. Polcyn J, Voumik LC, Ridwan M, Ray S, Vovk V. Evaluating the influences of health expenditure, energy consumption, and environmental pollution on life expectancy in Asia. *Int J Environ Res Public Health*. (2023) 20:4000. doi: 10.3390/ijerph20054000

13. Zhang L, Sun L. Life expectancy inequality between regions of China 2004-2020: contribution of age-and cause-specific mortality. *Front Public Health*. (2023) 11:1271469. doi: 10.3389/fpubh.2023.1271469

14. Hu A. Promoting common prosperity for all people by 2035 In: *Modernization with Chinese characteristics and great power*. Singapore: Springer Nature Singapore (2023)

15. Lopreite M, Zhu Z. The effects of ageing population on health expenditure and economic growth in China: a Bayesian-VAR approach. *Soc Sci Med*. (2020) 265:113513. doi: 10.1016/j.socscimed.2020.113513

16. Lopreite M, Misuraca M, Puliga M. An analysis of the thematic evolution of ageing and healthcare expenditure using word embedding: a scoping review of policy implications. *Socio Econ Plan Sci*. (2023) 87:101600. doi: 10.1016/j.seps.2023.101600

17. Sedghi F, Mahdizadeh M, Vahedian-Shahroodi M, Gholian-Aval M. Exploring the conceptual framework of a health-promotion faculty from the perspective of members: a qualitative study. *BMJ Open*. (2023) 13:e073059. doi: 10.1136/bmjopen-2023-073059

18. Gaspar T, Gomez-Baya D, Guedes FB, Correia MF. Health management: evaluating the relationship between organizational factors, psychosocial risks at work, performance management, and hospital outcomes. *Healthcare*. (2023) 11:2744. doi: 10.3390/healthcare11202744

19. Mtei GJ, Ruhago GM, Ngalesoni FN, Kapologwe NA, Kazibure Mapunda MK, Kalolo A. Primary health-care financing and resource mobilization In: *Primary health Care in Tanzania through a health systems Lens: a history of the struggle for universal health coverage*. Tanzania: CABI GB (2023)

20. Akbar A, Rehman A, Ullah I, Zeeshan M, Afridi FEA. Unraveling the dynamic nexus between trade liberalization, energy consumption, CO_2 emissions, and health expenditure in southeast Asian countries. *Risk Manag Healthc Policy*. (2020) 13:1915–27. doi: 10.2147/RMHP.S272801

21. Evans DB, Kurowski C, Tediosi F. Health system financing In: *Global health essentials*. Cham: Springer International Publishing (2023)

22. Lopreite M, Mauro M. The effects of population ageing on health care expenditure: a Bayesian VAR analysis using data from Italy. *Health Policy*. (2017) 121:663–74. doi: 10.1016/j.healthpol.2017.03.015

23. Liu H, Zafar MW, Sinha A, Khan I. The path to sustainable environment: do environmental taxes and governance matter? *Sustain Dev*. (2023) 31:2278–90. doi: 10.1002/sd.2505

24. Olaoye O. Environmental quality, energy consumption and economic growth: evidence from selected African countries. *Green Low Carbon Econ*. (2023) 2:28–36. doi: 10.47852/bonviewGLCE3202802

25. Akbar US, Bhutto NA, Rajput SKO. How do carbon emissions and eco taxation affect the equity market performance: an empirical evidence from 28 OECD economies. *Environ Sci Pollut Res*. (2023):1–13. doi: 10.1007/s11356-023-29882-y

26. Wang J, Tang D. Air pollution, environmental protection tax and well-being. *Int J Environ Res Public Health*. (2023) 20:2599. doi: 10.3390/ijerph20032599

27. Arltová M, Kot J. Do environmental taxes improve environmental quality? Evidence from OECD countries. *Prague Econ Paprs*. (2023) 32:26–44. doi: 10.18267/j.pep.821

28. Soku MG, Amidu M, William C. Environmental tax, carbon emmission and female economic inclusion. *Cogent Bus Manag*. (2023) 10:2210355. doi: 10.1080/23311975.2023.2210355

29. Wang W, Hafeez M, Jiang H, Ahmad W, Badar H, Salahodjaev R. Environmental factors and its influence on human health in BRICS: implications for human development. *Environ Sci Pollut Res*. (2023) 30:22509–19. doi: 10.1007/s11356-022-23678-2

30. Anwar A, Hyder S, Mohamed Nor N, Younis M. Government health expenditures and health outcome nexus: a study on OECD countries. *Front Public Health*. (2023) 11:1123759. doi: 10.3389/fpubh.2023.1123759

31. Awoyemi BO, Makanju AA, Mpapalika J, Ekpeyo RS. A time series analysis of government expenditure and health outcomes in Nigeria. *Public Health Afr*. (2023) 14:1409. doi: 10.4081/jphia.2023.1409

32. Ahmad N, Raid M, Alzyadat J, Alhawal H. Impact of urbanization and income inequality on life expectancy of male and female in south Asian countries: a moderating role of health expenditures. *Human Soc Sci Commun*. (2023) 10:1–9. doi: 10.1057/s41599-023-02005-1

33. Behera DK, Dash U. Is health expenditure effective for achieving healthcare goals? Empirical evidence from South-East Asia region. *Asia Pac J Reg Sci*. (2020) 4:593–618. doi: 10.1007/s41685-020-00158-4

34. Behera DK, Dash U. Impact of macro-fiscal determinants on health financing: empirical evidence from low-and middle-income countries. *Glob Health Res Policy*. (2019) 4:1–13. doi: 10.1186/s41256-019-0112-4

35. Pinto R, Lacerda J, Silva L, Araújo AC, Fontes R, Lima TS, et al. Text mining analysis to understand the impact of online news on public health response: case of syphilis epidemic in Brazil. *Front Public Health*. (2023) 11:1248121. doi: 10.3389/fpubh.2023.1248121

36. Wu Z, Zhao Y, Zhang N. A literature survey of green and low-carbon economics using natural experiment approaches in top field journal. *Green Low Carbon Econ*. (2023) 1:2–14. doi: 10.47852/bonviewGLCE3202827

37. Anssari MAA. Environmental cost accounting: literature review. *Sci Res J Econ Bus Manag*. (2023) 3:37–42.

38. Wang W, Jiang H, Shoukat A, Usmanovich BA. Quantifying the impact of green growth and digital transformation on health: new insights from Asian economies. *Environ Sci Pollut Res*. (2023) 30:107624–33. doi: 10.1007/s11356-023-29595-2

39. Liu L, Pang L, Wu H, Hafeez M, Salahodjaev R. Does environmental policy stringency influence CO_2 emissions in the Asia Pacific region? A nonlinear perspective. *Air Qual Atmos Health*. (2023) 16:2499–508. doi: 10.1007/s11869-023-01417-x

40. Shah MH, Wang N, Ullah I, Akbar A, Khan K, Bah K. Does environment quality and public spending on environment promote life expectancy in China? Evidence from a nonlinear autoregressive distributed lag approach. *Int J Health Plann Manag*. (2021) 36:545–60. doi: 10.1002/hpm.3100

41. Hasan MA, Mahjabin T, Hossain MA, Kibria MG, Haseeb M, Hossain ME. Towards green economy and sustainable development in Bangladesh: assessing the role of social and environmental indicators. *Environ Sci Pollut Res*. (2023) 30:110324–39. doi: 10.1007/s11356-023-30060-3

42. Zhao L, Wang D, Wang X, Zhang Z. Impact of green finance on total factor productivity of heavily polluting enterprises: evidence from green finance reform and innovation pilot zone. *Econ Anal Policy*. (2023) 79:765–85. doi: 10.1016/j.eap.2023.06.045

43. Sarpong KA, Xu W, Gyamfi BA, Ofori EK. Can environmental taxes and green-energy offer carbon-free E7 economies? An empirical analysis in the framework of COP-26. *Environ Sci Pollut Res*. (2023) 30:51726–39. doi: 10.1007/s11356-023-25904-x

44. Long Y, Yang B, Liu L. Can green credit policy promote green innovation in renewable energy enterprises: evidence from China. *Environ Sci Pollut Res*. (2023) 30:94290–311. doi: 10.1007/s11356-023-29041-3

45. Sarpong KA, Xu W, Gyamfi BA, Ofori EK. A step towards carbon neutrality in E7: the role of environmental taxes, structural change, and green energy. *J Environ Manag*. (2023) 337:117556. doi: 10.1016/j.jenvman.2023.117556

46. Darvas Z, Wolff GB. A green fiscal pact for the EU: increasing climate investments while consolidating budgets. *Clim Pol*. (2023) 23:409–17. doi: 10.1080/14693062.2022.2147893

47. Shabani E, Gilak Hakimabadi MT, Taghineghad Omran V. Investigation of the effects of green taxes on pollutant emissions and human development index in Iran: a model of simultaneous equations. *Q J Appl Theor Econ*. (2023) 9:193–222.

48. Ullah I, Ullah A, Ali S, Poulova P, Akbar A, Haroon Shah M, et al. Public health expenditures and health outcomes in Pakistan: evidence from quantile autoregressive distributed lag model. *Risk Manag Healthc Policy*. (2021) 14:3893–909. doi: 10.2147/RMHP.S316844

49. Yan H, Qamruzzaman M, Kor S. Nexus between green investment, fiscal policy, environmental tax, energy price, natural resources, and clean energy—a step towards sustainable development by fostering clean energy inclusion. *Sustain For*. (2023) 15:13591. doi: 10.3390/su151813591

50. Demir S, Demir H, Karaduman C, Cetin M. Environmental quality and health expenditures efficiency in Türkiye: the role of natural resources. *Environ Sci Pollut Res*. (2023) 30:15170–85. doi: 10.1007/s11356-022-23187-2

51. Margetts C. Health economics, healthcare funding including activity-based funding: what a medical manager needs to know In: *Textbook of medical administration and leadership*: Springer (2023)

52. Olawade DB, Wada OJ, David-Olawade AC, Kunonga E, Abaire O, Ling J. Using artificial intelligence to improve public health: a narrative review. *Front Public Health*. (2023) 11:1196397. doi: 10.3389/fpubh.2023.1196397

53. Rasulov I, Madrakhimova Z. "Ecology and environment" is the basis of human health. *Sci Innov*. (2023) 2:59–62.

54. Frankovic I, Kuhn M. Health insurance, endogenous medical progress, health expenditure growth, and welfare. *J Health Econ*. (2023) 87:102717. doi: 10.1016/j.jhealeco.2022.102717

55. Logarajan RD, Nor NM, Sirag A, Said R, Ibrahim S. The impact of public, private, and out-of-pocket health expenditures on under-five mortality in Malaysia. *Healthcare*. (2022) 10:589. doi: 10.3390/healthcare10030589

56. Chipunza T, Nhamo S. Fiscal capacity and public health expenditure in Zimbabwe. *Cogent Econ Fin*. (2023) 11:2175459. doi: 10.1080/23322039.2023.2175459

57. Khan S, Akbar A, Nasim I, Hedvičáková M, Bashir F. Green finance development and environmental sustainability: a panel data analysis. *Front Environ Sci*. (2022) 10:2134. doi: 10.3389/fenvs.2022.1039705

58. Ceko E, Cakrani E. Environmental tax reform in Western Balkan countries In: *Taking on climate change through green taxation*: IGI Global (2023)

59. Yang W, Zhang N. Does the carbon emissions trading scheme improve carbon total factor productivity? Evidence from Chinese cities. *Green Low Carbon Econ*. (2023) 2:87–96. doi: 10.47852/bonviewGLCE3202905

60. Akbar M, Hussain A, Akbar A, Ullah I. The dynamic association between healthcare spending, CO_2 emissions, and human development index in OECD countries: evidence from panel VAR model. *Environ Dev Sustain*. (2021) 23:10470–89. doi: 10.1007/s10668-020-01066-5

61. Usman M, Rofcanin Y, Ali M, Ogbonnaya C, Babalola MT. Toward a more sustainable environment: understanding why and when green training promotes employees' eco-friendly behaviors outside of work. *Hum Resour Manag*. (2023) 62:355–71. doi: 10.1002/hrm.22148

62. He X, Jing Q, Chen H. The impact of environmental tax laws on heavy-polluting enterprise ESG performance: a stakeholder behavior perspective. *J Environ Manag*. (2023) 344:118578. doi: 10.1016/j.jenvman.2023.118578

63. NBS. (2024). *China statistical yearbook 2022*. Available at: https://data.stats.gov.cn/english/publish.htm?sort=1.

64. Roffia P, Bucciol A, Hashlamoun S. Determinants of life expectancy at birth: a longitudinal study on OECD countries. *Int J Health Econ Manag*. (2023) 23:189–212. doi: 10.1007/s10754-022-09338-5

65. Maiolo V, Keilman N, Gjertsen F. Sex-differences in life expectancy at birth: A descriptive analysis of the contributions of age and causes of death to the gap in Norway, 1881–2011. *Soc Sci Human Open*. (2023) 8:100450. doi: 10.1016/j.ssaho.2023.100450

66. Fang G, Yang K, Chen G, Tian L. Environmental protection tax superseded pollution fees, does China effectively abate ecological footprints? *J Clean Prod*. (2023) 388:135846. doi: 10.1016/j.jclepro.2023.135846

67. Tenytska I, Palienko M. Environmental taxes impact on the population health protection: cross-country analysis. *HEM*. (2021) 2:78–86. doi: 10.21272/hem.2021.4-08

Frontiers in Public Health

TYPE Original Research
PUBLISHED 28 May 2024
DOI 10.3389/fpubh.2024.1351849

Check for updates

OPEN ACCESS

EDITED BY
Hai Fang,
Peking University, China

REVIEWED BY
Armando Sánchez Vargas,
National Autonomous University of Mexico, Mexico
Bhavesh Modi,
All India Institute of Medical Sciences, India

*CORRESPONDENCE
Tao Wang
✉ 18521316637@163.com
Weimin Gao
✉ 546270778@qq.com

†These authors share first authorship

RECEIVED 07 December 2023
ACCEPTED 03 May 2024
PUBLISHED 28 May 2024

CITATION
Dong E, Sun X, Xi Y, Wang Y, Wang T and Gao W (2024) Identifying determinants of spatial agglomeration of healthcare resources by using spatial econometric methods: a longitudinal study in China.
Front. Public Health 12:1351849.
doi: 10.3389/fpubh.2024.1351849

Identifying determinants of spatial agglomeration of healthcare resources by using spatial econometric methods: a longitudinal study in China

Enhong Dong[1,2†], Xiaoting Sun[3†], Yueming Xi[4], Yijia Wang[5], Tao Wang[6]* and Weimin Gao[7]*

[1]School of Nursing and Health Management, Shanghai University of Medicine and Health Science, Shanghai, China, [2]Institute of Health Yangtze River Delta, Shanghai Jiao Tong University, Shanghai, China, [3]Shanghai Tenth Peoples Hospital Affiliated to Tongji University, Shanghai, China, [4]School of Public Health, University of Hangzhou Normal University, Hanzhou, China, [5]School of Basic Medicine, Capital Medical University, Beijing, China, [6]Shanghai Tongji Hospital, Tongji University School of Medicine, Shanghai, China, [7]School of Nursing, Kunming Medical University, Kunming, China

Background: Healthcare resources are necessary for individuals to maintain their health. The Chinese government has implemented policies to optimize the allocation of healthcare resources and achieve the goal of equality in healthcare for the Chinese people since the implementation of the new medical reform in 2009. Given that no study has investigated regional differences from the perspective of healthcare resource agglomeration, this study aimed to investigate China's healthcare agglomeration from 2009 to 2017 in China and identify its determinants to provide theoretical evidence for the government to develop and implement scientific and rational healthcare policies.

Methods: The study was conducted using 2009–2017 data to analyze health-resource agglomeration on institutions, beds, and workforce in China. An agglomeration index was applied to evaluate the degree of regional differences in healthcare resource allocation, and spatial econometric models were constructed to identify determinants of the spatial agglomeration of healthcare resources.

Results: From 2009 to 2017, all the agglomeration indexes of healthcare exhibited a downward trend except for the number of institutions in China. Population density (PD), government health expenditures (GHE), urban resident's disposable income (URDI), geographical location (GL), and urbanization level (UL) all had positive significant effects on the agglomeration of beds, whereas both *per capita* health expenditures (PCHE), number of college students (NCS), and maternal mortality rate (MMR) had significant negative effects on the agglomeration of institutions, beds, and the workforce. In addition, population density (PD) and *per capita* gross domestic product (PCGDP) in one province had negative spatial spillover effects on the agglomeration of beds and the workforce in neighboring provinces. However, MMR had a positive spatial spillover effect on the agglomeration of beds and the workforce in those regions.

Conclusion: The agglomeration of healthcare resources was observed to remain at an ideal level in China from 2009 to 2017. According to the significant determinants, some corresponding targeted measures for the Chinese government and other developing countries should be fully developed to balance regional disparities in the agglomeration of healthcare resources across administrative regions.

KEYWORDS

determinants, healthcare resources, agglomeration, spatial econometric methods, China

1 Introduction

Healthcare resources are necessary for individuals to maintain their health. Thus, these resources should be rationally allocated to ensure sustainable health services. Moreover, to ensure the performance of the health system, people's growing and diversified needs for health services should be effectively met. China's vastness and diversity, imbalanced development and variety of economic activities, population growth, cultural differences, geography, and transportation conditions across regions, as well as the fragmentation of the urban–rural dual system structure [0–0], have resulted in the maldistribution of healthcare resources. Differences in healthcare resource allocation between and within regions can be observed in China.

The Chinese government has implemented policies to optimize the allocation of healthcare resources and achieve the goal of equality in healthcare for the Chinese people. Since the implementation of the new medical reform in 2009, the government has increased investment in healthcare resources, particularly prioritizing financial support in the central and western regions, expanding medical insurance coverage, improving primary health services, developing a hierarchical diagnosis and treatment system, and reducing health expenditures *per capita* and differences in healthcare resource allocation between developed and underdeveloped regions.

By employing the data envelopment analysis approach, Sha et al. (1) observed regional differences in the efficiency of healthcare resource allocation in China, with the allocation being more inefficient in five cities in the Shanxi province of China. Socioeconomic factors, including income, education, and insurance, were identified as the main determinants of regional differences in healthcare resource allocation. Gu J (2) identified population, *per capita* gross domestic product (GDP), number of urban employees, level of commercial and trade development, and proportion of the agricultural area as contributors to the allocation of healthcare resources in some counties in China. However, Tuvia et al. demonstrated that inequality in socioeconomic factors resulted in inequality in income, employment, and health investment, thus affecting the fairness of the distribution of health resources (3). Furthermore, Qiong reported that income, medical insurance, and health service supply and consumption demand were the determinants of differences in healthcare resource allocation between urban and rural areas (4). Moreover, Xie et al. demonstrated that urban residents' medical insurance and inequality in household income were the determinants of differences in healthcare resource allocation between urban and rural areas (5). Li et al. posited pro-wealthy inequality in the utilization of maternal health services in the rural areas of western China, and this inequality was identified as being associated with factors such as income, education level, and geographical transportation conditions (6). Although many studies have examined the time trend of differentiation in healthcare resource allocation in various regions of China by using many methods and healthcare resource indicators (e.g., health expenditures and numbers of health institutions beds and technicians), no study has investigated regional differences from the perspective of healthcare resource agglomeration and the spatial spillover effect of healthcare agglomeration by considering the spatial heterogeneity of these resources. In fact, agglomeration–the process by which economic activities cluster together in geographic space–is a complex phenomenon influenced by a variety of factors. It often occurs in healthcare resources within specific geographic areas or institutions. This phenomenon is influenced by a complex interplay of determinants, which can be analyzed through different theoretical lenses, such as Anderson's behavioral model, which was originally designed to explain and predict healthcare utilization. The model can also provide insights into the factors that contribute to the agglomeration of healthcare resources. According to this theoretical model, three types of factors contribute to healthcare utilization, namely predisposing characteristics (e.g., population density and age distribution), enabling resources (e.g., insurance coverage, healthcare facilities, and human resources), and need factors (e.g., high demand for certain types of care, self-reported health status, and population mortality); these factors would all lead to the concentration of healthcare resources (7). Scholars have posited the agglomeration of healthcare resources is a multifaceted phenomenon influenced by economic principles, demographic factors, technological advancements, and policy decisions (8). Therefore, understanding these determinants is crucial for policymakers and healthcare administrators as they work to optimize the distribution of healthcare resources to best meet the needs of the population.

China has gradually overcome geographical and administrative constraints by increasing investment in health services and expanding the number of healthcare resources across various administrative divisions. This type of agglomeration can demonstrate the spatial autocorrelation among various regions in China. Therefore, given the implementation of the new medical reform and the rapid development

Abbreviations: IA, Instituions agglomeration; BA, Beds agglomeration; DA, Doctor agglomeration; TA, Technicians agglomeration; NA, Nurses agglomeration; PD, Population Density; MMR, maternal mortality rate; RBWL25, rate of born-baby weighing less than 2. 5 kg; PMR, perinatal mortality rate; GHE, Government Health Expenditures; OOP, Out-of-Pocket; PCHE, *Per Capita* Health Expenditures; PCGDP, *per capita* gross domestic product; NI, Number of Insured; NCS, number of college students; URDI, Urban Residents Disposable Income;; FNI, Farmers Net Income; GL, Geographical Location; UL, Urbanization Level; SLM, spatial lag model; SAR, spatial autoregressive; SEM, spatial error model; SDM, spatial Durbin model; GMM, generalized method of moments; QML, Quasi-maximum likelihood.

of health services in China, regional differences in the agglomeration of healthcare resources and the spatial spillover effect of healthcare agglomeration should be investigated.

Using spatial econometric methods and longitudinal panel data (2010–2017), this study explored China's healthcare agglomeration and identified its determinants to provide theoretical evidence for the government to develop and implement scientific and rational healthcare policies.

2 Methods

2.1 Data sources

Secondary data for this study were obtained from the China Health Statistical Yearbook and China Statistical Yearbook for 31 provinces (municipalities or autonomous regions) in China from 2010 to 2018 (Considering the one-year time delay nearly existed in publishing Chinese official annual yearbooks). These yearbooks are published officially by the National Health Commission and the National Bureau of Statistics, and the raw data supporting the conclusions of this study will be made available from the corresponding author upon reasonable request.

In this study, the numbers of health institutions, beds, doctors, technicians, and nurses were included as healthcare resource indicators. Data on maternal mortality rate (MMR), rate of born-baby weight less than 2. 5 kg (RBWL25), perinatal mortality rate (PMR), government health expenditures (GHE), out-of-pocket (OOP) expense, and *per capita* health expenditures (PCHE) were retrieved from the China Health Statistical Yearbook (2009–2017), and those on the population density (PD), *per capita* gross domestic product (PCGDP), number of insured persons (NI), number of college students (NCS), urban residents disposable income (URDI), farmers net income (FNI), and urbanization level (UL) were retrieved from the China Statistical Yearbook (2010–2018); these factors were included as contributing variables. The description of the variables of interest and their units of measurement in the study can be seen in Table 1.

TABLE 1 Description of the variables of interest and its units of measurement in the study.

Variables	Description	Unit	Type
IA	Instituions agglomeration	None	Categorical variable
BA	Beds agglomeration	None	Categorical variable
DA	Doctor agglomeration	None	Categorical variable
TA	Technicians agglomeration	None	Categorical variable
NA	Nurses agglomeration	None	Categorical variable
PD	Population per unit land area	None	Categorical variable
MMR	The annual number of female deaths per 100,000 live births	Persons per 100,000 live births	Categorical variable
RBWL25	The annual number of live-born infants weighing less than 2,500 g per 100 live births	Percent	Categorical variable
PMR	The annual number of stillbirths and deaths in the first week of life per 1,000 total births	Per 1,000 births	Categorical variable
GHE	Annual government health expenditures	100,000,000Yuan	Categorical variable
OOPE	Out-of-pocket expenditure on health	Yuan	Categorical variable
PCHE	*Per capita* health expenditures	Yuan	Categorical variable
PCGDP	*Per capita* gross domestic product	Yuan	Categorical variable
NI	The number of Insured population	10,000 persons	Categorical variable
NCS	The number of college students	Persons	Categorical variable
URDI	Annual Urban Residents' Disposable Income	Yuan	Categorical variable
FNI	Annual Farmers 'Net Income	Yuan	Categorical variable
GL	Geographical Location		Continuous variable
UL	Urbanization Level	per cent	Categorical variable

2.2 Statistical methods

Based on the literature on location entropy, we used the agglomeration index to evaluate the degree of regional differences in healthcare resource allocation, which is represented by CYHR. CYHR refers to the total health resources in each province divided by the total population in each province. $CYHR_j$ refers to the total number of health resources available to the total population for the healthcare resource indicator j. $CYHJJ_{ij}$ is an index of regional differences in agglomeration and is calculated as follows:

$$CYHJJ_{ij} = \left(\frac{CYH_{ij} / P_{ij}}{CYH_j / P} \right), i = 1, 2, \ldots, 31; j = 1, 2, \ldots 5 \quad (1)$$

In Formula (1), where $CYHJJ_{ij}$ represents the agglomeration index of regional differences in unit i for the jth healthcare resource indicator, CYH_{ij} represents the resource allocation in a province i for the jth index, P_{ij} refers to the total population in unit i for the jth indicator, CYH_j refers to the jth indicator in one area, P represents the total population in one area, and j refers to one healthcare resource indicator among the five total indicators. According to the definition of the agglomeration index, if $CYHJJ_{ij}$ is>1, resource agglomeration in region i for the jth indicator is higher than the average national level, indicating a higher allocation of resources in region i for the jth indicator than in regions with the average national level. Otherwise, a $CYHJJ_{ij}$ value of <1 indicates a lower allocation of resources in region i for the jth indicator than in regions with the average national level.

First, we applied a multivariable linear regression model to investigate the factors associated with a quantitative variable as follows:

$$\begin{aligned} \mathrm{CYHJJ_{ij}} = {} & \beta_0 + \beta_1 PD\_{ij} + \beta_2 MMR\_{ij} + \beta_3 RBWL25\_{ij} \\ & + \beta_4 PMR\_{ij} + \beta_5 GHE\_{ij} + \beta_6 OOPE\_{ij} \\ & + \beta_7 PCHE\_{ij} + \beta_8 NI\_{ij} + \beta_9 NCS\_{ij} \\ & + \beta_{10} PCGDP\_{ij} + \beta_{11} URDI\_{ij} + \beta_{12} FNI\_{ij} \\ & + \beta_{13} GL\_{ij} + \beta_{14} UL\_{ij} + \varepsilon\_{ij} \end{aligned} \tag{2}$$

In Formula (2), where $CYHJJ_{ij}$ refers to the agglomeration index of regional differences in healthcare resources, *i* refers to the number of provinces in China, and *j* refers to the type of healthcare resources: healthcare institutions, beds, doctors, technicians, and nurses. β_i refers to the regression coefficient of the explanatory variable X, and the explanatory variable X refers to the predictors of PD_ij, MMR_ij, RBWL25_ij, PMR_ij, GHE_ij, OOPE_ij, PCHE_ij, NI_ij, NCS_ij, PCGDP_ij, URDI_ij, FNI_ij, GL_ij in a province i for the jth healthcare resource index and UL. Ɛ_ij is a random error term in a province i for the jth index.

However, upon the confirmation of spatial dependence in the data, the usage of linear regression is not justified, as spatial dependence violates the assumption that observations are independent of each other. Additionally, we tested the multicollinearity in the multivariable linear regression model with variance inflation factor (VIF), and we found that all the values of VIF of some predictors (such as PD_ij, MMR_ij, OOPE_ij, GHE_ij) regressing on the agglomeration indexes of five healthcare resource indicators were more than 5, indicating the existence of the multicollinearity. In the case of spatial dependence in data, spatial regression models such as the spatial lag model, spatial error model, and spatial Durbin model are often used for factors assessment. The spatial regression technique was employed to investigate the relationship between the values of a response variable and the values of explanatory variables. Many scholars have applied spatial techniques in health system research (9, 10), including a study on the COVID-19 pandemic (11). In doing so, for this study, we used longitudinal data to construct a spatial econometric regression model to analyze temporal and spatial evolution trends and to identify the contribution of various factors to healthcare resource agglomeration in China. To make the statistical analysis of the study clearer, a flow chart of the methodology was presented, starting from the source of data-to-data analysis (see Figure 1).

Before we conducted the spatial econometrics analyses, we first constructed the appropriate spatial weight matrix, which illustrates the location information of the geographical units to conduct the spatial econometric analysis of the target geographical units. In general, the construction of a spatial weight matrix can be based on various spatial phenomena, such as proximity, contiguity, similarity, or distance decay, and constructing a spatial weight matrix depending on the nature of the spatial phenomena being analyzed. In this study, we chose a contiguity-based spatial weight matrix, in which observations that share a common boundary or touch each other are assigned a weight of 1, while others are assigned a weight of 0, for our main interest lies in understanding spatial interdependence between adjacent administrative divisions and the contiguity-based spatial weight matrix best represents the spatial relationships between observations in their study area.

Then, we divided spatial econometric models into three types: spatial lag model (SLM) or spatial autoregressive (SAR) model, spatial error model (SEM), and spatial Durbin model (SDM).

2.2.1 SLM (or SAR model)

If the lag term of a dependent variable y is considered to have a spatial autocorrelation, then the dependent variable and its driver model can be expressed as follows:

$$\mathbf{y} = \rho \boldsymbol{W}\boldsymbol{y} + \boldsymbol{X}^{2} + \varepsilon \tag{3}$$

In Formula (3), where y represents the n × 1 dependent variable. X represents the n × K independent variable. ρ represents the spatial autoregressive coefficient to be estimated. W represents the n × n spatial weight matrix. β represents the K × 1 coefficient of independent variables to be estimated. ε represents the n × 1 error term.

2.2.2 SEM

If the spatial dependence of a dependent variable exists in the error disturbance term and is used to measure the effect of the error shock of a dependent variable in neighboring regions on the dependent variable in one region, then the spatial error model can be used in this study. The model is as follows:

$$\mathrm{y}=\mathrm{X}\beta+\mu \tag{4}$$

$$\mu=\lambda \mathrm{W}\mu+\mathrm{v} \tag{5}$$

In Formula (4) and (5), where y represents the n × 1 dependent variable. X represents the n × K independent variable. β represents the k × 1 coefficient of independent variables to be estimated. W represents the n × n spatial weight matrix. Mrepresents a vector of error terms (n × 1) assumed to have autocorrelation. λ represents the spatial lag coefficient to be estimated, which is called the spatial autocorrelation coefficient. ν represents the n × 1 error term.

2.3 SDM

The spatial Durbin model (SDM) is a development of the spatial autoregressive model (SAR), in which the effect of spatial lag takes into account the independent and dependent variables. To examine the effect between variables, we chose the SDM as follows:

$$\mathrm{y}=\rho \mathrm{Wy}+\mathrm{X}\beta+\mathrm{WX}\theta+\varepsilon \tag{6}$$

In Formula (6), where y represents the n × 1 dependent variable. X represents the n × k independent variable. ρ represents the spatial autoregressive coefficient to be estimated. W represents the n × n

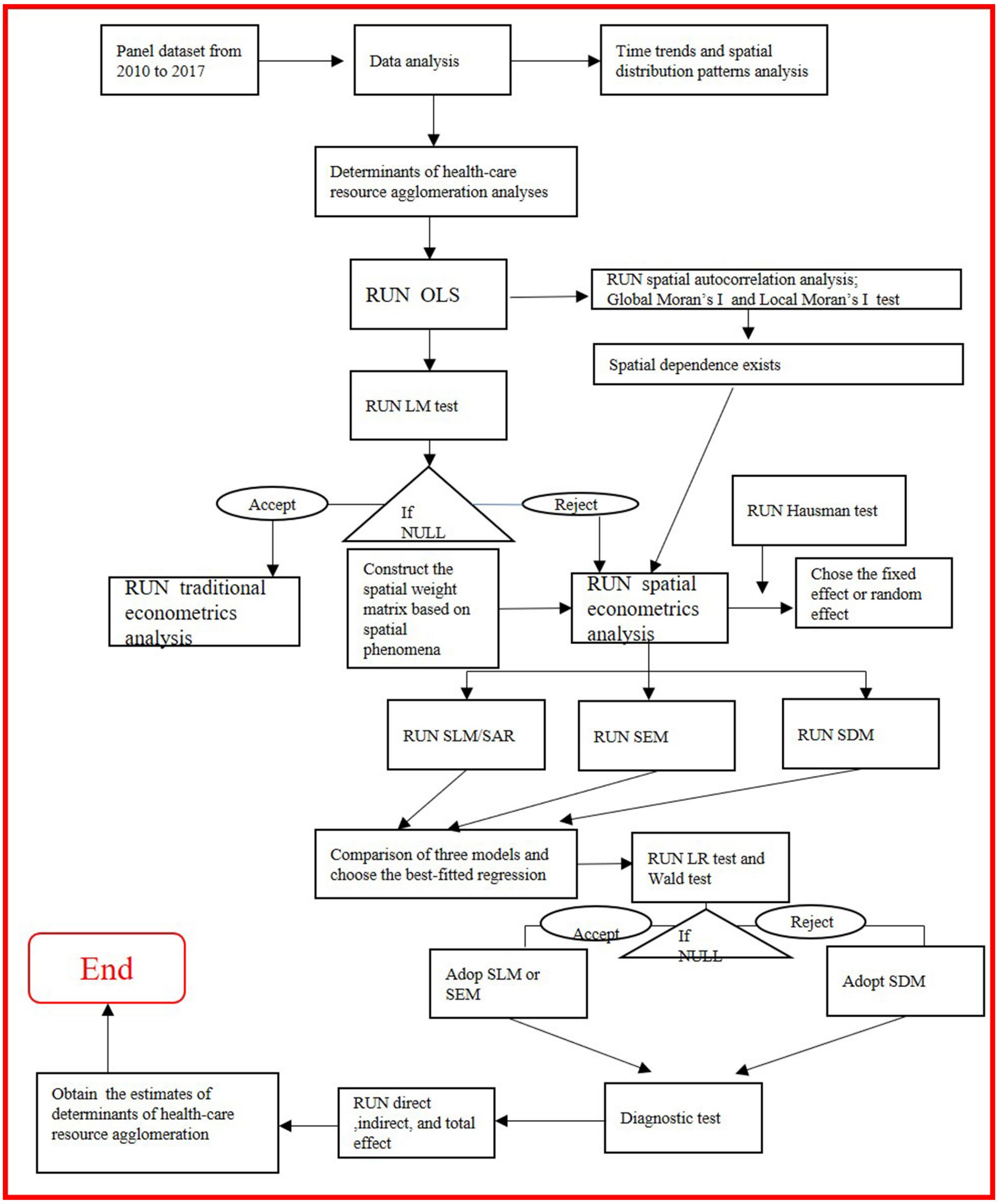


FIGURE 1
A flowchart of the methodology starting from the source of data-to-data analysis for the study (Source: Author created).

spatial weight matrix. β represents the $k \times 1$ coefficient of independent variables to be estimated. θ represents the $k \times 1$ coefficient of the spatial lag term of independent variables to be estimated. ε represents the $n \times 1$ error term.

When θ is zero, the SDM degenerates into the SLM/SAR. When $\theta + \rho\beta$ equals zero, the SDM degenerates into the SEM. **W** is a 31×31 spatial weight matrix, and off-diagonal blocks are all zeros. The parameter λ refers to the inter-regional spillover effect caused by the error term of observations. For convenience, we adopted the 0–1 adjacency matrix and set the Hainan and Guangdong provinces as the nearest neighbors.

2.4 Statistical criteria for model selection and estimation methods

The selection of the appropriate spatial econometric model was based on two null hypotheses: H0, $\theta = 0$ and H0, $\theta + \rho\beta = 0$. If both the

TABLE 2 Time trends of healthcare resource agglomeration in China from 2009 to 2017.

Year agglomeration	2009	2010	2011	2012	2013	2014	2015	2016	2017	Annual average agglomeration
Institutions	1.036	1.039	1.06	1.067	1.059	1.035	1.059	1.061	1.059	1.053
Beds	1.028	1.024	1.045	1.001	1.004	1.003	1.002	0.998	0.998	1.011
Doctors	1.111	1.092	1.066	1.038	1.05	1.013	1.014	1.032	1.031	1.050
Technicians	1.088	1.073	1.070	1.007	1.053	1.018	1.017	1.015	1.021	1.040
Nurses	1.091	1.074	1.069	1.017	1.04	1.006	1.032	1.004	1.008	1.038

null hypotheses are rejected, then SDM is selected. We performed the Wald and likelihood ratio (LR) tests under certain conditions to determine the appropriate top-down approach for model selection:

(1) SDM was selected if the findings of the Wald test were significant. (2) SLM/SAR or SEM was selected based on LR statistical values (when $\theta = 0$ or $\theta + \rho\beta = 0$). (3) SEM was selected if $\theta + \rho\beta = 0$ based on the LRλ test. (3) SLM/SAR was selected if $\theta = 0$ based on the LRθ test. Otherwise, a non-spatial model (e.g., ordinary least squares regression model) was selected if any probability value was not significant after conducting all the aforementioned tests (see Figure 1, for details).

With regards to estimation methods using spatial regression models, to the best of our knowledge, various methods of estimating spatial panel models have been proposed. Broadly, they fall into two categories: (i) generalized method of moments (GMM) and (ii) quasi-maximum likelihood (QML) estimators. All the models that can be estimated using the Stata command, xsmle, fall into the second category. The exception is the random effects of SEM, whose likelihood function involves a transformation using the Cholesky factors of a rather complicated matrix containing the parameters to be estimated, so that the matrix differentiation is extremely chaotic (12, 13).

2.5 Statistical analysis

We used the Geoda1. 14 software[1] for drawing maps, and Stata SE15. 0 (release 15. StataCorp LLC, College Station, TX, United States) to conduct statistical analyses.

3 Results

3.1 Time trends and spatial distribution patterns of healthcare resource agglomeration in China from 2009 to 2017

From 2009 to 2017, all the agglomeration indexes of healthcare exhibited a downward trend except for the number of institutions in China (Table 2). Moreover, the average agglomeration indexes for five types of healthcare resources were all >1.0 during the period, indicating the agglomeration of healthcare resources in China remained at a relatively higher level of resource allocation on average during the past 9 years.

In terms of spatial distribution patterns, regional differences in healthcare resource agglomeration were observed from 2009 to 2017. For example, in 2017, we noted a north–south differential spatial distribution of all the agglomeration indexes, with a diagonal angle pattern. Most of the provinces with agglomeration indexes of >1.0 were located in the north of China, accounting for >50% of all provinces. In contrast, other provinces with agglomeration indexes of <1.0 were located in the southwest and southeast of China (Figure 2).

3.2 Determinants of healthcare resource agglomeration in China from 2009 to 2017

Before we conducted spatial econometrics analyses, we tested the spatial dependence with Moran's I index and found the existence of the spatial correlation in the residuals of the OLS estimates (see Table 3). Based on the statistical criteria for selecting spatial econometric models, we chose the SDM for the number of beds, doctors, technicians, and nurses because the Wald test result was significant and the SEM for the number of institutions because the Wald test result was not significant (see Table 4). In addition, based on the Hausman test results, we selected the fixed effect for the number of institutions and the random effect for the number of beds, doctors, technicians, and nurses. Additionally, we used the QML estimation method in this study because we only needed to compute the fixed effect for the number of institutions, which was suitable for SEM analysis, while random effects of the number of beds, doctors, technicians, and nurses were suitable for SDM analyses. All the statistical assumptions required for the abovementioned methods have been satisfied (see Table 4, for details).

For the number of institutions, MMR ($p < 0.01$, $t = -5.061$) and UL ($p < 0.05$, $t = -2.359$), and PD ($p < 0.01$, $t = 6.664$) and URDI ($p < 0.10$, $t = 1.834$) were significantly associated with the agglomeration index at 1, 5, 1, and 10% levels, respectively, indicating that MMR and UL had significant negative effects on the agglomeration index for institutions, while PD and URDI had significant positive effects on it. Furthermore, the agglomeration of institutions exhibited a negative interprovincial spatial autocorrelation from 2009 to 2017 ($\lambda = -0.134$, $p < 0.10$, $t = -1.685$).

For the number of beds, the spatial autoregressive positive coefficient ($\rho = 0.056$) was significant at the 10% level, indicating that the bed agglomeration index exhibited a significant positive spatial correlation between provinces as a whole. PD ($p < 0.01$, $t = 2.071$), MMR ($p < 0.01$, $t = -2.114$), GHE ($p < 0.01$, $t = 2.615$), PCHE

1 http://geodacenter.Github.io/

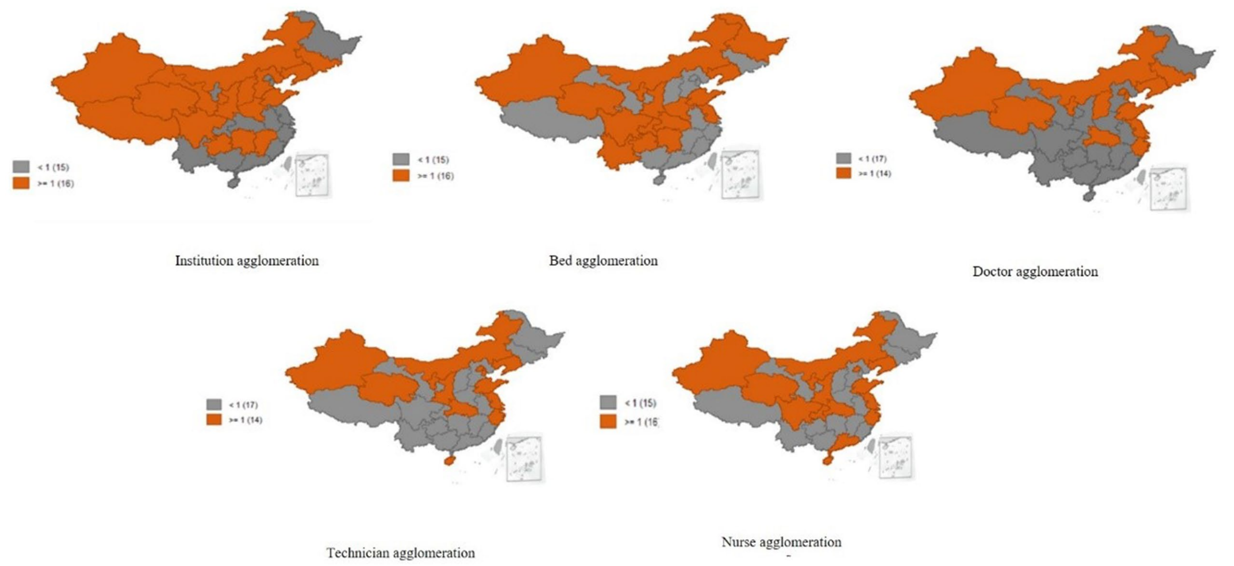


FIGURE 2
Spatial distribution patterns of healthcare resource agglomeration in China from 2009 to 2017.

TABLE 3 Global spatial correlation test of healthcare resource agglomeration in China from 2009 to 2017.

Year	IA		BA		DA		TA		NA	
	Moran's I	Z value	Moran's I	Z value	Moran's I	Z value	Moran's I	Z value	Moran's I	Z value
2009	0.204	2.057**	0.163	1.806**	0.259	2.878***	0.213	2.518**	0.159	1.914**
2010	0.240	2.419**	0.144	1.623	0.269	3.106***	0.216	2.584**	0.161	2.008**
2011	0.174	2.052**	0.135	1.625	0.255	2.967***	0.206	2.518**	0.151	1.924**
2012	0.186	2.169**	0.033	0.605	0.227	2.544**	−0.040	−0.048	−0.009	−0.262
2013	0.198	2.273**	0.146	1.551	0.242	2.888***	0.176	2.221**	0.145	1.862
2014	0.086	1.159	0.172	1.732	0.128	1.605	−0.055	−0.201	−0.100	−0.600
2015	0.198	2.240**	0.213	2.072**	0.110	1.423	−0.074	−0.391	−0.145	−0.931
2016	0.204	2.275**	0.195	1.922**	0.175	2.072**	−0.080	−0.451	−0.110	−0.670
2017	0.209	2.292**	0.263	2.482**	0.223	2.595**	−0.118	−0.800	−0.134	−0.875

**$p < 0.05$; ***$p < 0.01$.

($p < 0.01$, $t = -4.015$), NCS ($p < 0.01$, $t = -2.919$), GL ($p < 0.01$, $t = 3.772$), and UL ($p < 0.01$, $t = 8.062$) exerted a significant effect on bed agglomeration. Moreover, the coefficient of the spatial weight matrix and PD and RBWL25 was less than 0 and significant at the 1% ($p < 0.01$, $t = -3.189$) and 5% level ($p < 0.05$, $t = -2.461$), respectively, indicating that one region PD and RBWL25 had a spillover effect on bed agglomeration in neighboring regions. However, the coefficient of the spatial weight matrix and MMR was more than 0 and significant at the 1% level ($p < 0.01$, $t = 4.499$). Hence, an increase in the PD and BWL25 of one province reduced the bed agglomeration in its adjacent provinces, while an increase in the MMR of one province improved the bed agglomeration in its adjacent provinces.

For the workforce, the spatial autoregressive coefficients for the number of doctors, technicians, and nurses were all positively (all were > 0) significant at 1, 5, and 10% levels, respectively, indicating that the agglomeration of all the three types of the workforce exhibited significant positive spatial correlations among provinces. PD, URDI, GL, and UL exerted a significant positive effect on the agglomeration of the workforce, whereas both PCHE and NCS exerted a significant negative effect on the agglomeration of the three types of the workforce.

The findings concerning the interaction term coefficients of each variable and the spatial weight matrix indicated that MMR had a significantly positive spatial spillover effect on the agglomeration of doctors, medical technicians, and nurses in neighboring provinces. In contrast, PD and PCGDP had a significant negative spatial spillover effect on the agglomeration of the workforce in other provinces.

Table 5 presents the effect decomposition of factors affecting the agglomeration of beds and the workforce based on the SDM. In terms of direct effects, dependent variables of agglomeration of beds and the workforce and their independent variables demonstrated the same connections as shown in the aforementioned SDM in Table 4. In terms of indirect effects, we observed similar results in the aforementioned SDM in Table 4 that MMR exerted a positive spatial spillover effect on the agglomeration of beds and the workforce, whereas PD, RBWL25,

TABLE 4 Spatial econometric regression results for determinants of healthcare resource agglomeration in China from 2009 to 2017.

Variables	SEM		SDM							
	IA		BA		DA		TA		NA	
	Random effect	Fixed effect	Random effect	Fixed effect	Random effect	Fixed effect	Random effect	Fixed effect	Random effect	Fixed effect
PD	0.000052***	−0.000017	0.000009**	0.000015	0.000019**	−0.000040	0.000023***	−0.000042	0.000022**	−0.000042
	(6.664)	(−0.611)	(2.071)	(0.469)	(2.421)	(−0.930)	(3.034)	(−1.032)	(2.421)	(−0.722)
MMR	−0.003743***	−0.001833*	−0.001649**	−0.001627	−0.001002	0.000698	−0.000604	0.001411	−0.001807	−0.000231
	(−5.061)	(−1.774)	(−2.114)	(−1.401)	(−0.923)	(0.444)	(−0.585)	(0.927)	(−1.261)	(−0.109)
BWL25	−0.021498	−0.012576	−0.016970	0.002868	−0.022001	−0.016934	−0.002826	0.004264	−0.018107	−0.023543
	(−1.522)	(−0.922)	(−1.113)	(0.186)	(−1.069)	(−0.817)	(−0.145)	(0.212)	(−0.670)	(−0.838)
PM	−0.004410	−0.002472	0.009227	0.013274*	0.006187	−0.001597	−0.003258	−0.011011	0.002257	−0.000090
	(−0.612)	(−0.339)	(1.351)	(1.692)	(0.618)	(−0.149)	(−0.333)	(−1.022)	(0.176)	(−0.006)
GHE	0.000004	−0.000005	0.000222***	0.000104	0.000062	0.000084	−0.000023	−0.000016	−0.000078	−0.000083
	(0.049)	(−0.062)	(2.615)	(1.236)	(0.537)	(0.725)	(−0.209)	(−0.145)	(−0.500)	(−0.528)
OOPE	0.000008	−0.000011	−0.000113	−0.000201***	0.000058	0.000059	0.000240**	0.000233**	0.000269**	0.000283**
	(0.114)	(−0.174)	(−1.521)	(−2.827)	(0.575)	(0.601)	(2.497)	(2.493)	(1.994)	(2.141)
PCHE	−0.000016	−0.000017*	−0.000045***	−0.000050***	−0.000109***	−0.000120***	−0.000098***	−0.000106***	−0.000129***	−0.000136***
	(−1.635)	(−1.832)	(−4.035)	(−4.648)	(−7.127)	(−8.258)	(−6.740)	(−7.592)	(−6.337)	(−6.921)
NI	0.000002	0.000003	−0.000005	0.000002	0.000001	0.000006	−0.000012	−0.000008	−0.000011	−0.000004
	(0.335)	(0.489)	(−0.660)	(0.279)	(0.135)	(0.616)	(−1.168)	(−0.765)	(−0.743)	(−0.276)
NCS	−0.000000	0.000000	−0.000027***	−0.000026***	−0.000040***	−0.000043***	−0.000042***	−0.000044***	−0.000051***	−0.000051***
	(−0.016)	(0.021)	(−2.919)	(−2.970)	(−3.198)	(−3.655)	(−3.529)	(−3.916)	(−3.029)	(−3.225)
PCGDP	−0.000000	−0.000000	0.000001	0.000001*	0.000000	0.000000	0.000000	0.000000	−0.000000	0.000000
	(−0.603)	(−0.318)	(1.393)	(1.892)	(0.032)	(0.391)	(0.153)	(0.374)	(−0.040)	(0.255)
URDI	0.000003*	0.000003	−0.000003	−0.000003	0.000004	0.000004	0.000005*	0.000005**	0.000006*	0.000007**
	(1.834)	(1.643)	(−1.326)	(−1.604)	(1.503)	(1.577)	(1.790)	(2.085)	(1.786)	(2.221)
FNI	0.000003	0.000001	0.000002	0.000004	0.000007	0.000008*	0.000002	0.000003	0.000000	−0.000002
	(0.879)	(0.521)	(0.654)	(1.210)	(1.402)	(1.677)	(0.428)	(0.600)	(0.009)	(−0.262)
GL	0.092792	0.000000	0.125551***	0.000000	0.122954**	0.000000	0.172930***	0.000000	0.175201**	0.000000
	(1.536)	(.)	(3.772)	(.)	(1.995)	(.)	(3.074)	(.)	(2.518)	(.)
UL	−0.005738**	−0.002265	0.017756***	0.023654***	0.033257***	0.033204***	0.039416***	0.041260***	0.047665***	0.053226***
	(−2.359)	(−0.884)	(8.062)	(8.075)	(10.715)	(8.648)	(12.967)	(10.793)	(11.735)	(9.870)

(Continued)

TABLE 4 (Continued)

Variables	SEM		SDM							
	IA		BA		DA		TA		NA	
	Random effect	Fixed effect	Random effect	Fixed effect	Random effect	Fixed effect	Random effect	Fixed effect	Random effect	Fixed effect
Wx*PD			−0.000030***	0.000090			−0.000044***	−0.000007	−0.000062***	−0.000168
			(−3.189)	(1.339)			(−2.845)	(−0.080)	(−3.171)	(−1.370)
Wx*MMR			0.006540***	0.004582**	0.010072***	0.011121***	0.011647***	0.010754***	0.013026***	0.015797***
			(4.499)	(2.246)	(5.816)	(6.245)	(6.028)	(3.830)	(4.907)	(4.209)
Wx*BWL25			−0.054356**	−0.050807*						
			(−2.461)	(−1.768)						
Wx*PCGDP							−0.000002**	−0.000003**		
							(−1.998)	(−2.349)		
Hausman test	Chi2 (9)=26.14 Prob>chi2 = 0.026		Chi2 (9)=1.88 Prob>chi2 = 0.993		Chi2 (9)= 2.65 Prob>chi2 < 0.801		Chi2 (9)= 1.55 Prob>chi2 < 0.907		Chi2 (9)=1.19 Prob>chi2 < 0.761	
Wald test	Nesting SAR assumption:Chi2 (13)=31.62 Prob>chi2 = 0.0045 Nesting SEM assumption:Chi2 (13)= 17.95 Prob>chi2 = 0.2797		Nesting SAR assumption:Chi2 (13)=28.48 Prob>chi2 = 0.0123 Nesting SEM assumption:Chi2 (13)=30.94 Prob>chi2 = 0.0057		Nesting SAR assumption:Chi2 (13)=58.72Prob > chi2 < 0.0001 Nesting SEM assumption:Chi2 (13)=27.84 Prob>chi2 = 0.0149		Nesting SAR assumption:Chi2 (13)=48.86Prob > chi2 < 0.0001 Nesting SEM assumption:Chi2 (13)=26.36 Prob>chi2 = 0.0918		SAR assumption:Chi2 (13)=37.34 Prob>chi2 = 0.0007 SEM assumption:Chi2 (13)=26.42 Prob>chi2 = 0.0883	
LR test	Nesting SAR assumption:Chi2 (13)=15.20 Prob>chi2 = 0.0946 Nesting SEM assumption:Chi2 (13)=15.26 Prob>chi2 = 0.2916		Nesting SAR assumption:Chi2 (13)=21.95 Prob>chi2 = 0.0797 Nesting SEM assumption:Chi2 (13)=23.97 Prob>chi2 = 0.0314		Nesting SAR assumption:Chi2 (13)=19.92 Prob>chi2 = 0.0171 Nesting SEM assumption:Chi2 (13)=27.42 Prob>chi2 = 0.0809		Nesting SAR assumption:Chi2 (13)=20.25 Prob>chi2 = 0.0737 Nesting SEM assumption:Chi2 (13)=19.23 Prob>chi2 = 0.0552		SAR assumption:Chi2 (13)=28.262 Prob>chi2 = 0.0011 SEM assumption:Chi2 (13)=17.31 Prob>chi2 = 0.0854	
Rho			0.056039*	0.078552	0.003363*	0.055919	0.000056**	0.014079	0.017276*	0.028693
			(1.870)	(1.085)	(0.853)	(0.864)	(2.001)	(0.224)	(1.869)	(0.439)
ln_phi	2.474874***									
	(8.662)									
Lambda	−0.133749*	−0.141853								
	(−1.685)	(−1.442)								
lgt_theta			−1.219404***		−1.727356***		−1.656658***		−1.472303***	
			(−5.735)		(−10.208)		(−9.937)		(−8.397)	
sigma2_e	0.005605***	0.004847***	0.007017***	0.005924***	0.012690***	0.011106***	0.011523***	0.010097***	0.023030***	0.020168***
	(11.043)	(11.783)	(10.835)	(11.806)	(11.051)	(11.809)	(11.086)	(11.811)	(11.064)	(11.810)
Constant	1.161472***		−0.002249		−0.811778***		−1.073332***		−1.396510***	
	(5.284)		(−0.012)		(−2.999)		(−4.217)		(−4.198)	
Observations	279	279	279	279	279	279	279	279		279
R2	0.664	0.423	0.311	0.044	0.482	0.261	0.510	0.285	0.465	0.247
Units	31	31	31	31	31	31	31	31		31

***$p < 0.01$; **$p < 0.05$; *$p < 0.10$.

10.3389/fpubh.2024.1351849

TABLE 5 Decomposition of the spatial spillover effect of beds and workforce agglomeration index in China from 2009 to 2017.

Variables	BA			DA			TA			NA		
	Direct effect	Indirect effect	Total effect	Direct effect	Indirect effect	Total effect	Direct effect	Indirect effect	Total effect	Direct effect	Indirect effect	Total effect
PD	0.000008*	−0.000027***	−0.000018*	0.000020**	<0.000001	0.000020**	0.000023***	−0.000043***	−0.000020	0.000023**	−0.000059***	−0.000037*
	(1.854)	(−2.672)	(−1.691)	(2.394)	(0.194)	(2.345)	(2.978)	(−2.743)	(−1.104)	(2.414)	(−3.062)	(−1.707)
MMR	−0.001629**	0.006460***	0.004831***	−0.001038	0.009876***	0.008838***	−0.000660	0.011459***	0.010799***	−0.001936	0.012704***	0.010767***
	(−2.140)	(4.100)	(2.675)	(−0.980)	(5.670)	(4.223)	(−0.655)	(5.947)	(4.835)	(−1.384)	(4.610)	(3.449)
RBLW25	−0.018831	−0.063129***	−0.081960***	−0.019901	−0.000265	−0.020165	−0.000817	−0.000030	−0.000847	−0.015343	0.000191	−0.015152
	(−1.309)	(−2.653)	(−2.988)	(−1.010)	(−0.151)	(−1.000)	(−0.044)	(−0.028)	(−0.045)	(−0.593)	(0.104)	(−0.592)
PM	0.011546*	0.000602	0.012148*	0.006142	0.000006	0.006148	−0.003337	−0.000017	−0.003354	0.002197	−0.000076	0.002121
	(1.717)	(0.649)	(1.719)	(0.634)	(0.008)	(0.632)	(−0.351)	(−0.032)	(−0.353)	(0.177)	(−0.102)	(0.174)
GHE	0.000225***	0.000013	0.000238***	0.000062	0.000001	0.000063	−0.000023	<0.000001	−0.000023	−0.000078	0.000002	−0.000076
	(2.757)	(0.759)	(2.684)	(0.558)	(0.147)	(0.558)	(−0.216)	(0.079)	(−0.210)	(−0.522)	(0.219)	(−0.514)
OPPE	−0.000108	0.000111	0.000003	0.000064	<0.000001	0.000064	0.000246**	<0.000001	0.000246**	0.000276**	−0.000005	0.000272**
	(−1.453)	(1.264)	(0.025)	(0.631)	(0.049)	(0.625)	(2.561)	(0.004)	(2.566)	(2.057)	(−0.250)	(2.051)
PCHE	−0.000045***	−0.000003	−0.000048***	−0.000109***	> − 0.000001	−0.000111***	−0.000098***	<−0.000001	−0.000099***	−0.000129***	0.000002	−0.000127***
	(−3.922)	(−0.794)	(−3.684)	(−6.942)	(−0.195)	(−6.344)	(−6.536)	(−0.054)	(−5.966)	(−6.169)	(0.242)	(−5.679)
NI	−0.000006	−0.000000	−0.000007	0.000001	<0.000001	0.000001	−0.000013	> − 0.000001	−0.000013	−0.000012	<0.000001	−0.000011
	(−0.779)	(−0.426)	(−0.772)	(0.091)	(0.121)	(0.097)	(−1.229)	(−0.027)	(−1.214)	(−0.797)	(0.185)	(−0.792)
NCS	−0.000027***	−0.000001	−0.000028***	−0.000039***	> − 0.000001	−0.000039***	−0.000041***	> − 0.000001	−0.000041***	−0.000049***	<0.000001	−0.000049***
	(−2.953)	(−0.737)	(−2.901)	(−3.179)	(−0.198)	(−3.106)	(−3.518)	(−0.023)	(−3.465)	(−3.005)	(0.235)	(−2.949)
PCGDP	0.000001	<0.000001	0.000001	<0.000001	<0.000001	<0.000001	<0.000001	−0.000002**	−0.000002	> − 0.000001	<0.000001	> − 0.000001
	(1.431)	(0.636)	(1.411)	(0.059)	(0.042)	(0.061)	(0.181)	(−1.983)	(−1.568)	(−0.012)	(0.047)	(−0.009)
URDI	−0.000003	> − 0.000001	−0.000003	−0.000004	> − 0.000001	−0.000004	−0.000005*	> − 0.000001	−0.000005*	−0.000007*	<0.000001	−0.000006*
	(−1.554)	(−0.629)	(−1.545)	(−1.581)	(−0.149)	(−1.579)	(−1.876)	(−0.028)	(−1.864)	(−1.867)	(0.240)	(−1.860)
FNI	0.000002	<0.000001	0.000002	0.000007	<0.000001	0.000007	0.000002	<0.000001	0.000002	<0.000001	> − 0.000001	<0.000001
	(0.562)	(0.353)	(0.563)	(1.396)	(0.143)	(1.391)	(0.452)	(0.037)	(0.454)	(0.045)	(−0.013)	(0.045)
GL	0.110733***	0.006293	0.117026***	0.119714**	0.001798	0.121512**	0.170212***	0.000219	0.170432***	0.171661***	−0.002502	0.169159**
	(3.516)	(0.807)	(3.440)	(2.028)	(0.227)	(1.995)	(3.130)	(0.023)	(3.117)	(2.576)	(−0.230)	(2.550)
UL	0.017000***	0.000955	0.017955***	0.033172***	0.000407	0.033579***	0.039370***	0.000063	0.039433***	0.047562***	−0.000731	0.046831***
	(7.960)	(0.822)	(7.246)	(10.761)	(0.198)	(8.884)	(13.085)	(0.029)	(11.363)	(11.814)	(−0.255)	(9.856)

***p < 0.01; **p < 0.05; *p < 0.10.

and PCGDP exerted a negative spatial spillover effect on the agglomeration of beds and the workforce, i.e., MMR had a positive spatial spillover effect on the agglomeration of beds and the entire workforce, while PD had a negative spatial spillover effect on the agglomeration of beds, technicians, and nurses. RBWL25 had only a negative spatial spillover effect on the agglomeration of beds, and PCGDP had only a negative spatial spillover effect on the agglomeration of nurses. These results were consistent with those of the spatial Durbin regression for determining the agglomeration of healthcare resources in China from 2009 to 2017, as presented in Table 4.

4 Discussion

The findings of this study revealed a downward trend in the healthcare resource agglomeration index, except for the number of institutions that remained at a relatively higher level of resource allocation on average in China from 2009 to 2017. This finding can be attributed to China's health reform efforts since 2009 to optimize the allocation of healthcare resources in China. Each province increased its healthcare resources through various means, such as by expanding its healthcare expenditures, building hospitals, increasing the number of beds, implementing public hospital reforms, and improving primary health services. However, the increasing number of healthcare resources remained inadequate for the growing population, resulting in declining agglomeration indexes for the number of beds, doctors, technicians, and nurses. Moreover, the healthcare resource agglomeration index exhibited a north–south differential distribution pattern across provinces. In particular, the distribution of the healthcare resource agglomeration index in the northwest, north, and northeast regions was superior to that in the southwest and southeast regions. This may be due to China's preferential healthcare resource input into western regions in light of the implementation of China's western development strategies since the 2000s. In addition, this finding might be attributable to the lower population in western regions than in eastern and southern regions. These factors led to a high agglomeration index in western China. This finding is in line with those of some previous studies (14–16).

PD, GHE, URDI, GL, and UL all had positive significant effects on the agglomeration of beds. However, PD, BWL25, and PCGDP had negative spatial spillover effects, and MMR had a positive spatial spillover effect on both beds and the workforce in neighboring regions.

Regarding PD, for a province, having a larger population density means inadequate access to healthcare to meet the needs of residents there for health services, which stimulates an increase of government investment in healthcare resources and an improvement of the agglomeration of healthcare resources in that province. Similarly, as part of the total health expenditure, GHE ensures that the government provides adequate healthcare resources to individuals. The supply of healthcare resources effectively increased with an increase in GHE. A previous study reported that the average annual growth rate of *per capita* GHE increased by 10.68%, increasing from ¥191.08 in 2009 to ¥526.95 in 2018, which further increased the probability of the concentration and agglomeration of healthcare resources across various provinces in China (17). However, factors such as differences in GHE and URDI imbalances, economic development, and the segmentation of healthcare resources across various regions have led to large differences in healthcare resource agglomeration in China (18–20).

In terms of GL, in the central and western regions, the higher the healthcare resource agglomeration index was, the more reasonable the healthcare resource allocation in those areas. GL was demonstrated to play a crucial role in healthcare resource agglomeration (21, 22). This finding can be explained by China's focus on the coordinated development of regional economies to narrow economic and social gaps among the eastern, central, and western regions in light of the 12th Five-Year Plan and 13th Five-Year Plan since the implementation of the new medical reforms. The government had gradually increased healthcare investment in the western and central regions through various policy-related measures, including redirecting investment, capital arrangements, subsidy provisions, and supplying large-scale medical equipment (23), leading to the accumulation of beds and equipment in these regions. Moreover, the government has enhanced the agglomeration of the workforce in the western and central regions through various efforts, including the implementation of the east–west pairing health assistance programs (24, 25) and the application for special fiscal funds to the Ministry of Health, the establishment of the western health talent training project, the provision of aid to projects in Xinjiang and Tibet, and the development of policies to emphasize health talent development. The two-way mechanism of balancing the healthcare workforce between the eastern and western provinces improved the agglomeration of resources in corresponding neighboring regions (26).

In this study, UL was observed to exert a positive effect on the agglomeration of beds and healthcare human resources. This is because UL can boost economic growth by expanding demand and prompt the government to devote more energy to healthcare services and provide more beds, doctors, technicians, and nurses, thus promoting an increase in their agglomeration.

Notably, PD exerts negative spillover effects on the agglomeration of the beds and health workforce in terms of the interregional two-way flow of healthcare resources. As mentioned above, PD causes the health input of government and agglomeration of healthcare resources in one province and inevitably attracts the residents interprovincial-seeking more access to healthcare services and affects remaining agglomeration of healthcare resources in other adjacent provinces comparatively. Additionally, for one province, the higher the PCGDP is, the more it spends on healthcare, such as expanding the number of health institutions' beds and increasing salaries of the health workforce. When the medical institutions, salary, and career development opportunities in one region are attractive, the inflow of the healthcare workforce from neighboring regions accelerates, thus reducing the agglomeration of the health workforce in the neighborhood. This finding is in accordance with those of some previous studies reporting that the spillover effect of PCGDP weakened the agglomeration of the workforce in adjacent regions (27–29).

In this study, PCHE, NCS, and MMR exerted significant negative effects on the agglomeration of institutions, beds, and the workforce. MMR also exerted a positive spatial spillover effect on the agglomeration of beds and the workforce in neighboring provinces. The implementation of the new medical reform in 2009, the promotion of urbanization, and the aging of the population have caused a gradual increase in China's PCHE to meet the growing needs for healthcare services in the country. As a crucial component of total health expenditures consisting of GHE, SHE, and PCHE, the increase in PCHE in one region increases GHE, resulting in a decline in the agglomeration of healthcare resources in that region. Moreover, the increases in PCHE aggravate the burden of residents and decrease residents' consumption in other aspects, thus restricting the health service needs of residents and the economic development of the country and reducing the agglomeration of beds and the workforce. To prevent this situation, the Chinese government has focused on alleviating the medical care burden of residents by implementing various medical reform policies, such as the New Rural Cooperative Medical Insurance Scheme and the Urban Residents Basic Medical Insurance. Thus, each province has made considerable efforts to reduce PCHE through various measures such as guaranteeing quality and cutting down on unnecessary expenses, reducing drug prices, developing medical payment reforms to control the growth of unreasonable PCHE, meeting the health service needs of residents, and enhancing government investment in healthcare resources to develop the economy in the region (30, 31).

For NCS, the number of college students reflects the extent to which one province invests in higher education, thus under a certain limit of government spending, more spending on education indicates that more investment in health is virtually squeezed out, resulting in a decline in agglomeration of beds and health-human resources. This finding is also consistent with prior literature (32, 33). Through the same crowd-out mechanism of PCHE mentioned above, the MMR, widely accepted as a key indicator of health and socioeconomic development, also aggravates the burden of residents and decreases residents' consumption and government spending in other aspects, thus reducing the agglomeration of institutions and beds. Interestingly, MMR had a positive spillover effect on the agglomeration of beds and the health workforce in the neighborhood. This may be due to the "lesson-learning" effect, meaning that the reduction of MMR in one province compels neighboring provinces to implement stronger measures to reduce MMR in their regions, which results in their meeting the unmet health needs of residents and increasing the government health investment and agglomeration of healthcare resources. Some previous studies had supported one region's MMR positive spatial spillover effect on the agglomeration of healthcare resources in the adjacent regions (34, 35).

This study has some limitations that should be addressed. First, the longitudinal data used in this study can only reflect the healthcare resource allocation status at the cut-off point of this work and does not reflect the entire picture. Therefore, a future study on changes in healthcare resource allocation, especially changes due to COVID-19 from 2020, along with comparisons with the present study, can be carried out when the data from 2017 to the present are available. Second, the calculation of the agglomeration index depends on the population in one region instead of its geography. Different results might be obtained when using the geography-based agglomeration index; this should be examined in future studies. Third, we conducted spatial economic analysis by using an adjacency spatial matrix method. Because the construction of the spatial weight matrix includes adjacency, inverse distance, economic characteristics, and nested matrices (36, 37), using different weight matrices can produce different spatial economic regression results. Therefore, a follow-up study should perform a spatial econometric analysis using two other spatial weight matrices and compare their results with those of the present study.

To balance regional differences in the agglomeration index of healthcare resources between the west and east of China, some region-specific measures should be implemented. In light of the national-level China Central Rise and China Western Development strategies, the government has been increasing the number of beds and the healthcare workforce in the central and western regions to achieve the goal of equalizing the east–west allocation of health resources. The government should focus on optimizing the internal distribution structure of healthcare resources in western regions. In accordance with the government's latest health planning, some efforts, such as strictly controlling the number and scale of public hospitals and implementing a quality-oriented institutional development model that improves quality and efficiency instead of the rough quantity-oriented model, are required to reduce the agglomeration of institutions. Moreover, the allocation of health resources in some eastern regions should be optimized. Because healthcare resources in some eastern provinces, especially the workforce, were not adequately agglomerated, the agglomeration index in these regions was <1.0. Therefore, to increase the average level of healthcare resource agglomeration to meet the increasing needs of those regions, the government should increase the number of beds and the workforce in eastern provinces, especially in some key developed megacities with limited healthcare resources or non-central cities in the metropolitan area (38).

Considering the positive effects of PD, GHE, GL, and UL on the agglomeration of institutions, beds, and health workforce, the government should focus on consistently increasing PD, GHE, URDI, and UL. Moreover, the government should consider the negative spillover effects of PD and PCGDP on the workforce of neighboring regions and limit their development to prevent the imbalanced agglomeration of the health workforce. Correspondingly, a cross-regional consortium should be established to rationally allocate the healthcare workforce: provinces with a relatively low workforce, PD or PCGDP could coordinate with those with abundant resources and higher PD or PCGDP for the introduction and training of the healthcare workforce to maintain their balanced agglomeration.

To increase the agglomeration of healthcare resources, the government should consider the negative effect of MMR in one province and a spatial spillover effect in its adjacent provinces. For example, the government can place a high priority on maternal and child health (MCH) services and integrate vertical programs (e.g., family planning) related to MCH and alleviate the medical burden of individual residents (39). In addition, considering the positive spillover effect of MMR on the agglomeration of the beds and health workforce, the government should also construct and strengthen interprovincial cooperation in health planning and jointly formulate health development strategies to reduce MMR. Each province and its adjacent provinces should achieve a synchronous goal in terms of the agglomeration of the healthcare workforce, reduce regional differences in MMR and healthcare resource allocation, and guarantee the common sustainable development of people's health in two regions.

The data in our study were derived from secondary statistical yearbooks, which were officially published by the Chinese government. These yearbooks provide specific indicators for the 31 provinces (municipalities or autonomous regions) in China. However, it is important to note that some key variables, such as the cost of medical services, mortality rates, the density of older adult populations, the prevalence of certain diseases in each region, and the overall level of education, were only available for a subset of provinces (municipalities or autonomous regions) and not uniformly across all provinces in China for the period spanning from 2009 to 2017. To address this issue, we plan to incorporate these omitted indicators in our future research projects. This will enhance the comprehensiveness of our study and provide a more in-depth understanding of the healthcare agglomeration time trends and the determinant factors within China's diverse provinces (municipalities or autonomous regions).

5 Conclusion

The agglomeration of healthcare resources was observed to remain at a relatively higher level of resource allocation on average in China from 2009 to 2017. However, some north–south differential distributions in this agglomeration were noted across provinces. Using spatial econometric models, we identified that PD, GHE, URDI, GL, and UL all had positive significant effects on the agglomeration of beds, whereas both PCHE, NCS, and MMR expense had significant negative effects on the agglomeration of institutions, beds, and the workforce. In addition, PD and PCGDP in one province had negative spatial spillover effects on the agglomeration of beds and the workforce in neighboring provinces. However, MMR had a positive spatial spillover effect on the agglomeration of the beds and workforce in those regions. The findings of this study can help the Chinese government and other developing countries develop appropriate measures to balance regional disparities in the agglomeration of healthcare resources across administrative regions.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Author contributions

ED: Conceptualization, Funding acquisition, Supervision, Writing – original draft, Writing – review & editing. XS: Formal analysis, Investigation, Methodology, Software, Writing – review & editing. YX: Data curation, Formal analysis, Investigation, Methodology, Writing – original draft. YW: Investigation, Methodology, Writing – original draft. TW: Conceptualization, Data curation, Funding acquisition, Project administration, Resources, Supervision, Writing – review & editing. WG: Conceptualization, Funding acquisition, Project administration, Resources, Supervision, Writing – review & editing.

Funding

The author(s) declare that financial support was received for the research, authorship, and/or publication of this article. This research was funded National Social Science Foundation of China General Project (Grant Nos. 18BGL242; 19BGL246); National Social Science Foundation of China Major Project (Grant No. 18ZDA088); Basic Research Plan of Yunnan Provincial Science and Technology Department-Kunming Medical University (202101AY070001-067); Shanghai 2021 "Science and Technology Innovation Action Plan" Soft Science Key Project (Grant No. 21692104900); and National Natural Science Foundation of China (Grant No. 72104182). The funders had no role in the question design, analysis, or interpretation.

Acknowledgments

We are grateful to the Institute of Healthy Yangtze River Delta for their support and contribution to the study.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

References

1. Sha L, Jian G, Yongliang Y, Yaru W. The study of health resources allocation efficiency in Shaanxi province based on DEA method. *Chin Health Serv Manag*. (2012) 29:572–4.

2. Gu J. A spatial study on the allocation of healthcare resource. *Chin J Health Stat*. (2014) 31:21–3.

3. Horev T, Pesis-Katz I, Mukamel DB. Trends in geographic disparities in allocation of health care resources in the US. *Health Policy*. (2004) 68:223–32. doi: 10.1016/j.healthpol.2003.09.011

4. Qiong T, Ping W. An analysis of the gap of urban-rural basic medical and health resources allocation based on GE index method–taking Chengdu as an example. *Consum Econ*. (2013) 29:28–31.

5. Xie X, Wu Q, Hao Y, Yin H, Fu W, Ning N, et al. Identifying determinants of socioeconomic inequality in health service utilization among patients with chronic non-communicable diseases in China. *PLoS One*. (2014) 9:1–14. doi: 10.1371/journal.pone.0100231

6. Li C, Zeng L, Dibley MJ, Wang D, Pei L, Yan H. Evaluation of socio-economic inequalities in the use of maternal health services in rural western China. *Public Health*. (2015) 129:1251–7. doi: 10.1016/j.puhe.2015.07.002

7. Pan L, Wang C, Cao X, Zhu H, Luo L. Unmet healthcare needs and their determining factors among unwell migrants: a comparative study in Shanghai. *Int J Environ Res Public Health*. (2022) 19:5499. doi: 10.3390/ijerph19095499

8. Guo Q, Luo K, Hu R. The spatial correlations of health resource agglomeration capacities and their influencing factors: evidence from China. *Int J Environ Res Public Health*. (2020) 17:8705. doi: 10.3390/ijerph17228705

9. Tiwary B, Nilima N, Kumar A, Kaushik S, Khan MA, Pandey PK. Spatial evaluation of pregnancy loss among child-bearing women in India. *GeoJournal*. (2022) 87:3815–26. doi: 10.1007/s10708-021-10464-9

10. Singh M, Alam MS, Majumdar P, Tiwary B, Narzari H, Mahendradhata Y. Understanding the spatial predictors of malnutrition among 0–2 years children in India using path analysis. *Front Public Health*. (2021) 9:667502. doi: 10.3389/fpubh.2021.667502

11. Nilima N, Kaushik S, Tiwary B, Pandey PK. Psycho-social factors associated with the nationwide lockdown in India during COVID-19 pandemic. *Clin Epidemiol Glob Health*. (2021) 9:47–52. doi: 10.1016/j.cegh.2020.06.010

12. Belotti F, Hughes G, Mortari AP. Spatial panel-data models using Stata. *Stata J*. (2017) 17:139–80. doi: 10.1177/1536867X1701700109

13. Anselin L, Anselin L. The maximum likelihood approach to spatial process models. *Spatial Econ*. (1988) 1:57–80. doi: 10.1007/978-94-015-7799-1_6

14. Dong EH, Li GH, Cai YY, Wang TA. Review on regional difference in healthcare resource allocation. *Chin Health Resour*. (2016) 5:390–3.

15. Li JG, Li ZY. The regional differences of public health service and the countermeasures. *Rev Econ Res*. (2012) 34:62–7.

16. Zhang N, Sun XJ, Li C, Wang X, Liu K. Analyzing the equity of health resources allocation in China based on Theil index. *Chin Health Serv Manage*. (2014) 2:88–91.

17. Feng CY, Liang RH, Jiang XM. Analysis of the government health expenditure in the first decade of Chinese new medical reform(2009-2018):Xinjiang Uygur autonomous region as an example. *Risk Manag Healthc Policy*. (2020) 13:387–95. doi: 10.2147/RMHP.S252652

18. Li D, Zhou Z, Si Y, Xu Y, Shen C, Wang Y, et al. Unequal distribution of health human resource in mainland China:what are the determinants from a comprehensive perspective? *Int J Equity Health*. (2018) 17:1–2. doi: 10.1186/s12939-018-0742-z

19. Zhou Q, Ni J. Perspective on the equity of health human resources allocation in Sichuan Province. *Soft Sci Health*. (2017) 2:18–22.

20. Song S, Yuan B, Zhang L, Cheng G, Zhu W, Hou Z, et al. Increased inequalities in health resource and access to health care in rural China. *Int J Environ Res Public Health*. (2019) 16:49. doi: 10.3390/ijerph16010049

21. Baicker K, Chandra A. Understanding agglomerations in health care In: K Baicker, editor. *Agglomeration economics*. Chicago: University of Chicago Press (2010). 211–36.

22. Wan S, Chen Y, Xiao Y, Zhao Q, Li M, Wu S. Spatial analysis and evaluation of medical resource allocation in China based on geographic big data. *BMC Health Serv Res*. (2021) 21:1–8. doi: 10.1186/s12913-021-07119-3

23. Lou K, Liu B, Wang Y. Surveying the status of medical equipment in county and Township's medical institutions in Western. *China Chin Health Serv Manage*. (2009) 26:617–8.

24. Lu ZH, Meng QY, Wang Y. Equity in basic health human resource allocation in China before and after health reform. *Chin J Public Health*. (2017) 33:1086–868.

25. Wang CL, Liu XP, Xie ZY. Development strategy for prefecture-level public hospital in mid-west area under the new round health refrom in China. *Chin J Health Policy*. (2009) 2:32–6.

26. Wang XF, Hu B. Research on the temporal trend of Chinas driving factors of economy and the differentiation of regional factors–based on the perspective of the supply-side structural factor restructuring. *Economist*. (2016) 11:26–36.

27. Zhao AF, Wen-Lin FU, School B. Regional factor income mobility in China and its influencing elements in the high-quality economic development. *East China Econ Manage*. (2019) 33:47–53.

28. Zhou JL, Gang LI. Distance of regional economic development: new economic geography, element flow and economic policy. *Econ Theory Bus Manag*. (2008) 16:29–34.

29. Wu X, Zhang Y, Guo X. Research on the equity and influencing factors of medical and health resources allocation in the context of COVID-19:a case of Taiyuan, China. *Healthcare*. (2022) 10:1319. doi: 10.3390/healthcare10071319

30. Fang M, Shao-Long WU. Did "new medical and healthcare systems reform" bring medical expenses down:based on the trace data of CHARLS of Gansu & Zhejiang. *J Beijing Adm Inst*. (2017) 6:18–27.

31. Dai SY, Ai-Jun XU. Source analysis on total health expenditure in Jiangsu Province from 2010 to 2017. *Soft Sci Health*. (2019) 33:57–61.

32. Barnett MS, Brooks MR. *China: Does government health and education spending boost consumption?* Washington, DC: International Monetary Fund (2010).

33. Psacharopoulos G, Patrinos HA. Returns to investment in education: a decennial review of the global literature. *Educ Econ*. (2018) 26:445–58. doi: 10.1080/09645292.2018.1484426

34. Owusu PA, Sarkodie SA, Pedersen PA. Relationship between mortality and health care expenditure: sustainable assessment of health care system. *PLoS One*. (2021) 16:e0247413. doi: 10.1371/journal.pone.0247413

35. Odekunle FF. Maternal mortality burden: the influence of socio-cultural factors. *Int J Health Sci Res*. (2016) 6:316–24.

36. Dong K, Guo L. Research on the spatial correlation and spatial lag of COVID-19 infection based on spatial analysis. *Sustain For*. (2021) 13:12013. doi: 10.3390/su132112013

37. Safi A, Wang QS, Wahab S. Revisiting the nexus between fiscal decentralization and environment: evidence from fiscally decentralized economies. *Environ Sci Pollut Res*. (2022) 29:58053–64. doi: 10.1007/s11356-022-19860-1

38. Sheng L. Research on status and countermeasures of medical and health resources allocation in China. *Dev Res*. (2021) 38:68–76.

39. Acharya K, Subedi D, Acharya P. Health facility readiness to provide integrated family planning, maternal and child health(FPMCH)services in Nepal: evidence from the comprehensive health facility survey. *PLoS One*. (2022) 17:e0264417. doi: 10.1371/journal.pone.0264417

frontiers | Frontiers in Public Health

TYPE Original Research
PUBLISHED 11 June 2024
DOI 10.3389/fpubh.2024.1394527

Check for updates

OPEN ACCESS

EDITED BY
Hai Fang,
Peking University, China

REVIEWED BY
Eduardo Fernandez,
University of Salamanca, Spain
Ahmed Mohamed Habib,
Independent Researcher, Zagazig, Egypt
Wasi Ul Hassan Shah,
Zhejiang Shuren University, China

*CORRESPONDENCE
Zhaoting Zhang
✉ zhangzhaoting2024@163.com

RECEIVED 05 March 2024
ACCEPTED 29 May 2024
PUBLISHED 11 June 2024

CITATION
Zhang Z (2024) Survey and analysis on the resource situation of primary health care institutions in rural China.
Front. Public Health 12:1394527.
doi: 10.3389/fpubh.2024.1394527

Survey and analysis on the resource situation of primary health care institutions in rural China

Zhaoting Zhang*

School of Public Policy and Management, China University of Mining and Technology, Xuzhou, China

Background: China's rural population is immense, and to ensure the well-being of rural residents through healthcare services, it is essential to analyze the resources of rural grassroots healthcare institutions in China. The objective is to examine the discrepancies and deficiencies in resources between rural grassroots healthcare institutions and the national average, providing a basis for future improvements and supplementation of rural healthcare resources.

Methodology: The study analyzed data from 2020 to 2022 on the number of healthcare establishments, the capacity of hospital beds, the number of healthcare professionals, and the number of physicians in both rural and national settings. Additionally, it examined the medical service conditions and ratios of township health centers in rural areas to assess the resource gap between rural areas and the national average.

Results: Healthcare establishments: On average, there were 2.2 fewer healthcare institutions per 10,000 persons in rural areas compared to the national average over three years. Hospital beds: On average, there were approximately 36 fewer hospital beds per 10,000 persons in rural areas compared to the national average over three years. Healthcare professionals and physicians: On average, there were about 48 fewer healthcare technical personnel and 10 fewer practicing (including assistant) physicians per 10,000 persons in rural areas compared to the national average over three years.

Conclusion: Compared to the national average, there are significant discrepancies and deficiencies in grassroots healthcare resources in rural China. This underscores the necessity of increasing funding to progressively enhance the number of healthcare institutions in rural areas, expand the number of healthcare personnel, and elevate medical standards to better align with national benchmarks. Improving rural healthcare resources will strategically equip these institutions to cater to rural communities and effectively handle public health emergencies. Ensuring that the rural population in China has equal access to healthcare services as the rest of the country is crucial for promoting the well-being of rural residents and achieving health equity.

KEYWORDS

rural towns, medical institutions, health resources, medical services, national average

1 Introduction

There are large populations spread out over large areas in rural China. With 491.04 million people, or 34.78% of the entire population, residing in rural areas of China as of the end of 2022 (1). There are more than 691,500 administrative villages and 38,602 township-level administrative regions that make up the administrative backbone of rural governance (2).

When it comes to managing and providing services to rural areas around the country, this vast administrative network is crucial. But even with all this infrastructure, rural communities still have a lot of problems, especially when it comes to healthcare (3). The COVID-19 pandemic, which broke out in late 2019, revealed gaps in rural public health interventions and worsened preexisting imbalances (4, 5). There has to be better healthcare infrastructure because the virus was migratory and spread throughout rural areas, putting a burden on medical institutions and resources (4, 6).

There is an immediate need to improve healthcare infrastructure in rural areas due to the changing nature of public health crises. New infectious illnesses and public health emergencies continue to be major concerns, even if the COVID-19 pandemic has highlighted the weaknesses of healthcare in rural areas (7). Regions characterized by high unemployment rates and a lack of health insurance coverage show limited availability of COVID-19 testing and immunization facilities compared to wealthier areas (8). In recent years, the "Healthy China 2030 Strategy" has underscored the importance of health in China, a focus further intensified by the COVID-19 pandemic in 2020 (9), and people started living with anxiety and depression (10). Health issues in rural areas are complicated and unpredictable, made worse by factors including population growth, environmental deterioration, and climate change. To successfully address both the urgent healthcare demands and the long-term capacity to minimize future health crises, it is necessary to enhance the resilience and responsiveness of rural healthcare (11). To help rural healthcare in China progress, this study aims to delve into these complexities and look at how socio-economic issues intersect with healthcare services. The goal is to provide detailed insights and practical recommendations (5).

The safety of people living in rural areas depends on filling this gap. Healthcare for rural people has long been a priority for the World Health Organization, which has pushed for countries to invest in training and maintaining health workers in outlying regions (12). A care pathway is a means to enhance the quality of care across the continuum by improving risk-adjusted patient outcomes, promoting patient safety, increasing patient satisfaction, and optimizing the use of resources (13). To attain healthcare parity between urban and rural communities, academics in China continue to support the call for improved rural medical services (14). The healthcare insurance system is a significant institutional arrangement aimed at safeguarding the health of residents, enhancing their well-being, and maintaining social harmony and stability (15). Similarly, Patients with other diseases like diabetes in rural areas have poor glycemic control and a high incidence of diabetic complications. Patients with diabetes in rural areas have poor knowledge and inadequate health information-seeking behavior (16).

The purpose of this research is to assess the sufficiency of rural Chinese healthcare infrastructure, with an eye on how well it can address the medical service requirements of rural inhabitants. This research seeks to enhance rural public health and medical infrastructure by analyzing the current state of rural health management institutions through a statistical survey. The goal is to identify areas that could be improved and to influence future efforts in this area. To accomplish this, the study will examine a range of indicators, such as the quantity and quality of healthcare facilities and beds, the accessibility of healthcare workers, and the standard of medical treatment provided at the community level. The purpose of the present investigation is to evaluate the efficiency of current healthcare resources in meeting the health demands of rural areas by comparing the results to national averages and standards.

To lay the groundwork for creating individualized interventions, these investigations will shed light on the amount, condition, and degree of uniformity of rural healthcare services. This project seeks to improve the ability of local healthcare institutions in rural areas to respond to public health issues and meet the health security demands of local citizens by providing them with data-driven solutions. Recognizing the larger socio-economic dynamics affecting rural healthcare in China is vital for further explaining the significance of this study (17). Factors such as physical distance, inadequate infrastructure, and discrepancies in resource distribution frequently make it difficult for rural communities to get appropriate healthcare, compared to their metropolitan counterparts. An aging population in rural areas with unique healthcare requirements compounds these problems as younger people leave for cities in search of better prospects. Furthermore, the demand for healthcare resources and services may be shaped by the traditional beliefs and practices of healthcare that are common in rural areas. These practices and beliefs may impact how people seek medical treatment and how they perceive modern medical services.

2 Theoretical background

This study on primary healthcare resource situations in rural China is based on a complex theoretical framework. The study is positioned within frameworks that highlight the significance of primary healthcare in promoting population health and the relevance of equal access to healthcare services, drawing from literature on healthcare policy and management (18, 19). Comprehensive, community-based healthcare practices are particularly important in rural areas, as highlighted by the Alma-Ata Declaration's principles of primary healthcare (20). Study reveals that a significant portion of Egyptian private hospitals exhibit inefficiencies, particularly in technical efficiency (21). Numbers of factors play crucial roles in influencing both operational and financial efficiency, highlighting areas for improvement to enhance overall performance in the healthcare sector.

Further, the research is in line with the WHO's Health Systems Framework, which stresses the importance of healthcare facilities, personnel, and service provision in attaining healthcare coverage for all (22). Research on rural health disparities also helps put the specific problems, such as a lack of funding, qualified medical professionals, and physical space, that rural healthcare systems face into perspective (23). This study intends to promote rural healthcare and address gaps in access and quality of care in China by integrating various theoretical views and contributing to the growth of evidence-based policies (24).

3 Literature review

Persistent difficulties and inequalities in healthcare access and provision are highlighted in the research related to primary healthcare institutions in rural China (25, 26). Inadequate infrastructure, healthcare worker shortages, and resource inequality between urban and rural areas have been identified in earlier research (27, 28). Healthcare utilization and health outcomes in rural communities are influenced by socioeconomic factors, such as poverty and education levels, according to a study (19, 29).

Rural healthcare systems are more susceptible to public health crises like the COVID-19 pandemic, and studies looking at how these systems were handled have highlighted the importance of being better prepared and adaptable (30). Research has also looked at policy initiatives and community-based approaches as potential ways to improve healthcare delivery in rural areas (31, 32). This literature review (Table 1) lays the framework for the current survey and analysis to help address these critical healthcare challenges by combining these findings and providing a comprehensive understanding of the socioeconomic variables that influence the resource status of primary healthcare institutions in rural China.

4 Materials and methods

In China, rural primary medical establishments principally comprise township health clinics, village health centers, rural community health service centers, and others (12). The construction and improvement of these institutions aim to enhance the basic medical service levels of rural healthcare facilities, ensuring that rural residents can access timely and effective medical services. The development and quantity of rural grassroots medical institutions and

TABLE 1 List of relevant publications on the status of primary healthcare in chronological order.

Reported year	Description
2010	Title: Increasing Access to Health Workers in Remote and Rural Areas through Improved Retention: Global Policy Recommendations.
	Authors: World Health Organization
	Key Findings: Highlighted the significance of resolving healthcare inequalities in rural areas by focusing on the needs of those living there.
2010	Title: Evaluated Strategies to Increase Attraction and Retention of Health Workers in Remote and Rural Areas.
	Authors: C. Dolea, L. Stormont
	Key Findings: Addressed issues including workload and professional development possibilities as we looked for ways to keep healthcare workers in remote areas.
2013	Title: Enhancing Staffing in Rural Community Health Centers Can Help Improve Behavioral Health Care.
	Authors: X. Han, L. Ku
	Key Findings: Highlighted the potential of community health centers to increase access to healthcare by studying their efficacy in providing primary healthcare services in rural areas.
2015	Title: Consolidating the Social Health Insurance Schemes in China: Toward an Equitable and Efficient Health System.
	Authors: Q. Meng, et al.
	Key Findings: Results showed that rural areas lacked access to healthcare compared to urban areas, demonstrating the necessity for governmental initiatives to address this issue.
2018	Title: Health Status in a Transitional Society: Urban–Rural Disparities from a Dynamic Perspective in China.
	Authors: J. Jiang, P. Wang
	Key Findings: Examined difficulties such as resource limitations and uneven distribution of healthcare facilities, providing ways for increasing rural healthcare equity.
2020	Title: Impacts of COVID-19 on Agriculture and Rural Poverty in China.
	Authors: J. Huang
	Key Findings: Addressed the ways in which the pandemic affected healthcare systems in rural areas, finding weak spots and highlighting the critical need to fortify these systems immediately.
2022	Title: Resource Allocation Equity in China's Rural Three-Tier Healthcare System.
	Authors: Y. Ao, et al.
	Key Findings: Examination of the challenges of providing healthcare in rural areas and found ways to enhance the distribution of resources and the quality of services offered.
2022	Title: Traditional Chinese Medicine to Improve Rural Health in South Africa: A Case Study for Gauteng.
	Authors: Z. Hu, R. Venketsamy
	Key Findings: Investigated the pros and cons of incorporating traditional medical practices into healthcare systems in rural areas.
2023	Title: Impact of Health Insurance Equity on Poverty Vulnerability: Evidence from Urban–Rural Health Insurance Integration in Rural China.
	Authors: Z. Li, Y. Chen, J. Ding
	Key Findings: Researchers looked into how health insurance plans affect healthcare use in rural areas and what variables impact people's ability to get the treatment they need.
2024	Title: The Future of Healthcare and Patient-Centric Care: Digital Innovations, Trends, and Predictions.
	Authors: S. Aminabee
	Key Findings: Highlighted prospects for utilizing digital solutions after researching the significance of technological advancements in enhancing healthcare access and quality in rural areas.

resources are influenced by various factors, including policies, socio-economic development, changes in population structure, and advancements in medical technology (33). To determine if grassroots medical resources in rural regions are sufficient to meet their development needs, it is necessary to evaluate several indicators and determinants. These include indicators related to physical facilities and medical services. This study aimed to compare healthcare facility resources in rural and national contexts using the following variables: number of healthcare facilities, capacity of hospital beds, healthcare technical workers, and physicians. The goal was to draw comparisons with the national average. All of these things put the state of rural grassroots healthcare facilities in China into context and show their current level of development (5). Factors like changes in the national and rural population structure are also taken into account in the analysis.

4.1 Survey on the number of healthcare institutions and hospital bed capacity

The quantity of healthcare institutions and the number of hospital beds are crucial indicators for assessing the richness of medical resources in a region. They have a significant impact on the accessibility of medical services for residents and the coverage of medical services. The number of healthcare institutions in rural areas reflects the accessibility of the coverage of medical services (34). Rural populations would have easier access to basic medical services, medical services would be less overwhelmed, and healthcare institutions would have more options if there were more of them. A hospital's ability to treat patients is proportional to the number of beds it has. Better preparedness for emergencies, such as infectious disease epidemics, and enhanced skills for disease prevention and control are both contributed by an increase in bed capacity. The term "bed capacity" is used in this study to describe the total number of permanent hospital beds at the end of the year. This number includes both ordinary and basic beds, as well as intensive care beds, beds that are currently being cleaned and repaired, and beds that are temporarily unavailable because of renovations or expansions. The following types of beds are not included: maternity, newborn, delivery room, reserved, observation, temporary extra, and family member beds (35). When evaluating the number of healthcare institutions and hospital bed capacity in rural areas, demonstrating shifts within the rural population must be taken into consideration. According to the data from the seventh national population census, the rural population residing in mainland China was 509.78 million people in 2020, representing for 36.11% of the national population proportion (36). In 2021, according to the statistics from the China National Bureau of Statistics, the permanent rural population was 498.35 million people, constituting 35.28% of the national population (37). By the end of 2022, the China National Bureau of Statistics reported that the permanent rural population was 491.04 million people, making up 34.78% of the national population (1). The total mainland population in China was 1,411.75 million people (excluding Hong Kong, Macau, and Taiwan) (1).

As of the end of 2022, rural areas housed 33,917 township health clinics and 587,749 village health centers in rural areas. Compared to 2021, this represents a decrease of 1,026 and 11,543, respectively. In comparison to 2020, the numbers decreased by 1,845 and 21,079, respectively. Correspondingly, the total number of medical and health institutions nationwide at the end of 2022 was 1,032,918. This marks an increase of 1,983 from the previous year and 9,996 from 2020. The aggregate comprises 36,976 hospitals and 979,768 grassroots medical and health institutions (including community-based institutions and rural health centers). Compared to 2021, hospitals increased by 406, and grassroots medical and health institutions increased by 1,978. In comparison to 2020, hospitals increased by 1,582, and grassroots medical and health institutions increased by 9,732. In terms of bed capacity, as of the end of 2022, rural township health clinics had a total of 1,455,876 beds. This represents an increase of 38,466 beds from 2021 and 65,551 beds from 2020. Nationwide, the total number of beds in medical and health institutions was 9.75 million. Compared to 2021, this is an increase of 299,800 beds, and compared to 2020, it is an increase of 649,200 beds. This total includes 7.663 million beds in hospitals and 1.744 million beds in grassroots medical and health institutions. Compared to 2021, hospital beds increased by 248,700, and grassroots medical and health institution beds increased by 44,600. There was a 531,700-bed increase in hospitals and a 95,000-bed increase in community health centers and other grassroots medical facilities compared to 2020 (38–40). Although the number of rural township health clinics has decreased, the data shows that their bed capacity is on the rise. Table 2 is a statistical table of changes in the number of beds in national and rural health and medical institutions and medical institutions in 3 years from 2020 to 2022. The table counts the increases and decreases in various medical institutions in the past 3 years.

Figure 1 is a chart of the change trends of China's rural township health centers national hospitals and urban community health service institutions from 2020 to 2022. The total number of hospitals in China remained consistent at 35,000, 37,000, and 37,000, respectively. For urban community-based healthcare service institutions, the numbers were 33,000, 34,000, and 36,000 over the same period. Rural township health clinics saw figures of 36,000, 35,000, and 34,000 during the 3 years. One major factor contributing to the decline in rural township hospitals is the ongoing urbanization process in China. As a result, fewer people live in rural areas, which in turn reduces the need for these hospitals. Patients in rural locations sometimes have limited access to treatment beds, few amenities, and as few as one or two healthcare providers at each village health center. Due to a lack of individual analysis, these centers frequently offer healthcare services that are inadequate or nonexistent.

From the trend depicted in Figure 1, the number of township health clinics has been consistently experiencing a gradual decline, while the quantity of hospitals and community health institutions in urban areas has shown a slow but steady upward trend. It is necessary to take population fluctuations into account when analyzing the capacity of rural healthcare institutions and beds to meet developmental needs (41). The following statistical study of healthcare facilities on a national and rural level accounts for population changes. This analysis does not cover public health supervision and healthcare institutions because of their unique focus on the prevention, supervision, and care of residents' health, which sets them apart from healthcare institutions that mainly offer general treatment. In rural areas, village health centers often only have one or two healthcare workers on staff, no treatment beds, and very minimal facilities. As a result, the healthcare services they provide are

TABLE 2 Statistical table of national medical and health institutions and number of beds in 2020–2021.

Number of medical and health institutions and number of beds						
Institutions category	Number of institutions (number)			Number of beds (beds)		
	2020	2021	2022	2020	2021	2022
1. Hospital	35,394	36,570	36,976	7,131,186	7,414,228	7,662,929
Public hospital	11,870	11,804	11,746	5,090,558	5,207,727	5,363,364
Private hospital	23,524	24,766	25,230	2,040,628	2,206,501	2,299,565
Among them: tertiary hospitals	2,996	3,275	3,523	3,002,503	3,230,629	3,445,405
Secondary hospital	10,404	10,848	11,145	2,718,116	2,743,079	2,773,482
First class hospital	12,252	12,649	12,815	712,732	726,054	732,490
2. Professional public health institutions	14,492	13,276	12,436	296,063	301,566	313,558
Among them: Centers for Disease Control and Prevention	3,384	3,376	3,386		-	
Specialized disease prevention and treatment institutions	1,048	932	856	42,323	40,611	39,133
Maternal and child health care institutions, etc.	3,052	3,032	3,031	253,740	260,955	274,425
Health Supervision Institute (Center)	2,934	3,010	2,944			
Family planning technical service agencies, etc.	4,074	2,926	2,219			
3. Community primary medical and health institutions	325,446	343,555	358,102	259,059	282,366	288,549
Among them: community health service center	9,826	10,122	10,353	225,539	239,139	251,453
Community health service station	25,539	26,038	26,095	12,804	12,581	11,601
Clinic (nursing station), etc.	290,081	307,395	321,654	20,716	30,646	25,495
4. Rural Health Center (Room)	644,590	634,235	621,666	1,390,325	1,417,410	1,455,876
Rural and township health centers	35,762	34,943	33,917	1,390,325	1,417,410	1,455,876
rural clinic	608,828	599,292	587,749		-	-
5. Other institutions	3,000	3,299	3,738	24,067	34,540	29,021
Total	1,022,922	1,030,935	1,032,918	9,100,700	9,450,110	9,749,933

Data source: China Health Commission's 2020–2022 China Health Care Development Statistical Bulletin (38–40).

often inadequate (42). Therefore, village-level health centers are excluded from this analysis. According to the data in Table 1, from 2020 to 2022, and excluding specialized public health supervision and healthcare institutions and village health centers, the total number of moderately-sized healthcare institutions in the country was 399,602, 418,367, and 432,733, respectively. Over the 3 years, the total bed capacity of healthcare institutions nationwide was 8,804,637, 9,148,544, and 9,436,375, respectively. From 2020 to 2022, the number of township health clinics in rural areas was 35,762, 34,943, and 33,917, respectively. Over the same period, the bed capacity of rural township health clinics was 1,390,325, 1,417,410, and 1,455,876, respectively. From 2020 to 2022, the total population of mainland China was 1,411.77 million, 1,412.60 million, and 1,411.75 million, respectively. The rural population during the same period was 509.78 million, 498.35 million, and 491.04 million, respectively. Figures 2, 3 show the national and rural healthcare institution-to-population ratios and bed capacity per 10,000 people, respectively. As shown in Figure 2, the national healthcare institution-to-population ratio in 2020 was 2.83 (399,602/141,177 million people), with a rural area ratio of 0.7 (35,762/50,978 million people). Figure 3 shows that in 2020, there were 62.37 beds in healthcare institutions for every 10,000 persons in the United States (8,804,637/141,177 million people) and 27.27 beds in rural areas (1,390,325/50,978 million people). For both 2021 and 2022, comparable computations were performed.

4.2 Investigation of health technical personnel

In 2022, the total number of health technical personnel nationwide reached 11.658 million, an increase of 414,000 compared to 2021 and 980,000 compared to 2020. Both hospitals and community-based healthcare institutions experienced varying degrees of growth in health technical personnel. As of the end of 2022, rural healthcare institutions in China employed 1.991 million health technical personnel, representing an increase of 9,000 compared to 2021 and a decrease of 82,000 compared to 2020 (38–40). Examining the trend in the changes in health technical personnel, there is an inverse relationship between the change in rural health technical personnel and the national trend. This correlation can be attributed to the development dynamics in rural areas and overall changes in the population (Table 3).

To conduct a detailed analysis of the changes in rural health technical personnel, a comparison comparative assessment was undertaken between the ratio of health technical personnel per 10,000 individuals in rural regions and the national average. This assessment aimed to evaluate the disparities and deficiencies in the number of health technical personnel in rural areas due to the distinct focus of professional public health prevention and supervision institutions on residents' health prevention, supervision, and healthcare, differing

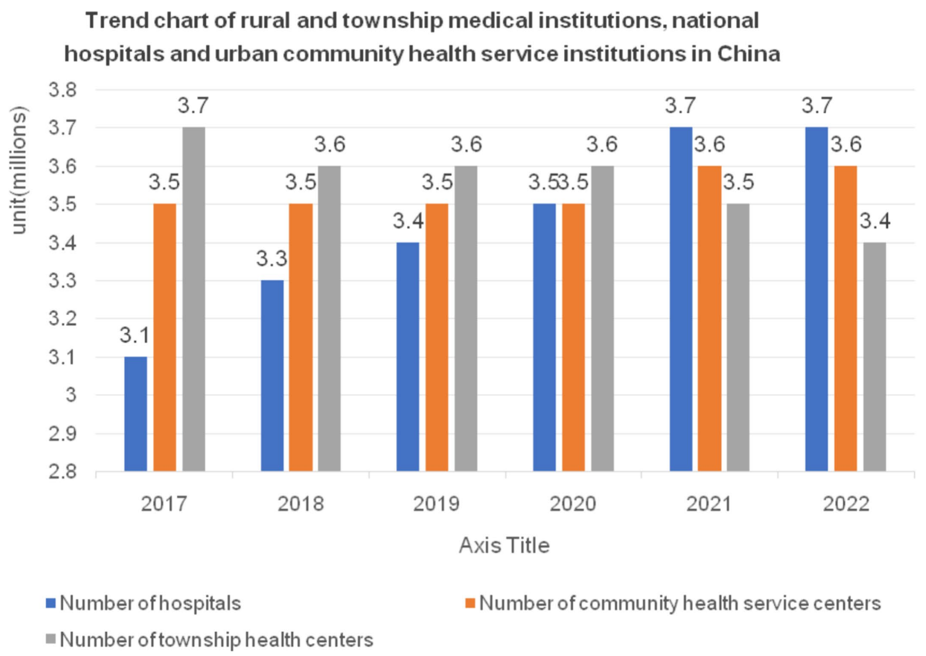


FIGURE 1
Change trends of rural and township medical institutions, national hospitals, and urban community health service institutions in China. Data source: China Health Commission's 2022 China Health Care Development Statistical Bulletin (40).

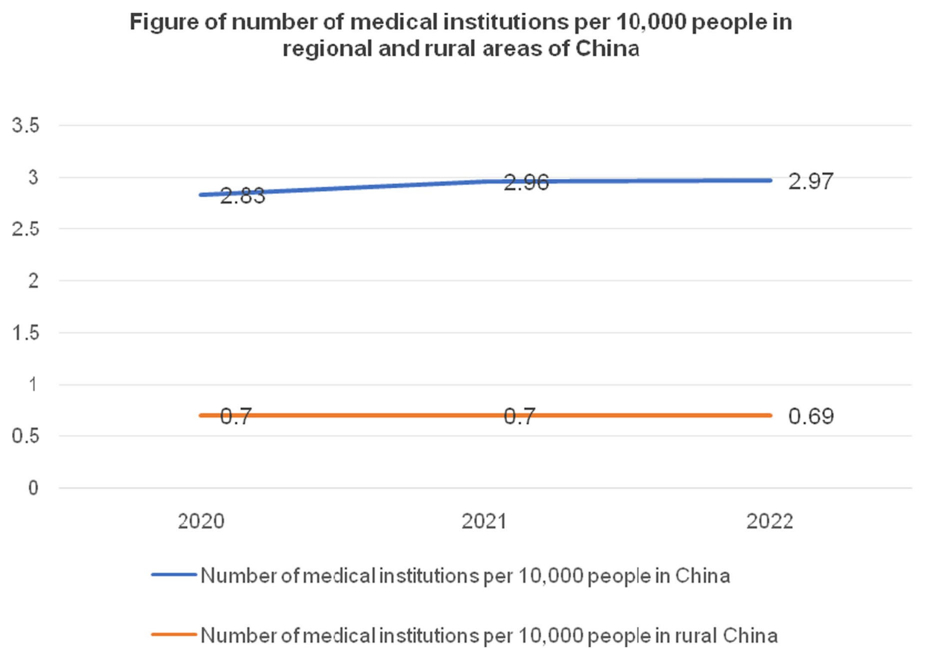


FIGURE 2
Number of medical institutions per 10,000 people nationwide and in rural areas from 2020 to 2022. Data source: China Health Commission's 2020–2022 China Health Care Development Statistical Bulletin (38–40).

from general treatment-oriented healthcare institutions, this analysis excluded health technical personnel from professional public health prevention and supervision institutions for uniformity in comparison. From 2020 to 2022, the number of health technical personnel in rural China was 1.277, 1.285, and 1.326 million, respectively. After excluding public health prevention and supervision personnel, the national total for health technical personnel over these 3 years was 9.951, 10.48, and 10.878 million, respectively. By Considering the total population of mainland China from 2020 to 2022 (1411.77, 1412.60, and 1411.75 million) and the rural population (509.78, 498.35, and

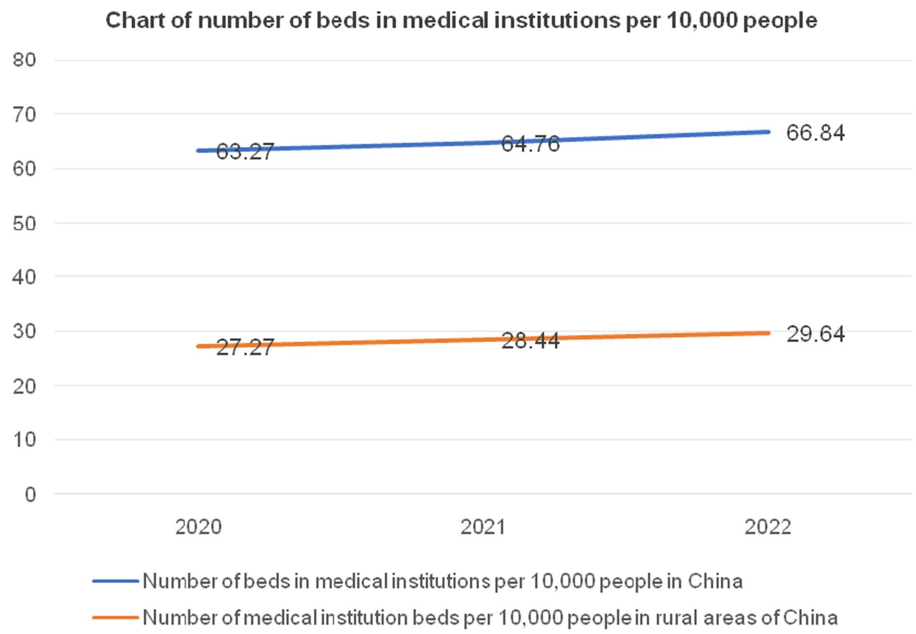


FIGURE 3
Number of beds in medical institutions per 10,000 people nationwide and in rural areas from 2020 to 2022. Data source: China Health Commission's 2020–2022 China Health Care Development Statistical Bulletin (38–40).

491.04 million), the ratio of health technical personnel per 10,000 people for both the nation and rural areas can be seen in Figure 4. In Figure 4, the number of health technical personnel per 10,000 people nationwide in 2020 was 70.49 (995.1/141.177 million people), while in rural areas, it was 25.05 (1.277/50.978 million people). The same methodology was applied for the years 2021 and 2022.

Health technical personnel include practicing physicians, nurses, pharmacists, and other categories, with practicing physicians being the most crucial as they directly interact with patients. According to Article 7 of the "Management Measures for the Registration of Physicians," both practicing physicians and assistant practicing physicians can practice within the administrative division of medical, preventive, and healthcare institutions. However, practicing physicians have a broader range of practice locations. Practicing physicians can practice within the provincial-level administrative division where the medical institution is located, while assistant practicing physicians are limited to the county-level (district) administrative division where the medical institution is located and cannot practice across different locations. As per the "Interim Measures for the Qualification Examination for Medical Practitioners," practicing physicians and practicing (assistant) physicians need to pass the medical qualification examination to obtain their qualifications. Practicing physicians or assistant practicing physicians must hold a "Physician Qualification Certificate" (43). In rural township health centers, there is a significant proportion of practicing (assistant) physicians. Table 4 provides statistics data on practicing physicians and assistant practicing physicians in national and rural township health institutions.

The calculation of the number of practicing physicians (including assistant physicians) per 10,000 people nationwide in Table 3 is as follows: In 2020, it was 28.94 = the total number of practicing physicians and (assistant) physicians in the country (4.086 million people)/the total national population in 2020 (1411.77 million people). The calculation of the number of practicing physicians (including assistant physicians) per 10,000 people in rural areas is as follows: In 2020, it was 19.32 = the total number of practicing physicians and (assistant) physicians in rural areas (52 + 46.5 million people)/the total rural population in 2020 (509.78 million people). The calculation of the number of physicians per 10,000 people in rural areas includes two levels: township health centers and village-level health institutions. The trends in the changes in the number of physicians per 10,000 people nationwide and in rural areas are illustrated in Figure 5.

4.3 Investigation into the medical service situation of rural health institutions

Rural health institutions provide medical services, including the diagnosis and treatment of common illnesses and minor injuries, emergency care for acute diseases and accidental injuries, management of chronic diseases, health check-ups, and other services. The delivery of medical services by rural township health institutions is typically influenced by diverse factors such as regional characteristics, the national healthcare system, and economic conditions (44).

This research project conducted a survey and analysis of the medical services offered by rural health institutions in China, with a focal emphasis on parameters including the count of practicing physicians and assistant physicians in rural township health centers, total outpatient consultations, administration to inpatients care at, I rural township health centers, daily patient load per physician, and daily bed occupancy per physician. Subsequently, these datasets were then compared with the national average to assess the level of medical services provided by rural township health institutions.

Table 5 summarizes and presents these statistics.

TABLE 3 Number of health technicians in various medical institutions across the country from 2020 to 2022.

Institutions category	Number of health technicians		
	2020 年	2021 年	2022 年
1. Hospital	677.5	711.5	735.3
Among them: public hospitals	529.2	552.7	571.7
Private hospital	148.2	158.9	163.6
2. Community primary medical and health institutions	184.7	201.7	212.4
Among them: community health service center	44.4	47.6	50.6
Community health service station	11.4	11.6	11.7
Medical nursing station, etc.	128.9	142.5	150.1
3. Rural health and medical institutions	127,7	128.5	132.6
Among them: rural and township health centers	127.7	128.5	132.6
4. Professional public health prevention and supervision agencies	72.7	76.4	78
Where: Centers for Disease Control and Prevention	14.5	15.8	16.9
Maternal and child health care institutions, etc.	51.8	54.9	55.6
Health Supervision Institute (Center)	6.4	5.7	5.5
5. Other institutions	5.2	6.3	7.5
total	1067.8	1124.4	1165.8

Unit: 10,000 people. Data source: China Health Commission's 2020–2022 China Health Care Development Statistical Bulletin (38–40).

According to the stipulations and calculation rules based on key statistical indicators from the National Bureau of Statistics of China, the interpretation and calculation rules for the relevant indicators in Table 5 are as follows: Total outpatient visits refer to the overall number of medical consultations, including outpatient visits, emergency visits, consultations provided, and medical consultations by the staff of the health center.

This also encompasses individual health check-ups conducted outside the center and health counseling sessions. Physicians' average daily patient load is calculated as the total number of outpatient visits divided by the average number of physicians and further divided by 251. Here, 251 represents the average annual working days in a year, considering a deduction for holidays and rest days.

Taking the actual number of occupied bed days, multiplying it by the hospital's service days (often taken as 365 days), dividing it by the average number of physicians, and then dividing it by 365 is the formula for physicians' average daily bed occupancy. A patient's average length of stay in the hospital is calculated as the number of discharges divided by the total number of bed days occupied by inpatients from admission to discharge. The number of hospital beds, number of practicing physicians and assistant physicians, number of outpatient visits, number of inpatient admissions, bed utilization rate, average length of hospital stay, and other statistics are taken from the National Health Commission of China's Annual Statistical Bulletin on the Development of Health and Health Care, which is where Tables 4, 5 are located.

In Table 5, the calculation for the daily patient load per physician in rural towns and village-level healthcare institutions in 2020 is 10.2, derived as the total outpatient visits (2.53 billion visits) divided by the total number of physicians (52,000 + 46,500) in town hospitals and village-level health institutions, and further divided by 251 days. The calculations for physician daily patient load in 2021 and 2022 in rural areas are performed using the same method. In Table 4, the calculation for the daily bed occupancy per physician in town hospitals in 2020 is 1.35. This is calculated using the actual occupied bed days (139 million bed days) multiplied by the bed utilization rate (50.4%), then multiplied by 365 days, and subsequently divided by the total number of physicians (52,000) in town hospitals, this result further divided by 365 days. As physicians, village-level health institutions in rural areas typically have small scales and no beds for inpatient admission, the physicians in these institutions are not included in the calculation for daily bed occupancy. The calculations for physician daily bed occupancy in 2021 and 2022 in town hospitals are performed using the same method. In Table 5, the calculations for the national average daily patient load per physician and the national average daily bed occupancy per physician follow the same method as described in Table 4.

This methodology that relies on data analysis offers a strong foundation of evidence to create specific policies and initiatives that aim to tackle inequalities in the distribution of healthcare resources in rural areas.

5 Results

Despite continuous government investments in rural healthcare resources, China's healthcare service system still faces issues of unreasonable distribution and configuration of medical resources. The differences seen in the medical resources between the national average and rural areas reflect the significant divide between urban and rural areas in China. The primary cause for this disparity is the "siphon effect" that occurs when large urban hospitals drain the health resources of smaller, community-based medical facilities. Healthcare is an essential kind of human capital. When it is distributed improperly, it worsens the development disparity between rural and urban regions. This misallocation also contributes to systemic problems such as shortages of medical resources and inefficiencies.

The data presented in Table 6 illustrates the differences between rural areas and the national average concerning medical institutions, bed numbers, and other aspects.

In Table 6, the disparity is calculated by subtracting the rural figures from the national figures, with the number of medical institutions per 10,000 people excluding specialized public health supervision and health care institutions, as well as village-level health clinics without beds in rural areas. From Table 7, notable differences are evident between the average quantities in rural areas and the national average in terms of healthcare institutions, bed numbers, health technical personnel, and specialized practicing physicians (including assistants). The average per 10,000 people in rural areas is notably lower than the national average.

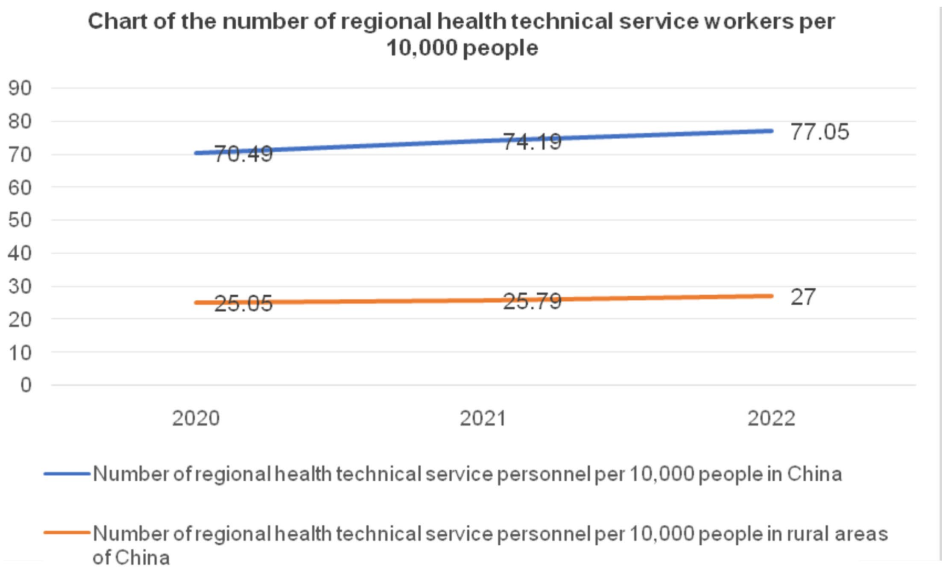


FIGURE 4
Number of health technicians per 10,000 people nationwide and in rural areas from 2020 to 2022. Data source: China Health Commission's 2020–2022 China Health Care Development Statistical Bulletin (38–40).

TABLE 4 Statistics of practicing (assistant) physicians nationwide and in rural areas.

Statistical indicators	2020	2021	2022
Number of practicing physicians and practicing (assistant) physicians nationwide	408.6	428.8	443.5
Number of practicing physicians and practicing (assistant) physicians in rural towns and village health institutions	98.5	100.1	103.9
Number of practicing physicians (including assistants) per 10,000 people nationwide	28.94	30.35	31.41
Number of practicing (assistant) physicians per 10,000 people in rural areas	19.32	20.09	21.16

Unit: 10,000 people. Data source: China Health Commission's 2020–2022 China Health Care Development Statistical Bulletin (38–40).

According to the statistics provided in Table 5, spanning from 2020 to 2022, the average daily number of patient diagnoses and treatments conducted by rural township and village-level practicing and assistant physicians were 10.2, 9.95, and 9.55, respectively.

The average daily number of diagnoses and treatments performed by practicing and assistant physicians nationwide were 7.55., 7.87, 7.56 times, the three-year average number of diagnoses and treatment visits in rural areas is 2.24 times more than the national number [(10.2 + 9.95 + 9.55)/3 − (7.55 + 7.87 + 7.56)/3]; Physician Days of Rural Township Health Centers from 2020 to 2022 The average number of inpatient bed days charged by doctors across the country were 1.35, 1.3, and 1.27, respectively. The average number of inpatient bed days charged by doctors nationwide were 1.56, 1.59, and 1.51. The three-year average number of inpatient bed days charged by doctors in rural areas was 0.25 bed days less than the national average; from 2020 to 2022, the average length of stay for patients hospitalized and discharged from rural township health centers will be 6.6, 6.6, and 6.5 days, respectively. The average length of stay for patients hospitalized and discharged from hospitals and medical institutions across the country will be 8.5, 9.2, and 9.2 days, respectively. For rural patients hospitalized the average number of days per year is 2.4 days less than the national average. The data shows that the number of diagnoses and treatments burdened by rural doctors is greater than the national average, and the pressure on doctors to receive medical treatment is greater than the national average; the average length of stay for rural patients is less than the national average, and the average number of hospitalization beds per day burdened by rural doctors is higher than the national three-year average in rural areas. It is less, indicating that the service conditions for patient treatment in rural medical institutions are lower than the national average, and the medical conditions and accommodation levels of hospitals and other medical institutions outside rural areas are better than those in rural township health centers.

6 Discussion

This study investigates and analyzes the resource status of primary healthcare institutions in rural China, providing insights into medical facilities, technical personnel, and healthcare services, comparing them with the national average to study the deficiencies and disparities in rural healthcare resources. The findings of this study align with prior research that has demonstrated the disparity in healthcare resources between urban and rural areas in China. Public health emergencies provide distinct problems to various circumstances, such as pregnant women, impacting their physiological, psychological, and social well-being. This study specifically examines the circumstances behind the COVID-19 pandemic in China (45). In reality, the Chinese government has consistently rolled out a series of policies and measures to narrow the gap between rural and national healthcare resources. These

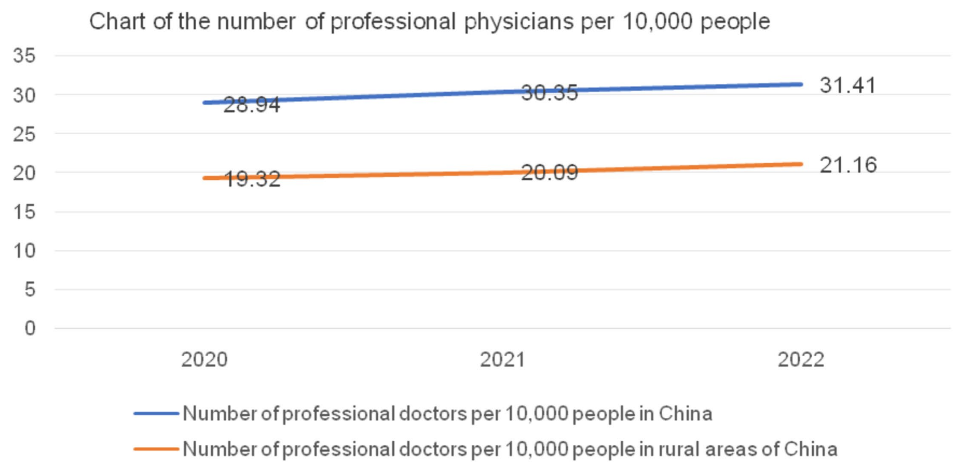


FIGURE 5
Number of practicing physicians (including assistants) per 10,000 people nationwide and in rural areas from 2020 to 2022. Data source: China Health Commission's 2020–2022 China Health Care Development Statistical Bulletin (38–40).

TABLE 5 Medical services in rural health and medical institutions from 2020 to 2022.

Statistical indicators	2020	2021	2022
Number of beds in township health centers (10,000)	139	141.7	145.6
Number of practicing physicians and practicing (assistant) physicians in rural and township health centers (10,000 people)	52	52.5	53.7
Number of practicing physicians and practicing (assistant) physicians in rural village-level health branches (offices) (10,000 people)	46.5	47.6	50.2
Rural diagnosis and treatment visits (100 million visits)	25.3	25	24.9
Number of admissions to rural and township health centers (10,000 persons)	3383.3	3,223	3,239
The average number of diagnoses and treatments performed by doctors at the township and village levels in rural areas every day	10.2	9.95	9.55
The average number of inpatient beds occupied by doctors in township health centers per day	1.35	1.3	1.27
Hospital bed utilization rate (%)	50.4	48.2	46.9
The average length of stay for discharged patients (days)	6.6	6.6	6.5

Data source: China Health Commission's 2020–2022 China Health Care Development Statistical Bulletin (38–40).

measures include increasing investment in rural healthcare, improving the mechanism for training medical personnel, and promoting telemedicine. As early as 2009, China's Ministry of Health, Ministry of Finance, and National Population and Family Planning Commission jointly issued the "Opinions on Promoting the Gradual Equalization of Basic Public Health Services," with the objection of achieving comprehensive coverage of national basic public health service projects and significantly reduce the gap in public health services between urban and rural areas. The document envisioned that by 2020, the mechanism for the gradual equalization of basic public health services would be substantially refined, major diseases and major health risk factors effectively controlled, and the health status of both urban and rural residents further improved. The primary cause of the disparities observed in various rural healthcare resources compared to the national average is the urban–rural gap. As of the end of 2022, China's rural population amounted to 491.04 million, individuals, constituting 34.78% of the total national population of 1,411.75 million (excluding Hong Kong, Macao, and Taiwan the urban population comprises 65.22%, of the total yet hospitals and the majority of public health resources are concentrated in large and medium-sized cities, resulting in differences between national and rural healthcare resources). There has been a gradual decline in the number of township health centers, while the count of hospitals and community healthcare institutions in cities has been consistently increasing. Similarly, the study (46) uncovered a very minor discrepancy between various regions and different tiers of hospitals in China, while certain areas still necessitate enhancement. There is a serious shortage of licensed medical professionals in township hospitals, which forces some facilities to hire unqualified healthcare technicians. Only the director of some township hospitals is qualified to practice medicine as an assistant, but other doctors may acquire rural doctor certifications (47). It is not uncommon for rural township hospitals to have a severe lack of practicing assistant physicians, whereas village health clinics rarely have any on staff. In rural areas, healthcare facilities are struggling to meet the medical treatment demands of their patients due to a lack of healthcare technical staff and practicing assistant physicians qualifying as (48). The primary factor contributing to the deficit of healthcare technical personnel is the relatively higher concentration of medical institutions in urban areas, which attract more healthcare professionals. Certain rural areas face challenges of healthcare professional outflow, as doctors and nurses prefer working in urban healthcare settings. This contributes to the shortage of medical personnel in rural areas.

The government needs to develop epidemic or pandemic strategies using data and customize them for certain demographic

TABLE 6 Medical services in national health and medical institutions from 2020 to 2022.

Statistical indicators	2020	2021	2022
Number of beds in medical institutions nationwide (10,000)	880.46	914.85	943.64
Practicing physicians and (assistant) physicians	408.6	428.8	443.5
Number of diagnosis and treatment visits (100 million)	77.4	84.7	84.2
Number of hospital admissions (10,000 people)	23,013	24,726	24,686
Average number of doctor visits per day	7.55	7.87	7.56
Physicians' average daily charge of inpatient beds	1.56	1.59	1.51
Hospital bed utilization rate (%)	72.50	74.6	71
The average length of stay for discharged patients (days)	8.5	9.2	9.2

Data source: China Health Commission's 2020–2022 China Health Care Development Statistical Bulletin (38–40).

TABLE 7 Differences in health and medical resources between the country and rural areas.

Statistical indicators		2020	2021	2022
Number of medical institutions per 10,000 people	Nationwide	2.83	2.96	2.97
	rural area	0.7	0.7	0.69
	difference	2.13	2.26	2.28
Number of beds in medical institutions per 10,000 people	Nationwide	62.37	64.76	66.84
	rural area	27.27	28.44	29.64
	difference	35.1	36.32	37.2
Number of health technicians per 10,000 people	Nationwide	70.49	74.19	77.05
	rural area	25.05	25.79	27
	difference	45.44	48.4	50.05
Number of practicing physicians (including assistants) per 10,000 people	Nationwide	28.94	30.35	31.41
	rural area	19.32	20.09	21.16
	difference	9.62	10.26	10.25

Data source: China National Health Commission's 2020–2022 China Health Care Development Statistical Bulletin and the above chart calculations.

groups to control the pandemic condition (49). In terms of healthcare institutions and facilities, Chinese hospitals are typically organized into various levels, categorized into first, second, third, and fourth grades (special grade). The classification is primarily determined by the number of beds: fewer than 100 beds, such as township health centers, are considered first-grade hospitals; between 100 and 500 beds, with over 100 beds, are classified as second-grade; over 500 beds are designated as third-grade. Besides these three grades, there is also a fourth grade (special grade) reserved for exceptionally large hospitals. Additionally, hospitals are classified into A, B, and C levels based on technical expertise, medical conditions, and management standards. First-level rural township hospitals do not have the A, B, and C classifications because their technical proficiency and medical conditions do not meet the requirements for these classifications. Second and third-grade hospitals may have A, B, and C classifications. According to statistical data, on the one hand, there are approximately 0.7 healthcare institutions with beds per 10,000 people in rural China, contrasting with around 2.9 healthcare institutions with beds per 10,000 people nationwide. Rural areas fall short of the national average by approximately 2.2 healthcare institutions with beds per 10,000 people. Concerning the bed count in healthcare institutions, rural areas exhibit a shortfall of about 36 fewer beds per 10,000 people compared to the national average. On the other hand, based on technical proficiency, medical conditions, and management standards, rural township hospitals are all considered first-grade hospitals and do not have the A, B, or C classifications that denote comprehensive service hospitals The healthcare conditions in rural areas are rudimentary and cannot handle patients with complex medical conditions. Whether in terms of the quantity of healthcare institutions and facilities or the level of medical technology, rural healthcare resources cannot directly meet the demands of rural residents for medical institutions. A comparison of rural areas to the rest of the country over the last 3 years reveals that there are around 48 fewer healthcare technical personnel per 10,000 people and about 10 fewer practicing (including assistant) physicians per 10,000 people than the national average. According to a study, the digital economy negatively impacts the effectiveness of public health services mainly in two ways: by encouraging the use of social media and by increasing the disparity in healthcare access between urban and rural areas. Furthermore, these effects and methods of transmission display spatial variability (50). In terms of healthcare services in rural healthcare institutions, between 2020 to 2022, the rural average frequency of several medical consultations per person was 2.24 times higher than the national average. Similarly, a prior study investigated the disparities in access to and requirements for general medical care based on the level of rurality among adult inhabitants of Washington State. The study analyzed several obstacles to healthcare access across rural and urban areas, revealing notable disparities in barriers at the system level but not at the individual level. After accounting for the characteristics of the respondents (51), data indicates that rural physicians manage a greater volume of medical consultations per person compared to the national average. Since secondary, tertiary, and special-grade hospitals are concentrated in large and medium-sized cities, rural patients with complex conditions generally seek treatment directly at these urban hospitals (52). With the migration of rural patients to urban areas, the average frequency of medical consultations per person for rural physicians is 2.24 times higher than the national average, suggesting that rural physicians have a relatively larger patient load. From another perspective, this implies a shortage of rural physicians. The average length of hospitalization for rural patients is less than the national average, and the daily average hospital bed days per rural physician are lower over the 3 years compared to the national average. This indicates that the medical conditions in rural township hospitals are below the national average (53). The underlying reason is the imbalance in medical resources and facilities. In urban areas especially large and medium-sized cities, medical facilities are relatively advanced, with high-level hospitals and clinics (54). However, in some rural areas, due to economic constraints, medical facilities may be relatively rudimentary with lower equipment levels. Due to the disparity in medical resources, urban residents typically have access to higher-quality medical services, while rural residents may face issues of inconsistent medical service quality (55).

This study is unique because it conducts a thorough examination of medical facilities, technical people, and healthcare services in rural China. It offers a comprehensive view of the resources available in primary healthcare institutions. The analysis identifies the precise areas where discrepancies exist and need to be addressed by comparing these features with national averages. Although this study offers a thorough examination of resource availability in primary healthcare institutions in rural China, it is crucial to recognize specific constraints. The analysis predominantly depends on statistical data obtained from National Health Commission bulletins, which restricts the scope to quantitative parameters. By integrating qualitative data sources, such as conducting field surveys or interviews with healthcare personnel and patients, a more profound understanding of the actual experiences and difficulties encountered in rural healthcare settings can be obtained (56). In addition, the study's emphasis on national-level patterns may mask regional discrepancies or inequalities within rural areas across various provinces or municipalities. Furthermore, the study does not thoroughly investigate the socioeconomic, policy, or geographic aspects that contribute to the observed differences in healthcare resources between urban and rural areas. Although there are limits, the findings emphasize important gaps and deficits in healthcare resources in rural areas. This underscores the necessity for ongoing efforts to overcome these inequities and guarantee fair access to high-quality healthcare services for rural residents in China (57).

7 Conclusion

The study's findings emphasize the notable discrepancies and inadequacies in the resource condition of primary healthcare institutions in rural China when compared to the national average. The current deficiencies in medical facilities, healthcare technical people, and the quality of healthcare services in rural areas highlight the immediate necessity for focused measures to address the disparity in healthcare resources between urban and rural communities. To tackle these difficulties, it is imperative to adopt a comprehensive strategy that includes augmenting funding for rural healthcare infrastructure, establishing incentive programs and retention initiatives for healthcare practitioners, advocating for telemedicine and remote consultation, enhancing the skills of rural healthcare workers, and fortifying the referral system between primary care facilities and higher-level hospitals. To provide equitable access to quality healthcare services for both urban and rural populations in China, authorities can address these concerns by implementing evidence-based policies and practices. This study offers significant insights and establishes a starting point for monitoring progress and evaluating the effectiveness of programs designed to diminish gaps in healthcare resources between urban and rural areas. It is imperative to recognize that guaranteeing access to high-quality healthcare is not solely a matter of distributing resources, but also a problem of social equity and long-term viability. Allocating resources to enhance rural healthcare infrastructure and staff will positively impact the overall welfare and efficiency of rural communities, ultimately yielding benefits for the entire nation. To tackle the intricate issues encountered by rural healthcare systems in China, it is imperative to have persistent endeavors, cooperation among diverse stakeholders, and sustained dedication in the long run. By giving priority to enhancing healthcare resources in rural areas, the government may make a substantial stride toward attaining universal health coverage and fostering health equity for all its residents.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

ZZ: Writing – review & editing, Writing – original draft, Visualization, Validation, Resources, Investigation, Data curation, Conceptualization.

Funding

The author declares that no financial support was received for the research, authorship, and/or publication of this article.

Conflict of interest

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

References

1. National Bureau of Statistics of China. Government Information Disclosure, Wang Pingping: The total population has declined slightly and the level of urbanization continues to increase. Available at: https://www.stats.gov.cn/xxgk/jd/sjjd2020/202301/t20230118_1892285.html (2023). (Accessed 28 December 2023).

2. Ministry of Civil Affairs of China. Statistical Bulletin on the Development of Civil Affairs. Available at: https://www.mca.gov.cn/n156/n2679/c1662004999979995221/attr/306352.pdf (2022) (Accessed 28 December 2023).

3. Li S, Chen JP, Teng YC. Rural revitalization on the road to common prosperity: issues, challenges, and suggestions. *J Lanzhou Univ*. (2021) 49:37–45. doi: 10.13885/j.issn.1000-2804.2021.03.004

4. Gao WJ, Wang B, Lu J, Yu CQ, Wang L, Li LM. Current status of Covid-19 pandemic and Progress in response strategy. *Chin J Epidemiol*. (2021) 42:22–7. doi: 10.3760/cma.j.cn112338-20201026-01275

5. Yan FR. Equity assessment of resources allocation of Chinese health services. *China Health Resourc*. (2010) 13:296–8.

6. Mourad N, Habib A, Tharwat A. Appraising healthcare systems' efficiency in facing Covid-19 through data envelopment analysis. *Decis Sci Lett*. (2021) 10:301–10. doi: 10.5267/j.dsl.2021.2.007

7. Panneer S, Kantamaneni K, Palaniswamy U, Bhat L, Pushparaj RRB, Nayar KR, et al. Economic and social development challenges of the Covid-19 pandemic: strategies for multiple and interconnected issues. *Healthcare*. (2022) 10:770. doi: 10.3390/healthcare10050770

8. Pacheco CM, Bridges KM, Ellerbeck EF, Ablah E, Greiner KA, Chen Y, et al. Communities organizing to promote equity: engaging local communities in public health responses to health inequities exacerbated by Covid-19–protocol paper. *Front Public Health*. (2024) 12:1369777. doi: 10.3389/fpubh.2024.1369777

9. Shi HY, Zhang YR. Development and validation of Chinese compensatory health beliefs scale. *Front Public Health*. (2024) 12:1271409. doi: 10.3389/fpubh.2024.1271409

10. Alsalman Z, Shafey MM, Al-Khofi A, Alessa J, Bukhamsin R, Bokhuwah M, et al. Barriers to mental health service utilization among medical students in Saudi Arabia. *Front Public Health*. (2024) 12:1371628. doi: 10.3389/fpubh.2024.1371628

11. Schmidt M, Gonda R, Transiskus S. Environmental degradation at Lake Urmia (Iran): exploring the causes and their impacts on rural livelihoods. *GeoJournal*. (2021) 86:2149–63. doi: 10.1007/s10708-020-10180-w

12. Qin Y. M., Zhang L. F., Lin C. M. Progress in comprehensive (2017), 20, 2683–2690. doi: 10.3969/j.issn.1007-9572.2017.22.001

13. Fraticelli L, Verot E, Späth H-M, Genton MC, Kempf C, Clement C, et al. Glossary of healthcare pathways: a methodological approach involving a transdisciplinary team in public health. *Front Public Health*. (2024) 12:1347774. doi: 10.3389/fpubh.2024.1347774

14. Zhang H, Zhou B-B, Liu S, Hu G, Meng X, Liu X, et al. Enhancing intercity transportation will improve the equitable distribution of high-quality health care in China. *Appl Geogr*. (2023) 152:102892. doi: 10.1016/j.apgeog.2023.102892

15. Qin C, Wang X. Does the increase in health insurance benefits have different effects on the health of middle-aged and older people individuals in rural areas? Analysis based on quantile difference-in-differences method. *Front Public Health*. (2024) 12:1322790. doi: 10.3389/fpubh.2024.1322790

16. Wang Y, Zhang Y, Guo T, Han J, Fu G. Full title: knowledge level and health information seeking behavior of people with diabetes in rural areas: a multicenter cross-sectional study. *Front Public Health*. (2024) 12:1285114. doi: 10.3389/fpubh.2024.1285114

17. Zhang Z, Zhang G, Su B. The spatial impacts of air pollution and socio-economic status on public health: empirical evidence from China. *Socio Econ Plan Sci*. (2022) 83:101167. doi: 10.1016/j.seps.2021.101167

18. Hanson K, Brikci N, Erlangga D, Alebachew A, De Allegri M, Balabanova D, et al. The lancet Global Health Commission on financing primary health care: putting people at the Centre. *Lancet Glob Health*. (2022) 10:E715–72. doi: 10.1016/S2214-109X(22)00005-5

19. Li C, Zeng L, Dibley MJ, Wang D, Pei L, Yan H. Evaluation of socio-economic inequalities in the use of maternal health services in rural Western China. *Public Health*. (2015) 129:1251–7. doi: 10.1016/j.puhe.2015.07.002

20. Keith R. *Universal health coverage by 2030, or the right to health? The continued relevance of the Alma Ata principles of voice and equity, through an Intersectoral approach, to reducing global inequalities*. London, England: University of Westminster (2021).

21. Habib AM, Shahwan TM. Measuring the operational and financial efficiency using a Malmquist data envelopment analysis: a case of Egyptian hospitals. *BIJ*. (2020) 27:2521–36. doi: 10.1108/BIJ-01-2020-0041

22. World Health Organization. *Who guidance for climate resilient and environmentally sustainable health care facilities*. Geneva, Switzerland: World Health Organization Editorial Board (2020).

23. Ziller E, Milkowski C. A century later: rural public Health's enduring challenges and opportunities. *Am J Public Health*. (2020) 110:1678–86. doi: 10.2105/AJPH.2020.305868

24. Huang X, Wu B. Impact of urban-rural health insurance integration on health care: evidence from rural China. *China Econ Rev*. (2020) 64:101543. doi: 10.1016/j.chieco.2020.101543

25. Sylvia S, Shi Y, Xue H, Tian X, Wang H, Liu Q, et al. Survey using incognito standardized patients shows poor quality care in China's rural clinics. *Health Policy Plan*. (2015) 30:322–33. doi: 10.1093/heapol/czu014

26. Yip W, Fu H, Chen AT, Zhai T, Jian W, Xu R, et al. 10 years of health-care reform in China: Progress and gaps in universal health coverage. *Lancet*. (2019) 394:1192–204. doi: 10.1016/S0140-6736(19)32136-1

27. Guo B, Xie X, Wu Q, Zhang X, Cheng H, Tao S, et al. Inequality in the health services utilization in rural and urban China: a horizontal inequality analysis. *Medicine*. (2020) 99:E18625. doi: 10.1097/MD.0000000000018625

28. Song S, Yuan B, Zhang L, Cheng G, Zhu W, Hou Z, et al. Increased inequalities in health resource and access to health care in rural China. *Int J Environ Res Public Health*. (2019) 16:49. doi: 10.3390/ijerph16010049

29. Li Z, Zhang L. Poverty and health-related quality of life: a cross-sectional study in rural China. *Health Qual Life Outcomes*. (2020) 18:1–10. doi: 10.1186/s12955-020-01409-w

30. Tan X, Song Y, Liu T. Resilience, vulnerability and adaptability: a qualitative study of Covid-19 lockdown experiences in two Henan villages, China. *PLoS One*. (2021) 16:E0247383. doi: 10.1371/journal.pone.0247383

31. Li B, Chen J. Barriers to community-based primary health care delivery in urban China: a systematic mapping review. *Int J Environ Res Public Health*. (2022) 19:12701. doi: 10.3390/ijerph191912701

32. Zhou S, Zhao C, Huang X, Li Z, Ye R, Shi H, et al. The effect of a community-based, integrated and nurturing care intervention on early childhood development in rural China. *Public Health*. (2019) 167:125–35. doi: 10.1016/j.puhe.2018.11.010

33. Lehmann U, Dieleman M, Martineau J. Staffing remote rural areas in middle- and low-income countries: a literature review of attraction and retention. *BMC Health Serv Res*. (2008) 8:78–83. doi: 10.1186/1472-6963-8-19

34. Strasser R, Kam S, Regalado SM. Rural health care access and policy in developing countries. *Annu Rev Public Health*. (2016) 37:395–412. doi: 10.1146/annurev-publhealth-032315-021507

35. Explanation of the Main Statistical Indicators of the National Bureau of Statistics of China. Available at: https://www.stats.gov.cn/zt_18555/ztsj/hstjnj/sh2009/202303/t20230303_1926973.html (2009). (Accessed 29 December 2023).

36. Bulletin of the Seventh Census of the Central People's Government of China. Available at: https://www.gov.cn/guoqing/2021-05/13/content_5606149.htm (2021) (Accessed 29 December 2023).

37. National Economic and Social Development Statistical Bulletin of the National Bureau of Statistics of China Available at: http://politics.people.com.cn/n1/2022/0228/c1001-32361864.html (2021). (Accessed 29 December 2023).

38. Statistical Bulletin on my Country's Health Care Development in 2020 by the National Health Commission of China. Available at: http://www.nhc.gov.cn/guihuaxxs/s10743/202107/af8a9c98453c4d9593e07895ae0493c8.shtml (2021) (Accessed 29 December 2023).

39. Statistical Bulletin on my Country's Health Care Development in 2021 by the National Health Commission of China. Available at: http://www.nhc.gov.cn/wjw/gongb/list_2.shtml (2022) (Accessed 29 December 2023).

40. Statistical Bulletin on my Country's Health Care Development in 2022 by the National Health Commission of China. Available at: http://www.nhc.gov.cn/guihuaxxs/s3585u/202309/6707c48f2a2b420fbfb739c393fcca92/files/8a3994e41d944f589d914c589a702592.pdf (2023) (Accessed 29 December 2023).

41. Tan JF, Yao YK, Wang QQ. Comparative analysis of health resource development and service utilization in Guangxi's township health centers and the country as a whole. *Health Soft Sci*. (2019) 11:46–50.

42. Ding G. L. *Medical institution marketing, 1st*Edn.; Tsinghua University Press: Beijing, China, (2005); 55–66.

43. Order No. 4 of the Ministry of Health of the People's Republic of China on Interim Measures for Physician Qualification Examination. Available at: http://www.nhc.gov.cn/fzs/s3576/200804/ebf6b26e41544d4c8f236907f7e03592.shtml (1999) (Accessed 29 December 2023).

44. Gao JM, Yang XW, Xue QX, Huang HF. Analysis of rural residents' medical service needs and influencing factors. *China Health Resourc*. (2004) 3:116–8.

45. Su X, Zhang Y, Chen M, Xu X, Liu G. Understanding health education needs of pregnant women in China during public health emergencies: a qualitative study amidst the Covid-19 pandemic. *Front Public Health*. (2024) 12:1271327. doi: 10.3389/fpubh.2024.1271327

46. Zhang J, Jin L, Feng P, Fei Y, Li W, Jiang T, et al. Up-to-date quality survey and evaluation of neonatal screening programs in China. *BMC Pediatr*. (2024) 24:65. doi: 10.1186/s12887-024-04528-1

47. Zhang YF, Wang Y. Survey on rural primary medical and health service networks in underdeveloped areas. *J Chongqing Univ*. (2014) 20:11–7. doi: 10.11835/j.issn.1008-5831.2014.06.002

48. Huang YX, Wang CQ. From mismatch to adaptation: the logical transformation of rural medical and health service accessibility. *Xue Hai*. (2022) 5:90–6.

49. Zhu W. Public attitudes towards Covid-19 prevention and control in China. *Front Public Health*. (2024) 12:1292747. doi: 10.3389/fpubh.2024.1292747

50. Zhao X, Wu S, Yan B, Liu B. New evidence on the real role of digital economy in influencing public health efficiency. *Sci Rep*. (2024) 14:7190. doi: 10.1038/s41598-024-57788-3

51. Graves JM, Abshire DA, Alejandro AG. System-and individual-level barriers to accessing medical care services across the rural-urban Spectrum, Washington state. *Health Serv Insights*. (2022) 15:11786329221104667. doi: 10.1177/11786329221104667

52. Shang FP. Equalization of basic public health services in urban and rural areas: experience and next steps. *Reformation*. (2012) 5:150–3.

53. Opinions of the Ministry of Health, Ministry of Finance, and Population and Family Planning Commission of China on Promoting the Gradual Equalization of Basic Public Health Services. Available at: https://www.gov.cn/gongbao/content/2010/content_1555969.htm (2010) (Accessed 30 December 2023).

54. "Standards for Classified Management of General Hospitals (Trial Draft)" by The Ministry of Health of China. Available at: http://www.100md.com/html/westmed/manage/006/02/0060202.htm (2019) (Accessed 30 December 2023).

55. Dong B. K. The past and future of hospital accreditation in my country. Nursing management in China. (2004), 4, 6–9. Available at: https://www.cqvip.com/qk/87227x/200404/10437356.html

56. Li X, Krumholz HM, Yip W, Cheng KK, De Maeseneer J, Meng Q, et al. Quality of primary health care in China: challenges and recommendations. *Lancet*. (2020) 395:1802–12. doi: 10.1016/S0140-6736(20)30122-7

57. Song X, Han D, Zhang J, Fan J, Ning P, Peng Y. Study on the impact of Covid-19 pandemic on the mental health of Chinese college students: a cross-sectional analysis. *Front Public Health*. (2024) 12:1340642. doi: 10.3389/fpubh.2024.1340642

Frontiers in Public Health

TYPE Original Research
PUBLISHED 03 July 2024
DOI 10.3389/fpubh.2024.1324334

Check for updates

OPEN ACCESS

EDITED BY
Hai Fang,
Peking University, China

REVIEWED BY
Dinesh Pendharkar,
Sarvodaya Hospital and Research Centre, India
Rinshu Dwivedi,
Indian Institute of Information Technology Tiruchirappalli, India

*CORRESPONDENCE
Eduardo J. Fernandez-Rodriguez
edujfr@usal.es
Alberto Garcia-Martin
albergm@usal.es

RECEIVED 19 October 2023
ACCEPTED 19 June 2024
PUBLISHED 03 July 2024

CITATION
Fernandez-Rodriguez EJ, Taboada-Taboada R, Garcia-Martin A, Sanchez-Gomez C, Saez-Gutierrez S, Rihuete-Galve MI and Fonseca-Sánchez E (2024) Study on the additional financial burden of breast cancer disease on cancer patients and their families. Financial toxicity in cancer. *Front. Public Health* 12:1324334. doi: 10.3389/fpubh.2024.1324334

Study on the additional financial burden of breast cancer disease on cancer patients and their families. Financial toxicity in cancer

Eduardo J. Fernandez-Rodriguez[1,2]*, Rocio Taboada-Taboada[1], Alberto Garcia-Martin[3]*, Celia Sanchez-Gomez[2,4], Susana Saez-Gutierrez[1], Maria I. Rihuete-Galve[1,2,5] and Emilio Fonseca-Sánchez[2,5,6]

[1]Deparment of Nursing and Physiotherapy, University of Salamanca, Salamanca, Spain, [2]Institute of Biomedical Research (IBSAL), Salamanca, Spain, [3]Deparment of Labour Law and Social Work, University of Salamanca, Salamanca, Spain, [4]Deparment of Evolutionary and Educational Psychology, University of Salamanca, Salamanca, Spain, [5]Deparment of Medicine, University of Salamanca, Salamanca, Spain, [6]Medical Oncology Unit, University Hospital of Salamanca, Salamanca, Spain

Introduction: Breast cancer is among the most frequently diagnosed cancers worldwide, with 2.3 million new cases reported annually. The condition causes a social and economic impact known as financial toxicity of cancer. The study aims to explore the extra expenses borne by patients and their families on being diagnosed with breast cancer.

Methodology: An observational, descriptive, cross-sectional study was conducted. The data was collected between November 2021 and March 2022 at the Medical Oncology Service in Complejo Asistencial Universitario de Salamanca, Spain. The variables under investigation were additional economic costs, physical disability (as measured by the Barthel Index), instrumental activities of daily living (as measured by the Lawton-Brody Scale), and caregiver burden (measured using the ZARIT scale).

Results: The final sample size was $N = 107$. The study yielded the following outcomes: the median age was 55 years old and the majority of participants were female, with a proportion of 99.1%. The incidence rates for stage I and II were 31.8 and 35.5%, respectively. The median Barthel score was 100 points, while the Lawton and Brody score were 8 points and the ECOG score was 2 points. The analysis of primary caregiver burden resulted in a median ZARIT score of 15 points. The expenses related solely to the cancer diagnosis totaled 1511.22 euros per year (316.82 euros for pharmaceuticals; 487.85 euros for orthopedic equipment; 140.19 euros for home help; and 566.36 euros for housing adaptation or transfer to a hospital). The average annual income before diagnosis was 19962.62 euros. However, after being diagnosed with breast cancer, there is a significant income decrease of 15.91%, resulting in a reduced average annual income of 16785.98 euros. Additionally, a significant correlation was found between total expenditure and the level of dependency ($p = 0.032$) and functional status ($p = 0.045$).

Conclusion: These findings indicate that breast cancer patients experience a considerable economic burden, which worsens as their functional status deteriorates. Therefore, we believe policies should be implemented to help control this economic deterioration resulting from a serious health condition.

KEYWORDS

financial toxicity cancer care, healthcare disparities, cost, socio-economic impact, breast cancer

1 Introduction

Cancer is a widespread ailment with a significant impact on global health. While survival rates have substantially improved over time, cancer diagnosis continues to be one of the primary causes of illness and death worldwide (1).

Cancer is a concern for public health since it influences social, political, economic and cultural transformation. Moreover, breast cancer has a significant impact on the living conditions of a vast segment of society, negatively affecting the quality of life and economic potential of patients and their families due to the substantial social and economic costs associated with the disease (2).

Breast cancer is among the most frequently identified cancers and is expected to affect one in two women during their lifetime. Notably, there were 2.3 million new breast cancer cases globally in 2020 (3), and a total of 34,088 new diagnoses of breast cancer were reported in Spain in 2022 (4).

The cycle of illness affects not only the physical body, but also the personal, family, and environmental spheres. Therefore, a biopsychosocial approach is required. Additionally, the impact of the disease extends beyond the individual and involves their social, familial, and professional surroundings (5).

The patient's life and family members' lives will undoubtedly experience alterations throughout the disease's progression. These changes can impact family and social ties, household duties, and even the patient's and their relatives' employment (6).

The adverse effects resulting from cancer treatment, such as nausea, vomiting, dizziness, diarrhea and constipation, can lead to a decline in life quality. In addition to this, the emotional turmoil faced by many patients, encompassing feelings of sadness, anxiety, fear and depression, as well as their social circumstances exacerbate the situation (7).

Cancer patients have diverse physical and psychological requirements throughout their illness and thus necessitate extensive care, including continuous care (8).

The disease's impact extends to the patient's ability to reintegrate into the labor market due to periodic absenteeism for check-ups (9).

Cancer remains the most significant socio-health issue, despite its high economic burden on both the patient and their family (10).

The estimated cost of cancer in Spain is €19.3 billion, with breast cancer accounting for €2.2 billion (11). In Spain, the Social Security system covers the expenses of patients' care. Nevertheless, patients are still responsible for various expenses, including the cost of dietary products, wigs, transportation from home to hospital, alterations to the home, and changes to their diet.

Additionally, it should be noted that this is not the case in all parts of the world, as the costs of the disease largely depend on current healthcare policies. If oncological treatments are not covered by national health systems, the estimated average cost of breast cancer treatment can vary significantly depending on the country, the type of treatment, and the resources used. In the United States, for example, according to a study by the American Cancer Society, the average cost of breast cancer treatment can range from $20,000 to $100,000 per year, depending on factors such as the stage of cancer, the type of treatment, and whether costs of surgery, radiotherapy, chemotherapy, medications, and continuous care are included. In the United Kingdom, the NHS covers most of the treatment costs for residents, but the costs associated with breast cancer treatment (in terms of market value) can be similar to those in other European countries, ranging from £20,000 to £40,000 per year. Meanwhile, in countries with mixed or private healthcare systems, such as some in Latin America or Asia, costs can vary widely. In Brazil, for example, the cost can range from $15,000 to $25,000 per year depending on the type of treatment and insurance coverage.

Cancer has an economic impact on both patients and their family members, as there is a reduction in income that varies based on the length and severity of the illness. This can result in different types of incapacity. In addition, there are costs associated with treatment such as dietary changes and transportation to the hospital.

Illness costs are accepted by families who try to cope as best they can. However, such costs can harm family dynamics, particularly among vulnerable and low-income groups, where expenses increase and income decreases (2). Families bear 45% of the overall costs of the disease, whereas the remaining 55% of these costs are covered by the health care system (11).

Due to time off work because of treatment side effects or the disease itself, patients may experience a severe decrease in income of up to 75%. The disease may have also caused a decrease in income due to disability. Furthermore, there has been a 15% rise in expenses (11).

Breast cancer results in higher household spending on pharmaceuticals, parapharmaceuticals (particularly skin care products), and orthopedic equipment such as wigs, bra fittings, and breast prostheses. Additionally, third-party assistance is required for any task that the diagnosed individual needs help, support, or supervision with. This incurs additional costs (10).

Moreover, there is an income loss for both the affected individual and their caregiver. Breast cancer has a more significant effect on the patient's income than on the long-lasting costs of the disease, making it challenging to make the financial toxicity of the illness apparent (10).

The economic consequences of cancer result in 24,942 instances of social vulnerability each year solely due to the diagnosis of the disease (11).

Cancer generates a range of needs in patients and families, including social, economic, and employment issues, that are often not considered despite their crucial importance throughout the course of the disease.

We hypothesize that breast cancer patients and their families bear the costs of the disease, which could potentially impact household finances, rather than the Spanish state.

2 Materials and methods

2.1 Aim and design of the study

An observational, descriptive, cross-sectional, non-probabilistic sampling study was designed without replacement with prevalence of breast cancer disease at baseline.

The aim of the study was to examine the current socioeconomic situation of breast cancer patients at the Salamanca Hospital and to assess the repercussions that may exist depending on the personal situation of each patient.

The study sought to demonstrate that breast cancer patients have difficulties related to the disease in biological terms, but also in economic terms and extraordinary expenses (pharmacy, parapharmacy, support products, help from a third person, etc.).

2.2 Participants

Breast cancer patients at the University Hospital of Salamanca were selected for the study according to predetermined inclusion and exclusion criteria.

Inclusion criteria include an oncological breast cancer diagnosis, being a patient at the University Hospital of Salamanca, being over 18 years old, and voluntarily agreeing to participate (by signing an informed consent form).

Exclusion criteria consisted of patients diagnosed with cancers other than breast cancer, those not meeting the age criteria, those who did not consent to participate in the study by not signing the informed consent form, and those who had been previously assessed.

To determine the sample size, we considered the incidence of the disease under study in Spain, in this case breast cancer. In this case, we applied the formula used to estimate the average sample size required. Therefore, we considered that the incidence of breast cancer in the year prior to the study was 34,750 cases, according to the Spanish Society of Medical Oncology (SEOM) (1). Based on this, and assuming a 95% confidence level, with a precision (d) of 3 and a variance (S2) of 250, we obtained a necessary sample size of $N = 107$ individuals. This is adjusted for expected attrition by setting an expected attrition rate (R) of 15%, giving a loss-adjusted sample of 127 individuals.

A sample of 107 participants was obtained between November 2021 and March 2022. The participants were randomly selected without replacement from patients affiliated with the Salamanca Hospital Complex, including those who were admitted to the Medical Oncology department or receiving outpatient care at the Oncology Day Hospital. Details on the sampling procedure can be found in Figure 1.

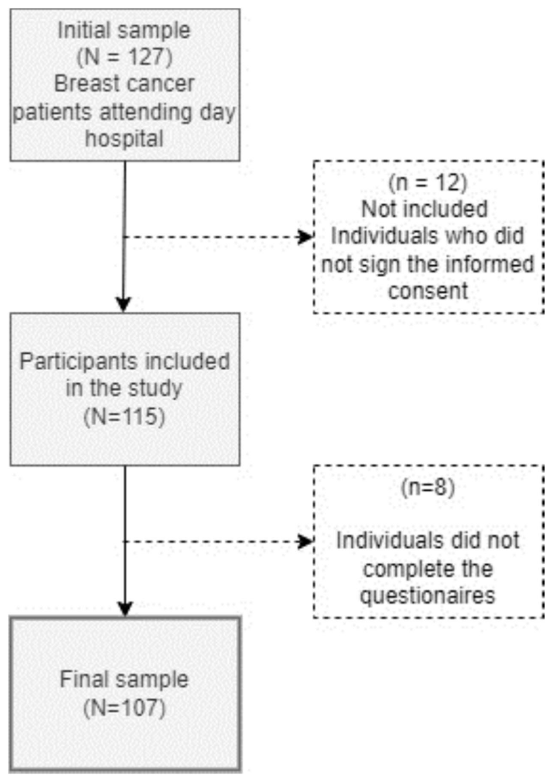


FIGURE 1
Sample selection flowchart.

2.3 Procedure and data collection

The technique used for sample selection was non-probabilistic sampling, simple, without replacement. We used a questionnaire created specifically for this study, which was then passed on to the participants after they had completed the informed consent form. The time taken to complete the questionnaire individually ranged from 10 to 15 min depending on the situation of the patient being interviewed.

After the questionnaire, the patients and caregivers themselves were assessed on different measurement scales chosen on the basis of their reliability and validity to take into consideration the level of dependency, primary caregiver overload and quality of life.

2.4 Primary and secondary outcomes

The primary variable under consideration was the supplementary expenses incurred by breast cancer patients and their families, which are not covered by the publicly-funded Social Security or Public Health System. A study-specific questionnaire was employed to quantify these expenses. The secondary variables comprise patient health data encompassing cancer type, date of diagnosis, disease stage, treatment methods, side effects, and level of dependency. We also captured various socio-demographic data and intervening variables related to the employment and financial circumstances of the patient and their family, such as economic standing, employment status, disabilities, pensions/benefits, economic earnings in the last fiscal year, earnings before diagnosis, and changes in family income.

10.3389/fpubh.2024.1324334

We have considered the study of these outcome variables based on two fundamental factors: firstly, the literature review, understanding and extracting from it those factors that could influence our study; and secondly, based on our daily clinical practice, what patients express to us, and our considerations derived from the experience gained in recent years in the Medical Oncology Service.

2.5 Variables and measurement instruments

Barthel Index (BI) (12): This tool is used to evaluate patients' physical disability and assess their functional disability regarding their activities of daily living (ADLs). The BI is highly reliable and valid, and it is straightforward to use and interpret. The scale is divided into 10 items that measure basic ADLs, including eating, washing, dressing, grooming, bowel movements, urination, using the toilet, transferring, ambulation, and walking up and down stairs. Scoring ranges between 0 and 100. The total of scores determines if a patient is classified as Total, having less than 20 score points, Severe, with between 20 and 35 score points, Moderate, with between 40 and 55 score points, Mild, with greater than or equal to 60 score points or fully independent, having 100 score points.

Lawton-Brody Scale (13): This tool assesses independence and dependence in performing instrumental activities of daily living (IADLs). The scale comprises 8 items, including the ability to use a mobile phone, go shopping, take care of the house, do laundry, use means of transport, be responsible for taking medication or drugs, and handle money. Scores range from 0 to 8. The calculation's outcome can determine the patient's level of dependency, which may fall under Total (0–1 points), Severe (2–3 points), Moderate (4–5 points), Slight (6–7 points), or Independence (8 points).

ZARIT Caregiver Burden Interview (14): is employed to evaluate stress experienced by the primary caregiver of the patient by means of a 22-item questionnaire with 5 possible responses (never, rarely, quite often, almost always). The responses range from 1 (never) to 5 (always). The total scores may lead to no overload (score of 46 or lower), mild overload (score between 47 and 55), or severe overload (score exceeding 55).

ECOG scale (15): The ECOG scale, also known as the "Performance Status," assesses the patient's overall health status and quality of life. It considers the changes in the patient's daily life activities and is divided into five levels or groups from ECOG 0 (full independence) to ECOG 5 (deceased patient) with only one of the items being scored. Technical terms are explained on first use. Results obtained from this assessment can be: ECOG 0—Patients displaying no symptoms and being able to perform daily activities and exertion normally. ECOG 1—Patients experiencing symptoms that obstruct their exertion but are still capable of carrying out daily activities and light work. The patient is confined to bed only during sleeping hours.

ECOG 2—Patients unable to execute any work due to symptoms and are forced to be in bed for several hours a day along with nighttime sleeping hours, but not more than 50% of the time. The patient is able to meet most personal needs independently. According to the Eastern Cooperative Oncology Group (ECOG) criteria, the patient falls under the ECOG 3 category, requiring to be confined to bed for more than half of the day due to symptoms and requiring assistance with most daily activities. In the ECOG 4 category, the patient remains bedridden and needs assistance with all activities of daily living, including personal hygiene, mobilization in bed, and even feeding. Lastly, in the ECOG 5 category, the patient is deceased.

All measurements were recorded on a data collection sheet for each patient and subsequently entered into a database created specifically for this research.

The instruments necessary to obtain the data were administered on a single occasion and were not carried out sequentially in time.

The study's objective and the voluntary nature of participation were communicated to the participants and primary caregivers, who authorized their involvement by signing an informed consent form.

The lead researcher provided the patient with the study questionnaire, which was later retrieved and collected by the same individual. The designated measurement scales were then used to obtain the study results.

The questionnaire and measurement scales, based on the sample size and inclusion/exclusion criteria, provided the requisite data to conduct this study.

2.6 Statistical analysis

Statistical analysis was performed using International Business Machines' (IBM) Statistical Package for the Social Sciences (SPSS) version 25 (IBM Corp., Armonk, NY, United States).

We have carried out a descriptive analysis considering maximum and minimum values, as well as the presence of possible outliers, considering or not their suitability by means of a box diagram as a standardized method.

We performed an analysis of the socio-demographic characteristics of the sample and the scores of the instruments and measurement scales of the study.

The variables were analyzed using Kolmogorov–Smirnov statistics by means of which we were able to determine normality by parametric means (normal variables) or non-parametric means (non-normal or ordinal variables).

In all cases we have described the variables with the corresponding statistics. Normally distributed variables have been defined by means of mean and standard deviation using parametric methods. Variables with non-normal distribution have been defined by median and interquartile range following a non-parametric approach.

Categorical or qualitative variables were defined using frequencies and percentages.

2.6.1 Statistical analysis

In all cases we have described the variables with the corresponding statistics. Normally distributed variables have been defined by means of mean and standard deviation (m and s = following parametric methods). Variables with non-normal distribution were defined by median and interquartile range (M and IQR) following a non-parametric approach.

The normality test oriented most of the calculations toward the non-parametric way ($p < 0.05$).

The analysis of correlations was solved with Spearman's correlation coefficient (Spearman's rho).

In all cases a 95% confidence interval was considered, i.e., an alpha risk, type I error, set at 0.05 ($\alpha = 0.05$); with significance indices of $p < 0.05$. The results obtained have been expressed with the value of the statistic, as well as the *p*-values and those data that are most interesting for the interpretation of the results.

Data were analyzed with the SPSS Statistics version 26.0 software (IBM Corp, Armonk, NY, United States).

2.7 Ethical aspects of the study

The study was conducted in accordance with the Declaration of Helsinki, and approved by the Bioethics Committee of the University of Salamanca (ID507). The Bioethics Committee of the University of Salamanca has favorably agreed to carry out this research with registration number ID507, complying with the ethical requirements for its execution on 3 February 2021.

3 Results

3.1 Descriptive statistics

The final sample of the study comprised $n = 107$ individuals.

Tables 1–3 provide a comprehensive overview of the descriptive data related to the sociodemographic variables and the variables under consideration in the study. The data show that the median age of patients is 55 years, while the median age of primary caregivers is 57 years. There is an overwhelming majority of women, accounting for 99.1% of the sample's gender distribution. Regarding the educational level of the study subjects, primary education predominates, with 43% of the sample. In terms of occupation, the majority are employed by others (43.9%). Additionally, almost half of the sample is married (48.6%). Lastly, concerning the stage of the oncological disease, we observed a higher incidence of stages I and II, with 31.8 and 35.5%, respectively.

In the descriptive analysis of the study variables, it is notable that patients exhibit a median Barthel Index score of 100 points (indicating independence in daily activities), 8 points on the Lawton and Brody scale (indicating independence in instrumental activities of daily living), and 2 points on the ECOG scale. Furthermore, analyzing the primary caregiver's level of burden, a median ZARIT questionnaire score of 15 points was obtained, indicating a high level of burden.

The descriptive analysis of the economic expenses related to the oncological disease is presented below. These results are depicted in Table 3. The average total expenditure amounts to 1511.22 euros per year, expenses solely attributed to the diagnosis of cancer. It is also observed that the average annual income before diagnosis is 19962.62 euros, while after the onset of the oncological disease, it decreases by 15.91%, resulting in an average annual income reduction of 16785.98 euros.

Upon further analysis of different components, a distinction has been made in expenses related to the acquisition of orthopedic material, home assistance, pharmacy, the need for hiring a third party, and the necessity for home adaptation or hospital transfer. The data are presented in Table 4.

TABLE 1 Descriptive analysis of study variables I.

Variable	Median (M)	Interquartile range (RIQ)
Age	55	15
Caregiver age	57	16
Months since diagnosis	12	22
Barthel index	100	20
Lawton Brody scale	8	2
ECOG	2	2
ZARIT questionnaire	15	37

3.2 Analytical statistics

Subsequently, analytical statistics were conducted, initially involving a correlation analysis of the variables under scrutiny.

The first correlation analysis is presented in Table 5, wherein:

A direct correlation is established between Barthel, Lawton Brody, ECOG, and Zarit scores ($p < 0.005$). This implies that higher levels of dependency are associated with a poorer quality of life among cancer patients and a heightened level of burden for the primary caregiver.

A direct correlation is also identified between age and levels of dependency and caregiver burden among cancer patients ($p < 0.005$). In essence, the older the patient, the higher the levels of dependency observed, consequently leading to increased caregiver burden.

Finally, a secondary regression analysis was performed, aiming to ascertain the relationship between expenditure levels and the various variables under examination. The following results were obtained:

A direct relationship exists between the level of dependency, as measured by the Barthel index, and expenses related to home assistance ($r = -0.488$; $p < 0.05$), as well as with expenses associated with home adaptation ($r = -0.252$; $p < 0.05$).

Similarly, a direct correlation is observed between the level of dependency in instrumental activities of daily living, measured via the Lawton Brody scale, and expenses related to home assistance ($r = -0.476$; $p < 0.05$).

Further exploration of the relationship between variables was conducted through a linear regression study, with total extraordinary expenditure and expenditure in each of the studied areas (pharmacy, orthopedics, home assistance, and housing) serving as dependent variables. This analysis yielded statistically significant relationships:

- Total expenditure and level of dependency (Barthel Index), $p = 0.032$.
- Total expenditure and patient functional status (ECOG), $p = 0.045$.
- Expenditure on orthopedic material and patient functional status (ECOG), $p = 0.025$.
- Expenditure on home care and level of dependency (Barthel index), $p = 0.043$.
- Expenditure on housing and level of dependency (Barthel index), $p = 0.033$.

4 Discussion

The main objective of this study was to examine the socioeconomic consequences of breast cancer on patients and their families. Cancer represents one of the most significant health issues worldwide (16–18), affecting individuals to varying degrees and incurring additional expenses that impact their daily lives. This study provides evidence of the costs associated with cancer, with the most significant ones being those related to the acquisition of pharmaceutical materials (€316.82 per year), orthopedic materials (€487.85 per year), home assistance (€140.19 per year), and hospital transportation (€566.36 per year), along with a decrease in income by 15.91%. It is worth noting that previous literature has analyzed these same categories in studies of similar characteristics in other countries (19–21). A clear pattern emerges from the variables analyzed in various studies, which is similar to our findings. These variables include gender, sex, cancer type, stage, educational level, place of residence, employment status, annual household income, months elapsed since diagnosis, disability and type (22–24).

It is crucial to highlight the importance of financial support for cancer patients. Numerous studies, including this one, have demonstrated that the public health system fails to adequately meet the financial needs of patients (25, 26). This shortcoming is particularly evident in Spain, where Dependency Law 39/2006, designed to aid individuals with intensive support needs, has an excessively long resolution period, sometimes extending up to 6 months. This bureaucratic delay not only hinders access to necessary resources at critical times but also exacerbates the financial strain on families already dealing with additional costs associated with the disease, such as uncovered medical expenses, transportation, and home adaptations.

The most tragic aspect of this situation is that many patients who urgently require this support pass away before receiving the necessary assistance. This unfortunate outcome highlights a systemic failure in delivering essential services, underscoring the need for immediate reforms in the process of granting aid under the Dependency Law. The delay in resolving these applications not only has a devastating impact on the quality of life of patients and their families but also perpetuates socioeconomic inequality by leaving the most vulnerable individuals unattended. A review and streamlining of these procedures are imperative to ensure that the public health system fulfills its goal of providing effective and timely support to those who need it most.

The quantity of income for households is greater when the patient was employed or self-employed prior to their diagnosis, as opposed to receiving any disability, retirement, or other benefits. There are many patients in our sample who, due to their diagnosis, are not able to continue working in their own company despite being self-employed and are required to continue paying contributions and other expenses.

Certainly, a cancer diagnosis is accompanied by a decrease in functionality, including impairments in both basic and instrumental activities of daily living (ADLs), and an associated increase in dependence. These issues have been observed in studies that examine a range of aspects, such as patient mobility and levels of autonomy (25, 26). This finding is of significant importance for our research since our results indicate that higher scores on scales assessing patient autonomy correspond to greater healthcare expenditures.

Difficulties arise when deciding to become the primary caregiver for a patient due to the risk of developing claudication, Burnout Syndrome, or overload (16, 27). This is particularly relevant as our study has shown that caregiver overload has a direct impact on the family's expenditure.

Having said all of this, one of the most crucial findings was the identification of a link between cancer and household income. The lower an individual's socio-economic status, the more significant the detrimental impact on their prognosis (28). We can therefore infer that the key factor contributing to the reduction in income is the cancer itself and its progression.

To assess the socio-economic effects on other pathologies, we conducted a comprehensive literature review and identified a significant study in our country that addresses a variety of neurodegenerative conditions.

A study by Garcés et al. (29) featured an extensive patient cohort with various neurodegenerative diseases, such as Alzheimer's and other

TABLE 2 Descriptive analysis of study variables II.

Variable		Frequency	Percentage
Gender	Man	1	0.9%
	Woman	106	99.1%
Marital status	Single	22	20.6%
	Married	52	48.6%
	Separated	19	17.7%
	Widowed	14	13.1%
Level of education	Primary education	46	43%
	Secondary education	33	30.8%
	Higher education	28	26.2%
Profession	Self-employed	9	8.4%
	Employed by others	47	43.9%
	Not in employment	25	23.4%
	Other	26	24.3%
Stage of cancer disease	Stage I	34	31.8%
	Stage II	38	35.5%
	Stage III	18	16.8%
	Stage IV	17	15.9%

TABLE 3 Average descriptive analysis of the financial costs of cancer disease.

Extraordinary expenditure	*N*	Minimum	Maximum	Media	SD
Extraordinary expenditure on pharmaceuticals for oncological disease	107	0	2,100	316.82	284.998
Extraordinary expenditure on orthopedic equipment for oncological disease	107	0	3,300	487.85	636.427
Extraordinary expenditure on home help	107	0	3,300	140.19	533.033
Extraordinary expenditure on housing adaptation or transfer to a hospital	107	0	3,300	566.36	769.090
Amount of annual net household income prior to diagnosis	107	3,000	150,000	19962.62	15452.255
Amount of annual net household income during the last fiscal year	107	2,100	33,000	16785.98	8974.339

TABLE 4 Descriptive analysis of cancer-related economic expenditure.

Expenditure situations		Frequency	Percentage
Expenditure on orthopedic equipment related to oncological disease	No expenditure	38	35.5%
	Less than 600 euros	36	33.6%
	From 600 to 1,200 euro	25	23.4%
	From 1,201 to 1,800 euro	4	3.7%
	From 1,801 to 2,400 euro	2	1.9%
	From 2,401 to 3,000 euro	1	0.9%
	More than 3,000 euro	1	0.9%
Expenditure on home help related to oncological disease	No expenditure	96	89.7%
	Less than 600 euros	7	6.5%
	From 600 to 1,200 euro	0	–
	From 1,201 to 1,800 euro	2	1.9%
	From 1,801 to 2,400 euro	0	–
	From 2,401 to 3,000 euro	0	–
	More than 3,000 euro	2	1.9%
Expenditure on home adaptation or hospital transfer related to the oncological disease	No expenditure	29	27.1%
	Less than 600 euros	47	43.9%
	From 600 to 1,200 euro	17	15.9%
	From 1,201 to 1800 euro	6	5.6%
	From 1.801 to 2,400 euro	2	1.9%
	From 2,401 to 3,000 euro	1	0.9%
	More than 3,000 euro	5	4.7%
Expenditure on necessary third parties related to the oncological disease	No expenditure	77	72%
	Less than 600 euros	11	10.3%
	From 600 to 1,200 euro	9	8.4%
	From 1,201 to 1,800 euro	5	4.7%
	From 1,801 to 2,400 euro	1	0.9%
	From 2,401 to 3,000 euro	1	0.9%
	More than 3,000 euro	3	2.8%
Pharmacy expenditure related to oncological disease	No expenditure	20	18.7%
	Less than 600 euros	74	69.2%
	From 600 to 1,200 euro	12	11.2%
	From 1,201 to 1,800 euro	0	–
	From 1,801 to 2,400 euro	1	0.9%
	From 2,401 to 3,000 euro	0	–
	More than 3,000 euro	0	–

dementias, Parkinson's disease, multiple sclerosis (MS), neuromuscular disorders, and amyotrophic lateral sclerosis (ALS).

The findings closely resemble those of our study. Both neurodegenerative and oncological diseases inflict a substantial socio-economic burden on patients and their loved ones. This burden is shaped by numerous factors, including pharmacy costs, assistive products, home modifications, transportation, and more.

It is worth noting that all illnesses entail significant expenses for their sufferers and families. Regrettably, these increased costs are not covered by the national healthcare system.

The study conducted by Mutyambizi et al. (30) on diabetes at two public hospitals in South Africa affirms that patients are accountable for up to 50% of healthcare expenses, leading to disparities between poor and affluent families and acting as a catastrophic determinant of patients' health.

This study underscores how various pathologies generate costs that are indirectly borne by patients and their families.

The study undertaken by Russella and Gilson (31) examined the direct relationship between health and economic impact in diverse households. The results indicated that chronic or serious illnesses

TABLE 5 Correlation analysis.

Rho de Spearman		Age	Barthel	Lawton Brody	ECOG	ZARIT
Age	Correl. coefficient	1,000	−0.534**	−0.571**	0.505**	0.341**
	Sig.	–	<0.001	<0.001	<0.001	0.003
Barthel	Correl. coefficient	−0.534**	1,000	0.881**	−0.799**	−0.557**
	Sig.	<0.001	–	<0.001	<0.001	<0.001
Lawton y Brody	Correl. coefficient	−0.571**	0.881**	1,000	−0.815**	−0.530**
	Sig.	<0.001	<0.001	–	<0.001	<0.001
ECOG	Correl. coefficient	0.505**	−0.799**	−0.815**	1,000	0.520**
	Sig.	<0.001	<0.001	<0.001	–	<0.001
ZARIT	Correl. coefficient	0.341**	−0.557**	−0.530**	0.520**	1,000
	Sig.	0.003	<0.001	<0.001	<0.001	–

**The correlation is significant at the 0.01 level (two-way).

result in high costs for families and may negatively affect their means of subsistence.

He concluded that in Sri Lanka, where there is a free public health service, household expenditures caused by severe illnesses were indirect costs that arose from the illness and were not paid for by the public service.

The study by Chuma et al. (32) is significant for demonstrating the direct and indirect costs households can incur due to chronic illness. This can exacerbate the socio-economic situation of the patient and family, resulting in decreased well-being.

Financially-stricken households with chronic illnesses are more common among lower-income families, who primarily use the sale of family assets and real estate to fund healthcare costs (32).

Regrettably, the significant impact on quality of life is often overlooked.

Public policies must address situations where not only the disease is significant from a health and biological standpoint, but also from social, socio-economic, and financial perspectives.

Furthermore, it is important to emphasize a noteworthy finding from our study, revealing a direct correlation between individuals' level of dependence and increased financial expenses. This contrasts with the results of Garcia et al. (33) previous studies. Where inconsistent data was observed, a statistically significant relationship could not be established. The studies differed only in their anatomopathological diagnosis; our study solely involved patients diagnosed with breast cancer, whereas the analyzed study included all types of cancer without stratification by diagnosis. This finding may serve as a foundation for future studies.

4.1 Limitations

4.1.1 Direct and indirect causality

We were only able to observe this in patients already diagnosed with oncological disease, but not from the beginning, rendering our study incomplete as we cannot ascertain with total accuracy the evolution of the impact caused.

4.1.2 Lack of evidence and reliability

The bibliographic search conducted has been scarcer than expected, due to resource constraints and the scarcity of scientific evidence in some cases.

4.1.3 Ethics and morality

Money as a taboo subject. By this point, I mean that a significant limitation has been the reluctance of many patients, especially the older adult or women in more traditional settings, to discuss their income. Consequently, many questionnaires had to be discarded, leading to a decrease in the obtained sample size.

Despite findings from multiple studies supporting our hypothesis that cancer deteriorates the functionality of the sufferer and generates additional expenses, we recognize that oncological disease is influenced by multiple factors, with cancer itself being the primary driver of the socioeconomic impact.

The widespread lack of awareness is the main obstacle to addressing this significant problem that affects us all, directly or indirectly, diminishing quality of life.

Based on the findings, it's imperative to further investigate the economic shortcomings stemming from diagnoses of serious illnesses like cancer. This exploration is crucial for gaining a precise understanding of the origins of these financial limitations, with a particular focus on distinguishing between different types of oncological diagnoses. Once these deficits and their causes are identified, it becomes essential to implement necessary changes aimed at alleviating the severe impact of diseases like cancer on individuals' lives. This includes ensuring that economic challenges resulting from the illness do not exacerbate the already significant burden faced by patients and their families.

5 Conclusion

The study has identified various socio-economic challenges encountered by oncology patients, including expenses related to pharmacy, parapharmacy, orthopedic materials, accompanying services, external professional caregivers, or transportation to the hospital. Additionally, the degree of dependency or autonomy affected by the oncological disease impacts socio-economic status, as incapacity often leads to the abandonment of occupations, resulting in a decrease in income. Furthermore, household income experiences a significant reduction when primary caregivers experience overload.

In summary, the overarching conclusion of the study is that the additional expenses incurred by breast cancer patients are primarily attributable to the diagnosis of breast cancer itself.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary material, further inquiries can be directed to the corresponding authors.

Ethics statement

The studies involving humans were approved by the Bioethics Committee of the University of Salamanca. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

EF-R: Conceptualization, Investigation, Methodology, Writing – original draft. RT-T: Formal analysis, Resources, Software, Writing – original draft. AG-M: Conceptualization, Data curation, Methodology, Writing – review & editing. CS-G: Conceptualization, Data curation, Validation, Writing – review & editing. SS-G: Data curation, Investigation, Writing – review & editing. MR-G: Formal analysis, Validation, Writing – review & editing. EF-S: Formal analysis, Methodology, Writing – review & editing.

Funding

The author(s) declare that no financial support was received for the research, authorship, and/or publication of this article.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2024.1324334/full#supplementary-material

SUPPLEMENTARY MATERIAL 1
Bioethics committee approval.

SUPPLEMENTARY MATERIAL 2
Informed consent and information sheet for participants.

SUPPLEMENTARY MATERIAL 3
STROBE checklist.

SUPPLEMENTARY MATERIAL 4
Statistical data study.

SUPPLEMENTARY MATERIAL 5
Questionnaire on the socio-economic impact of breast cancer disease on patients and their families.

References

1. Sociedad Española de Oncología Médica (SEOM). La incidencia del cáncer de mama en España aumenta y supone el 28.9% del total de cánceres en las mujeres, y desciende la mortalidad. *Nota de Prensa*. (2022) Available at: https://seom.org/images/NP_Cancer_de_Mama_SEOM_REDECAN_2022.pdf

2. Campos M, Chaparro OL, Páez A, Quintero N, Solano S, Torres C. Costos directos e indirectos derivados del cuidado familiar del paciente con enfermedad crónica no transmisible. *Aquichan*. (2020) 20

3. Organización Mundial de la Salud (OMS). Cáncer de Mama (en línea). (2021). Available at: https://www.who.int/es/news-room/fact-sheets/detail/breast-cancer#:~:text=El%20c%C3%A1ncer%20de%20mama%20es,de%20mortalidad%20en%20las%20mujeres.

4. Fundación Grupo Español de Investigación en Cáncer de Mama (GEICAM). El cáncer de mama en España: situación actual. Nota de Prensa. (2023). Available at: https://www.geicam.org/sala-de-prensa/el-cancer-de-mama-en-espana.

5. Robert V, Álvarez C, Valdivieso F. Psicooncología: un modelo de intervención y apoyo psicosocial. *Rev Med Clin Condes*. (2013) 24:677–84. Available at: https://reader.elsevier.com/reader/sd/pii/S0716864013702074?token=0EC885561A5D19978C463D09C9BD4F6F41C4DDCE13DCB89F98F16B5678DE6E60606E0A03BC5E649AE41F6DB7A4250B89&originRegion=eu-west-1&originCreation=20230518222220

6. Paredes M. Intervenciones en psicooncología. Asociación Catalana Contra el Cáncer: Abordaje integral del paciente y su familia (2010) Available at: https://associacio.catcancer.eu/art9.pdf.

7. Valentín V, Murillo MT, Valentín M, Royo D. Cuidados continuos. *Una necesidad del paciente oncológico Psicooncología*. (2004) 1:155–64. Available at: https://revistas.ucm.es/index.php/PSIC/article/view/PSIC0404110155A

8. Grupo Español de pacientes con cáncer (GEPAC). Informe sobre las necesidades de los supervivientes de cáncer. (2012). Available at: http://www.gepac.es/multimedia/gepac2016/pdf/informe_melanoma.pdf.

9. Asociación Española Contra el Cáncer (AECC). Toxicidad financiera del cáncer de mama. *Observatorio del Cáncer*. (2020) Available at: https://observatorio.contraelcancer.es/sites/default/files/informes/Toxicidad_financiera_cancer_mama.pdf

10. Wyman O. El impacto económico y social del cáncer en España. *Informe*. (2020) Available at: https://www.oliverwyman.es/content/dam/oliver-wyman/Iberia/Publications/el-impacto-economico-y-social-del-cancer-en-espana.pdf

11. Torres B. Impacto económico del cáncer en las familias [Entrevista]. España: Málaga (2020) Available at: https://www.youtube.com/watch?v=_hNsbofPQ4g.

12. Cid-Ruzafa J, Damián-Moreno J. Valoración de la discapacidad física: el índice de Barthel. *Rev Esp Salud Publica*. (1997) 71:127–37. doi: 10.1590/S1135-57271997000200004

13. Hernández K, Neumann V. Análisis de instrumento para evaluación del desempeño en actividades de la vida diaria instrumentales Lawton y Brody. *Revista Chilena de Terapia Ocupacional*. (2016) 16:55–62. doi: 10.5354/0719-5346.2016.44751

14. Larrian ME, Zegers B, Orellana Y. Traducción y adaptación de una Escala para Evaluar Generatividad en abuelos en Santiago de Chile. *Psyhe*. (2017) 26:1–18. doi: 10.7764/psykhe.26.2.966

15. Alonso A, Gonzalez M. Medidas de capacidad funcional. Valoración clínica del paciente con cáncer. *Editorial Médica Panamericana*. (2006) 20:1–16.

16. Esteban ANP, Torres Contreras CC, Campos de Aldana MS, Solano Aguilar S, Quintero Lozano N, Chaparro Díaz OL. Direct and indirect costs of caring for patients with chronic non-communicable diseases. *Aquichan*. (2020) 20:1–16. doi: 10.5294/aqui.2020.20.2.2

17. Zaharia M. El cáncer como problema de salud pública en el Perú. *Rev Peru Med Exp Salud Publica*. (2014) 30:23–29. doi: 10.17843/rpmesp.2013.301.147

18. Cajamarca-Barón JH. El cáncer y su impacto en salud pública. *Medunab*. (2014) 17:41–5. doi: 10.29375/01237047.1965

19. BOE - Agencia Estatal Boletín Oficial del Estado. Ley 21/2021, de 28 de diciembre, de garantía del poder adquisitivo de las pensiones y de otras medidas de refuerzo de la sostenibilidad financiera y social del sistema público de pensiones. (2021). Available at: https://www.boe.es/buscar/doc.php?id=BOE-A-2021-21788.

20. Castro S, Sosa E, Lozano V, Akhtar A, Love K, Duffels J, et al. The impact of income and education on lung cancer screening utilization, eligibility, and outcomes: a narrative review of socioeconomic disparities in lung cancer screening. *J Thorac Dis*. (2021) 13:3745–57. doi: 10.21037/jtd-20-3281

21. Obeng-Gyasi S, O'Neill A, Zhao F, Kircher SM, Lava TR, Wagner LI, et al. Impact of insurance and neighborhood socioeconomic status on clinical outcomes in therapeutic clinical trials for breast cancer. *Cancer Med*. (2020) 9:7537–47. doi: 10.1002/cam4.3420

22. Endale H, Mulugeta T, Habte T. The socioeconomic impact of cervical cancer on patients in Ethiopia: evidence from Tikur Anbessa specialized hospital. *Cancer Manag Res*. (2022) 14:1615–25. doi: 10.2147/CMAR.S352389

23. Booth CM, Li G, Zhang-Salomons J, Mackillop WJ. The impact of socioeconomic status on stage of cancer at diagnosis and survival: a population-based study in Ontario, Canada. *Cancer*. (2010) 116:4160–7. doi: 10.1002/cncr.25427

24. Byers TE, Wolf HJ, Bauer KR, Bolick-Aldrich S, Chen VW, Finch JL, et al. The impact of socioeconomic status on survival after cancer in the United States: findings from the National Program of Cancer registries patterns of care study. *Cancer*. (2008) 113:582–91. doi: 10.1002/cncr.23567

25. Ingleby FC, Woods LM, Atherton IM, Baker M, Elliss-Brookes L, Belot A. An investigation of cancer survival inequalities associated with individual-level socio-economic status, area-level deprivation, and contextual effects, in a cancer patient cohort in England and Wales. *BMC Public Health*. (2022) 22:90. doi: 10.1186/s12889-022-12525-1

26. Rubino C, Di Maria C, Abbruzzo A, Ferrante M. Socio-economic inequality, interregional mobility, and mortality among cancer patients: a mediation analysis approach. *Socioecon. Plan. Sci.* (2022) 82:101247. doi: 10.1016/j.seps.2022.101247

27. Arık A, Dodd E, Cairns A, Streftaris G. Socioeconomic disparities in cancer incidence and mortality in England and the impact of age-at-diagnosis on cancer mortality. *PLoS One*. (2021) 16:e0253854. doi: 10.1371/journal.pone.0253854

28. Derette K, Rollet Q, Launay L, Launoy G, Bryere JFrench Network of Cancer Registries (FRANCIM group). Evolution of socioeconomic inequalities in cancer incidence between 2006 and 2016 in France: a population-based study. *Eur J Cancer Prev*. (2022) 30:457–61. doi: 10.1097/CEJ.0000000000000656

29. Garcés M, Crespo Puras MDC, Finkel Morgenstern L, Arroyo Menéndez M. Estudio sobre las enfermedades neurodegenerativas en España y su impacto económico y social. (2016).

30. Mutyambizi C, Pavlova M, Hongoro C, Booysen F, Groot W. Incidente, socio-economic inequalities and determinants of catastrophic health expenditure and impoverishment for diabetes care in South Africa: a study at two public hospitals in Tshwane. *Int J Equity Health*. (2019) 18:73. doi: 10.1186/s12939-019-0977-3

31. Russella S, Gilson L. Are health services protecting the livelihoods of the urban poor in Sri Lanka? Findings from two low-income areas of Colombo. *Soc Sci Med*. (2006) 63:1732–44. doi: 10.1016/j.socscimed.2006.04.017

32. Chuma J, Gilson L, Molyneux C. Treatment-seeking behaviour, cost burdens and coping strategies among rural and urban households in coastal Kenya: an equity analysis. *Trop Med Int Health*. (2007) 12:673–86. doi: 10.1111/j.1365-3156.2007.01825.x

33. Garcia A, Fernandez EJ, Sanchez C, Rihuete MI. Study on the socio-economic impact of Cancer disease on Cancer patients and their relatives. *Healthcare (Basel)*. (2022) 10:2370. doi: 10.3390/healthcare10122370

frontiers | Frontiers in Public Health

TYPE Original Research
PUBLISHED 12 July 2024
DOI 10.3389/fpubh.2024.1335115

Check for updates

OPEN ACCESS

EDITED BY
Massimo Massi-Benedetti,
International Diabetes Federation, Belgium

REVIEWED BY
Eduardo Gutiérrez-Abejón,
Universidad de Valladolid, Spain
Abdene Weya Kaso,
Arsi University, Ethiopia

*CORRESPONDENCE
David Steinl
✉ dsteinl@healthecon.com

RECEIVED 08 December 2023
ACCEPTED 01 July 2024
PUBLISHED 12 July 2024

CITATION
Steinl D, Holzerny P, Ruckdäschel S, Fäh D, Pataky Z, Peterli R, Schultes B, Landolt S and Pollak T (2024) Cost of overweight, obesity, and related complications in Switzerland 2021.
Front. Public Health 12:1335115.
doi: 10.3389/fpubh.2024.1335115

Cost of overweight, obesity, and related complications in Switzerland 2021

David Steinl[1*], Pascale Holzerny[1], Stephan Ruckdäschel[1], David Fäh[2,3], Zoltan Pataky[4], Ralph Peterli[5], Bernd Schultes[6], Susanne Landolt[7] and Timo Pollak[8]

[1]HealthEcon AG, Basel, Switzerland, [2]School of Health Professions, Bern University of Applied Sciences (BFH), Bern, Switzerland, [3]Department of Epidemiology, Biostatistics and Prevention Institute, University of Zurich, Zurich, Switzerland, [4]Unit of Therapeutic Patient Education, Division of Endocrinology, Diabetology, Nutrition and Therapeutic Patient Education, World Health Organization Collaborating Centre, Geneva University Hospitals and University of Geneva, Geneva, Switzerland, [5]Clarunis, Department of Visceral Surgery, University Centre for Gastrointestinal and Liver Diseases, St. Clara Hospital and University Hospital Basel, Basel, Switzerland, [6]Metabolic Center St. Gallen, friendlyDocs Ltd., St. Gallen, Switzerland, [7]Novo Nordisk Pharma AG, Zürich, Switzerland, [8]Novo Nordisk Denmark A/S, Copenhagen, Denmark

Background: The prevalence of obesity has increased significantly in recent decades. Today, it is estimated that more than one-third of the world's population has overweight or obesity, rendering it one of the most significant global health concerns. This article provides a current estimate of the direct costs associated with managing overweight and obesity, including treatment of related complications, among adolescents (≥15 years) and adults in Switzerland.

Methods: Prevalence of overweight and obesity based on the BMI reported in the 2017 Swiss Health Survey was extrapolated to 2021. Systematic literature searches were performed to identify treatment costs and epidemiological data of obesity-related complications and costs were extrapolated to 2021. Costing methodology was based on available source data for individual related complications. Treatment costs for complications attributable to overweight and obesity were estimated by applying their population attributable fraction (PAF).

Results: More than 3.1 million inhabitants of Switzerland aged ≥15 years met the criteria for overweight or obesity in 2021. The prevalence of overweight increase over the past decades from 30.4% in 1992 to 41.9% in 2017 while prevalence of obesity doubled from 5.4 to 11.3%. Overall, the total attributable costs of overweight and obesity caused by seven assessed obesity-related complications (asthma, coronary heart disease, depression, diabetes mellitus, hypertension, osteoarthritis, and stroke) are estimated at CHF 3657–5208 million with most of the costs (97–98%) caused by the assessed obesity-related complications. Only 2–3% of the total costs were attributable to the combined direct management of overweight and obesity by bariatric surgery (CHF 83 million), pharmacological therapy (CHF 26 million) and dietary counseling (CHF 18 million).

Conclusion: Overweight and obesity impose a significant cost impact on the Swiss healthcare system, accounting for 4.2–6.1% of total healthcare expenditures in 2021. Notably, direct treatment of overweight and obesity accounts for only 0.08–0.18% of the total healthcare expenditures. The analysis also revealed a significant lack of available health economic evidence, necessitating the use of assumptions and approximations in this estimation. This is noteworthy, as respective data would be available in healthcare systems but are either unpublished or inaccessible.

KEYWORDS

overweight, obesity, epidemiology, treatment, healthcare costs, Switzerland, obesity-related complications, bariatric surgery

1 Introduction

Obesity is a complex, multifactorial, and difficult-to-treat chronic disease that is associated with premature mortality and chronic morbidity such as diabetes, cardiovascular diseases, or malignancies, which may severely compromise patients' life expectancy and their overall quality of life (1, 2). The impairment of activities of daily living and the perceived stigmatization contribute significantly to the burden, resulting in a self-perpetuating cycle that adversely impacts the individual's health, as well as psychological and psychosocial functioning, further solidifying this vicious cycle (3, 4).

In addition to the adverse effects of overweight and obesity on the individual, these conditions also contribute to the development of several noncommunicable diseases from a public health perspective, leading to an increased consumption of healthcare resources with implications for healthcare systems and societies (5, 6). In response to the global rise in obesity prevalence, the World Health Organization (WHO) declared obesity an epidemic in 1997, citing the overwhelming consequences on personal health as well as public healthcare systems (7). The prevalence of obesity has increased significantly in recent decades, with estimates indicating that more than one-third of the world's population has overweight or obesity, rendering it one of the most significant global health concerns (8).

The determination of the health economic costs of a disease is essential for determining preventive measures and decisions about allocation of healthcare budgets. Unfortunately, estimating the cost of obesity is challenging for this chronic condition, that can be thought of as a risk factor for other diseases with a complex health economic footprint. Published data regarding the cost of obesity is rare. Especially for Switzerland, there is only very limited data available with the most relevant publication by Schneider and Venetz in June 2014, which was commissioned by the Federal office of public health (FOPH) (9). The primary objective of the present study therefore was to update a previous cost estimate with most current economic and epidemiologic data. This update focuses on direct costs, i.e., the costs directly incurred by the management of overweight and obesity, as well as the treatment of the seven most health economically impactful obesity-related complications. Indirect costs typically including productivity losses, as well as presenteeism and absenteeism, although significant in their magnitude and a major cost driver for the chronic diseases presented here, play a less important role in public health decision making, although they represent a substantial economic burden. This is due to their inherent challenges of accurately quantifying such costs and the structural allocation of these costs to the social systems rather than healthcare funds, which is why this study focused on estimating of direct costs only.

The direct costs of managing and treating patients with overweight or obesity considered in this study include dietary counseling, pharmacologic therapy, and bariatric surgery, as well as treatment of obesity-related complications (inpatient and outpatient services as well as prescription medications). The obesity-related complications assessed were based on the highest costs attributable to overweight and obesity as reported by Schneider and Venetz in 2014 and include asthma, coronary heart disease (CHD), depression, diabetes mellitus, hypertension, osteoarthritis, and stroke (9). To estimate the costs of the selected obesity-related complications, it was necessary to determine the contribution of overweight and obesity to the occurrence of each disease. The population attributable fraction (PAF) expresses the extent to which a specific risk factor (or group of risk factors) contributes to the burden of a disease (i.e., the incidence of the disease and, if monetary values are assigned, the cost of the disease) (10).

2 Materials and methods

The Body Mass Index (BMI) is an internationally applied measure to classify individuals according to the relationship between their body height and weight and allows comparison of data between populations or longitudinally within a population (11). The range for (non-Asian) adults is defined by the WHO as underweight <18.5 kg/m^2, normal weight 18.5–24.9 kg/m^2, overweight (pre-obesity) 25.0–29.9 kg/m^2 and obesity $\geq$30.0 kg/m^2 (12). These definitions were used in the present analysis.

2.1 Prevalence of overweight and obesity Switzerland

Data from six Swiss Health Survey (SHS) conducted at 5-year intervals since 1992/93 were used to estimate the prevalence of overweight and obesity in adolescents aged 15 years and older and the adult Swiss population (permanent residents, regardless of citizenship status) (13). The adjustment of the population to 2021 was based on the 2017 SHS, the most recent version available at the time of the present study, with linear extrapolation for the Swiss population as reported by the Federal Statistical Office (FSO) for 31.12.2021 (14).

2.2 Dietary counseling costs

The number of dietary consultations was requested from Santésuisse for January to June 2022, as the COVID-19 pandemic led to a reduction in consultations in 2021 and would have underestimated the costs. The number of inpatient and outpatient consultations was requested, broken down by category of consultation (e.g., first, second to sixth) and the corresponding tax point values (15, 16). One tax point value was equal to one Swiss franc (CHF) at the time of this study (17, 18). Due to a lack of available data on underlying diagnoses for dietary counseling, expert interviews were conducted to inquire about the proportions of counseling due to obesity and overweight.

2.3 Pharmacology therapy costs

Swiss market data was available detailing anti-obesity medications (AOM) packages sold including orlistat and liraglutide for January to June 2022, to account for changes in market patterns following the initiation of reimbursement of liraglutide in 2020 for treatment of overweight and obesity in Switzerland (19).

2.4 Bariatric surgical therapy costs

The swissDRG Datenspiegel v.11 was systematically searched for all Swiss Classification of Procedures Classification (CHOP) codes designated by the Swiss Society for the Study of morbid Obesity and metabolic Disorders (SMOB) for bariatric surgeries in 2019 (20, 21). Information was extracted including number of performed procedures per diagnosis related group (DRG) and average DRG prices. Classification and allocation to a DRG was based on treatment type and complexity. Bariatric surgery costs were estimated based on the number of procedures performed in 2019, as the COVID-19 pandemic led to a reduction in surgical procedures performed in 2021 and would have underestimated the costs. Data for 2022 were not available at the time of preparation.

2.5 Cost of selected overweight and obesity-related complications

Selection of obesity-related complications was based on the highest cost attributable to overweight and obesity in 2012 and included asthma, CHD, depression, diabetes mellitus, hypertension, osteoarthritis and stroke (9). Cost of illness were multiplied with the specific PAF for each disease to estimate the fraction of cost that are attributable to overweight and obesity.

To identify respective cost data as well as data for PAF estimation, two systematic literature searches were performed. The search strategy is detailed in Supplementary Tables S8, S9.

1. Systematic literature search to identify costs of selected obesity-related complications: MEDLINE, guideline search portals (AWMF, G-I-N), selected medical societies (SMOB, SGE, SGES, SGED,) and Swiss bodies of interest (BAG, BFS, Obsan, Swiss Medical Board)
2. Systematic literature search to identify relative risks (RR), odds ratios (OR) or PAF of selected obesity-related complications regarding the BMI: MEDLINE

In accordance with established protocols, duplicates within the search results were removed, and a title and abstract screening was performed to identify relevant publications, which were then subjected to a comprehensive full-text assessment. Publications were included for analysis if they addressed the research question and provided Swiss data. If neither Swiss nor data for countries with a comparable socio-economic structure (preference given to neighboring countries with similar health systems, e.g., Germany) were available, the best available evidence was applied under consideration of data validity as well as comparability to Switzerland. Subsequently, additional cost data from Germany, France and the Netherlands and reported data for RRs, ORs or PAFs based on analyses of German, French, UK, USA, Swedish, Finnish datasets as well as a European meta-analysis were used and discussed in the result section of this publication.

2.6 Extrapolation of costs for Switzerland 2021

Relevant costs of identified publications were converted to Swiss Francs (CHF) in a two-step method involving conversion and extrapolation. First, all costs data of foreign currency were converted to CHF by applying the Purchasing Power Parity (PPP) for that respective source year (22). In a second step, the cost data in CHF for that source year prices were extrapolated to 2021 price level based on the annual changes in the Consumer Price Index (CPI, “Landesindex der Konsumentenpreise”) (23).

An alternative extrapolation based on the annual changes in total healthcare expenditures was performed and is shown in the appendix for the purpose of comparison with Schneider and Venetz 2014 (see Supplementary Tables S6, S7) (24). However, the extrapolation based on CPI is preferred, as it is more sensitive for individual cost components and less prone to grossly overestimate cost data from older sources. After conversion to 2021 CHF price levels, costs were adjusted to the Swiss population of adolescents aged 15 years and older and adults in 2021 based on linear extrapolation from data reported by the FSO for 31.12.2021 (14).

2.7 Estimating the cost of selected complications attributable to overweight and obesity

The costs of treating overweight and obesity-related long-term complications were estimated using PAFs. Wherever possible, published RRs or ORs from two independent sources were used to calculate two PAFs to minimize bias and a range is presented (see Table 1). Disease-specific PAFs were calculated based on the RR (or OR) reported in the identified publication for both overweight and obesity according to the formula with (p) as the SHS 2017 prevalence of overweight and obesity, respectively, and the corresponding disease-specific RR (or respectively):

$$PAF = \frac{p(RR-1)}{p(RR-1)+1}$$

For three diseases (asthma, diabetes mellitus and stroke), PAFs reported by Swiss TPH were directly applied (see Table 1) (10).

TABLE 1 Population attributable fractions (PAF) for Switzerland for selected diseases by overweight and obesity.

Disease	PAF overweight $25 \leq BMI < 30$	PAF obesity $BMI \geq 30$	References
Asthma	6.2*	6.4*	Zemp Stutz et al. (10)
	20.3*	18.7*	Ma et al. (25)
CHD	14.1*	11.3*	Flint et al. (26)
	6.6	4.7	Liu et al. (27)
Depression	3.7*	5.4*	Luppino et al. (28)
Diabetes mellitus	16.2*	42.9*	Davin et al. (29)
	38.4*	41.4*	Zemp Stutz et al. (10)
Hypertension	18.1*	16.8*	Davin et al. (29)
	23.7*	24.9*	Guh et al. (30)
Osteoarthritis (hip)	13.3*	15.7*	Lohmander et al. (31)
	14.9*	14.4*	Holliday et al. (32)
Osteoarthritis (knee)	35.5	34.3	Lohmander et al. (31)
	23.8	24.7	Muthuri et al. (33)
Stroke	5.9*	5.4*	Zemp Stutz et al. (10)
	18.3*	17.4*	Winter et al. (34)

*Weighted mean to account for differences between males and females in the respective incidence/prevalence.
BMI, Body mass index; CHD, Coronary heart disease; PAF, Population attributable fraction.

3 Results

3.1 Prevalence of overweight and obesity in Switzerland in 2021

Over the past 25 years, the percentage of people living with overweight and obesity among adolescents aged 15 years and older and adults in Switzerland has increased significantly from 30.4% in 1992 to 41.9% in 2017 (see Figure 1). The observed prevalence of overweight was 25.0% in 1992 and 30.6% in 2017. Both sexes experienced an equal increase in the prevalence of overweight over time with men reporting a prevalence twice as high as women in absolute numbers. Specifically for obesity, the prevalence in Switzerland doubled from 5.4% in 1992 to 11.3% overall in 2017 (men: 6.1% to 12.3%; women: 4.7% to 10.2%), with the increase evenly distributed across all age groups.

Extrapolating from the 2017 SHS results, more than 3.1 million Swiss residents aged 15 years and older are considered having overweight or obesity based on the definition of $BMI \geq 25 kg/m^2$. The number of patients with overweight or obesity is higher in men (1.8 million) compared to women (1.3 million).

3.2 Direct cost of overweight and obesity

Treatment of overweight and obesity in Switzerland through lifestyle changes include a combination of approaches including dietary education, exercise, physiotherapy, and general behavioral therapies with weight-reducing drugs and/or bariatric surgery as a potential add-on therapy.

3.2.1 Dietary counseling

Extrapolated data provided by Santésuisse for Switzerland in 2022 amounted to 429148 dietary consultations (see Supplementary Table S1). The experts consulted estimate that outpatient dietary consultations for overweight and obesity account about 80% of the reported outpatient consultations. For inpatient consultations, this rate is lower at about 20%, because inpatient consultations focus primarily on dietary therapy during hospitalization for conditions such as gastrointestinal surgery, cardiovascular events, renal disease, severe malnutrition, diabetes mellitus and others.

A total of 230,481 consultations attributable to overweight and obesity were estimated for 2022 (see Supplementary Table S1). Based on the currently valid tariff contracts, the total costs for dietary consultations in Switzerland for 2022 is estimated at CHF 18.3 million overall, with 84% of the costs attributable to outpatient dietary consultations (CHF 15.4 million) (15, 16).

3.2.2 Pharmacological therapy

Anti-obesity medication (AOM) approved by Swissmedic for weight reduction include orlistat and liraglutide for adult patients presenting with obesity ($BMI \geq 30 kg/m^2$) or for patients presenting with overweight (orlistat: $BMI \geq 28 kg/m^2$; liraglutide: $BMI \geq 27 kg/m^2$) and at least one weight-related comorbidity (pre-diabetes or diabetes mellitus type 2, arterial hypertension, or dyslipidemia) (35, 36).

Based on confidential sales data for the first half of 2022, it is estimated that 184,461 packages of AOMs were sold, representing an estimated total sales volume of CHF 26.0 million in Switzerland in 2022 (37) (see Table 2). Notably, experts interviewed for this study indicated that a significant portion of this amount will not be covered by the Swiss mandatory health insurance (OKP) but will be paid out-of-pocket by the patients themselves.

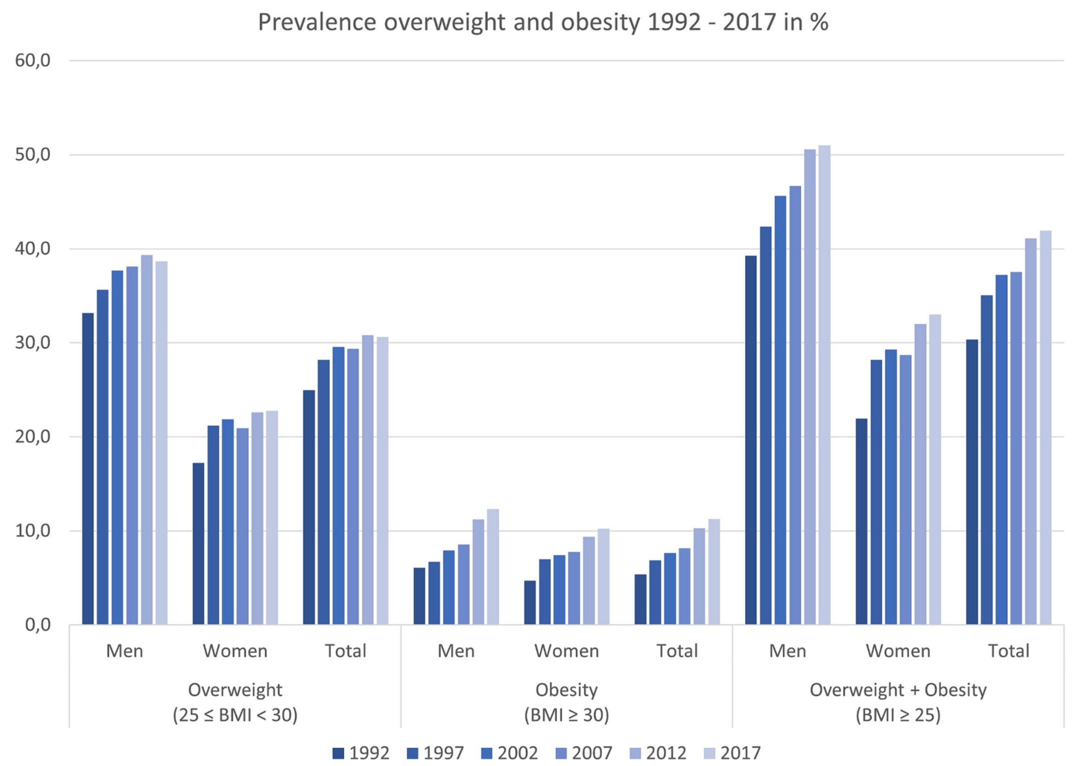


FIGURE 1
Overall development of overweight and obesity prevalence in Switzerland from 1992 to 2017 (Inhabitants ≥15 years of age) (13).

3.2.3 Bariatric surgical therapy

Of the 4926 bariatric surgeries performed in Switzerland 2019, the most common procedures were forms of gastric bypasses and sleeve resection, that together made up 73.7 and 20.4%, respectively (see Supplementary Tables S2, S3). Other bariatric procedures were available and included restrictive gastric procedures (e.g., implementation of an adjustable gastric band; pouch-forming in vertical banded gastroplasty), but are historically declining in total numbers of procedures in favor of the more effective procedures that are gastric bypasses and sleeve resections (38). Biliopancreatic diversion, although highly effective, is performed very rarely due to complexity of the procedure and negative long-term effects.

The total costs of bariatric surgeries in Switzerland in 2021 is estimated at CHF 82.6 Mio, based on the number of procedures per DRG and the average costs of each DRG in 2019, adjusted for population increase and inflation with an average costs of CHF 16,768 per procedure (see Table 2).

3.3 Costs of selected overweight and obesity-related complications

3.3.1 Asthma

In 2017, overall 5.1% (4.6% in men and 5.6% in women) of the Swiss population ≥ 15 years of age stated they had asthma within the last 12 months (39). There are 377,567 people (166,245 men, 211,322 women) in Switzerland suffering from asthma in 2021 (14, 39). To estimate the costs for 2021, published Swiss representative data reported by Scuzs et al. was extrapolated (40). Using the described extrapolation methods for annual changes in CPI in healthcare and adjustment to the 2021 Swiss population, the resulting direct costs for asthma in Switzerland 2021 were CHF 574 million (including inpatient CHF 340.9 million, outpatient: CHF 77.4 million and prescribed medication CHF 155.6 million; see Supplementary Table S5).

PAFs for asthma due to overweight and obesity were calculated based on the risks reported by Ma et al. (US data 2005–2006) and the current overweight and obesity prevalence data from the SHS 2017, resulting in a PAF for overweight of 20.3% and a PAF for obesity of 18.7% (see Table 1) (13, 25). To consider the uncertainty, a second data source of adjusted PAFs was included, that based on a meta-analysis from Guh et al. (published by Zemp Stutz et al.) of 6.2 and 6.4%, respectively (10, 30).

Depending on the PAFs applied, the attributable fraction of the direct costs of asthma related to overweight and obesity in Switzerland 2021 are estimated at CHF 72–224 million overall, with CHF 35–116 million attributable to overweight and CHF 37–107 million attributable to obesity (see Table 3).

3.3.2 Coronary heart disease

CHD is the most common form of cardiovascular disease (CVD) and is responsible for 20% of deaths worldwide (48). For Switzerland, data on the number of patients hospitalized due to CVD events or the incidence of myocardial infarction (MI) are widely available. However, reliable data on the prevalence of CHD are scarce. Comparable data for Germany in 2017 estimated a total of 3.7% of women and 6.0% of men with CHD (defined as MI or chronic symptoms due to MI or angina) in the previous 12 months (49).

TABLE 2 Total costs of overweight and obesity for Switzerland 2021 based on the annual changes of CPI in healthcare.

Type of costs	Costs (Million CHF)
Direct costs of treatment overweight and obesity	
Dietary counseling costs[a]	18
Pharmacological therapy costs[b]	26
Bariatric surgical therapy costs[c]	83
Total direct costs of treatment overweight and obesity	**126**
Direct costs of obesity-linked selected overweight and obesity-related complications	
Asthma	72–224
CHD	210–513
Depression	595
Diabetes mellitus	808–1,090
Hypertension	536
Osteoarthritis (hip & knee)	1,104–1,398
Stroke	206–725
Total direct costs attributable to overweight and obesity	**3,530–5,081**
Total costs of overweight and obesity	**3,657–5,208**

[a]Costs for dietary counseling were estimated by the most current statistical information of Jan-Jun 2022.
[b]Costs for pharmacological therapy were estimated by the most current sales information of Jan-Jun 2022.
[c]Costs for bariatric surgical therapy costs were estimated based on the number of procedures performed in 2019, as the COVID-19 pandemic led to a significant reduction in elective surgical procedures performed in 2020 and 2021.CHD, Coronary heart disease; CPI, Consumer Price Index; PAF, Population attributable fraction. Bold values are overall values (sum).

The costs of CHD are estimated using an indirect approach, as direct cost data are not available for Switzerland. The costs of acute and subsequent MI (ICD-10 I21 – I22) are used to extrapolate the costs of CHD (ICD-10 I20 – I25) based on the German cost structure, where MI accounts for 35.5% of the total costs of CHD in 2020 (41). In addition, it is assumed that the number of MI directly corresponds to the burden of CHD. Based on current Swiss population data, 18,966 cases of MI are to be expected in Switzerland 2021 (12,462 men and 6,506 women) (50). The costs of heart failure were not considered.

Taking into account the published cost data for acute and subsequent MI in Switzerland by Wieser et al., the extrapolated costs for MI in Switzerland in 2021 were estimated at CHF 718 million (including primary care, emergency and hospital care, rehabilitation and outpatient costs, see Supplementary Table S5) (42). Assuming that cost of MI is 35.5% of the total cost of CHD, the direct cost of CHD in Switzerland in 2021 is estimated to be CHF 2,022 million (41, 42). To account for uncertainty, the extrapolation and adjustment for Switzerland 2021 of the published German DESTATIS 2,020 data for Switzerland in 2021 yields a comparable figure of CHF 1,862 million (41).

PAFs for CHD due to overweight and obesity were calculated based on the risks reported by Flint et al. (US data 1986–2020) and the current overweight and obesity prevalence data from the SHS 2017, resulting in a PAF for overweight of 14.1% and a PAF for obesity of 11.3% (13, 26). In contrast to other studies, the reference category for BMI in the Flint et al. study was 18–22.9, which was adjusted accordingly in the calculation of the PAFs for this analysis. To consider the uncertainty, a second data source of PAFs was included based on the risks reported by Liu et al. (US 2012–2013), resulting in 6.6 and 4.7%, respectively, (see Table 1) (13, 27).

Depending on the PAFs applied, the attributable fraction of the direct costs of CHD related to overweight and obesity in Switzerland in 2021 is estimated to be CHF 210–513 million with CHF 123–285 million attributable to overweight and CHF 87–228 million attributable to obesity (see Table 3).

3.3.3 Depression

In Switzerland in 2017, 5.3% of men, and 7.9% of women aged 15 years and older stated reported having suffered from depression in the past 12 months. The age group 55–64 years had the highest prevalence for both sexes (8.4% for men and 10.5% for women) (14, 51). Extrapolated to the permanent residential population of Switzerland in 2021, this corresponds to 493,364 inhabitants with depression (196,589 men; 296,775 women). Cost estimates and the distribution of severity grades of depression (21.5% mild, 46.9%moderate and 31.6% severe) in Switzerland were based on published data by Tomonaga et al. (43). Using the described extrapolation methods and population adjustment, the resulting direct costs of depression in Switzerland in 2021 were estimated at CHF 6,590 million over all severities (inpatient: CHF 5,040 million; outpatient: CHF 437 million; psychotherapy: CHF 739 million; prescribed medication CHF 373 million). The total costs for individual degrees of severity mild, moderate, and severe were CHF 486 million, 2,876 million and 3,228 million, respectively (see Supplementary Table S5).

PAFs for depression due to overweight and obesity were calculated based on the odds ratios reported by Luppino et al. (European and US data 2003–2008) and the current overweight and obesity prevalence data from the SHS 2017, resulting in a PAF for overweight of 3.7% and a PAF for obesity of 5.4% (see Table 1) (13, 28).

The attributable fraction of the direct costs of depression related to overweight and obesity in Switzerland in 2021 are estimated at CHF 595 million overall, with CHF 241 million attributable to overweight and CHF 354 million attributable to obesity (see Table 3).

3.3.4 Diabetes mellitus

In 2017, 5.4% of men and 3.5% of women ≥15 years of age in Switzerland confirmed to have high blood sugar or to receive medication for diabetes (52). Extrapolated to the permanent residential population of Switzerland in 2021, this corresponds to 341,460 patients with diabetes (201,774 men; 139,685 women) (14, 52). The cost estimation of diabetes was based on data by Szucs et al. (reported in Schneider and Venetz 2012) (9). In addition to the extrapolation and population adjustment, the increase in prevalence of diabetes from 4.2% in 2012 to 4.4% in 2017 was considered as well (52).

PAFs for diabetes due to overweight and obesity were calculated based on the risks reported by Davin et al. from the Swiss CoLaus study (Swiss data 2003–2006), as BMI was calculated using standardized weight and height measurements, resulting in a PAF for overweight of 16.2% and a PAF for obesity of 42.9% (see Table 1) (29).

TABLE 3 Attributable fraction of overweight and obesity of the direct costs of seven selected obesity-related complications for Switzerland 2021 based on the annual changes of CPI in healthcare.

Disease	Direct cost of illness (Mio. CHF)[a]	PAF (%)		PAF-based cost (Million CHF)		
		Overweight 25 ≤ BMI < 30	Obesity BMI ≥ 30	Overweight 25 ≤ BMI < 30	Obesity BMI ≥ 30	Total Attributable direct costs BMI ≥ 25
Asthma	574 Based on Szucs et al. (40)	6.2	6.4	35	37	**72**
		20.3	18.7	116	107	**224**
CHD	1,861–2,022 Based on Destatis (41) and Wieser et al. (42)	6.6	4.7	123–133	87–95	**210–228**
		14.1	11.3	262–285	210–228	**473–513**
Depression	6,590 Based on Tomonaga et al. (43)	3.7	5.4	241	354	**595**
Diabetes mellitus	1,366 Based on Huber et al. (44)	16.2	42.9	221	586	**808**
		38.4	41.4	525	565	**1,090**
Hypertension	1,538 Based on Destatis (41)	18.1	16.8	278	258	**536**
Osteoarthritis (hip and knee)	2,830 Based on Destatis (45)	19.4[b]	19.6[b]	549	555	**1,104**
		24.4[c]	25.0[c]	690	707	**1,398**
Stroke	1,812–2,033 Based on Maercker et al. (46) and Luengo-Fernandez et al. (47)	5.9	5.4	108–121	98–110	**206–231**
		18.3	17.4	331–371	315–354	**646–725**
Overall				**1,555–2,506**	**1,954–2,594**	**3,530–5,081**

[a]Extrapolation of costs for Switzerland 2021 by conversion with PPP and extrapolation with CPI.
[b]Combined PAF based on relative risks for hip osteoarthritis from Holliday et al 2010 and knee osteoarthritis from Holliday et al. (32) and Muthuri et al. (33).
[c]Combined PAF based on relative risks for hip osteoarthritis and knee osteoarthritis both from Lohmander et al. (31).
BMI, Body mass index; CHD, Coronary heart disease; CPI, Consumer Price Index; PAF, Population attributable fraction. Bold values are overall values (sum).

A second data source of PAFs reported by Zemp Stutz et al. was included and amounted to 38.4 and 41.4%, respectively, (10).

The attributable fraction of the direct costs of diabetes related to overweight and obesity in Switzerland in 2021 are estimated at CHF 808–1,090 million overall, with CHF 221–525 million attributable to overweight and CHF 565–586 million attributable to obesity (see Table 3).

3.3.5 Arterial hypertension

High blood pressure increases the risk of serious cardiovascular diseases, the most common cause of death in Switzerland in 2020. In 2017, 19.6% of men and 16.0% of women aged 15 years and older confirmed to have high blood pressure or to receive medication to lower their blood pressure with the highest prevalence in age group ≥75 years for both genders with over 55% of patients (53). Extrapolated to the permanent residential population of Switzerland in 2021, this would correspond to 1,371,955 inhabitants with high blood pressure (722,288 men; 649,667 women) (14, 53).

No publications reporting overall direct costs of hypertension based on Swiss data, which have been published after 2011, could be identified. As in available studies, the estimation of costs is limited to costs of drug therapy, using these data would underestimate the costs of the disease. For determining the full costs of hypertension, data from DESTATIS (Germany) was used (41). Considering the direct costs of disease from Germany in 2020, this will result in costs of disease for hypertension in Switzerland in 2021 of CHF 1,538 million (see Supplementary Table S5).

PAFs for hypertension due to overweight and obesity were calculated based on the risks reported by Davin et al. from the Swiss CoLaus study (Swiss data 2003–2006). BMI was calculated using standardized weight and height measurements, resulting in a PAF for overweight of 18.1% and a PAF for obesity of 16.8% (see Table 1) (29).

The attributable fraction of the direct costs of hypertension related to overweight and obesity in Switzerland in 2021 is estimated at CHF 536 million overall, with CHF 278 million attributable to overweight and CHF 258 million attributable to obesity (see Table 3).

3.3.6 Osteoarthritis

Osteoarthritis is one of the most common outpatient diagnoses in general practice, internal medicine, or orthopedics and is defined by focal areas of articular cartilage loss within the synovial joints, associated with bone hypertrophy and joint capsule thickening, predominantly affecting hip and knee and to a lesser extent the hand, spine, foot or other joints (54).

No relevant publication could be identified, that estimated the cost of osteoarthritis in Switzerland. Therefore, costs are extrapolated based on German healthcare data. Both countries are similar, e.g., in the number of implantations and revisions of artificial knee joints (210 per 100,000 inhabitants in 2009) or hip joints, (290 per 100,000 inhabitants in 2009) (54). A German health survey in 2015 found that 17.9% of adults in Germany aged 18 years or older reported having osteoarthritis during the last 12 months, with higher prevalence among women (21.8%) than in men (13.9%) (55). The proportion of people with osteoarthritis increases with age; among people aged 65 years or older, almost half of the women (48.1%) and almost one third of men (31.2%) are affected (54, 55).

The direct costs for osteoarthritis (ICD-10 M15-M19), based on the German DESTATIS data, are estimated at CHF 2,830 million in Switzerland in 2021 (see Supplementary Table S5) (45, 54).

The PAFs for osteoarthritis of the hip or the knee due to overweight and obesity were calculated based on the risks reported by Lohmander et al. (31) (Sweden 1991–1996) and using the prevalence of overweight and obesity data from 2017 SHS. This results in PAFs of 13.3% for overweight and of 15.7% for obesity (see Table 1) (13, 31). To account for uncertainties in the epidemiologic data, a second source for PAF calculation was included and resulted in PAFs of 14.9 and 14.4% for hip osteoarthritis based on the risks reported by Holliday et al. (25) (UK 2002–2006) and PAFs of 23.8 and 24.7% for knee osteoarthritis based on the risks reported in a meta-analysis by Muthuri et al. including data from 1988 to 2010, respectively (13, 33).

The attributable fraction of the direct costs of osteoarthritis related to overweight and obesity in Switzerland in 2021 are thus estimated at CHF 1,104–1,398 million in total, with CHF 549–690 million attributable to overweight and CHF 555–707 million attributable to obesity depending on the PAFs applied (see Table 3).

3.3.7 Stroke

In 2020, 21,041 people in Switzerland suffered a stroke (11,359 men; 9,682 women) (56). Extrapolated to the 2021 population, this equates to an incidence of stroke of 21,208 people in 2021 (11,453 for men and 9,755 for women). An Update of the EBC Study, that was considered in the analysis by Schneider and Venetz estimated, that inclusion of prevalent cases would result in 25% of the costs for stroke in addition to the incident cases (57). Extrapolating the Global Burden of Disease Study data, the prevalence of stroke in in Switzerland 2021 would result in 94,785 prevalent cases (58).

The cost estimate was based on total direct healthcare and non-medical care costs reported by Maercker et al. (Switzerland, Germany 2002–2004) (46). Extrapolation of these costs to the Swiss population with stroke (incident and prevalent) in the year 2021 resulted in direct costs of CHF 2033 million Due to the extrapolation of older data by Maercker et al. (46), a population-based cost analysis of European countries by Luengo-Fernandez et al. (Switzerland 2017) was included to consider the uncertainty evaluating the costs of stroke (including costs for overall healthcare, social care, and informal care), which amounted to CHF 1,812 million after extrapolation for Switzerland 2021 (see Supplementary Table S5) (47).

PAFs for stroke due to overweight and obesity were calculated based on the RR reported by Winter et al. (Germany 2005–2006) using the overweight and obesity prevalence from the SHS from 2017. PAFs resulted in 18.3% for overweight and 17.4% for obesity (see Table 1) (13, 34). To consider the uncertainty, an additional PAF published by Zemp Stutz et al. was included and amounted to 5.9 and 5.4%, respectively (10).

The attributable fraction of the direct costs of stroke related to overweight and obesity in Switzerland in 2021 is estimated at CHF 206–725 million In total, with CHF 108–371 million attributable to overweight and CHF 98–354 million attributable to obesity (see Table 3).

4 Discussion

The estimated total cost for overweight and obesity in Switzerland is CHF 3,656–5,207 million. The vast majority of these costs (97–98%) were accounted for by the seven obesity-related complications (CHF 3,530–5,081, see Figure 2). Direct treatment costs for overweight and obesity were 1.5–2.3% for bariatric surgery (CHF 83 million), 0.3–0.7% for the most recent pharmacological therapies (CHF 26 million) and 0.2–0.5% for dietary counseling (CHF 18 million), respectively (Table 2). While accounting for only a small proportion of total costs, pharmacological therapies, especially those with GLP-1 receptor agonists, represent a highly effective tool in management of overweight and obesity (59). Noteworthy, based on market analyses, a significant portion of the cost of pharmacological therapy is not covered by the OKP and is instead borne by the patients themselves, partly due to legal regulations on cost coverage, experienced feelings of shame, or simplified access in combination with an individually perceived high medical need.

The direct costs of overweight and obesity in Switzerland in 2021, estimated in this analysis, range from 0.49 to 1.07% of Swiss gross domestic product (GDP) in 2021, depending on the method used to account for inflation. Okunogbe et al. estimated the total burden of overweight and obesity, including direct and indirect costs for Switzerland at 2.0% of its GDP in 2019 (assuming that 50.3% of the population has overweight or obesity) (60). These costs include direct medical and non-medical expenditures for the treatment of obesity and related diseases, with direct costs accounting for only 38.2% of the total costs, while 61.8% is due to absenteeism, presenteeism, and premature mortality.

Considering Okunogbe et al.'s estimates, this implies that the direct costs of overweight and obesity are approximately 0.76% of Swiss GDP in 2019. This is consistent with the reported direct costs estimated in this study for 2021. Okunogbe et al. further estimated the average total health economic burden of obesity in high-income countries to be 2.46% of GDP in 2019, rising to 2.88% in 2030 and 3.8% in 2060 (60).

On average, 53.1% of Europeans are considered to have overweight or obesity compared to 41.9% of Swiss inhabitants. Although Switzerland reports a lower obesity prevalence of 11.3% compared to the European average of 16.8%, there is reason for concern. A unidirectional trend toward an increase of both overweight and obesity is reported for each country included in the aforementioned OECD analysis, including Switzerland, which should be addressed with the necessary vigor.

These findings underscore the significant challenges that overweight and obesity present for individual and public health. At the patient level, there are direct consequences, including stigmatization and a negative impact on various aspects of quality of life. Additionally, overweight and obesity significantly increase the risk of developing a variety of non-communicable diseases, which has a significant impact on personal health, as well as on the consumption of healthcare resources and thus on the costs to the healthcare system and society. The results of the present study are important for two

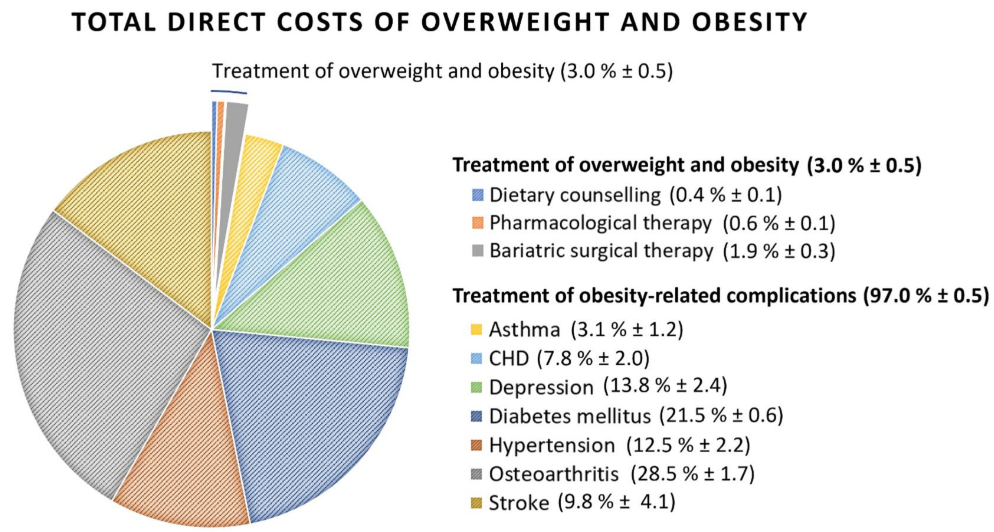


FIGURE 2
Total direct costs of treatment of overweight and obesity and related complications in Switzerland 2021.

reasons. First, they provide the most recent information available on the costs of overweight and obesity in Switzerland. Second, they indicate that the cause of this substantial contribution to healthcare costs and OKP expenditures can potentially be influenced, by measures targeting the reduction of overweight and obesity.

However, the monetary magnitude of this identified preventive potential is subject to the scope and methods applied. Firstly, only the costs of seven selected obesity-related complications were considered, despite the fact that there are in excess of 50 diseases associated with overweight and obesity (e.g., anxiety, sleep apnea, non-alcoholic liver disease and non-alcoholic steatohepatitis, gallstones, gout, infertility, incontinence, chronic back pain as well as malignant neoplasms of breast, colon, kidney or other cancers) (61). Second, it should be noted that some relevant healthcare costs were not considered in this analysis. These include alternative therapeutic interventions, diagnostic procedures, consultations with healthcare professionals, accompanying therapies as well as follow-up examinations and long-term complications such as micronutrient supplementation after bariatric surgery and more. In addition, the estimate does not include cost of psychological therapy for overweight and obesity-related mental health problems other than depression, which have a high prevalence in this population (62). Third, the focus of this study was on the direct costs associated with the management of overweight and obesity as well as seven related complications. Indirect costs, which typically include productivity losses as well as absenteeism, have not been included, as they typically play a lesser role in public decision-making due to their inherent challenges in accurately quantifying and weighing such costs. However, estimates by Okunogbe et al. suggest that the indirect costs of overweight and obesity are approximately 1.6 times the direct costs (60). Fourth, the cost estimate is based on self-reported BMI of the 2017 SHS data, which is prone to underestimate body weight and overestimate body height in individuals with overweight or obesity (29, 63, 64). To address this uncertainty, an additional analysis was performed with BMI data from menuCH in 2014, based on standardized weight and height measurements, which indicated an even higher prevalence of both overweight and obesity (65, 66). Overall, the health economic burden presented in our study represents is a *de facto* conservative estimate of the cost of overweight and obesity in Switzerland.

Beyond the cost estimate, there is a second key finding: the available health economic evidence is scarce. Most of the sources used in the 2012 report are still the most relevant today. This is particularly disappointing as respective primary data are available but to this day are unpublished or hardly accessible. Given the scarcity of evidence, a standard procedure for updating and estimating costs was not feasible due to the substantial variation in disease-specific evidence. Substantial conversions, extrapolations, and adjustments were therefore necessary to estimate the direct costs of overweight and obesity and related comorbidities for Switzerland in 2021. In particular, the reported PAFs vary widely, leading to large variations and uncertainty in the costs of overweight and obesity-related complications in Switzerland.

Another assumption relates to the extrapolation of costs from the respective source year of the available data to the year 2021. To extrapolate costs from a source year to 2021, annual changes in total health expenditures have been used previously (9). However, this method is considered to be a rough approximation as it includes expansion of services, which may overcompensate for price changes while not considering improvements in treatment pattern, e.g., due to changes in treatment paradigms or newly approved pharmaceuticals and technologies. Therefore, for this analysis, the annual changes in the relevant subcodes of the consumer price index in healthcare were used instead to better incorporate changes of individual cost components (23). Changes in this index account only for changes in prices and tariffs, but not volume changes. The annual change of health expenditures was used for information purposes only, to allow for comparison with previous estimates and are presented in Supplementary Tables S6, S7.

Despite the heterogeneous data and the scarcity of evidence, two main conclusions can be drawn from this study. First, regardless of the exact figures and considering only the results of this conservative approach, the estimated direct costs of overweight and obesity and related complications have a substantial impact on the Swiss healthcare system, accounting for 4.4–6.3% of total healthcare expenditures. Although direct management of overweight and obesity with dietary counseling, pharmacologic therapy, and bariatric surgery accounts for only 0.15% of the total Swiss healthcare expenditures, reduction of the prevalence of overweight and obesity would significantly lower the costs of treating obesity-related complications and thus reduce the burden and costs of overweight and obesity in Switzerland. This is of considerable significance, as the cause for these expenditures can be reduced through treatment and prevention. A recently published systematic review and meta-analysis demonstrated that therapeutic patient education interventions result in significant improvements in several health indicators among patients with obesity and the efficacy of these interventions was confirmed across a range of biomedical, psychosocial and psychological outcomes (67).

While other countries have implemented stricter regulations such as sugar taxes, Switzerland's approach emphasizes voluntarism. In addition, preventive measures regarding overweight and obesity are scarce in Switzerland and vary widely in their allocation and implementation, as they are the responsibility of the individual cantons. While some preventive measures for children and adolescents are successfully implemented at a local level, there is a notable lack of provision for adults. It is therefore essential to facilitate the adoption and implementation of preventive measures at the national level for Switzerland in the future.

Secondly, there is a paucity of health economic evidence, which is largely outdated, both in Switzerland and internationally. The opportunities offered by the digitization for health economic and health services research have not yet been fully exploited. Inadequate use of available data for research, information, and decision making creates high uncertainty for prioritization and impact assessment in health policy. Missing or incomplete disclosure of data ultimately leads to a lack of transparency, which in turn leads to a significant information asymmetry, as access to this information is primarily restricted to health insurers.

Recommendations and proposals for the introduction of multidisciplinary programs for the treatment of people with obesity have been formulated for Switzerland (68). However, in the face of ever-increasing rates of overweight and obesity, a major effort is needed in scientific research to develop effective prevention and treatment strategies. The urgency of this matter cannot be overstated. Investing in both scientific research and research-guided adaptation of preventive measures should be accorded a high priority in order to combat obesity.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

DS: Conceptualization, Investigation, Methodology, Writing – original draft, Writing – review & editing. PH: Conceptualization, Investigation, Methodology, Project administration, Writing – original draft, Writing – review & editing. SR: Conceptualization, Investigation, Methodology, Writing – original draft, Writing – review & editing. DF: Validation, Writing – review & editing. ZP: Validation, Writing – review & editing. RP: Validation, Writing – review & editing. BS: Validation, Writing – review & editing. SL: Funding acquisition, Methodology, Writing – review & editing. TP: Funding acquisition, Methodology, Writing – review & editing.

Funding

The author(s) declare that financial support was received for the research, authorship, and/or publication of this article. This publication was funded by Novo Nordisk Pharma AG.

Acknowledgments

We like to thank our former colleague Elisabeth Brock (HealthEcon AG), who contributed significantly to the design of the systematic literature searches. In addition, we would like to thank Elisa Biacchi for her input during an expert interview.

Conflict of interest

DS, PH, and SR were employed by the HealthEcon AG. BS was employed by the friendlyDocs Ltd. SL was employed by the Novo Nordisk Pharma AG. TP was employed by the Novo Nordisk Denmark A/S.

The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

The author(s) declared that they were an editorial board member of Frontiers, at the time of submission. This had no impact on the peer review process and the final decision.

Publisher's note

Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2024.1335115/full#supplementary-material

References

1. Bray GA. Medical consequences of obesity. *J Clin Endocrinol Metab*. (2004) 89:2583–9. doi: 10.1210/jc.2004-0535

2. Zhang X, Ha S, Lau HC, Yu J. Excess body weight: novel insights into its roles in obesity comorbidities. *Semin Cancer Biol*. (2023) 92:16–27. doi: 10.1016/j.semcancer.2023.03.008

3. Puhl RM, King KM. Weight discrimination and bullying. *Best Pract Res Clin Endocrinol Metab*. (2013) 27:117–27. doi: 10.1016/j.beem.2012.12.002

4. Kolotkin RL, Andersen JR. A systematic review of reviews: exploring the relationship between obesity, weight loss and health-related quality of life. *Clin Obes*. (2017) 7:273–89. doi: 10.1111/cob.12203

5. Edwards CH, Aas E, Kinge JM. Body mass index and lifetime healthcare utilization. *BMC Health Serv Res*. (2019) 19:696. doi: 10.1186/s12913-019-4577-0

6. Raebel MA, Malone DC, Conner DA, Xu S, Porter JA, Lanty FA. Health services use and health care costs of obese and nonobese individuals. *Arch Intern Med*. (2004) 164:2135–40. doi: 10.1001/archinte.164.19.2135

7. WHO Consultation on Obesity (1999: Geneva, Switzerland) & World Health Organization (2000). Obesity: preventing and managing the global epidemic. Report of a WHO consultation. Available at: https://iris.who.int/handle/10665/42330

8. World Obesity Federation. World obesity atlas 2023. Available at: https://www.worldobesity.org/resources/resource-library/world-obesity-atlas-2023 (2023).

9. Schneider H., Venetz W. Cost of obesity in Switzerland in 2012. Available at: https://www.bag.admin.ch/dam/bag/fr/dokumente/npp/forschungsberichte/forschungsberichte-e-und-b/cost-of-obesity.pdf.download.pdf/cost-of-obesity.pdf (2014).

10. Zemp Stutz E., Ferrari G., Schneidera C. Quantitativer Einfluss verhaltensbezogener Risikofaktoren auf das Auftreten nichtübertragbarer Krankheiten. Zusammenstellung der Evidenzen (2020). Available at: https://www.bag.admin.ch/dam/bag/de/dokumente/npp/forschungsberichte/forschungsberichte-ncd/einfluss-risikofaktoren-ncd.pdf.download.pdf/NCD-Bericht_2020-03-06.pdf

11. Malatesta D. Validité et pertinence de l' index de masse corporelle (IMC) comme indice de surpoids et de santé au niveau individuel ou épidémiologique. Berne: Promotion Santé Suisse. Available at: https://promotionsante.ch/assets/public/documents/fr/5-grundlagen/publikationen/ernaehrung-bewegung/arbeitspapiere/Document_de_travail_008_PSCH_2013-08_-_Validite_et_pertinence_Index_de_masse_corporelle.pdf (2013).

12. WHO Consultation on Obesity. Obesity: preventing and managing the global epidemic: report of a WHO consultation. Geneva: World Health Organization (2000).

13. Bundesamt für Statistik (BFS). Body Mass Index (BMI) nach Geschlecht, Alter, Bildungsniveau, Sprachgebiet. (2018). Available at: https://www.bfs.admin.ch/bfs/de/home/statistiken/gesundheit/determinanten/uebergewicht.assetdetail.6466017.html

14. Bundesamt für Statistik (BFS). Ständige Wohnbevölkerung nach Alter, Geschlecht und Staatsangehörigkeitskategorie. Available at: https://www.bfs.admin.ch/asset/de/je-d-01.02.03.02 (2022).

15. Schweizerischer Verband diplomierter ErnährungsberaterInnen (SVERB), Medizintarif-Kommission-UVG (MTK), Bundesamt für Militärversicherung (BMV). Tarif Anhang A. Available at: https://www.mtk-ctm.ch/fileadmin/user_upload/tarife/Ernaehrungsberatung/Ernaehrungsberatung_ambulant/01_deutsch/ambulante_tarife_ernaehrungsberatung_Tarif_deu.pdf (1999).

16. Die Spitäler der Schweiz (H+), Medizinaltarif-Kommission UVG (MTK), Bundesamt für Sozialversicherung (BSV), Bundesamt für Militärversicherung (BAMV). Tarif Anhang 1. Available at: https://www.hplus.ch/fileadmin/hplus.ch/public/Tarife/Ernaehrungsberatung/Tarif_1_.pdf (2022).

17. Schweizerischer Verband diplomierter ErnährungsberaterInnen (SVERB), Medizintarif-Kommission-UVG (MTK), Bundesamt für Militärversicherung (BMV), Vereinbarung über den Taxpunktwert. Available at: https://www.mtk-ctm.ch/fileadmin/user_upload/tarife/Ernaehrungsberatung/Ernaehrungsberatung_ambulant/01_deutsch/ambulante_tarife_ernaehrungsberatung_TPW_deu.pdf (1999).

18. Die Spitäler der Schweiz (H+), Medizinaltarif-Kommission UVG (MTK), Bundesamt für Sozialversicherung (BSV), Bundesamt für Militärversicherung (BAMV) Vereinbarung übr den Taxpunktwert. Available at: https://www.mtk-ctm.ch/fileadmin/user_upload/tarife/Ernaehrungsberatung/Ernaehrungsberatung_im_Spital/01_deutsch/ambulante_tarife_paramed_ernaehrungsberatung_spital_TPW_deu.pdf (2022).

19. Bundesamt für Gesundheit (BAG). Spezialitätenliste (SL) und Geburtsgebrechen-Spezialitätenliste (GGSL). (2024). Available at: https://www.spezialitätenliste.ch/

20. SwissDRG. Datenspiegel 11.0 - Plausibilisierte Leistungs- und Kostendaten der Netzwerkspitäler aus dem Jahr 2019. Available at: https://datenspiegel110.swissdrg.org/ (2019).

21. Swiss Society for the Study of morbid Obesity (SMOB). CHOP codes Bariatrischer Operationen ab 1.1.2019. Available at: https://smob.ch/de/component/jdownloads/?task=download.send&id=99&catid=3&m=0&Itemid=101 (2019).

22. Bundesamt für Statistik (BFS). EUROSTAT-Database: Datenbankabfrage: Purchasing power parities (38 European countries) Available at: https://www.bfs.admin.ch/asset/de/20584047 (2021).

23. Bundesamt für Statistik (BFS). Landesindex der Konsumentenpreise. Available at: https://www.bfs.admin.ch/bfs/de/home/statistiken/preise/erhebungen/lik/warenkorb.assetdetail.21484892.html (2020).

24. Bundesamt für Statistik (BFS). Kosten und Finanzierung des Gesundheitswesens seit 1960. Available at: https://www.bfs.admin.ch/bfs/de/home/statistiken/querschnittsthemen/wohlfahrtsmessung/alle-indikatoren/gesellschaft/gesundheitsausgaben.assetdetail.22324823.html (2022).

25. Ma J, Xiao L, Knowles SB. Obesity, insulin resistance and the prevalence of atopy and asthma in US adults. *Allergy*. (2010) 65:1455–63. doi: 10.1111/j.1398-9995.2010.02402.x

26. Flint AJ, Hu FB, Glynn RJ, Caspard H, Manson JE, Willett WC, et al. Excess weight and the risk of incident coronary heart disease among men and women. *Obesity*. (2010) 18:377–83. doi: 10.1038/oby.2009.223

27. Liu L, Núñez AE, An Y, Liu H, Chen M, Ma J, et al. Burden of cardiovascular disease among multi-racial and ethnic populations in the United States: an update from the National Health Interview Surveys. *Front Cardiovasc Med*. (2014) 1:8. doi: 10.3389/fcvm.2014.00008

28. Luppino FS, de Wit LM, Bouvy PF, Stijnen T, Cuijpers P, Penninx BWJH, et al. Overweight, obesity, and depression: a systematic review and meta-analysis of longitudinal studies. *Arch Gen Psychiatry*. (2010) 67:220–9. doi: 10.1001/archgenpsychiatry.2010.2

29. Davin C, Vollenweider P, Waeber G, Paccaud F, Marques-Vidal P. Cardiovascular risk factors attributable to obesity and overweight in Switzerland. *Nutr Metab Cardiovasc Dis*. (2012) 22:952–8. doi: 10.1016/j.numecd.2011.01.004

30. Guh DP, Zhang W, Bansback N, Amarsi Z, Birmingham CL, Anis AH. The incidence of co-morbidities related to obesity and overweight: a systematic review and meta-analysis. *BMC Public Health*. (2009) 9:88. doi: 10.1186/1471-2458-9-88

31. Lohmander LS, Gerhardsson de Verdier M, Rollof J, Nilsson PM, Engström G. Incidence of severe knee and hip osteoarthritis in relation to different measures of body mass: a population-based prospective cohort study. *Ann Rheum Dis*. (2009) 68:490–6. doi: 10.1136/ard.2008.089748

32. Holliday KL, McWilliams DF, Maciewicz RA, Muir KR, Zhang W, Doherty M. Lifetime body mass index, other anthropometric measures of obesity and risk of knee or hip osteoarthritis in the GOAL case-control study. *Osteoarthr Cartil*. (2011) 19:37–43. doi: 10.1016/j.joca.2010.10.014

33. Muthuri SG, Hui M, Doherty M, Zhang W. What if we prevent obesity? Risk reduction in knee osteoarthritis estimated through a meta-analysis of observational studies. *Arthritis Care Res*. (2011) 63:982–90. doi: 10.1002/acr.20464

34. Winter Y, Rohrmann S, Linseisen J, Lanczik O, Ringleb PA, Hebebrand J, et al. Contribution of obesity and abdominal fat mass to risk of stroke and transient ischemic attacks. *Stroke*. (2008) 39:3145–51. doi: 10.1161/strokeaha.108.523001

35. Novo Nordisk Pharma AG. Product information Saxenda®. (2023). Available at: https://compendium.ch/product/1339731-saxenda-inj-los-6-mg-ml/mpro

36. CPS Cito Pharma Services GmbH. Product information Xenical. Available at: https://compendium.ch/product/65354-xenical-kaps-120-mg/mpro (2023).

37. Novo Nordisk Pharma AG. Marketanalytics pharmaceutical sales of anti-obesity medications in Switzerland. (2022).

38. Klein S., Krupka Simon, Behrendt Susann, Pulst Alexandra, Bleß H.-H. Weißbuch Adipositas: Versorgungssituation in Deutschland. Available at: https://www.iges.com/presse/2016/weissbuch-adipositas/e14613/e14614/attr_objs14616/Weissbuch_Adipositas_Klein_et_al_ger.pdf (2016).

39. Bundesamt für Statistik (BFS). Krankheiten und gesundheitliche Probleme (2 von 2); Dargestellter Zeitraum 2017 Available at: https://www.bfs.admin.ch/bfs/de/home/statistiken/gesundheit/gesundheitszustand/krankheiten.assetdetail.7586047.html (2019).

40. Szucs TD, Anderhub H, Rutishauser M. The economic burden of asthma: direct and indirect costs in Switzerland. *Eur Respir J*. (1999) 13:281–6. doi: 10.1034/j.1399-3003.1999.13b10.x

41. Destatis. Krankheitskosten, Krankheitskosten je Einwohner: Deutschland, Jahre, Krankheitsdiagnosen (ICD-10) - Krankheiten des Kreislaufsystems. Available at: https://www-genesis.destatis.de/genesis/online?sequenz=tabelleErgebnis&selectionname=23631-0001&sachmerkmal=ICD10Y&sachschluessel=ICD10-I00-I99,ICD10-I10-I15,ICD10-I20-I25,ICD10-I21,ICD10-I22,Icd10-I30-I52,ICD10-I50,ICD10-I60-I69,ICD10-I60-I61,ICD10-I63,ICD10-I64,ICD10-I69,ICD10-I80-I89,ICD10-I83#abreadcrumb (2022).

42. Wieser S, Rüthemann I, De Boni SN, Eichler K, Pletscher M, Radovanovic D, et al. Cost of acute coronary syndrome in Switzerland in 2008. *Swiss Med Wkly*. (2012) 142:w13655. doi: 10.21256/zhaw-3954

43. Tomonaga Y, Haettenschwiler J, Hatzinger M, Holsboer-Trachsler E, Rufer M, Hepp U, et al. The economic burden of depression in Switzerland. *Pharmacoeconomics*. (2013) 31:237–50. doi: 10.1007/s40273-013-0026-9

44. Huber CA, Schwenkglenks M, Rapold R, Reich O. Epidemiology and costs of diabetes mellitus in Switzerland: an analysis of health care claims data, 2006 and 2011. *BMC Endocr Disord*. (2014) 14:44. doi: 10.1186/1472-6823-14-44

45. Destatis. Krankheitskosten, Krankheitskosten je Einwohner: Deutschland, Jahre, Krankheitsdiagnosen (ICD-10) - Alle Krankheiten und Folgen äußerer Ursachen Available at: https://www-genesis.destatis.de/genesis/online?operation=table&code=23631-0001&bypass=true&levelindex=0&levelid=1665749890144#abreadcrumb (2022).

46. Maercker A, Perkonigg A, Preisig M, Schaller K, Weller M. The costs of disorders of the brain in Switzerland: an update from the European brain council study for 2010. *Swiss Med Wkly*. (2013) 143:w13751. doi: 10.4414/smw.2013.13751

47. Luengo-Fernandez R, Violato M, Candio P, Leal J. Economic burden of stroke across Europe: a population-based cost analysis. *Eur Stroke J*. (2020) 5:17–25. doi: 10.1177/2396987319883160

48. Townsend N, Wilson L, Bhatnagar P, Wickramasinghe K, Rayner M, Nichols M. Cardiovascular disease in Europe: epidemiological update 2016. *Eur Heart J*. (2016) 37:3232–45. doi: 10.1093/eurheartj/ehw334

49. Busch MA, Kuhnert R. 12-Monats-Prävalenz einer koronaren Herzkrankheit in Deutschland. *J Health Monit*. (2017) 2. doi: 10.17886/rki-gbe-2017-009

50. Schweizerisches Gesundheitsobservatorium (Obsan). Indikator Myokardinfarkt. Available at: https://ind.obsan.admin.ch/indicator/obsan/myokardinfarkt (2022).

51. Bundesamt für Statistik (BFS). Krankheiten und gesundheitliche Probleme (1 von 2); Dargestellter Zeitraum 2017. Available at: https://www.bfs.admin.ch/bfs/de/home/statistiken/gesundheit/gesundheitszustand/krankheiten.assetdetail.7586031.html (2019)

52. Bundesamt für Statistik (BFS). Personen mit Diabetes nach Geschlecht, Alter, Bildungsniveau, Sprachgebiet. Available at: https://www.bfs.admin.ch/bfs/de/home/statistiken/gesundheit/gesundheitszustand/krankheiten/diabetes.assetdetail.6466016.html (2018).

53. Bundesamt für Statistik (BFS). Personen mit Bluthochdruck; Dargestellter Zeitraum: 1992, 2002, 2007, 2012, 2017. Available at: https://www.bfs.admin.ch/bfs/de/home/statistiken/gesundheit/gesundheitszustand/krankheiten.assetdetail.7586044.html (2019).

54. Rabenberg M. Gesundheitsberichterstattung des Bundes - Heft 54, Arthrose. Available at: https://www.rki.de/DE/Content/Gesundheitsmonitoring/Gesundheitsberichterstattung/GBEDownloadsT/arthrose.pdf?__blob=publicationFile (2013).

55. Fuchs J, Kuhnert R, Scheidt-Nave C. 12-Monats-Prävalenz von Arthrose in Deutschland. Berlin, Germany: Robert Koch-Institut, Epidemiologie und Gesundheitsberichterstattung (2017).

56. Bundesamt für Statistik (BFS). Herz- und Kreislauf-Erkrankungen. Available at: https://www.bfs.admin.ch/bfs/de/home/statistiken/gesundheit/gesundheitszustand/krankheiten/herz-kreislauf-erkrankungen.html (2022).

57. Gustavsson A, Svensson M, Jacobi F, Allgulander C, Alonso J, Beghi E, et al. Cost of disorders of the brain in Europe 2010. *Eur Neuropsychopharmacol*. (2011) 21:718–79. doi: 10.1016/j.euroneuro.2011.08.008

58. GBD. Stroke collaborators global, regional, and national burden of stroke and its risk factors, 1990-2019: a systematic analysis for the global burden of disease study 2019. *Lancet Neurol 2021*. (2019) 20:795–820. doi: 10.1016/s1474-4422(21)00252-0

59. Chakhtoura M, Haber R, Ghezzawi M, Rhayem C, Tcheroyan R, Mantzoros CS. Pharmacotherapy of obesity: an update on the available medications and drugs under investigation. *EClinicalMedicine*. (2023) 58:101882. doi: 10.1016/j.eclinm.2023.101882

60. Okunogbe A, Nugent R, Spencer G, Powis J, Ralston J, Wilding J. Economic impacts of overweight and obesity: current and future estimates for 161 countries. *BMJ Glob Health*. (2022) 7:e009773. doi: 10.1136/bmjgh-2022-009773

61. Westbury S, Oyebode O, van Rens T, Barber TM. Obesity stigma: causes, consequences, and potential solutions. *Curr Obes Rep*. (2023) 12:10–23. doi: 10.1007/s13679-023-00495-3

62. Hert MDE, Correll CU, Bobes J, Cetkovich-Bakmas M, Cohen D, Asai I, et al. Physical illness in patients with severe mental disorders. I. Prevalence, impact of medications and disparities in health care. *World Psychiatry*. (2011) 10:52–77. doi: 10.1002/j.2051-5545.2011.tb00014.x

63. Mozumdar A, Liguori G. Corrective equations to self-reported height and weight for obesity estimates among U.S. adults: NHANES 1999-2008. *Res Q Exerc Sport*. (2016) 87:47–58. doi: 10.1080/02701367.2015.1124971

64. Schutz Y, Woringer V. Obesity in Switzerland: a critical assessment of prevalence in children and adults. *Int J Obes Relat Metab Disord*. (2002) 26:S3–s11. doi: 10.1038/sj.ijo.0802122

65. Bender N., Vinci L., Fäh D., Rohrmann S., Krieger J.-P., Pestoni G, et al. Übergewicht und Lebensstil - Auswertung der menuCH-Daten. Available at: https://www.zora.uzh.ch/id/eprint/151859/1/Ubergewicht_und_Lebensstil_-_Auswertung_der_menuCH-Daten.pdf (2018).

66. Bochud M., Chatelan A., Blanco J.-M., Beer-Borst S. Anthropometric characteristics and indicators of eating and physical activity behaviors in the Swiss adult population. Results from menuCH 2014–2015. Available at: https://boris.unibe.ch/101641/1/Bochud%20menuCH-Report%202017.pdf (2017).

67. Correia JC, Waqas A, Huat TS, Gariani K, Jornayvaz FR, Golay A, et al. Effectiveness of therapeutic patient education interventions in obesity and diabetes: a systematic review and meta-analysis of randomized controlled trials. *Nutrients*. (2022) 14:3807. doi: 10.3390/nu14183807

68. Malatesta D. Programmes multi-professionnels/multidisciplinaires de la prise en charge de l'obésité en Suisse: synthèse des interviews d'experts de l'obésité et de professionnels de la santé intéressés par l'obésité en Suisse. Available at: https://www.bag.admin.ch/dam/bag/fr/dokumente/npp/forschungsberichte/forschungsberichte-e-und-b/programmes-multiprofessionnels-obesite.pdf.download.pdf/Rapport_Programmes%20mutiprofessionels%20ob%C3%A9sit%C3%A9_mai21.pdf (2021).

69. Organisation for Economic Co-operation and Development (OECD). Overweight or obese population (indicator) Available at: https://www.oecd-ilibrary.org/content/data/86583552-en (2018).

70. Organisation for Economic Co-operation and Development (OECD), European Union (EU). Health at a glance: Europe 2020: State of health in the EU. Paris: OECD Publishing (2020).

frontiers | Frontiers in Public Health

TYPE Original Research
PUBLISHED 24 July 2024
DOI 10.3389/fpubh.2024.1437304

Check for updates

OPEN ACCESS

EDITED BY
Hai Fang,
Peking University, China

REVIEWED BY
Valentin Marian Antohi,
Dunarea de Jos University, Romania
Joanna Wang,
University of Technology Sydney, Australia

*CORRESPONDENCE
Emre Atilgan
✉ emreatilgan@trakya.edu.tr

RECEIVED 23 May 2024
ACCEPTED 15 July 2024
PUBLISHED 24 July 2024

CITATION
Atilgan E, Ertuğrul HM, Baycan O and Ulucan H (2024) Health-led growth hypothesis and health financing systems: an econometric synthesis for OECD countries. *Front. Public Health* 12:1437304. doi: 10.3389/fpubh.2024.1437304

Health-led growth hypothesis and health financing systems: an econometric synthesis for OECD countries

Emre Atilgan[1]*, H. Murat Ertuğrul[2], Onur Baycan[2] and Hakan Ulucan[2]

[1]Department of Health Management, Trakya University, Edirne, Türkiye, [2]Department of Economics, Anadolu University, Eskişehir, Türkiye

Introduction: This study investigates the Health-Led Growth Hypothesis (HLGH) within OECD countries, examining how health expenditures influence economic growth and the role of different health financing systems in this relationship.

Methods: Utilizing a comprehensive analysis spanning 2000 to 2019 across 38 OECD countries, advanced econometric methodologies were employed. Both second-generation panel data estimators (Dynamic CCEMG, CS-ARDL, AMG) and first-generation models (Panel ARDL with PMG, FMOLS, DOLS) were utilized to test the hypothesis.

Results: The findings confirm the positive impact of health expenditures on economic growth, supporting the HLGH. Significant disparities were observed in the ability of health expenditures to stimulate economic growth across different health financing systems, including the Bismarck, Beveridge, Private Health Insurance, and System in Transition models.

Discussion: This study enriches the ongoing academic dialog by providing an exhaustive analysis of the relationship between health expenditures and economic growth. It offers valuable insights for policymakers on how to optimize health investments to enhance economic development, considering the varying effects of different health financing frameworks.

KEYWORDS

health-led growth hypothesis, health expenditure, economic growth, OECD countries, health financing systems, second generation panel data analysis

1 Introduction

For over 50 years since Mushkin's foundational study (1), the link between health expenditure and economic growth has been a crucial topic in academic and policy discussions. This persistent focus highlights the complexity of the relationship between health investments and economic development. Scholars generally agree that health is a vital component of human capital, which is critical for economic growth. As countries strive to provide high-quality healthcare, the connection between health spending and economic growth becomes increasingly important, with significant implications for policy formulation, economic development, and societal well-being.

10.3389/fpubh.2024.1437304

The health-economic growth nexus refers to the reciprocal relationship between health expenditures and economic growth. This perspective recognizes that health expenditures can influence economic growth through various channels, such as human capital accumulation, labor productivity, and demographic dividends. Simultaneously, economic growth can enable higher health expenditures, as wealthier countries have more resources to invest in healthcare. This nexus suggests a dynamic and interdependent relationship, with feedback effects that can either strengthen or weaken the link between the two variables (2).

The Health-Led Growth Hypothesis (HLGH) posits that investments in health positively impact economic growth. This hypothesis is linked to endogenous growth theory, which emphasizes the importance of human capital accumulation and investment as drivers of economic growth (3–7). The rationale is that healthier populations are more productive and possess higher human capital, leading to greater output, innovation, and adaptability to economic changes. Health expenditure, in this context, is seen as an investment yielding economic returns through improved health outcomes, increased labor productivity, and demographic dividends (1, 8–13).

On the other hand, the wealth hypothesis suggests that economic growth leads to higher health expenditures, as countries with higher GDP *per capita* can allocate more resources to healthcare. This hypothesis indicates that as countries grow wealthier, they can afford to invest more in healthcare, resulting in better health outcomes for their populations (14). Accordingly, economic growth acts as a prerequisite for increased healthcare spending and the improvement of health results (15). The wealth hypothesis is based on the "income elasticity of demand" for healthcare, which indicates that as incomes rise, the demand for healthcare services also increases, leading to higher health expenditures (16). Health care is considered a luxury good, with its demand rising faster than income (17).

The discussion on the interplay between healthcare spending and economic growth is extensive and multifaceted. Various econometric methodologies have been used to study this complex relationship across different national contexts. The literature commonly indicates a favorable association between healthcare expenditure and economic advancement; however, divergences in methodology and geographical disparities result in a spectrum of outcomes, emphasizing the intricate characteristics of this relationship.

Methodologically, there is a division within the academic community, characterized by a significant divergence in the methodologies favored for studying the HLGH in OECD countries. Scholars such as Gerdtham and Lothgren (18), Baltagi and Moscone (19) and Kumar (20) support the use of panel data techniques for capturing broader trends across nations. On the contrary, Atilgan, Kilic and Ertugrul (21) and Tang and Ch'ng (22) advocate for the utilization of time-series methodologies. They argue that these approaches are more appropriate for examining the distinctive attributes of specific countries and questioning the presumption of uniformity that underlies panel data techniques.

Empirical evidence from Newhouse (23) and Gerdtham and Jönsson (17) supports a positive link between GDP *per capita* and health expenditures across various economies, regardless of their development status. This consensus is echoed by Behera and Dash (24) and Beylik, Cirakli, Cetin, Ecevit and Senol (25) who found a positive relationship between healthcare spending and economic growth in Indian states and OECD countries, respectively, by using ARDL models. Additionally, Jakovljevic, Timofeyev, Ranabhat, Fernandes, Teixeira, Rancic and Reshetnikov (26) explored this relationship within G7 and EM7 nations, while Ozyilmaz, Bayraktar, Isik, Toprak, Er, Besel, Aydin, Olgun and Collins (27) found a bidirectional causal relationship in EU countries. However, in MENA countries, the correlation between health expenditure and economic growth is not straightforward, as evidenced by research employing panel OLS, FMOLS, and DOLS approaches (28). Inquiries into the connection between healthcare expenditure and economic growth in developing countries provide a contrast to the focus on OECD nations. This sheds light on the policy implications of healthcare spending in boosting a healthier and more productive population, which in turn could stimulate economic progress (29–32).

The scholarly landscape is enriched by a variety of econometric approaches, from the panel VAR method (33) and Baumol's model of 'Unbalanced Growth' (33) to panel regression analysis (34). This diversity extends to the exploration of the convergence hypothesis (35) and the Driscoll-Kraay approach (25), emphasizing the multifaceted nature of the health expenditure-economic growth paradigm. Time series analysis also plays a significant role in elucidating long-term relationships and expenditure behavior within OECD countries (9, 36, 37).

The intricate relationship between health expenditures and economic growth is influenced by factors such as economic development stages, healthcare system structures, financing configurations, governance quality, and policy efficacy. These elements impact developed and developing nations differently, highlighting the need for ongoing research to understand this relationship fully. Central to this discourse is the role of governance and institutional quality, as underscored by Rodrik, Subramanian and Trebbi (38), who emphasize the critical importance of sound governance and institutional integrity in mediating the health expenditure-economic growth dynamic. This claim is supported by additional studies (39, 40), that emphasize the crucial importance of strong institutions, indicating that efficient governance and institutional excellence play a key role in utilizing health expenditure for economic progress.

Our study aims to empirically analyze the HLGH within the OECD countries. We will examine the health-economic growth nexus across different national settings, considering unique parameter estimates for each country. This analysis will explore how different health financing systems—Bismarck, Beveridge, private insurance, and System in Transition (former Semaschko) models—affect the relationship between health investments and economic outcomes. By categorizing nations based on their health funding frameworks, we hope to provide insights into how these systems influence economic growth. This research is crucial for developing health strategies and fiscal models that promote health and economic prosperity in diverse national contexts.

In our study, we utilize panel data techniques to analyze the complex relationship between health expenditures and economic growth. Panel data techniques are essential for analyzing datasets that combine cross-sectional and time series data, providing a richer analytical framework compared to pure time series or cross-sectional methods. These techniques allow for the control of unobserved heterogeneity, capture dynamic relationships, and improve the efficiency of estimates (41).

In the literature, many studies have utilized panel data techniques to analyze the HLGH. However, these studies predominantly employed first-generation models, which are constrained under certain conditions. First-generation methods, such as the Panel ARDL with the Pooled Mean Group (PMG) estimator, Fully Modified Ordinary Least Squares (FMOLS), and Dynamic Ordinary Least Squares (DOLS), assume cross-sectional independence and homogeneity among the units (42–44). These assumptions often do not hold in real-world datasets, leading to biased estimates in the presence of cross-sectional dependence and heterogeneity. It is noteworthy that previous studies have been limited to first-generation methods, highlighting a significant constraint in panel data approaches.

To address these limitations, our study employs both first-generation and second-generation panel data estimators. First-generation methods provide a baseline for comparison and robustness checks. For a more robust and reliable analysis, we utilize second-generation panel data estimators, including the Dynamic Common Correlated Effects Mean Group (CCEMG), Cross-Sectionally Augmented Autoregressive Distributed Lag (CS-ARDL), and Augmented Mean Group (AMG) estimators. These advanced methods account for cross-sectional dependence and heterogeneous slopes, offering more accurate and comprehensive estimates (45). By employing both generations of panel data estimators, we aim to mitigate the constraints of previous studies and provide a more nuanced understanding of how health investments impact economic growth across different health financing systems. This comprehensive approach allows us to derive more reliable policy implications that can guide the development of effective health strategies and fiscal policies aimed at fostering health and economic prosperity in diverse national contexts.

Our study's significance lies in its potential to contribute to the academic discussion on the HLGH. By offering new insights into the relationship between health expenditures and economic growth, particularly concerning varied healthcare financing systems, we aim to address gaps in the current literature. The implications of our research extend beyond academic interest, providing essential information for policymakers and stakeholders to enhance the synergy between health expenditure and economic growth, ultimately promoting societal welfare and sustainable progress. Our findings will contribute to the ongoing dialog in this field and set the stage for future research and policy initiatives.

The structure of our study is as follows: after this introduction, we describe the data and methodology used, followed by an empirical analysis of the data. We then discuss the policy implications of our findings and conclude with a summary of the key results and recommendations for future research.

2 Data and methodology

As discussed in the introduction section, the relationship between health expenditures and GDP growth is complex and potentially bidirectional. We acknowledge that causality may run from health expenditures to GDP growth or vice versa. However, our main research question specifically focuses on analyzing the effect of health expenditure on GDP growth using a production function within a growth model. While the relationship may indeed be bidirectional, our study aims to maintain a clear focus on this primary objective.

To achieve this, we have adopted an analytical approach that isolates the impact of health expenditures on economic growth, consistent with the HLGH. This focused approach allows us to provide targeted insights and policy recommendations regarding the role of health investments in promoting economic development. Although the bidirectional nature of this relationship warrants further exploration, for the purposes of our current study, we have chosen to prioritize the analysis of the effects of health expenditures on GDP growth.

In our study, HLGH was empirically examined across 38 OECD countries, utilizing an annual dataset spanning from 2000 to 2019. The variables employed within this research encompassed Gross Domestic Product (GDP) *per capita* at constant prices, Gross Capital Formation at constant prices, labor force prices, and *per capita* health expenditures at constant prices. The dataset for these variables was carefully acquired from the World Development Indicators (WDI) database, which is curated by the World Bank (46). Consistent with scholarly conventions, natural logarithms of the variables were computed to facilitate an analysis centered on elasticity values.

We employed both first-generation and second-generation panel data models to analyze the impact of health expenditures on economic growth. First-generation panel data models, such as the Pooled Mean Group (PMG) estimator, Fully Modified Ordinary Least Squares (FMOLS), and Dynamic Ordinary Least Squares (DOLS), are designed under the assumption of cross-sectional independence and homogeneity among units (42–44). These models are effective when such assumptions hold true but may produce biased estimates when there is cross-sectional dependence or heterogeneity in the data. First-generation models typically focus on estimating long-run relationships and cointegration in panel datasets. In contrast, second-generation panel data models, such as the Dynamic Common Correlated Effects Mean Group (CCEMG), Cross-Sectionally Augmented Autoregressive Distributed Lag (CS-ARDL), and Augmented Mean Group (AMG) estimators, account for cross-sectional dependence and heterogeneous slopes (45). These models are more flexible and robust in dealing with complex data structures commonly found in macroeconomic datasets. Second-generation models incorporate common factors and unobserved heterogeneity, making them particularly suitable for analyzing data with cross-sectional dependencies.

First-generation models operate under the presumption that the cross-sectional units in the panel are independent of each other. This means that they do not account for potential correlations between units, which can arise due to shared shocks or common trends. As a result, while these models are suitable for simpler datasets where such independence can be reasonably assumed, they may lead to biased or inefficient estimates in more complex datasets. Furthermore, these models typically assume homogeneity in the slopes of the explanatory variables across different units, which can be a significant limitation when analyzing diverse datasets with varying underlying relationships.

In contrast, second-generation models offer a more advanced approach by explicitly addressing these limitations. These models incorporate mechanisms to account for cross-sectional dependence by including common factors that can capture the shared influences affecting the different units in the panel. This inclusion helps mitigate the biases that arise from ignoring such dependencies. Moreover, second-generation models allow for heterogeneous slopes, which means they can provide more accurate and tailored estimates for each cross-section. This flexibility is crucial when dealing with datasets that encompass a wide variety of units with different characteristics and relationships.

Another key advantage of second-generation models is their ability to handle both short-term and long-term dynamics. For instance, the CS-ARDL model can simultaneously estimate short-term fluctuations and long-term equilibrium relationships, providing a comprehensive view of the interactions between variables over different time horizons. This dual capability is particularly valuable in macroeconomic analyses where short-term and long-term effects often differ significantly. Furthermore, second-generation models are generally better suited for dealing with complex datasets. They are designed to manage the intricacies of macroeconomic data, which often exhibit both cross-sectional dependence and heterogeneity. This makes them more versatile and reliable for a wide range of applications, from policy analysis to forecasting.

In summary, while first-generation panel data models are useful for basic applications with simpler data structures, second-generation models offer significant improvements in terms of flexibility, robustness, and accuracy. By explicitly accounting for cross-sectional dependence and allowing for heterogeneous slopes, second-generation models provide a more nuanced and reliable analysis of complex datasets. This makes them particularly well-suited for our study, which aims to explore the intricate relationship between health expenditures and economic growth across different health financing systems in OECD countries. By including this overview, we aim to provide a clearer understanding of the advantages and limitations of both first- and second-generation panel data models, thereby enhancing the methodological rigor and transparency of our study.

The model presented in Equation (1) has been employed to test the Health-Led Growth Hypothesis.

$$\mathrm{LY}_{\mathrm{it}} = \lambda_{\mathrm{i}} d_t + \alpha_{1\mathrm{i}}\mathrm{LGCF}_{\mathrm{it}} + \alpha_{2\mathrm{i}}\mathrm{LL}_{\mathrm{it}} + \alpha_{3\mathrm{i}}\mathrm{LH}_{\mathrm{it}} + u_{\mathrm{it}} \quad (1)$$

$$u_{it} = \theta_i f_t + \varepsilon_{it},\ i = 1,2,\ldots,N \ and\ t = 1,2,\ldots T$$

In equation (1), LY is the dependent variable, LGCF, LL and LH are the explanatory variables as described in Table 1. The variables d_t and f_t correspond to observed and unobserved common effects respectively, reflecting the influences that are both measurable and latent across the dataset. Lastly, ε_{it} signifies the error term, encapsulating the random variations not explained by the model.

In our applied modeling, we systematically addressed cross-sectional dependency, a critical concern in panel data econometrics, by initially applying the bias-adjusted LM test formulated by Pesaran, Ullah and Yamagata (47). This step is foundational, given that overlooking such dependencies may engender distortions in unit root test results and bias in model estimations, as delineated by O'Connell (48) and Sarafidis and Robertson (49). The assumption of slope homogeneity was critically evaluated using the test by Pesaran and Yamagata (50) and Blomquist and Westerlund (51) given that heterogeneity in slopes is a frequent characteristic in extensive panel data (52, 53). In instances of detected cross-sectional dependency and slope heterogeneity, we incorporated the CIPS unit root test designed by Pesaran (54) to adjust for these dependencies, moving beyond the restrictive assumptions of first-generation panel data models. Upon establishing that the variables were I (1), we assessed the cointegration relationships utilizing Westerlund (55) Durbin Hausman cointegration test, a second-generation test that accounts for cross-sectional dependency.

TABLE 1 Variable list.

Variable	Description	Abbreviations
GDP	GDP *per capita*, deflated to 2010 USD	LY
Gross Capital Formation	Gross Capital Formation, deflated with 2010 USD	LGCF
Labor Force	Labor Force	LL
Health Expenditure	Health Expenditure *per Capita*, deflated to 2010 USD	LH

Subsequent to detecting slope heterogeneity and cross-sectional dependency we applied the second generation panel data models, Dynamic CCEMG (Common Correlated Effects Mean Group) estimator devised by Chudik and Pesaran (45), CS-ARDL (Cross-Sectional Augmented Distributed Lag) estimator and AMG (Augmented Mean Group) estimator. The Dynamic CCEMG estimator accounts for cross-sectional dependence by incorporating common factors into the regression model. This method allows for heterogeneous slopes and intercepts across cross-sections, making it suitable for datasets with diverse country characteristics as mentioned before. The primary effect estimated by CCEMG is the long-term relationship between health expenditures and GDP growth while controlling for unobserved common shocks. The CS-ARDL estimator is designed to handle both short-term and long-term dynamics in the presence of cross-sectional dependence. This method augments the standard ARDL model by including cross-sectional averages of the dependent and independent variables, addressing potential biases from cross-sectional correlations (56). CS-ARDL estimates both the immediate (short-term) effects of health expenditures on economic growth and the long-term equilibrium relationship. The AMG estimator is particularly effective in dealing with heterogeneous slopes and unobserved common factors that might affect the panel data. This method extends the Mean Group (MG) estimator by augmenting it with common correlated effects, allowing for the estimation of both short-term and long-term coefficients while accounting for cross-sectional dependence. AMG provides robust estimates of the impact of health expenditures on GDP growth by addressing potential endogeneity and omitted variable bias (57, 58).

We utilized these three estimators to cross-validate our findings and ensure that our results are not sensitive to the choice of estimation technique. Each estimator has unique strengths: CCEMG excels in capturing long-term relationships under cross-sectional dependence. CS-ARDL provides insights into both short-term and long-term dynamics. AMG addresses unobserved common factors and heterogeneity, enhancing the robustness of our estimates. By applying these estimators, we ensure a comprehensive analysis that robustly supports our conclusions regarding the impact of health expenditures on economic growth across OECD countries.

The Dynamic CCEMG model is as:

$$LY_{\{it\}} = \alpha_i + \beta_1 LY_{\{it-1\}} + \beta_2 LGCF_{\{it\}} + \beta_3 LL_{\{it\}} + \beta_4 LH_{\{it\}} + \psi\left(\overline{\{LY_t\}},\overline{\{LGCF_t\}},\overline{\{LL_t\}},\overline{\{LH_t\}}\right) + \varepsilon_{\{it\}} \quad (2)$$

In Equation (2), LY is the dependent, $LCGF$, LL and LH are the independent variables, for country i at time t, α_i is the country-specific intercept, β_1, β_2, β_3 and β_4 are the coefficients for the lagged dependent variable and independent variables, ψ is a function representing the common correlated effects, which are typically approximated by the cross-sectional averages of the dependent and independent variables (denoted by overbars) and ε_{it} is the error term.

The CS-ARDL model is as:

$$LY_{it} = \alpha_i + \sum_{j=0}^{p} \beta_j LY_{i,t-j} + \sum_{j=0}^{q} \gamma_{1j} LGCF_{i,t-j} + \sum_{j=0}^{q} \gamma_{2j} LL_{i,t-j} + \sum_{j=0}^{q} \gamma_{3j} LH_{i,t-j} + \lambda_1 \overline{LY}_t + \lambda_2 \overline{LGCF}_t + \lambda_3 \overline{LL}_t + \lambda_4 \overline{LH}_t + \varepsilon_{it} \quad (3)$$

In Equation (3) LY is the dependent, $LCGF$, LL and LH are the independent variables, for country i at time t, α_i is the country-specific intercept, β_j represents the coefficients for the lagged dependent variable (for lags $(\ j=0\ )$ to $(\ p\ )$), γ_{1j}, γ_{2j} and γ_{3j} are the coefficients for the lagged independent variables, respectively, (for lags $(\ j=0\ )$ to $(\ q\ )$), $\overline{LY}_t, \overline{LGCF}_t, \overline{LL}_t$ and $\overline{LH}_t$` are the cross-sectional averages of the dependent and independent variables at time t, λ_1, λ_2, λ_3 and λ_4 are the coefficients for the cross-sectional averages, capturing the common correlated effects and ε_{it} is the idiosyncratic error term.

The AMG model is as:

$$LY_{\{it\}} = \alpha_i + \gamma_t + \beta_{1i} LY_{\{it-1\}} + \beta_{2i} LGCF_{\{it\}} + \beta_{3i} LL_{\{it\}} + \beta_{4i} LH_{\{it\}} + \lambda \hat{\{dt\}} + \varepsilon_{\{it\}} \quad (4)$$

In Equation (4) α_i is the country-specific intercept, γ_t represents the time-specific effects, $\lambda\{dt\}$ represents the coefficient multiplied by the demeaned time trend, where dt is the dynamic process capturing the common dynamic process and ε_{it} is the idiosyncratic error term. After estimating the above model, the mean group estimator for AMG is obtained by averaging the country-specific coefficients as given in Equation (5):

$$\text{AMG}\left({}^{2}{}_{j}\right) = \frac{1}{N}\sum_{i=1}^{N} \tilde{\beta}_{ji} \quad (5)$$

Where $\text{AMG}\left(\beta_j\right)$ is the mean group estimate for the parameter β_j, N is the number of cross-sectional units (countries), $\tilde{\beta}_{ji}$ represents the estimated coefficient β_j for the $(\ j\ )-th$ independent variable for country (i). $j = 1,\ldots 4$, stands for the different independent variables in the model.

We performed a stratified analysis using the AMG estimator to investigate the impact of health expenditures (LH) on economic growth across different health financing models. Our approach involved two key steps. First, we calculated country-specific parameter estimates for LH using the AMG estimator. This provided us with insights into the unique impact of health expenditures on economic growth for each country. Second, we grouped the countries according to their health financing systems: Bismarck, Beveridge, Private Health Insurance, and System in Transition. Within each group, we calculated the mean of the country-specific estimates. This stratified analysis allowed us to understand the average effect of health expenditures on economic growth within each type of health financing system.

By estimating country-specific coefficients, we ensured that our analysis accurately reflects the distinct economic contexts and health financing environments of each country. The stratified analysis for health financing systems provided us with a comprehensive view of how different health financing models influence the effectiveness of health expenditures in promoting economic growth, which is a core objective of our research. In our analysis, we focused specifically on reporting the stratified coefficient of LH, as our primary goal is to examine the Health-Led Growth Hypothesis (HLGH). This targeted approach enables us to draw clear and precise conclusions about how health expenditures influence economic growth across different health financing frameworks, thereby enhancing the relevance and applicability of our findings.

We specifically chose the AMG estimator for our stratified analysis and country-specific estimations over other second-generation models due to its unique advantages in handling cross-sectional dependence and heterogeneous slopes. The AMG estimator effectively incorporates common dynamic processes, which is crucial given the shared economic and health shocks among OECD countries. This capability is essential for accurately capturing the interdependencies across countries within our panel data. This heterogeneity is particularly important when analyzing a diverse group of countries with different health financing systems, as it provides a more nuanced understanding of how health expenditures affect economic growth in different contexts. The AMG estimator is also adept at addressing cross-sectional dependence by incorporating common factors into the regression model. This feature is essential for our study, as it helps mitigate biases that could arise from ignoring such dependencies. By including these common factors, the AMG estimator ensures that the estimated effects are not distorted by unobserved common shocks that affect all countries in the panel. Other second-generation models, while effective, do not offer the same level of flexibility in capturing country-specific effects and managing cross-sectional dependencies simultaneously.

To validate the robustness of our results obtained from the Dynamic CCEMG, CS-ARDL and AMG models, we performed parallel estimations using the conventional panel data models, Panel ARDL model employing the PMG estimator by Pesaran, Shin and Smith (42), as well as the FMOLS and DOLS models, which address concerns of serial correlation and potential endogeneity (44). These models were chosen for their ability to manage the issues identified in our methodological examination, ensuring that our analysis remains coherent, and the conclusions drawn are firmly grounded in empirical evidence.

FMOLS, developed by Phillips and Hansen (43) is designed to provide asymptotically efficient estimates of cointegrating vectors by adjusting for serial correlation and endogeneity. This method modifies the traditional Ordinary Least Squares (OLS) estimator through a series of non-parametric adjustments based on the long-run covariance matrix of the error terms. FMOLS corrects for serial correlation in the residuals using a non-parametric approach and handles endogeneity by modifying the OLS estimator, utilizing corrections derived from the long-run covariance matrix. It involves the use of kernel estimators to adjust the long-run covariance matrix and, as a non-parametric method, avoids assumptions about the specific form of the error distribution. Consequently, FMOLS produces consistent and efficient estimators for cointegration relationships, making it suitable for large samples with complex error structures.

On the other hand, DOLS, introduced by Stock and Watson (44), offers a different approach by augmenting the cointegrating regression with leads and lags of the first differences of the regressors. This parametric method aims to provide consistent estimates of the cointegration vector, directly addressing endogeneity and serial correlation through dynamic adjustments. DOLS adds leads and lags of the differenced independent variables to the cointegrating regression, directly addressing serial correlation by incorporating dynamic terms into the model. It mitigates endogeneity by including leads and lags, reducing the correlation between the error term and the independent variables. As a parametric approach, DOLS relies on the inclusion of specific dynamic terms, making it straightforward to implement. This methodology is often preferred in small samples due to its parametric nature and ease of implementation.

Both FMOLS and DOLS aim to provide robust estimates of cointegrating relationships in the presence of endogeneity and serial correlation, ensuring asymptotically efficient estimates under specific conditions. Despite these similarities, notable differences exist between the two methodologies. FMOLS employs non-parametric corrections based on the long-run covariance matrix, involving more complex adjustments suitable for larger samples. In contrast, DOLS uses parametric corrections by incorporating leads and lags of the differenced regressors, offering a more straightforward implementation, particularly effective in small samples. By employing both DOLS and FMOLS, we ensure that the long-term relationships between health expenditures and economic growth are accurately estimated, taking into consideration the dynamic and potentially endogenous nature of the data. This dual approach enhances the robustness and reliability of our findings, providing a comprehensive understanding of the health-economic growth nexus in OECD countries.

The Panel ARDL approach is used to estimate the relationships between the dependent variable (GDP) and its lags, along with other independent variables and their lags. The model is specified as:

$$\mathrm{L}Y_{i,t} = \pm + \sum_{j=1}^{p} \phi_j LY_{i,t-j} + \sum_{j=0}^{q} {}^{2}{}_{1j} LGCF_{i,t-j} + \sum_{j=0}^{q} {}^{2}{}_{2j} LL_{i,t-j} + \sum_{j=0}^{q} {}^{2}{}_{3j} LH_{i,t-j} + \mu_{i,t} \quad (6)$$

In Equation (6) the variables represent the logarithmic transformations of the actual data values to stabilize variance and improve the model's interpretability.

The DOLS model in the panel data setting is expressed as Equation (7):

$$\mathrm{L}Y_{i,t} = \pm_i + {}^{2}{}_1 \mathrm{LGC}F_{i,t} + {}^{2}{}_2 \mathrm{L}L_{i,t} + {}^{2}{}_3 \mathrm{L}H_{i,t} + \sum_{j=-k}^{k} {}'_{1j} \, {}'' LGCF_{i,t-j} + \sum_{j=-k}^{k} {}'_{2j} \, {}'' LL_{i,t-j} + \sum_{j=-k}^{k} {}'_{3j} \, {}'' LH_{i,t-j} + \mu_{i,t} \quad (7)$$

Fully Modified OLS (FMOLS) provides an estimator of cointegrating relationships among non-stationary panel data, correcting for both serial correlation and potential endogeneity. The FMOLS formula is specified as Equation (8):

$$\mathrm{LY}_{i,t} = \alpha_i + \beta_1 \mathrm{LGCF}_{i,t} + \beta_2 \mathrm{LL}_{i,t} + \beta_3 \mathrm{LH}_{i,t} + \varepsilon_{i,t} \quad (8)$$

In employing these methods, appropriate diagnostic tests, including stationarity tests, cointegration tests, and post-estimation diagnostics, are performed to ensure the robustness and reliability of the estimated models.

3 Results

We used STATA 17 for performing the tests and estimation of the models. The descriptive statistics of the variables is presented in Table 2.

Our research commenced by analyzing the presence of cross-sectional dependence. This was evaluated using the bias-adjusted Lagrange Multiplier (LM) test for cross-sectional dependence (47). The findings pertaining to the cross-sectional dependence are tabulated in Table 3.

For assessing cross-sectional dependency, the null hypothesis posited in the trio of applied tests postulated the absence of such dependency. As evident from the data in Table 3, this initial hypothesis is refuted across all tests, indicating the presence of cross-sectional dependency within the data set.

Slope homogeneity tests are crucial in the realm of econometric analysis, particularly in the study of panel data and linear panel models. These tests are designed to ascertain whether the relationships between variables remain consistent across various units or groups within a dataset. The assumption of slope homogeneity, a cornerstone of first-generation panel data models, if invalidated, could introduce bias into conventional panel data estimators. Consequently, following the cross-sectional dependency analysis, this research undertook an examination of slope heterogeneity within the model. For this purpose, the slope heterogeneity tests formulated by Pesaran and Yamagata (50) and Blomquist and Westerlund (51) were utilized.

Table 4 presents results from the Pesaran and Yamagata (50), and Blomquist and Westerlund (51) slope homogeneity tests, with both tests revealing significant test statistics at the 1% level. This statistical significance suggests a rejection of the null hypothesis that slope coefficients are homogeneous across the panel data. The presence of adjusted statistics further supports this finding, indicating slope heterogeneity, which implies that different units in the panel exhibit varying slope coefficients. This result is critical for model specification and interpretation within the associated study.

Subsequently, acknowledging the confirmed cross-sectional dependency and slope heterogeneity, the study progressed to employ the Cross-sectional unit root test (CIPS) (54). The outcomes of this unit root analysis are comprehensively detailed in Table 5.

The CIPS Unit Root Test results indicate that the variables LY, LGCF, LL, and LH are non-stationary at their levels as their test statistics are not significant. However, once differenced, all variables exhibit stationarity: LY and LGCF at the 5% significance level, and LL and LH at the 1% significance level. Upon consideration of the cross-sectional dependence present within the dataset, the decision has been made to rely on the outcomes of the CIPS test. Consequently, it is

TABLE 2 Descriptive statistics.

Variable	n	Mean	Std. Dev.	Min	Max
LY	760	10,174	0,741	8,077	11,725
LGCF	760	25,052	1,592	21,372	28,989
LL	760	15,636	1,488	12,040	18,934
LH	760	7,834	0,621	6,227	9,139

TABLE 3 Cross-sectional dependence test results.

	Value
LM Test	1842*
CD Test	28.05*
Bias Adjusted LM Test	58.59*

*Denote statistical significance at the 1% level. The null hypothesis is no cross-sectional dependence.

TABLE 4 Slope homogeneity test results.

	Pesaran – Yamagata	Blomquist – Westerlund
Δ	21.951*	16.281*
Δ_{adj}	25.346*	18.800*

*Denote statistical significance at the 1% level. In both tests the null hypothesis is slope coefficients are homogenous.

TABLE 5 CIPS unit root test results.

Variable	Level	First-difference
LY	−1.544	−3.283*
LGCF	−1.751	−3.192*
LL	−2.006	−3.495**
LH	−1.870	−3.505**

*, **Denote statistical significance at the 5 and 1% levels, respectively. The null hypothesis is non-stationarity.

assumed that all series exhibit integration of order one, denoted as I (1).

Given that the series were determined to be integrated of order one I (1), the exploration of the cointegration relationship among the series was undertaken utilizing the Durbin–Hausman cointegration test, as formulated by Westerlund (55), which is chosen for its robust accommodation of cross-sectional dependence. This test affords a more sophisticated analysis of cointegration relationships, thereby enhancing the integrity of the results. The Westerlund Durbin–Hausman test's ability to account for cross-sectional dependence is essential in ensuring that the long-run equilibria inferred from the time series data are not spurious but indicative of a genuine cointegration relationship. The outcomes of the Westerlund Durbin–Hausman cointegration test are presented in Table 6.

According to the Westerlund cointegration test results, the Variance Ratio statistic is found as −1.6845 with a *p*-value of 0.0460. This p-value, being below the conventional significance threshold of 0.05, provides a statistically significant basis to reject the null hypothesis of no cointegration at the 5% level. Hence, the data reveal

TABLE 6 Westerlund Durbin–Hausman cointegration test result.

	Value
Variance ratio	−1.6845**

**Denote statistical significance at the 5% level. The null hypothesis is no cointegration.

a long-term equilibrium relationship among the variables within certain panels, suggesting that these non-stationary time series variables are cointegrated and move in tandem over time.

Upon the results of cross-sectional dependence, slope homogeneity, unit root, cointegration tests, it was ascertained that the series exhibit cross-sectionally dependent errors, slope heterogeneity, presence of a unit root and cointegration. The subsequent discourse will revolve around potential estimators, in order to obtain long-run cointegration coefficients, that demonstrate robustness to cross-sectional dependence and/or slope heterogeneity. We employed advanced econometric models including Dynamic CCEMG, CS-ARDL and AMG to rigorously test the HLGH. To substantiate the robustness and reliability of the findings derived from these models, we conducted conventional estimations utilizing the Panel ARDL approach by adopting the PMG estimator. The estimated outcomes derived from the models are delineated in Tables 7, 8.

The empirical investigation into the HLGH across OECD countries yielded substantive evidence, as encapsulated in the estimations presented in Table 7. When applying Dynamic CCEMG, CS-ARDL and AMG econometric methodologies, we discerned a consistent and statistically significant relationship between health expenditure *per capita* and GDP *per capita*, providing robust support for the HLGH. LGCF exerted a positive influence on economic output, with significant coefficients at the 1% level across all models: 0.631 (CCEMG), 0.591 (CS-ARDL), and 0.515 (AMG). This underscores the assertion that capital investment is a pivotal component of economic growth. LL variable revealed a complex pattern, with a significantly positive impact in the CCEMG model at the 5% level (2.696), contrasted by a significant negative influence in the CS-ARDL and AMG models at the 1% level (−0.3440 and − 0.0185, respectively). This complexity may reflect the nuanced effects of labor force size on *per capita* economic output, contingent upon the diverse economic landscapes and labor market dynamics within the OECD countries.

The difference in parameter estimates across various models, particularly when they exhibit different signs, can be attributed to the underlying assumptions and methodological approaches of each estimator. Dynamic CCEMG estimator accounts for cross-sectional dependence by incorporating common factors into the regression model, allowing for heterogeneous slopes and intercepts. This flexibility can lead to more precise estimates but also to differences in parameter signs if common factors influence countries differently (59). The CS-ARDL model captures both short-term and long-term dynamics by including cross-sectional averages of the dependent and independent variables (45). This approach can result in different parameter estimates due to its focus on dynamic relationships and adjustment processes. The AMG (Augmented Mean Group) estimator builds upon the Mean Group (MG) approach by incorporating common correlated effects to address cross-sectional dependence and unobserved heterogeneity. This extension allows the AMG estimator to provide different parameter estimates, especially when significant unobserved common factors are present. By accounting for these common factors, the AMG estimator offers a more robust analysis in

TABLE 7 Second-generation panel data estimation results.

Variable	CCEMG	CS-ARDL	AMG
LGCF	0.6316*** (0.1748)	0.5915*** (0.0599)	0.5159*** (0.0318)
LL	2.6963** (1.3500)	−0.3440*** (0.1162)	−0.01851*** (0.0732)
LH	0.6000** (0.2916)	0.3744*** (0.1220)	0.2261*** (0.0552)
The HLGL Holds	Yes	Yes	Yes

*, **, ***Denote statistical significance at the 10, 5 and 1% levels, respectively.

TABLE 8 Robustness check: conventional panel data estimation results.

Variable	Panel ARDL	DOLS	FMOLS
LGCF	0.7476*** (0.0223)	0.7056*** (0.0211)	0.7130*** (0.0249)
LL	−0.1827** (0.0811)	−0.6179*** (0.0469)	−0.4651*** (0.0051)
LH	0.1021*** (0.0304)	0.2228*** (0.0158)	0.3556*** (0.0067)
The HLGL Holds	Yes	Yes	Yes

*, **, ***Denote statistical significance at the 10, 5 and 1% levels, respectively.

panel data models with heterogeneous slopes and weak cross-sectional dependence of the errors (60).

LH maintained a positive and statistically significant effect on GDP *per capita* at the 5% level in the CCEMG model (0.600) and at the 1% level in both the CS-ARDL (0.374) and AMG (0.226) models, signifying the vitality of health investment as an engine for economic advancement. The consistency in health expenditure's impact across varied analytical frameworks emphasizes its indispensable role in fostering economic development. The findings conclusively affirm the HLGH for the OECD countries.

While our study spans a diverse set of OECD countries, we acknowledge the inherent variability in structural and economic contexts across these nations. This diversity is a critical factor that our methodology addresses using second-generation panel data models. These models provide a nuanced understanding of the health expenditure-economic growth nexus by accounting for country-specific characteristics. Consequently, our findings offer valuable insights that are both generalizable and context-specific, enhancing their relevance for policymaking across different OECD countries. Even though these second-generation models capture the differences among countries in terms of structural and economic contexts, there may still be other factors not captured by our model specifications. This limitation is important to consider when generalizing our results.

After performing the second-generation models, which effectively address cross-sectional dependency and slope heterogeneity, we also employed first-generation panel data models, namely Fully Modified Ordinary Least Squares (FMOLS), Dynamic Ordinary Least Squares (DOLS), and the Pooled Mean Group (PMG) estimator. Even though the results from the second-generation models indicate the presence of cross-sectional dependency and slope heterogeneity, we included first-generation models for several reasons.

First, incorporating first-generation estimators provides a benchmark for comparing the results obtained from second-generation methods. By presenting these estimates, we can illustrate the differences and potential biases that arise when cross-sectional dependency and heterogeneity are not accounted for. This comparative analysis is essential for understanding the extent to which more advanced estimators improve the accuracy and reliability of our findings. Additionally, including first-generation estimations helps validate the robustness of our findings. If the results from both first-generation and second-generation estimators are consistent, it strengthens the credibility of our conclusions by demonstrating that our findings are not sensitive to the choice of estimation technique. Conversely, significant differences between the two sets of results highlight the importance of using advanced techniques to obtain reliable estimates. This approach ensures that our analysis is thorough and that our conclusions are well-supported by multiple methodological perspectives. By employing both first- and second-generation estimators, we aim to provide a comprehensive and robust analysis, demonstrating the improvements and necessity of advanced methods while ensuring that our findings are reliable and credible across different estimation techniques.

Table 8 provides a coherent and compelling set of results from first-generation panel data methodologies. LGCF exhibits a consistently positive and statistically significant effect on the GDP *per capita* across all three methods, with coefficients of 0.7476 (Panel ARDL), 0.7056 (DOLS), and 0.7130 (FMOLS), all significant at the 1% level. This reinforces the notion that investments in the form of capital formation are a pivotal factor in promoting economic prosperity. LL presents an intriguing case with its negative association with GDP *per capita*, significant at the 5% level in the Panel ARDL (−0.1827) and at the 1% level in both DOLS (−0.6179) and FMOLS (−0.4651) estimations. This counterintuitive finding may suggest that an increasing labor force without concurrent increases in job creation or productivity could potentially dilute GDP *per capita*. It might also reflect structural issues within the labor market, such as underemployment or a mismatch between the skills of the labor force and the needs of the economy.

The differences between first- and second-generation panel data models are evident in the parameter estimates for key variables such as gross capital formation (LGCF) and health expenditure (LH). First-generation models, such as FMOLS, DOLS, and PMG, generally produce larger estimates for LGCF and smaller estimates for LH compared to second-generation models. This can be attributed to the assumptions of cross-sectional independence and homogeneity inherent in these models. These assumptions can lead to biased estimates when there is cross-sectional dependence and heterogeneity in the data. Moreover, first-generation models tend to have smaller standard errors due to their parametric nature and the specific handling of dynamic relationships.

Second-generation models, such as Dynamic CCEMG, CS-ARDL, and AMG, account for cross-sectional dependence and heterogeneous slopes, providing more robust and reliable estimates. These models typically yield smaller estimates for LGCF and larger estimates for LH, reflecting a more nuanced understanding of the underlying relationships. The standard errors are generally larger in second-generation models, reflecting the added complexity and flexibility in the estimation process. Second-generation models incorporate cross-sectional dependence by including common factors or averages, which helps to mitigate biases that may inflate estimates in first-generation models. On the other hand, the ability of second-generation models to allow for heterogeneous slopes results in more accurate and representative estimates for variables like LH, which may vary significantly across different countries and contexts. Second-generation models, particularly CS-ARDL, capture both short-term and long-term dynamics, offering a comprehensive view of the relationships between health expenditures and economic growth. This contrasts with the more static approach of first-generation models. The standard errors in second-generation models are larger due to the robust corrections for endogeneity and cross-sectional dependence, providing a more conservative and reliable estimate.

The robustness of the HLGH is further substantiated through the estimations presented in Table 8. The findings of these estimations further corroborate the HLGH in the context of the 38 OECD countries under study. Health Expenditure *per Capita*, the independent variable of particular interest, shows a positive relationship with GDP *per capita* across all models, with coefficients of 0.1021 (Panel ARDL), 0.2228 (DOLS), and 0.3556 (FMOLS), all significant at the 1% level.

The findings of this study indicate that expenditures on health care do not merely lead to enhanced health outcomes but also substantially contribute to economic growth. This highlights the critical value of health as a form of human capital investment. The positive influence of health expenditure on economic growth is particularly compelling, given its consistency across different estimators and robustness checks. It is a finding that holds profound implications for policy formulation, emphasizing the significance of health sector investments in the broader economic agenda of the OECD countries.

In our scholarly endeavor, one of our primary objectives was to meticulously analyze the impact of health financing systems on the HLGH. Understanding how different systems either facilitate or impede the translation of health expenditures into economic growth is crucial for crafting effective health and economic policies. To achieve this, we estimated country-specific coefficients using the AMG estimator, categorizing the countries by their respective health financing models health financing models—namely the Bismarck Model, Beveridge Model, Private Health Insurance Model, and System in Transition (formerly Semaschko) model. These models represent different approaches to delivering and financing health care: The Bismarck model typically involves health insurance funded by employers and employees through payroll deduction, the Beveridge model is characterized by financing through taxation and the health care being provided by the government, the Private Health Insurance model relies heavily on private health insurance as the principal means of covering health costs and the System in Transition country model introduces a unique group, unlike other categories that are often defined by their source of financing, this classification congregates the transitioning economies of Central Europe which characterized by the ongoing transformation of their health systems, indicating a shift from previous models toward new, more market-oriented or mixed systems of healthcare provision and financing (61, 62). This stratified analysis, as presented in our results, allowed us to not only quantify the effect of health expenditure on GDP *per capita* within each country but also to draw comparisons across differing systemic frameworks. The AMG estimator was chosen for estimating country-specific coefficients to effectively manage data heterogeneity and cross-sectional dependence in the global dataset, which also handles unobserved dynamic factors, ensuring robust assessment of the long-term link between health spending and economic growth in each country.

Table 9 presents the country-specific parameter estimations of LH, elucidating the impact of health expenditure on economic growth. We employed the classification framework delineated by Torbica, Fornaro, Tarricone and Drummond (61) for categorizing countries by their health financing mechanisms in the table.

Within the Bismarck Model countries, there is considerable heterogeneity in how health expenditures relate to economic growth. Nations like Belgium, Lithuania, Luxembourg, Switzerland, and Turkiye demonstrate a robust and positive association, while France and Colombia's negative coefficients suggest a different scenario where health spending does not translate into economic growth. Several countries show positive but not statistically significant results, indicating a potential trend that requires further exploration. The standard deviation within this group is the highest among the health financing models at 0.393, indicating a substantial dispersion in the coefficients and suggesting that the relationship between health spending and economic growth is complex and likely influenced by multiple country-specific factors.

The Beveridge Model countries predominantly show positive coefficients, with several countries like Greece, Latvia, New Zealand, Portugal, Spain, Sweden, and the United Kingdom indicating a statistically significant positive relationship between health expenditures and GDP growth. These findings suggest that, in many cases, the government's role in financing healthcare is associated with beneficial economic outcomes. However, the case of Australia demonstrates a significant negative impact, highlighting that the relationship between health spending and economic growth can vary greatly even within a similar healthcare financing framework. The standard deviation for the Beveridge Model group is 0.341, which is relatively high but less than the Bismarck Model group, indicating some degree of variability in the impact of health expenditures on economic growth.

The countries operating under the Private Health Insurance Model demonstrate a more varied impact of health expenditures on GDP growth compared to the Beveridge or Bismarck models. The United States shows a clear positive and significant impact, while Mexico and Chile exhibit coefficients that are not statistically significant, with Mexico showing a negative coefficient and Chile a positive one.

The countries transitioning from the Semaschko model demonstrate a uniformly positive and statistically significant impact of health expenditures on GDP growth, which is quite remarkable. The strong coefficients across these countries suggest that the reforms and restructuring of their healthcare systems have been conducive to leveraging health expenditures for economic growth. The transition appears to be associated with improved efficiency and effectiveness in health spending. The standard deviation for this group is relatively low (0.129), indicating a consistent pattern of positive economic outcomes from health expenditures across these countries. This consistency might be due to the focused efforts and reforms undertaken by these countries to improve their healthcare systems during the transition phase.

Across all models, the mean coefficients are positive, indicating that health expenditure *per capita* generally has a favorable impact on GDP *per capita* across different health financing systems. Yet, the variability within and between these models suggests that the efficiency and effectiveness of health expenditure may be influenced by the particular health financing system in place. The significant

TABLE 9 Health financing systems and country-specific results of the AMG estimator.

Bismarck model	Coeff.	Beveridge model	Coeff.	Private health insurance model	Coeff.	System in transition (former Semaschko model)	Coeff.
Austria	0.131	Australia	−0.581**	Mexico	−0.211	Czechia	0.366***
Belgium	0.396***	Canada	0.108	Chile	0.203	Estonia	0.569***
Colombia	−0.33	Denmark	−0.022	United States	0.128***	Hungary	0.487***
Costa Rica	0.279	Finland	0,019			Poland	0.466***
France	−0.331*	Greece	0.572***			Slovak Republic	0.259***
Germany	0.083	Iceland	0.28**			Slovenia	0.607***
Israel	−0.295	Ireland	0.076				
Japan	0.063*	Italy	−0.057				
Korea, Rep.	−0.159	Latvia	0.733***				
Lithuania	0.727***	New Zealand	0.663**				
Luxembourg	0.381***	Norway	0.112				
Netherlands	−0.066	Portugal	0.591***				
Switzerland	0.885**	Spain	0.394***				
	0.596***	Sweden	0.176***				
Turkiye		United Kingdom	0.292**				
Mean	0.169	Mean	0.224	Mean	0,040	Mean	0.459
Median	0.107	Median	0.176	Median	0,128	Median	0.477
Std. Dev	0.393	Std. Dev	0.341	Std. Dev	0,221	Std. Dev	0.129

*, **, *** Denote statistical significance at the 10, 5 and 1% levels, respectively.

coefficients in many countries reinforce the notion that health expenditure is a key factor in economic growth, supporting the HLGH. Moreover, the negative coefficients in some nations indicate that increased health spending alone does not guarantee higher economic output, highlighting the importance of efficiency and the alignment of health expenditures with broader economic policies and objectives.

4 Discussion

As the world continues to confront challenges such as aging populations, escalating healthcare costs, and the growing prevalence of chronic illnesses, comprehending the relationship between health spending and economic development is increasingly crucial. In our empirical analysis, health expenditure *per capita* delivered a uniformly positive and significant influence on GDP *per capita*, decisively affirming the HLGH across all econometric estimators. Our findings strengthen the argument for health expenditure as a pivotal component of human capital investment which is crucial for economic advancement. This study's affirmation of the HLGH holds profound implications for health policy and planning within OECD nations. The empirical evidence that health spending can boost economic growth provides a compelling rationale for investing in robust, efficient healthcare systems. It positions health spending as part of a value-creation strategy rather than just a cost center.

In this research, we also sought to examine the mechanisms through which health systems can facilitate economic prosperity. Our findings indicate that no single health system model consistently surpasses others in performance. Within the Bismarck and Beveridge models, there is a notable variation among countries, highlighting the role of national-specific elements. The Private Health Insurance Model shows less promise for economic benefits arising from health expenditures, albeit with variable outcomes. In contrast, the System in Transition demonstrates a consistently positive effect. The heterogeneity observed across health financing models suggests that merely increasing health expenditures in a vacuum may not guarantee economic dividends. These insights suggest possible avenues for improving the alignment between health system frameworks and overarching economic policy objectives.

The variability observed in the outcomes of the Bismarck model suggests that while payroll-based insurance provides a stable funding mechanism, there is potential for improvement through reforms aimed at increasing flexibility and enhancing strategic purchasing capabilities (63). It is imperative that the structure of contribution rates and the composition of benefits packages are meticulously designed to strike a harmonious balance between the principles of equity and efficiency. The efficacy of the Beveridge model, as evidenced in numerous countries, highlights the significant role that tax-funded healthcare systems can play in fostering economic growth through judicious allocation of resources and ensuring universal health coverage. The implementation of universal coverage is pivotal within the ambit of economic growth and sustainable development initiatives, chiefly because of its profound influence on augmenting human capital through enhanced health outcomes. It serves as a bulwark against the economic ruin caused by steep out-of-pocket healthcare costs, underpins economic productivity by sustaining a workforce that is both healthy and capable, and necessitates the convergence of efforts across various sectors and the determination of political leadership to drive systemic reforms. These reforms are crucial for guaranteeing equitable access to high-quality healthcare services for the entire populace (64). Within the framework of the private insurance model, HLGH was found to be statistically significant exclusively for the United States. In contrast, for other countries within this category, despite significant reforms, initiatives and policy interventions undertaken in Mexico (65, 66) and Chile (67) during the period from 2000 to 2018, our analysis did not identify a statistically significant link between health expenditure and economic growth. This lack of significant correlation may be attributed to the challenges these countries face in adapting to demographic expansion and fluctuations in inflation, which have adversely impacted *per capita* health expenditure, as reported by the OECD (68). The enduring positive influence of health expenditures on economic growth in Post Semaschko Model countries can be attributed to the strategic implementation of health system reforms within these nations (62, 69). Early initiation of comprehensive health reforms is recognized as a key determinant in achieving superior outcomes within their health systems (69).

This study contributes significantly to the academic literature and policy discussions surrounding the relationship between health and economic growth. By empirically supporting the HLGH and providing insights into the structure of health systems, this research lays a groundwork for further academic exploration. The findings highlight the importance of health expenditure as a high-yield investment for policymakers, emphasizing that such spending can substantially benefit economic growth. However, the impact's magnitude is heavily influenced by the health system's design and efficiency, as well as the financing methods employed. A deeper analysis of the specific features of each health financing model that account for these differences could provide valuable direction for improving health policies and developing more robust strategies for economic growth.

Despite these methodological precautions, the study acknowledges that its findings are subject to the limitations inherent in econometric modeling. These include the possibility of measurement errors in the variables used, the challenge of fully capturing the complex relationship between health expenditures and economic growth, and the potential for unobserved variables to influence the results. Moreover, the study's reliance on available data and the assumptions underlying the econometric models may also limit the generalizability of its conclusions.

This study employs advanced econometric techniques to explore the Health-Led Growth Hypothesis across OECD countries. However, several methodological limitations and assumptions need to be acknowledged. Firstly, while the use of second-generation panel data models addresses cross-sectional dependence and heterogeneity, the accuracy of these models depends on the quality and completeness of the available data. Any measurement errors in the data could affect the results. Secondly, the assumption of homogeneity within health financing models may not fully capture the complex and multifaceted nature of health systems in different countries. Although our models account for heterogeneity, there may still be unobserved factors influencing the relationship between health expenditures and economic growth. Thirdly, the study period (2000–2019) does not account for more recent global events such as the COVID-19 pandemic, which could have significant impacts on health expenditures and economic growth. Future research should consider these recent developments to provide updated insights. Lastly, the potential for reverse causality, where economic growth influences health expenditures, is acknowledged. While our primary focus is on the effect of health expenditures on economic growth, the bidirectional nature of this relationship warrants further investigation. By outlining these limitations and assumptions, we aim to provide a clearer understanding of the context in which our results are applicable and the scope for future research.

5 Conclusion

This study provides important empirical evidence on the relationship between health expenditures and economic growth across OECD countries. The econometric analysis utilizing advanced panel data estimation techniques consistently affirms the HLGH, demonstrating that health spending exerts a statistically significant positive impact on GDP *per capita*. The results highlight that health expenditures should not merely be viewed from the lens of achieving health outcomes but also as a critical form of human capital investment that can stimulate economic development. The study reveals health spending as an engine of economic growth rather than just a byproduct of growing income levels. Our analysis of country-specific effects reveals nuances in how different health financing systems influence the efficiency of health expenditures in boosting economic output.

Data availability statement

Publicly available datasets were analyzed in this study. This data can be found at: https://databank.worldbank.org/source/world-development-indicators.

Author contributions

EA: Conceptualization, Formal analysis, Methodology, Supervision, Writing – original draft, Writing – review & editing. HE: Formal analysis, Methodology, Writing – original draft, Writing – review & editing. OB: Data curation, Funding acquisition, Writing – original draft, Writing – review & editing. HU: Conceptualization, Data curation, Writing – original draft, Writing – review & editing.

Funding

The author(s) declare that financial support was received for the research, authorship, and/or publication of this article. This research received support from the Scientific Research Coordination Unit of Anadolu University, associated with project number 2406.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

References

1. Mushkin SJ. Health as an investment. *J Polit Econ*. (1962) 70:129–57. doi: 10.1086/258730

2. Acemoglu D, Johnson S. Disease and development: the effect of life expectancy on economic growth. *J Polit Econ*. (2007) 115:925–85. doi: 10.1086/529000

3. Klotzbach H, Delling G, Richter E, Sperhake JP, Puschel K. Post-mortem diagnosis and age estimation of infants' fractures. *Int J Legal Med*. (2003) 117:82–9. doi: 10.1007/s00414-002-0338-3

4. Lucas RE. On the mechanics of economic-development. *J Monet Econ*. (1988) 22:3–42. doi: 10.1016/0304-3932(88)90168-7

5. Subramanian SV, Subramanyam MA. Economic growth & health of poor children in India. *Indian J Med Res*. (2011) 106:407–6. doi: 10.2307/2937943

6. Barro RJ, Lee JW. Sources of economic growth. *Carn Roch Conf Serie*. (1994) 40:1–46. doi: 10.1016/0167-2231(94)90002-7

7. Romer PM. Increasing returns and long-run growth. *J Polit Econ*. (1986) 94:1002–37. doi: 10.1086/261420

8. Hansen P, King A. The determinants of health care expenditure: a cointegration approach. *J Health Econ*. (1996) 15:127–37. doi: 10.1016/0167-6296(95)00017-8

9. Hartwig J. Is health capital formation good for long-term economic growth? – panel granger-causality evidence for OECD countries. *J Macroecon*. (2010) 32:314–25. doi: 10.1016/j.jmacro.2009.06.003

10. Bloom DE, Canning D. Policy forum: public health. The health and wealth of nations. *Science*. (2000) 287:1207–9. doi: 10.1126/science.287.5456.1207

11. Bloom D, Canning D, Sevilla J. The Demographic Dividend: A New Perspective on the Economic Consequences of Population Change Rand Corporation. RAND Corporation. (2003).

12. Bloom DE, Canning D, Sevilla J. The effect of health on economic growth: a production function approach. *World Dev*. (2004) 32:1–13. doi: 10.1016/j.worlddev.2003.07.002

13. Wang KM. Health care expenditure and economic growth: quantile panel-type analysis. *Econ Model*. (2011) 28:1536–49. doi: 10.1016/j.econmod.2011.02.008

14. Preston SH. The changing relation between mortality and level of economic development. *Popul Stud*. (1975) 29:231–48. doi: 10.1080/00324728.1975.10410201

15. Wagstaff A. Inequalities in health in developing countries: swimming against the tide? *Policy Res*. (2002) 1–40. doi: 10.1596/1813-9450-2795

16. Getzen TE. Health care is an individual necessity and a national luxury: applying multilevel decision models to the analysis of health care expenditures. *J Health Econ*. (2000) 19:259–70. doi: 10.1016/S0167-6296(99)00032-6

17. Gerdtham U-G, Jönsson B. International comparisons of health expenditure: theory, data and econometric analysis In: Handbook of health economics, vol. *1*. eds. A. J. Culyer and J. P. Newhouse Elsevier (2000). 11–53.

18. Gerdtham UG, Lothgren M. On stationarity and cointegration of international health expenditure and GDP. *J Health Econ*. (2000) 19:461–75. doi: 10.1016/s0167-6296(99)00036-3

19. Baltagi BH, Moscone F. Health care expenditure and income in the OECD reconsidered: evidence from panel data. *Econ Model*. (2010) 27:804–11. doi: 10.1016/j.econmod.2009.12.001

20. Kumar S. Systems GMM estimates of the health care spending and GDP relationship: a note. *Eur J Health Econ*. (2013) 14:503–6. doi: 10.1007/s10198-012-0394-7

21. Atilgan E, Kilic D, Ertugrul HM. The dynamic relationship between health expenditure and economic growth: is the health-led growth hypothesis valid for Turkey? *Eur J Health Econ*. (2017) 18:567–74. doi: 10.1007/s10198-016-0810-5

22. Tang CF, Ch'ng KS. The granger causality between health expenditure and income in Southeast Asia economies. *Afr J Bus Manag*. (2011) 5:6814–24. doi: 10.5897/AJBM10.1550

23. Newhouse JP. Medical-care expenditure: a cross-national survey. *J Hum Resour*. (1977) 12:115. doi: 10.2307/145602

24. Behera DK, Dash U. The impact of macroeconomic policies on the growth of public health expenditure: an empirical assessment from the Indian states. *Cogent Econ Finance*. (2018) 6:1–21. doi: 10.1080/23322039.2018.1435443

25. Beylik U, Cirakli U, Cetin M, Ecevit E, Senol O. The relationship between health expenditure indicators and economic growth in OECD countries: a Driscoll-Kraay approach. *Front Public Health*. (2022) 10:1050550. doi: 10.3389/fpubh.2022.1050550

26. Jakovljevic M, Timofeyev Y, Ranabhat CL, Fernandes PO, Teixeira JP, Rancic N, et al. Real GDP growth rates and healthcare spending - comparison between the G7 and the EM7 countries. *Glob Health*. (2020) 16:64. doi: 10.1186/s12992-020-00590-3

27. Ozyilmaz A, Bayraktar Y, Isik E, Toprak M, Er MB, Besel F, et al. The relationship between health expenditures and economic growth in EU countries: empirical evidence using panel Fourier Toda-Yamamoto causality test and regression models. *Int J Environ Res Public Health*. (2022) 19:1–17. doi: 10.3390/ijerph192215091

28. Faruk BU, Haque MI, Tausif MR, Khan MR. Health expenditure, institutions, and economic growth: insights from selected MENA countries. *Health Promot Perspect*. (2022) 12:92–100. doi: 10.34172/hpp.2022.12

29. Mehrara M, Musai M. Granger causality between health and economic growth in oil exporting countries. *Interdis J Res Business*. (2011) 1:103–8.

30. Elmi ZM, Sadeghi S. Health care expenditures and economic growth in developing countries: panel co-integration and causality. *Middle-East J Sci Res*. (2012) 12:88–91. doi: 10.5829/idosi.mejsr.2012.12.1.64196

31. Ye L, Zhang X. Nonlinear granger causality between health care expenditure and economic growth in the OECD and major developing countries. *Int J Environ Res Public Health*. (2018) 15:1953. doi: 10.3390/ijerph15091953

32. Fazaeli AA, Ghaderi H, Salehi M, Fazaeli AR. Health care expenditure and GDP in oil exporting countries: evidence from OPEC data, 1995-2012. *Global J Health Sci*. (2015) 8:93–8. doi: 10.5539/gjhs.v8n2p93

33. Hartwig J. What drives health care expenditure?--Baumol's model of 'unbalanced growth' revisited. *J Health Econ*. (2008) 27:603–23. doi: 10.1016/j.jhealeco.2007.05.006

34. Cetin M, Ecevit E. Sağlık Harcamalarının Ekonomik Büyüme Üzerindeki Etkisi: OECD Ülkeleri Üzerine Bir Panel Regresyon Analizi. *Doğuş Üniversitesi Dergisi*. (2010) 2:166–82. doi: 10.31671/dogus.2019.160

35. Celik EU, Omay T, Tengilimoglu D. Convergence of economic growth and health expenditures in OECD countries: evidence from non-linear unit root tests. Front. *Public Health*. (2023) 11:11. doi: 10.3389/fpubh.2023.1125968

36. Artekin AÖ, Konya S. Health Expenditure and Economic Growth: Is the Healthled Growth Hypothesİs Supported for Selected Oecd Countries? *Pi-be*. (2020) 14:77–89. doi: 10.22598/pi-be/2020.14.1.77

37. Nghiem SH, Connelly LB. Convergence and determinants of health expenditures in OECD countries. *Heal Econ Rev*. (2017) 7:29. doi: 10.1186/s13561-017-0164-4

38. Rodrik D, Subramanian A, Trebbi F. Institutions rule: the primacy of institutions over geography and integration in economic development. *J Econ Growth*. (2004) 9:131–65. doi: 10.1023/B:Joeg.0000031425.72248.85

39. Bhattacharyya S. Deep determinants of economic growth. *Appl Econ Lett*. (2004) 11:587–90. doi: 10.1080/1350485042000228826

40. Schomaker R. Institutional quality and private sector participation: theory and empirical findings. *European J Government Econ*. (2014) 3:104–18. doi: 10.17979/ejge.2014.3.2.4300

41. Baltagi BH. Econometric analysis of panel data. *6th* ed. Cham, Switzerland: Springer Nature (2021). 424 p.

42. Pesaran MH, Shin YC, Smith RP. Pooled mean group estimation of dynamic heterogeneous panels. *J Am Stat Assoc*. (1999) 94:621–34. doi: 10.1080/01621459.1999.10474156

43. Phillips PCB, Hansen BE. Statistical inference in instrumental variables regression with I(1) processes. *Rev Econ Stud*. (1990) 57:99. doi: 10.2307/2297545

44. Stock JH, Watson MW. A simple estimator of Cointegrating vectors in higher-order integrated systems. *Econometrica*. (1993) 61:783–820. doi: 10.2307/2951763

45. Chudik A, Pesaran MH. Common correlated effects estimation of heterogeneous dynamic panel data models with weakly exogenous regressors. *J Econ*. (2015) 188:393–420. doi: 10.1016/j.jeconom.2015.03.007

46. WDI. World development indicators. DataBank (2023). Available from: https://databank.worldbank.org/source/world-development-indicators.

47. Pesaran MH, Ullah A, Yamagata T. A bias-adjusted LM test of error cross-section independence. *Econ J*. (2008) 11:105–27. doi: 10.1111/j.1368-423x.2007.00227.x

48. O'Connell PGJ. The overvaluation of purchasing power parity. *J Int Econ*. (1998) 44:1–19. doi: 10.1016/S0022-1996(97)00017-2

49. Sarafidis V, Robertson D. On the impact of error cross-sectional dependence in short dynamic panel estimation. *Econ J*. (2009) 12:62–81. doi: 10.1111/j.1368-423X.2008.00260.x

50. Pesaran MH, Yamagata T. Testing slope homogeneity in large panels. *J Econ*. (2008) 142:50–93. doi: 10.1016/j.jeconom.2007.05.010

51. Blomquist J, Westerlund J. Testing slope homogeneity in large panels with serial correlation. *Econ Lett*. (2013) 121:374–8. doi: 10.1016/j.econlet.2013.09.012

52. Pesaran MH, Smith R. Estimating long-run relationships from dynamic heterogeneous panels. *J Econ*. (1995) 68:79–113. doi: 10.1016/0304-4076(94)01644-F

53. Im KS, Pesaran MH, Shin Y. Testing for unit roots in heterogeneous panels. *J Econ*. (2003) 115:53–74. doi: 10.1016/S0304-4076(03)00092-7

54. Pesaran MH. A simple panel unit root test in the presence of cross-section dependence. *J Appl Econ*. (2007) 22:265–312. doi: 10.1002/jae.951

55. Westerlund J. Panel cointegration tests of the fisher effect. *J Appl Econ*. (2008) 23:193–233. doi: 10.1002/jae.967

56. Chudik A, Pesaran MH, Tosetti E. Weak and strong cross-section dependence and estimation of large panels. *Econ J*. (2011) 14:C45–90. doi: 10.1111/j.1368-423x.2010.00330.x

57. Eberhardt M, Bond S. Cross-section dependence in nonstationary panel models: A novel estimator [Munich Personal RePEc Archive MPRA paper]. (2009).

58. Francis T, Markus E. Productivity analysis in global manufacturing production. Oxford: University of Oxford, Department of Economics (2010).

59. Baltagi BH, Feng Q, Kao C. Structural changes in heterogeneous panels with endogenous regressors. *J Appl Econ*. (2019) 34:883–92. doi: 10.1002/jae.2712

60. Chudik A, Pesaran MH. Mean group estimation in presence of weakly cross-correlated estimators. *Econ Lett*. (2019) 175:101–5. doi: 10.1016/j.econlet.2018.12.036

61. Torbica A, Fornaro G, Tarricone R, Drummond MF. Do social values and institutional context shape the use of economic evaluation in reimbursement decisions? An Empirical Analysis. *Value Health*. (2020) 23:17–24. doi: 10.1016/j.jval.2019.11.001

62. Łyszczarz B. The effect of health care model on health systems' responses to economic crises. *Ekonomia i Prawo*. (2016) 15:493. doi: 10.12775/EiP.2016.033

63. Lagomarsino G, Garabrant A, Adyas A, Muga R, Otoo N. Moving towards universal health coverage: health insurance reforms in nine developing countries in Africa and Asia. *Lancet*. (2012) 380:933–43. doi: 10.1016/s0140-6736(12)61147-7

64. Frenk J, de Ferranti D. Universal health coverage: good health, good economics. *Lancet*. (2012) 380:862–4. doi: 10.1016/s0140-6736(12)61341-5

65. González Block MA, Hernández Galdámez DR, Heredia Pi IB. Health systems of Mexico, Central America, and the Caribbean. Reference module in biomedical sciences Elsevier (2023).

66. Gómez-Dantés O, Fuentes-Rivera E, Escobar J, Serván-Mori E. An assessment of the performance of the Mexican health system between 2000 and 2018. *Health Policy Plan*. (2023) 38:689–700. doi: 10.1093/heapol/czad028

67. Méndez CA, Greer SL, McKee M. The 2019 crisis in Chile: fundamental change needed, not just technical fixes to the health system. *J Public Health Policy*. (2020) 41:535–43. doi: 10.1057/s41271-020-00241-2

68. OECD. Health at a glance: Latin America and the Caribbean 2020. Paris: OECD Publishing (2020).

69. Romaniuk P, Szromek AR. The evolution of the health system outcomes in central and Eastern Europe and their association with social, economic and political factors: an analysis of 25 years of transition. *BMC Health Serv Res*. (2016) 16:95–5. doi: 10.1186/s12913-016-1344-3

frontiers | Frontiers in Public Health

TYPE Original Research
PUBLISHED 25 July 2024
DOI 10.3389/fpubh.2024.1418179

Older adults 's hospitalizational costs and burden study in China——analysis from CHARLS data 2018

Shanheng He[1,2,3] and Ying Bian[1,2,3]*

[1]Institute of Chinese Medical Sciences, University of Macau, Macau, China, [2]State Key Laboratory of Quality Research in Chinese Medicine, University of Macau, Macau, China, [3]Department of Public Health and Medicinal Administration, Faculty of Health Sciences, University of Macau, Macau, China

Check for updates

OPEN ACCESS

EDITED BY
Hai Fang,
Peking University, China

REVIEWED BY
Sime Smolic,
University of Zagreb, Croatia
Zhenghui Li,
Guangzhou University, China

*CORRESPONDENCE
Ying Bian
✉ bianyingumac@126.com

RECEIVED 16 April 2024
ACCEPTED 19 June 2024
PUBLISHED 25 July 2024

CITATION
He S and Bian Y (2024) Older adults 's hospitalizational costs and burden study in China——analysis from CHARLS data 2018.
Front. Public Health 12:1418179.
doi: 10.3389/fpubh.2024.1418179

Objective: The aging Chinese population is driving up health care costs, with hospitalizational accounting for a large portion of total health care costs. By 2012, hospitalization costs for people over 60 years of age exceeded outpatient costs, marking a change in the allocation of medical resources. Further research is needed on the factors influencing changes in hospitalizational costs and burden. This paper examines the costs and burden of hospitalization for older adults from a micro perspective, providing new evidence to explain how social, medical, family, personal, and geographic factors affect them.

Methods: Utilizing data from the 2018 China Health and Retirement Longitudinal Study (CHARLS), a linear regression model was constructed to investigate the impact of various factors on the hospitalization costs and burden among the older adult in China. To ensure the heterogeneity of the results, the sample was divided into subgroups based on different regions for comparative analysis. Additionally, collinearity among the variables was examined.

Results: The average hospitalization costs for the older adult are $1,199.24, with a burden score of 0.5. Residence, type of chronic diseases, region, family size, type of health service facility, received distance, smoke and alcoholic significantly affect the out-of-pocket expenses for older adult hospitalizations. In terms of the burden of hospitalization for the older adult, Residence, health insurance, education, type of chronic diseases, region, family size, ethnic, type of health service facility, received distance, smoke, alcoholic and pension significantly impact the hospitalization burden for the older adult.

Conclusion: This paper provides a new perspective to explain the factors influencing hospitalizational costs and burden in China. The policy recommendations include expanding health insurance coverage and promoting commercial insurance to enhance the accessibility and financial security of healthcare services. Strengthening primary care is suggested to reduce the burden on hospitals and lower the overall cost of hospitalization. Policies aimed at addressing regional healthcare disparities are proposed, along with targeted support for vulnerable groups, including subsidies and culturally sensitive services.

KEYWORDS

China, older adult people, medical expenditures, hospitalizational costs, hospitalizational burden

1 Introduction

The improvement of living standards and better medical conditions have led to a decline in the birth rate and an extension of life expectancy, gradually transitioning China into an aging society. Since the 1980s, the proportion of the population aged 0–14 has been decreasing, while the proportion of those aged 65 and above has been steadily increasing. In the year 2000, individuals aged 60 and above constituted 10% of the total population in China, marking the country's entry into the internationally recognized stage of an aging society. According to the sixth national population census conducted in 2010, the proportion of people aged 60 and above exceeded 13.26% of the total population. By the time of the seventh ethnical population census in 2020, the percentage of the population aged 60 and above had risen to 18.7% of the total population. This is a notable increase from the 7% recorded in 2000. It indicates that within a span of 21 years, the proportion of China's older adult population aged 65 and older doubled from 7 to 14%. In comparison, it has typically taken high-income countries (HICs) around 55 years to achieve a similar doubling of this demographic segment (1–4). It is projected that by the year 2050, the proportion of the population aged 65 and above will reach 26%, with the proportion of those aged 80 and above accounting for 8% (5). These findings indicate that China has long entered the aging period, and the degree of aging is becoming increasingly severe.

Since the beginning of the 21st century, healthcare expenditure in the People's Republic of China has been on the rise. The *per capita* healthcare expenditure soared rapidly from 1,407.74 Yuan (CNY) in 2008 to 3,783.83 Yuan (CNY) in 2017 (6). Concurrently, the proportion of government health expenditures increased from 5.7 to 7.5%, and as a percentage of the overall gross domestic product (GDP), it rose from 1.1 to 1.8% (7). Aging is a pivotal determinant influencing healthcare expenditure. While the aggregate level of public health spending is largely driven by societal determinants, its distribution is significantly dictated by health and disability. Consequently, additional increments in medical innovation and healthcare spending are often targeted towards the older adults, exacerbating the impact of population aging (8, 9). Evidence from Beijing indicates that the age effect on healthcare expenditure is most pronounced among the population aged 65 or over. The *per capita* healthcare expenditure for individuals aged 65 years or older is 7.25 times that of the population aged under 25 years, 1.61 times that of the population aged 25 to 59 years, and 3.47 times that of the population aged 60 to 64 years (10).

Hospitalization costs represent a substantial portion of overall medical expenses. According to the OECD Health Statistics 2021 report, inpatient care accounts for 28% of healthcare expenditure in OECD countries. From 2009 to 2013, the annual growth rate of hospitalization expenditure was 0.3%, while from 2013 to 2019, it increased by 2.1%. The expenditure and burden of hospitalization reflect the condition of hospitalized patients (11). The higher the hospitalization costs and burden, the higher the economic risk of illness for patients. Understanding the proportion of hospitalization costs in healthcare spending and its growth trend is essential for assessing the overall costs of the healthcare system and can serve as a basis for allocating medical resources.

In China, existing research has shown that the total outpatient expenses for individuals aged 60 and above were 1056.44 billion yuan in 2009, while the total hospitalizational costs were 957.02 billion yuan. By 2012, hospitalizational costs had increased to 2132.10 billion yuan, surpassing outpatient expenses, which totaled 2073.88 billion yuan (12). This reversal in expenditure highlights the shifting dynamics and patterns in healthcare utilization and resource allocation, underscoring the need for further investigation into the factors driving changes in hospitalization costs and burden.

The research by De Foor (13) indicates that there is a significant difference in hospitalization costs between older adult men and women, with men incurring higher hospitalization costs than women. Research by Zhang Rong and Li Fang demonstrates that medical insurance significantly increases outpatient and inpatient medical expenses for older adult individuals with chronic diseases. China's health insurance system has been effective in increasing health care utilization and reducing out-of-pocket (OOP) hospitalization expenditures (14). China's medical insurance system has successfully facilitated greater access to healthcare services and decreased out-of-pocket expenses for hospital stays (15, 16). According to the research by Ye Ziyi et al. variations exist in hospitalization costs among older adult patients of different genders, ethnicities (2–4). Ouyang Jing and colleagues have also pointed out that there are statistically significant differences in hospitalization costs among older adult patients across different genders, ethnicities, and healthcare institutions visited (17). The level of medical facilities also affects inpatient medical expenses, and the rational utilization and distribution of town-level and county-level hospitals may help to reduce medical costs (18). The study conducted by Yanghe et al. (19) indicates that there are statistically significant differences in the average hospitalizational costs and burden among patients with different educational levels, marital statuses, and types of medical insurance. The size of the household, origin from different regions, as well as the distance to medical facilities, have been shown to influence expenses (20, 21). Additionally, for chronic diseases and their types, many scholars have included them in the scope of factors affecting hospitalization costs (21, 22). Lifestyle and income are also significant factors influencing older adult hospitalization costs (23).

2 Research program

2.1 Data sources

This study used data from The China Health and Retirement Longitudinal Study (CHARLS) database. CHARLS is an ethnically representative population-based survey designed to study social, health, and economic issues of residents aged ≥45 years in light of the burgeoning aging population in China (24). Using the Probabilities Proportional to Size (PPS) sampling method, by adopting regional status, urban-rurality, and gross domestic product data in 2009 as stratified indicators, CHARLS followed the top-down county-neighborhood-household-individual order procedure in sampling. For sample weighting, CHARLS constructed sample weights for households, individuals, and biomarker data directly from the sampling probabilities (24). Face-to-face computer-assisted personal interviews (CAPI), physical measurements, and blood tests were conducted every 2 years to collect data. This study used data from 2018 and covered 17,970 residents in 10,524 households in 28 provinces in China, with a response rate of 83.84%.

According to the current legal retirement age in China, we have taken the definition of the older adult as 60 years old for men and 55 years old for women.

2.2 Research hypothesis

Rongfei et al. (25) research shows that in 2010, the provinces with the highest inpatient medical expenses in China were also twice as high as the lowest. Empirical studies have illustrated that in 2017, the maximum *per capita* hospitalization expenditure was 3.64-fold that of the minimum, a disparity that increased to 3.79-fold by 2019. This indicates a secular upward trend with significant variability in *per capita* costs across different regions. Spatial analysis of *per capita* hospitalization costs has revealed a pattern of geographic concentration, with a pronounced disparity characterized by higher costs in the eastern coastal regions compared to the western regions of China (26).

In terms of impact on the medical burden of the older adult, Chen et al. (23) made a systematic regression review to identify the factors that affect the medical expense burden of the older adult population and studied these factors from different angles. Various factors have been identified as having a significant impact on changes in health costs for older adults, including social, medical, family, and personal factors (23).

Accordingly, the design idea of the study is to first analyze the hospitalizational costs and burden of the older adults in various provinces, and then select the social, medical, family and personal factors that affect the hospitalization costs and burden of the older adult in the data sources. Due to the impact of residency and region on costs and burdens, the fifth factor, geographic factors, is selected. OLS regressions are used to determine how they affect costs and burdens. In the study, we took the exchange rate value of December 2018 and discounted it to 2023, where 1 US dollar is equal to 6.51 yuan.

2.3 Study variables

In our study, we focused on older adults' hospitalizational costs and burden in 2018 as the outcome variable. The hospitalizational costs of the sample are measured by asking 'What is the total cost of hospitalization in the past year (excluding escort, family transportation and accommodation)?' 'How much of it was self-paid?'. The hospitalizational costs are the out-of-pocket (OOP). The hospitalizational burden is constituted by the ratio of self-payment expenses to total expenses. Because personal hospitalization costs generally have a positively skewed distribution. So, take the natural logarithm of it. If out-of-pocket medical costs are 0, still take 0.

The explanatory variables encompass social factors such as health insurance and pension, medical factors including the type of health service facility and received distance, family factors like family size, and personal factors which involve gender, education, chronic disease, type of chronic diseases, marital status, ethnicity, smoking status, and alcohol consumption. Additionally, geographic factors are considered, specifically focusing on residence and region. The variable definitions and descriptions are as shown in Table 1.

TABLE 1 Definition of variables.

Variable	Variable definition and assignment	
Hospitalizational costs	Measured by asking 'What was the out-of-pocket medical cost for all the inpatient care you received during the past year?'	
Hospitalizational burden	The ratio of out-of-pocket medical costs to total costs.	
Residence	0 for Rural; 1 for Urban	
Gender	0 for Male; 1 for Female	
Health insurance	Basic health insurance	No health insurance is the baseline
	Other health insurance	
Education	"0" is Under primary school education; "1" refers to those who have received elementary school; "2" is the Middle school education; "3" is a Above middle school.	
Chronic disease	0 for no; 1 for yes	
Type of chronic diseases	Hypertension	0 for no; 1 for yes
	Dyslipidemia	
	Diabetes	
	Malignancy	
	Chronic lung disease	
	Liver disease	
	Heart attack	
	Stroke	
	Kidney disease	
	Stomach or digestive disorders	
	Emotional and mental problems	
	Memory-related disorders	
	Arthritis or rheumatism	
	Asthma	
Region	Central areas	Eastern areas are the baseline
	Western areas	
	Northeast areas	
Family size	The people who live with the interviewee and the interviewee jointly form a Household member and share the household income and expenses.	
Marital status	Unmarried, divorced (separated as a spouse, divorced, widowed) is "0," married is "1."	
Ethnic	0 for Other; 1 for Han	
Type of health service facility	General hospital	Chinese Medicine Hospital is the baseline
	Specialized hospital	
	Township Hospital	
	Other	
Received distance	The distance from the interviewer's home to the last outpatient medical facility	
Smoke	0 for Never smoke; 1 for Now or have smoked	
Alcoholic	0 for Haven't drunk alcohol in the past year; 1 for Have drunk alcohol in the past year	
Pension	0 for interviewees who participated in or receive benefits; 1 for interviewees who not participated in or receive benefits	

3 Empirical analysis

3.1 Descriptive statistics

The Table 2 presents a comprehensive analysis of hospitalization costs incurred by older adult individuals in China during the year 2018. It provides detailed statistics categorized by various demographic and socioeconomic variables, shedding light on the intricate patterns of healthcare expenditure among this population segment.

In the 2018 cohort of hospitalized patients in China, females constituted a larger proportion at 55.0% (1,238/2254), while males accounted for 45.0% (1,016/2254). Regarding residential areas, rural patients made up 56.5% (1,270/2254) of the sample, with urban patients comprising 43.5% (984/2254). The vast majority of patients were covered by basic health insurance, with 95.8% (2,160/2254) having access, while a small fraction had other types of health insurance (2.5%, 56/2254) or no health insurance at all (0.7%, 38/2254). In terms of educational attainment, 31.7% (715/2254) of the patients were illiterate, 20.7% (466/2254) did not complete primary school, 24.2% (536/2254) had completed primary school, 14.2% (319/2254) had completed secondary school, and only 9.7% (218/2254) had attained education levels beyond secondary school.

Among the hospitalized patients, 95.7% (2,158/2254) suffer from at least one chronic disease. Hypertension was the most prevalent, affecting 56.4% (1,275/2254) of the patients, followed by arthritis or rheumatism (52.5%, 1184/2254) and gastrointestinal diseases (42.3%, 953/2254). Other common chronic conditions include heart attack (39.2%, 883/2254), dyslipidemia (34.4%, 774/2254), chronic lung disease (28.9%, 650/2254), diabetes (22.1%, 498/2254), stroke (18.5%, 418/2254), kidney disease (17.7%, 398/2254), asthma (13.7%, 309/2254), liver disease (10.6%, 239/2254), memory-related disorders (10.2%, 230/2254), malignancy (5.28%, 119/2254), and emotional and mental problems (4.7%, 107/2254).

The regional distribution of hospitalized patients revealed that the western region had the highest proportion of patients, at 43.3% (972/2254), followed by the central region (30.5%, 688/2254), the eastern region (20.1%, 452/2254), and the northeastern region (6.3%, 142/2254). These data reflect the health status and medical needs of the older adult population across different regions in China, providing crucial insights for the development of public health policies and the allocation of resources.

The average total cost for hospitalization among the older adult is $2518.83, with a notable standard deviation of $4980.29, indicating a wide range of expenses within this demographic group. On average, out-of-pocket (OOP) expenses amount to $1199.24, with a standard deviation of $2428.75, suggesting significant variability in the financial burden borne by older adult patients. Male older adult individuals tend to incur slightly higher average total costs ($2732.60) and OOP expenses ($1201.82) compared to their female counterparts, although the difference in burden is marginal. Urban older adult individuals generally face higher average total costs ($3030.21) and OOP expenses ($1274.26) compared to their rural counterparts. However, rural elders exhibit a slightly higher burden. Older adult individuals covered by basic health insurance schemes report higher average total costs ($2523.81) and OOP expenses ($1205.34) compared to those with other forms of health insurance or without coverage. However, the burden is relatively lower for the former group. The level of educational attainment among older adult individuals correlates with healthcare expenses, with those with lower educational levels (e.g., illiterate, or incomplete primary education) experiencing lower average total costs and OOP expenses but bearing a higher burden. Older adult individuals diagnosed with chronic diseases generally face higher average total costs and OOP expenses compared to those without such conditions. However, the burden remains relatively consistent across both groups. Different chronic diseases exhibit varying impacts on healthcare expenses. For instance, malignancy is associated with significantly higher expenses compared to other chronic conditions. Older adult individuals residing in eastern regions incur substantially higher average total costs and OOP expenses compared to their counterparts in other regions, leading to a relatively higher burden.

3.2 Older adult's hospitalizational costs and burden in each province

In China, the relationship between the ranking of *per capita* GDP and the out-of-pocket expenses and burden for older adult residents' hospitalizations across various provinces provides a critical perspective for understanding the link between economic development and the affordability of healthcare services. Comparative analysis reveals some striking patterns.

This is shown in Figure 1, the data indicates significant disparities in the out-of-pocket medical burden among different provinces. Beijing has the lowest proportion of medical burden, at 0.39, with out-of-pocket expenses for hospitalization amounting to $5027.92. Shanghai's medical burden ratio is 0.54, with out-of-pocket hospitalization costs at $4273.09. In contrast, Tianjin has the highest medical burden ratio, reaching 0.77, yet the out-of-pocket expenses are relatively lower, at $1724.59. Furthermore, provinces such as Jiangsu, Zhejiang, and Guangdong, despite their high GDP rankings, do not exhibit the lowest ratios of medical burden. This may reflect the higher cost of medical services in these regions. On the other hand, provinces like Guizhou, Yunnan, and Gansu, which have lower GDP rankings, do not necessarily have the highest ratios of medical burden, possibly due to local living costs, healthcare policies, and residents' health needs.

Overall, it can be observed from the data that as the ranking of *per capita* GDP decreases, the *per capita* out-of-pocket expenses for older adult hospitalization tend to decrease as well, while there is no distinct trend in the *per capita* hospitalization burden, which mostly hovers around 0.5.

This analysis underscores the complexity of the relationship between economic development and healthcare affordability. It suggests that while economic prosperity generally correlates with lower out-of-pocket medical expenses, other factors, including healthcare policies and the cost of living, also play significant roles in determining the medical burden on the older adult population. Policymakers may need to consider these multifaceted factors when designing interventions to improve healthcare affordability and accessibility for the aging population across different economic settings.

3.3 Multicollinearity test

The Table 3 presents the results of multicollinearity diagnostics through the calculation of Variance Inflation Factors (VIF) and their reciprocals (1/VIF). These metrics assess the degree of collinearity among the independent variables in a regression model. In regression

TABLE 2 Hospitalizational costs and burden of the older adults of China in 2018.

Variables		Number	Total costs		OOP of inpatient		Burden	
			Mean	SD	Mean	SD	Mean	SD
All		2,254	2518.83	4980.29	1199.24	2428.75	0.50	0.28
Gender	Male	1,016	2732.60	5989.91	1201.82	2522.22	0.48	0.28
	Female	1,238	2343.39	3958.17	1197.13	2350.30	0.51	0.28
Residence	Rural	1,270	2122.60	3994.98	1141.11	2450.91	0.53	0.29
	Urban	984	3030.21	5981.67	1274.26	2399.01	0.46	0.27
Health insurance	Basic health insurance	2,160	2523.81	5028.40	1205.34	2449.78	0.50	0.28
	Other health insurance	56	2633.30	3118.87	948.35	1307.35	0.41	0.31
	No health insurance	38	2067.08	4497.47	1222.50	2522.41	0.79	0.35
Education	Illiterate	715	2214.98	3880.58	1102.89	2195.13	0.53	0.29
	Did not Finish Primary School	466	2274.40	4755.27	1163.38	2704.76	0.53	0.27
	Elementary School	536	2649.88	4429.20	1300.26	2309.33	0.50	0.27
	Middle School	319	2904.80	7019.35	1179.41	2544.56	0.43	0.26
	Above middle School	218	3150.87	6152.27	1372.53	2643.37	0.44	0.29
Chronic disease	Yes	2,158	2555.34	5049.16	1213.24	2448.36	0.50	0.28
	No	96	1698.11	2944.65	884.45	1919.51	0.50	0.29
Type of chronic diseases	Hypertension	1,275	2634.67	5282.26	1242.89	2487.22	0.50	0.28
	Dyslipidemia	774	2759.27	5971.68	1257.03	2642.68	0.49	0.28
	Diabetes	498	2992.28	5170.46	1336.91	2505.55	0.47	0.27
	Malignancy	119	7625.51	13480.41	3581.88	5270.70	0.53	0.29
	Chronic lung disease	650	2707.67	4709.12	1240.30	2289.36	0.49	0.29
	Liver disease	239	3419.36	8766.98	1486.33	2989.25	0.53	0.29
	Heart attack	883	2685.92	5838.91	1219.85	2457.80	0.48	0.28
	Stroke	418	2747.68	4179.31	1314.29	2458.05	0.48	0.28
	Kidney disease	398	3319.55	7780.01	1423.92	2796.01	0.47	0.27
	Stomach or digestive disorders	953	2393.87	4285.55	1178.67	2345.32	0.51	0.28
	Emotional and mental problems	107	2801.08	5737.31	1481.02	2984.47	0.47	0.28
	Memory-related disorders	230	2801.47	5343.23	1208.62	2257.19	0.47	0.29
	Arthritis or rheumatism	1,184	2287.07	4110.11	1122.90	2120.73	0.51	0.29
	Asthma	309	2574.47	4907.72	1090.42	2004.03	0.47	0.28
Region	Eastern areas	452	3138.66	5263.93	1603.45	2869.47	0.53	0.28
	Central areas	688	2236.61	4380.82	952.13	1783.25	0.48	0.28
	Western areas	972	2359.10	4296.66	1156.36	2478.90	0.50	0.29
	Northeast areas	142	3006.60	9220.52	1403.38	3038.38	0.49	0.26

analysis, multicollinearity occurs when independent variables are highly correlated with each other, which can lead to unreliable coefficient estimates and inflated standard errors. VIF measures the extent to which the variance of an estimated regression coefficient is increased due to collinearity (27).

The VIF values range from 1.03 to 2.71, with an average VIF of 1.49, indicating that multicollinearity is generally not severe in the model. According to convention, VIF values below 10 are considered acceptable, suggesting that the model does not suffer from severe multicollinearity issues.

The reciprocal of VIF (1/VIF) provides a complementary perspective, where values closer to 1 indicate lower collinearity. Conversely, values closer to 0 suggest higher collinearity.

In summary, the VIF analysis indicates that while some variables show moderate collinearity, the overall model does not suffer from severe multicollinearity issues.

3.4 Benchmark regression results

3.4.1 Analysis of influencing factors on older adult's hospitalizational costs

The conducted linear regression analysis aims to explore the determinants of hospitalizational costs, shedding light on the intricate interplay between various demographic, socio-economic, and health-related factors.

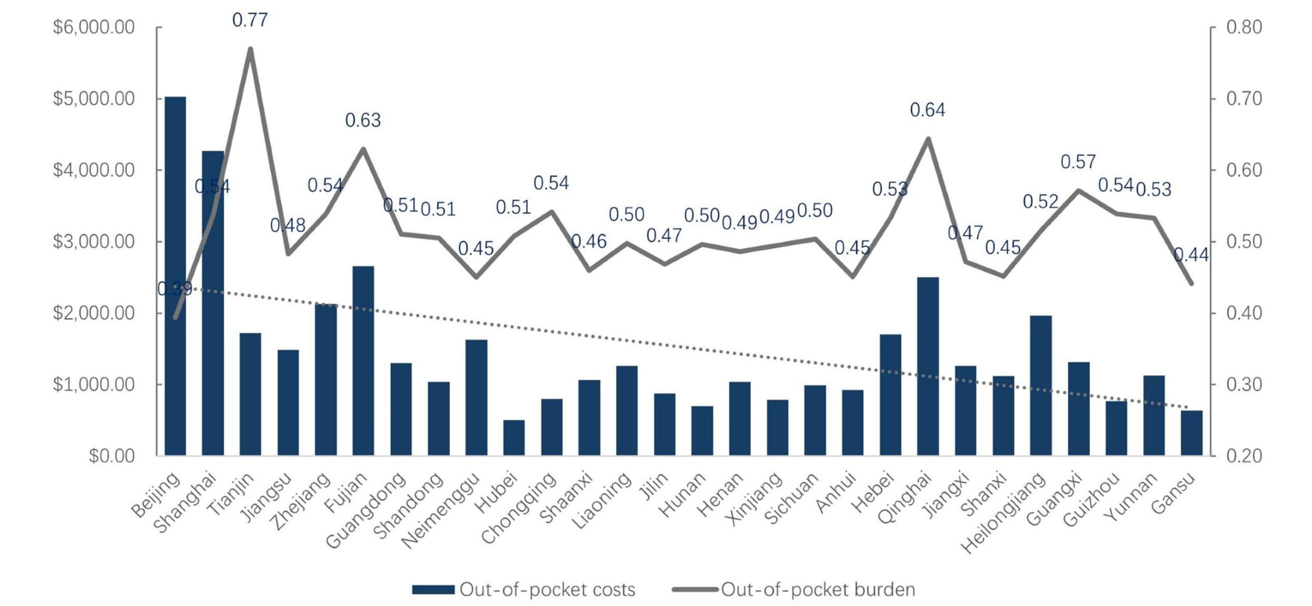


FIGURE 1
Older adult's hospitalizational costs and burden in each province.

As shown in Table 4, residence status emerged as a significant predictor, revealing that individuals residing in urban areas tend to incur higher inpatient out-of-pocket costs compared to their rural counterparts ($\beta = 0.1550$, $p = 0.05$). However, gender did not exhibit a statistically significant association with out-of-pocket costs, indicating no discernible difference between males and females ($\beta = -0.1199$, $p = 0.25$). Health insurance status displayed varied effects, with individuals possessing basic health insurance showing a marginal increase in costs ($\beta = 0.2692$, $p = 0.30$), while those with other health insurance experienced a non-significant decrease ($\beta = -0.0808$, $p = 0.81$).

Among chronic diseases, malignancy ($\beta = 0.9451$, $p < 0.01$), chronic lung disease ($\beta = 0.2558$, $p < 0.01$), and liver disease ($\beta = 0.2582$, $p = 0.02$) were significantly associated with higher inpatient costs. Additionally, hypertension exhibited a significant positive association ($\beta = 0.1523$, $p = 0.04$). Regional disparities were evident, with individuals residing in central ($\beta = -0.4074$, $p < 0.01$) and western areas ($\beta = -0.3814$, $p < 0.01$) experiencing significantly lower inpatient costs compared to those in eastern areas. Type of health service facility also played a pivotal role, with individuals receiving care from township hospitals incurring significantly lower costs ($\beta = -1.0191$, $p < 0.01$) compared to those utilizing Chinese Medicine Hospitals. Similarly, those utilizing other health service facilities exhibited decreased expenses ($\beta = -0.6607$, $p < 0.01$). Notably, distance traveled to receive healthcare services demonstrated a significant positive association with inpatient expenses ($\beta = 0.0009$, $p < 0.01$), indicating that longer distances were associated with higher expenses.

Furthermore, individuals who had drunk alcohol in the past year exhibited significantly lower inpatient expenses ($\beta = -0.1001$, $p = 0.04$), while other demographic and socio-economic factors such as education level, marital status, and pension status did not display significant associations.

3.4.2 Analysis of influencing factors on older adult's hospitalizational burden

In this section, the ordinary least squares model was used to perform a regression analysis on the relationship between the self-payment burden (dependent variable) and the respective variables of the older adult population in China. Considering various demographic, socio-economic, and health-related factors. The results, summarized in the Table 5, provide insights into the associations between these factors and the financial burden borne by individuals in accessing healthcare services.

The residence variable demonstrated a significant association with burden, with individuals residing in urban areas experiencing a slightly lower burden compared to their rural counterparts ($\beta = -0.0317$, $p = 0.02$). Regarding gender, no significant difference was observed in the burden between males and females ($\beta = -0.0011$, $p = 0.95$). Health insurance coverage emerged as a significant predictor of burden, with individuals having basic health insurance or other health insurance experiencing lower burden compared to those without health insurance ($\beta = -0.2708$, $p < 0.01$; $\beta = -0.3028$, $p < 0.01$, respectively), residents with other insurance have a lower burden of hospitalization than those with only basic insurance. Education level also showed a significant association, indicating that individuals with higher education tend to have lower burden ($\beta = -0.0103$, $p = 0.04$).

Among chronic diseases, liver disease was significantly associated with higher burden ($\beta = 0.0486$, $p = 0.01$), while patients with kidney disease had a lower burden ($\beta = -0.0256$ $p = 0.10$). Other chronic diseases did not show significant associations. Region-wise, individuals in central areas and the western areas exhibited a significantly lower burden compared to those in eastern areas ($\beta = -0.0470$, $p = 0.01$; $\beta = -0.0354$, $p = 0.03$). Moreover, family size was positively associated with burden ($\beta = 0.0299$, $p = 0.01$). Regarding marital status, being married was not significantly associated with burden compared to other marital statuses ($\beta = -0.0206$, $p = 0.19$). Ethnicity demonstrated a marginal association, with individuals of other ethnicities showing slightly higher burden compared to Han ethnicity ($\beta = 0.0384$,

TABLE 3 Results of multicollinearity between variables.

		VIF	1/VIF
Residence	Rural	For reference	
	Urban	1.36	0.737626
Gender	Male	For reference	
	Female	2.49	0.401392
Health insurance	No health insurance	For reference	
	Basic health insurance	2.47	0.405459
	Other health insurance	2.51	0.397931
Education		1.39	0.72
Chronic disease		1.20	0.83
Type of chronic diseases	Hypertension	1.20	0.83
	Dyslipidemia	1.26	0.80
	Diabetes	1.13	0.88
	Malignancy	1.03	0.97
	Chronic lung disease	1.38	0.72
	Liver disease	1.07	0.94
	Heart attack	1.18	0.85
	Stroke	1.11	0.90
	Kidney disease	1.11	0.90
	Stomach or digestive disorders	1.16	0.86
	Emotional and mental problems	1.08	0.93
	Memory-related disorders	1.14	0.88
	Arthritis or rheumatism	1.19	0.84
	Asthma	1.34	0.74
Region	Eastern areas	For reference	
	Central areas	1.80	0.56
	Western areas	1.91	0.52
	Northeast areas	1.29	0.78
Family size		1.37	0.73
Marital status	Married	1.42	0.70
	Other	For reference	
Ethnic	Han	For reference	
	Other	1.06	0.94
Type of health service facility	General hospital	2.71	0.37
	Specialized hospital	1.76	0.57
	Chinese Medicine Hospital	For reference	
	Township Hospital	2.22	0.45
	Other	1.26	0.80
Received distance		1.04	0.96
Smoke	Now or have smoked	2.24	0.45
	Never smoke	For reference	
Alcoholic	Have drunk alcohol in the past year	1.16	0.86
	Haven't drunk alcohol in the past year		
Pension	Yes	1.56	0.64
	No	For reference	
Mean VIF		1.49	

$p = 0.09$). Type of health service facility also played a role, with individuals receiving care from specialized hospitals or general hospitals experiencing higher burden compared to those utilizing Chinese Medicine Hospitals ($\beta = 0.0602$, $p = 0.02$; $\beta = 0.0388$, $p = 0.05$, respectively), conversely, those who were hospitalized in township hospitals had a lower burden. The distance traveled to receive healthcare services showed a significant association, with longer distances associated with slightly higher burden ($\beta = 0.0001$, $p < 0.01$).

Other factors such as smoking status, alcohol consumption, and pension status were also found to be associated with burden. Individuals who had not drunk alcohol in the past year and those receiving pensions experienced lower burden, while current smokers exhibited slightly higher burden.

3.5 Heterogeneity analysis

The heterogeneity analysis results were examined through a comparative analysis between the overall sample and its four subgroups representing distinct regions. This analysis aimed to assess the consistency of the relationships between independent variables and the natural logarithm of inpatient out-of-pocket costs across different geographical areas. In Table 4, the coefficients represent the estimated effects of independent variables on inpatient out-of-pocket costs, with significance denoted by asterisks (0.1*, 0.05 **, 0.01 ***). The Table 6 is organized into columns for the overall sample and each of the four subgroups (Eastern, Central, Northeast, and Western regions).

Urban residence exhibits a positive coefficient in the overall sample and Central region. The female gender generally shows negative coefficients across all subgroups and the overall sample. Basic health insurance demonstrates a positive coefficient in the overall sample and several subgroups, with no significant results in the Northeast region. Other health insurance also shows varied effects across subgroups. Generally, education exhibits negative coefficients across all subgroups and the overall sample, although not always statistically significant.

The presence of chronic diseases generally shows positive coefficients across subgroups and the overall sample. The coefficient for hypertension patients suggests a slight increase in inpatient expenses. The coefficient for diabetes patients suggests a potential increase in inpatient expenses, notably significant in the Central and Western regions within the overall sample. The coefficient for malignancy indicates a significant positive effect on inpatient expenses, particularly in the Eastern region. The coefficient for chronic lung disease patients suggests a potential increase in inpatient costs, especially significant in the Eastern region within the overall sample. The coefficient for liver disease patients indicates a positive impact on inpatient expenses, especially significant in the Central and Western regions. The coefficient for stroke patients suggests a potential increase in inpatient expenses, particularly significant in the Eastern region.

The coefficient for family size is positive in the overall sample and most subgroups. Coefficients vary across different types of health service facilities, with significant effects observed for specialized hospitals in the overall sample and Township Hospitals in various subgroups. Generally, received distance exhibits positive coefficients, with statistically significant results in all subgroups. People who have smoked cigarettes and those who have drunk alcohol in the past year usually show a negative correlation. People with pensions generally have higher costs, although the level of significance varies among different subgroups.

TABLE 4 Older adults 'hospitalizational costs linear regression model.

		Coef.	Std.Err.	*t*	*P* > |t|	[95% Conf. Interval]	
Residence	Rural	For reference					
	Urban	0.16	0.08	2.01	0.05	0.00	0.31
Gender	Male	For reference					
	Female	−0.12	0.10	−1.15	0.25	−0.32	0.08
Health insurance	No health insurance	For reference					
	Basic health insurance	0.27	0.26	1.04	0.30	−0.24	0.77
	Other health insurance	−0.08	0.33	−0.24	0.81	−0.74	0.57
Education		0.00	0.03	−0.11	0.92	−0.06	0.05
Chronic disease		0.20	0.18	1.14	0.25	−0.15	0.55
Type of chronic diseases	Hypertension	0.15	0.07	2.10	0.04	0.01	0.29
	Dyslipidemia	−0.06	0.08	−0.71	0.48	−0.21	0.10
	Diabetes	0.11	0.08	1.27	0.21	−0.06	0.27
	Malignancy	0.95	0.15	6.35	0.00	0.65	1.24
	Chronic lung disease	0.26	0.09	3.00	0.00	0.09	0.42
	Liver disease	0.26	0.11	2.34	0.02	0.04	0.47
	Heart attack	0.00	0.07	0.04	0.97	−0.14	0.15
	Stroke	0.15	0.09	1.67	0.10	−0.03	0.32
	Kidney disease	0.09	0.09	0.98	0.33	−0.09	0.27
	Stomach or digestive disorders	0.08	0.07	1.15	0.25	−0.06	0.22
	Emotional and mental problems	−0.11	0.16	−0.70	0.48	−0.43	0.20
	Memory-related disorders	−0.06	0.12	−0.56	0.58	−0.29	0.16
	Arthritis or rheumatism	−0.11	0.07	−1.58	0.11	−0.25	0.03
	Asthma	−0.13	0.11	−1.16	0.25	−0.34	0.09
Region	Eastern areas	For reference					
	Central areas	−0.41	0.10	−4.26	0.00	−0.59	−0.22
	Western areas	−0.38	0.09	−4.16	0.00	−0.56	−0.20
	Northeast areas	−0.21	0.15	−1.36	0.17	−0.51	0.09
Family size		0.13	0.13	0.07	1.92	0.06	0.00
Marital status	Married	0.08	0.09	0.87	0.38	−0.10	0.26
	Other	For reference					
Ethnic	Han	For reference					
	Other	0.02	0.13	0.16	0.87	−0.24	0.28
Type of health service facility	General hospital	0.20	0.11	1.80	0.07	−0.02	0.42
	Specialized hospital	0.38	0.15	2.45	0.01	0.08	0.68
	Chinese Medicine Hospital	For reference					
	Township Hospital	−1.02	0.14	−7.39	0.00	−1.29	−0.75
	Other	−0.66	0.22	−2.98	0.00	−1.10	−0.23
Received distance		0.00	0.00	0.00	5.01	0.00	0.00
Smoke	Now or have smoked	−0.17	0.10	−1.67	0.10	−0.36	0.03
	Never smoke	For reference					
Alcoholic	Have drunk alcohol in the past year	−0.10	0.05	−2.08	0.04	−0.19	−0.01
	Haven't drunk alcohol in the past year	For reference					
Pension	Yes	For reference					
	No	0.06	0.10	0.67	0.51	−0.13	0.25
Constant		5.38	0.44	12.09	0.00	4.51	6.25

TABLE 5 Older adults 'hospitalizational burden linear regression model.

		Coef.	Std.Err.	*t*	*P* > |t|	[95% Conf. Interval]	
Residence	Rural	For reference					
	Urban	−0.03	0.01	−2.38	0.02	−0.06	−0.01
Gender	Male	For reference					
	Female	0.00	0.02	−0.06	0.95	−0.04	0.03
Health insurance	No health insurance	For reference					
	Basic health insurance	−0.27	0.04	−6.07	0.00	−0.36	−0.18
	Other health insurance	−0.30	0.06	−5.23	0.00	−0.42	−0.19
Education		−0.01	0.01	−2.03	0.04	−0.02	0.00
Chronic disease		0.03	0.03	0.85	0.39	−0.03	0.09
Type of chronic diseases	Hypertension	0.00	0.01	−0.10	0.92	−0.03	0.02
	Dyslipidemia	0.01	0.01	1.10	0.27	−0.01	0.04
	Diabetes	−0.01	0.01	−0.89	0.37	−0.04	0.02
	Malignancy	0.04	0.03	1.44	0.15	−0.01	0.09
	Chronic lung disease	0.00	0.01	0.00	1.00	−0.03	0.03
	Liver disease	0.05	0.02	2.59	0.01	0.01	0.09
	Heart attack	−0.01	0.01	−0.97	0.33	−0.04	0.01
	Stroke	−0.02	0.02	−1.23	0.22	−0.05	0.01
	Kidney disease	−0.03	0.02	−1.66	0.10	−0.06	0.00
	Stomach or digestive disorders	0.01	0.01	0.70	0.49	−0.02	0.03
	Emotional and mental problems	−0.04	0.03	−1.31	0.19	−0.09	0.02
	Memory-related disorders	0.00	0.02	−0.24	0.81	−0.04	0.03
	Arthritis or rheumatism	−0.01	0.01	−0.72	0.47	−0.03	0.02
	Asthma	−0.02	0.02	−0.99	0.32	−0.06	0.02
Region	Eastern areas	For reference					
	Central areas	−0.05	0.02	−2.84	0.01	−0.08	−0.01
	Western areas	−0.04	0.02	−2.23	0.03	−0.07	0.00
	Northeast areas	0.00	0.03	−0.13	0.90	−0.06	0.05
Family size		0.03	0.01	2.25	0.01	0.05	0.05
Marital status	Married	−0.02	0.02	−1.30	0.19	−0.05	0.01
	Other	For reference					
Ethnic	Han	For reference					
	Other	0.04	0.02	1.69	0.09	−0.01	0.08
Type of health service facility	General hospital	0.04	0.02	2.00	0.05	0.00	0.08
	Specialized hospital	0.06	0.03	2.25	0.02	0.01	0.11
	Chinese Medicine Hospital	For reference					
	Township Hospital	−0.05	0.02	−2.00	0.05	−0.09	0.00
	Other	0.10	0.04	2.66	0.01	0.03	0.18
Received distance		0.00	0.00	0.00	3.57	0.00	0.00
Smoke	Now or have smoked	−0.03	0.02	−1.83	0.07	−0.07	0.00
	Never smoke	For reference					
Alcoholic	Have drunk alcohol in the past year	0.02	0.01	2.38	0.02	0.00	0.04
	Haven't drunk alcohol in the past year	For reference					
Pension	Yes	For reference					
	No	0.10	0.02	5.76	0.00	0.06	0.13
Constant		0.28	0.07	3.96	0.00	0.14	0.41

TABLE 6 Heterogeneity analysis of older adults 'hospitalizational costs.

		All	Eastern	Central	Northeast	Western
Residence	Rural	For reference				
	Urban	0.16**	0.08	0.28**	−0.19	0.20*
Gender	Male	For reference				
	Female	−0.12	−0.17	−0.19	−0.07	−0.07
Health insurance No health insurance for reference	Basic health insurance	0.27	−1.02	0.61	3.16***	0.16
	Other health insurance	−0.08	−1.15	0.77	−0.87	−0.10
Education		0.00	−0.04	−0.06	0.13	0.00
Chronic disease		0.20	0.13	−0.03	−0.84	0.47
Type of chronic diseases	Hypertension	0.15**	0.01	0.00	0.47	0.20*
	Dyslipidemia	−0.06	−0.03	−0.16	0.19	−0.03
	Diabetes	0.11	−0.24	0.36**	0.56**	0.10
	Malignancy	0.95***	0.72**	1.63***	0.75	0.79***
	Chronic lung disease	0.26***	0.44**	0.34**	−0.04	0.20
	Liver disease	0.26**	0.11	0.36*	0.96**	0.13
	Heart attack	0.00	−0.03	0.12	−0.35	−0.02
	Stroke	0.15*	0.67***	0.04	−0.38	0.18
	Kidney disease	0.09	−0.10	0.13	−0.07	0.13
	Stomach or digestive disorders	0.08	−0.06	0.07	−0.41	0.18*
	Emotional and mental problems	−0.11	0.34	−0.20	1.16*	−0.29
	Memory-related disorders	−0.06	0.08	0.11	−1.02***	−0.02
	Arthritis or rheumatism	−0.11	0.01	−0.04	−0.23	−0.23*
	Asthma	−0.13	−0.31	−0.16	0.62	−0.12
Region	Eastern areas	For reference				
	Central areas	−0.41***	0.00	0.00	0.00	0.00
	Western areas	−0.38***	0.00	0.00	0.00	0.00
	Northeast areas	−0.21	0.00	0.00	0.00	0.00
Family size		0.13*	0.22	0.22	−0.10	0.08
Marital status	Married	0.08	−0.21	0.00	0.46	0.20
	Other	For reference				
Ethnic	Han	For reference				
	Other	0.02	−0.19	0.75	−0.61	0.00
Type of health service facility	General hospital	0.20*	0.00	0.02	0.07	0.36**
	Specialized hospital	0.38**	0.40	0.14	0.02	0.40*
	Chinese Medicine Hospital	For reference				
	Township Hospital	−1.02***	−0.95***	−1.18***	−1.60**	−0.95***
	Other	−0.66***	−0.65	−1.40***	0.07	−0.44
Received distance		0.00***	0.00***	0.00**	0.00*	0.00***
Smoke	Now or have smoked	−0.17*	−0.40*	−0.07	0.22	−0.17
	Never smoke	For reference				
Alcoholic	Have drunk alcohol in the past year	−0.10**	0.03	−0.10	−0.25	−0.15**
	Haven't drunk alcohol in the past year	For reference				
Pension	Yes	For reference				
	No	0.06	−0.15	−0.03	0.27	0.26*
Constant		5.38***	7.48***	5.14***	3.47**	4.29***

Overall, the coefficients demonstrate consistency in directionality across subgroups and the overall sample for many independent variables. However, there are also notable variations in significance levels and magnitudes of effects.

The Table 7 presents the results of robustness tests for the burden across different subgroups and the overall sample. The coefficients represent the estimated effects of various independent variables on the dependent variable, with emphasis on the consistency and significance of coefficients across different subgroups and the entire sample.

In urban areas, there is a statistically significant negative effect on the burden, which is consistent across all regions. However, the effect is only significant in the Northeast at a lower level of significance. Females generally have a negative effect on the burden, but the effect is not statistically significant across all regions and the entire sample. Both basic health insurance and other health insurance have significant negative effects on the burden, consistent across all regions and the entire sample except for the northeast. Higher levels of education have a significant negative effect on the burden, consistent across all regions and the entire sample except for the northeast.

Liver disease is usually positively correlated with hospitalization burden, while kidney disease has a negative coefficient in both the total sample and subgroups and has some significance. A higher family size generally leads to a higher burden, with significant positive effects in some regions and the entire sample. Belonging to a non-Han ethnicity has varying effects on the burden across regions and the entire sample.

The type of health facility has varying effects on the burden across regions and the entire sample. Compared to Chinese Medicine Hospitals, both Specialized Hospitals and other types of health service facilities exhibit positive coefficients, except in the Northeast region. Township Hospitals, on the other hand, consistently show negative coefficients across all regions and the overall sample. There is a statistically significant positive effect of distance on the burden, consistent across all regions and the entire sample.

Individuals who have smoked tend to have lower burden, whereas those who have consumed alcohol in the past year exhibit higher burden. Moreover, individuals without pension tend to incur higher costs for hospitalization. Furthermore, some coefficients exhibit varying levels of significance across regions, highlighting the nuanced impact of these factors on healthcare expenses.

Overall, the results highlight the importance of considering various factors and their nuanced effects on the burden, with some consistent patterns across regions and the entire sample.

4 Discussion

4.1 Social factors

4.1.1 Health insurance

Insurance has no significant impact on hospitalization costs, but for older adult individuals without insurance, those with basic medical insurance and additional insurance coverage beyond basic medical insurance experience significantly reduced burden, with those possessing additional insurance experiencing even greater reductions.

Firstly, basic medical insurance typically provides some degree of coverage for medical expenses, which can reduce residents' economic burden in seeking medical care, increase accessibility to healthcare services, and meeting residents' medical service needs. It is particularly crucial for older adult individuals who often face more health issues and higher medical expenses (28). However, basic medical insurance may not cover all types of medical services and expenses, especially for expensive treatments and medications. In such cases, having additional insurance (such as commercial medical insurance or supplementary medical insurance) may further reduce older adult individuals' medical expense burden (29).

4.1.2 Pension

Older adult individuals with pensions tend to incur greater burden. Research has indicated that receiving a pension can increase hospitalization costs by 2,538 yuan, and other medical expenses by 1,203 yuan (30). Individuals with pensions may be more inclined to seek expensive medical services and treatments because they have financial support to cover these expenses. In contrast, those without pensions or with less economic support may avoid or delay medical treatment due to costs, leading to lower medical expenses.

4.2 Medical factors

4.2.1 Type of health service facility

Compared to traditional Chinese medicine hospitals, comprehensive and specialized hospitals tend to incur higher expenses and burden, while township hospitals typically have lower costs.

Comprehensive hospitals typically offer a wide range of medical services and comprehensive scope, these hospitals often possess more medical resources and specialized personnel capable of handling various complex medical conditions. This comprehensive approach may result in higher medical expenses for patients seeking treatment at comprehensive hospitals.

Specialized hospitals, on the other hand, focus on specific types of medical services such as cardiac care and cancer treatment. Physicians and equipment at specialized hospitals are usually tailored to address specific diseases. In some cases, specialized hospitals may offer more cost-effective treatment options. However, for conditions outside their specialty, patients may need to be referred to other hospitals, potentially increasing overall medical costs and burden.

Township hospitals may invest less in medical equipment and human resources, leading to lower unit service costs. Additionally, due to their smaller scale, township hospitals may find it easier to control costs. These hospitals mainly provide basic medical services and may have limited capabilities for treating complex diseases, thus resulting in lower hospitalization costs.

4.2.2 Received distance

The geographical location of medical institutions directly affects patients' medical expenses and burden. In real-life scenarios, not all patients opt for the nearest healthcare facility. This is because not every medical institution is equipped to handle a wide range of illnesses. Therefore, the distance or time required to reach the closest medical service point must consider the varying capabilities of different healthcare providers (31–33). For patients diagnosed with complex and critical conditions, they may choose to travel to more distant

TABLE 7 Heterogeneity analysis of older adults 'hospitalizational burden.

		All	Eastern	Central	Northeast	Western
Residence	Rural	For reference				
	Urban	−0.03**	−0.03	−0.03	−0.12*	−0.02
Gender	Male	For reference				
	Female	−0.00	0.02	−0.03	−0.07	0.02
Health insurance	No health insurance	For reference				
	Basic health insurance	−0.27***	−0.49***	−0.23**	0.25	−0.32***
	Other health insurance	−0.30***	−0.50***	−0.17	0.17	−0.42***
Education		−0.01**	0.00	−0.02**	0.01	−0.01
Chronic disease		0.01	0.06	0.02	−0.12	−0.01
Type of chronic diseases	Hypertension	0.00	0.01	0.01	0.01	−0.01
	Dyslipidemia	0.01	0.00	−0.01	0.02	0.03
	Diabetes	−0.01	−0.03	0.02	−0.02	−0.02
	Malignancy	0.04	0.05	0.06	−0.10	0.04
	Chronic lung disease	0.00	−0.01	0.03	0.03	−0.02
	Liver disease	0.05***	0.00	0.04	0.04	0.09***
	Heart attack	0.00	−0.01	0.00	−0.08	−0.01
	Stroke	−0.02	0.00	−0.04	−0.06	−0.01
	Kidney disease	−0.03*	−0.05	−0.01	−0.04	−0.02
	Stomach or digestive disorders	0.01	−0.01	0.00	−0.03	0.01
	Emotional and mental problems	0.00	0.02	0.00	−0.05	−0.01
	Arthritis or rheumatism	0.00	−0.02	0.00	0.00	0.00
	Asthma	−0.02	−0.02	−0.06*	0.07	0.00
Region	Eastern areas	For reference				
	Central areas	−0.05***	0	0	0	0
	Western areas	−0.03**	0	0	0	0
	Northeast areas	−0.00	0	0	0	0
Family size		0.03**	0.05*	0.06**	0.10*	0.01
Marital status	Married	−0.02	−0.04	−0.08**	−0.06	0.03
	Other	For reference				
Ethnic	Han	For reference				
	Other	0.04*	0.02	−0.01	−0.10	0.07**
Type of health service facility	General hospital	0.04**	−0.04	0.06	−0.02	0.05*
	Specialized hospital	0.06**	0.07	0.10*	−0.06	0.02
	Chinese Medicine Hospital	For reference				
	Township Hospital	−0.05**	−0.10*	−0.04	−0.14	−0.03
	Other	0.10***	0.03	0.12	−0.11	0.12**
Received distance		0.00***	0.00**	0.00**	0.00*	0.00
Smoke	Now or have smoked	−0.03*	−0.03	−0.03	−0.05	−0.03
	Never smoke	For reference				
Alcoholic	Have drunk alcohol in the past year	0.02**	0.01	0.01	0.03	0.03**
	Haven't drunk alcohol in the past year	For reference				
Pension	Yes	For reference				
	No	0.10***	0.15***	0.05	0.01	0.13***
Constant		0.58***	0.67***	0.58***	0.49	0.52***

hospitals in pursuit of superior medical care, even though the cost of treating these symptoms is inherently not low.

4.3 Family factor

Older adult individuals with a larger number of family members tend to incur higher hospitalization costs and burden. Firstly, a larger family size may potentially equate to a higher household income, which could enable them to allocate greater financial resources towards hospitalization costs (34). Secondly, larger family sizes may face challenges in coordinating care and making decisions, potentially leading to fragmented or inefficient healthcare utilization, which contribute to increased hospitalization costs (35).

4.4 Personal factors

4.4.1 Education

The impact of education level on hospitalization costs is not conspicuous; however, higher-educated older adult individuals tend to bear lower hospitalization burden. For the older adult population, higher education levels may be linked to better understanding and utilization of health insurance policies and benefits. This can result in more effective utilization of the healthcare system and proper utilization of healthcare resources, ultimately reducing hospitalization rates and burden among older adult individuals with higher education levels (36, 37).

4.4.2 Chronic diseases

Firstly, chronic diseases such as hypertension, malignancy, chronic lung disease, liver disease, and stroke significantly increase hospitalization costs. These conditions typically require long-term, sustained treatment and care, often involving costly medications and medical procedures. For instance, cancer treatment may entail chemotherapy, radiation therapy, targeted therapy, among others (38). Similarly, patients with chronic lung disease and stroke may require interventions such as ventilator support, rehabilitation (39).

However, the impact of liver disease and kidney disease on hospitalization burden may vary. Some studies suggest that liver disease may lead to increased medical costs because patients may utilize more emergency care hospitalization (40). On the other hand, the effect of kidney disease on medical costs may differ in certain circumstances. This could be because after receiving treatments such as dialysis, the condition of patients with kidney disease may be partially controlled, thereby reducing the occurrence of other complications and related medical burden (41).

4.4.3 Personal habits

Smokers tend to have lower hospitalization costs and burden, while individuals who consumed alcohol in the past year tend to have higher burden and lower costs. In general, regular smokers have a longer hospital stay than those who never smoke regularly (42), there will be greater hospitalization costs and burden. However, smokers may reduce their demand for and utilization of medical services due to poorer health conditions. This reduction may be due to barriers or biases in accessing health services among smokers, or because they may lack sufficient financial resources to cover medical expenses or may lack adequate medical insurance coverage. Another study found that smokers are typically associated with lower socioeconomic status (43).

There is a negative correlation or U-shaped relationship between alcohol consumption levels and health service use (44), abstainers, in particular, are more likely to use health care services than low-risk alcohol consumers (45), A 4-year prospective study by Anzai et al. (46) found, Lifelong abstinent alcoholics and alcoholics have higher inpatient health care utilization. A higher proportion of people were likely to be light and moderate drinkers in the sample, as a result, fewer people will take advantage of inpatient services and incur lower costs.

4.4.4 Ethnic

The study by Qiu Yulin and Zhang Zhongchao indicates that the probability of poverty due to illness in ethnic minority areas of Guizhou is significantly higher than in non-ethnic areas. Notably, within non-ethnic regions, the poverty incidence in areas with ethnic minority autonomy is even higher. This suggests that ethnic differences may be associated with economic resources and medical insurance coverage, thereby affecting the burden of hospitalization costs. If older adult individuals from other ethnic groups have lower medical insurance coverage rates or smaller insurance reimbursement ratios, they may have to bear a greater burden of inpatient medical expenses (47).

4.5 Geographic factors

4.5.1 Residency

Research indicates that hospitalization costs for urban residents are generally higher than those for rural residents, possibly due to higher medical service costs and more advanced medical technologies in urban areas. Urban older adult individuals are more likely to receive regular health check-ups (48), which facilitate early detection of chronic diseases. The prevalence of chronic diseases is higher among urban older adult individuals compared to rural counterparts (49, 50). However, the hospitalization burden for urban residents is relatively lower, possibly attributed to the greater benefits in health insurance coverage in urban areas (51).

4.5.2 Region

Compared to the eastern region, the central and western regions of China tend to have lower hospitalization costs and burden. Firstly, the eastern region of China is characterized by its abundant medical resources, which include a higher concentration of top-tier hospitals, state-of-the-art medical equipment, and a more extensive network of medical professionals. This abundance may lead to more costly medical treatments in the area, consequently driving up hospitalization costs. In contrast, the central and western regions face a scarcity of medical resources, which could result in more affordable medical expenses (52, 53). Secondly, income plays a significant role in the hospitalizational costs and the financial burden of hospitalizations for the older adult (54). The eastern region, with its higher economic development, provides residents with higher income levels. This increased financial capacity may enable residents to bear higher medical expenses, further contributing to the elevated hospitalization costs in the region. On the other hand, the central and western regions, where economic development is relatively lower, may see residents opting for more cost-effective medical services due to their limited ability to pay. This could lead to a reduction in hospitalization costs in these areas.

5 Conclusion

This study utilizes data from the China Health and Retirement Longitudinal Study (CHARLS) spanning from 2011 to 2018 to investigate the costs and burden of hospitalization for the older adult in China from a micro-perspective. It also explores the factors that may influence these costs and burden. Empirical findings reveal that the average out-of-pocket expenditure for hospitalization among Chinese older adult in 2018 was $1,199.24, with a burden ratio of 0.5. Several factors were identified to significantly increase the out-of-pocket hospitalization costs, including urban, hypertension, malignancy, chronic lung disease, liver disease, and stroke as prevalent chronic conditions, family size, general hospital, specialized hospital, received distance, and absence of pension. Conversely, certain factors were found to significantly reduce the hospitalization costs for the older adult, including residence in central and western regions; utilization of township and other hospitals; and a history of smoking or drinking. In terms of the burden of hospitalization for the older adult, conditions such as liver disease, family size, ethnic minorities, health service facility other than township hospitals, received distance, a history of alcohol consumption within the past year, and lack of a pension were significant contributors to increased burden. On the other hand, factors such as urban, basic health insurance and other health insurance, level of education, kidney disease, central and western regions, township hospitals, and a history of smoking were found to significantly alleviate the burden of hospitalization for the older adult. This research provides valuable insights into the financial implications of hospitalization for China's aging population and highlights the need for targeted policies to mitigate the economic burden on this vulnerable group.

In view of the above situation, we recommend the following targeted strategies: Continue to expand medical insurance coverage to ensure more equitable access to healthcare services. Actively promote commercial insurance options that can complement basic health insurance, providing additional financial protection against high medical costs. Strengthen primary medical services to reduce the burden on higher-level hospitals, thereby potentially lowering the overall cost of hospitalization. Implement policies that promote equity in health resources and work to reduce regional disparities in healthcare availability and quality. Introduce targeted interventions for vulnerable groups, such as medical cost subsidies, special insurance schemes, and financial assistance programs, to alleviate the financial stress associated with hospitalization. Acknowledge and address ethnic differences in healthcare by providing language translation services and culturally tailored health education materials to ensure inclusive and effective healthcare communication.

This study acknowledges certain limitations in its design and scope. Firstly, the analysis was based solely on data from the 2018 China Health and Retirement Longitudinal Study (CHARLS), which restricts the ability to conduct a comparative analysis of the hospitalization hospitalizational costs and burden for the older adult across different years, thereby precluding the observation of trends and changes over time. Secondly, the hospitalization cost data collected in the 2018 CHARLS survey encompassed only the expenses paid to the hospital itself, excluding additional costs such as the wages of accompanying caregivers, transportation fees for the patient or family members, and accommodation expenses. However, it did include the cost of hospital room charges. As a result, this study was unable to analyze non-medical expenses associated with hospitalization. Furthermore, the cost data only distinguished between hospitalizational costs and did not break down into specific categories such as material fees, medication costs, and room charges, which limits the detailed analysis of the composition of hospitalization costs. Lastly, this research is retrospective in nature and does not incorporate any predictive modeling or forecasting. The findings are based on the exam ethnic of past data without projection into future trends or outcomes.

These limitations should be taken into account when interpreting the results of this study and when considering its implications for policy and practice. Future research efforts may address these gaps by incorporating multi-year data, a more comprehensive range of hospitalization costs, and potentially predictive analytics to provide a more robust understanding of the financial burden faced by the older adult during hospitalization.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary material, further inquiries can be directed to the corresponding author.

Ethics statement

The studies involving humans were approved by Biomedical Ethics Review Committee of Peking University. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

SH: Writing – original draft, Writing – review & editing. YB: Writing – review & editing.

Funding

The author(s) declare that no financial support was received for the research, authorship, and/or publication of this article.

Acknowledgments

We would like to acknowledge the China Health and Retirement Longitudinal Study team.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2024.1418179/full#supplementary-material

References

1. WH K Kinsella. U.S. Census Bureau, International Population Reports, P95/09-1, An Aging World: 2008, U.S. Government Printing Office, Washington, DC, (2009).

2. Mondal B, Dubey JD. Gender discrimination in health-care expenditure: an analysis across the age-groups with special focus on the elderly. *Soc Sci Med*. (2020) 258:113089. doi: 10.1016/j.socscimed.2020.113089

3. Gaskin DJ, Hoffman C. Racial and ethnic differences in preventable hospitalizations across 10 states. *Med Care Res Rev*. (2000) 57:85–107. doi: 10.1177/1077558700057001s05

4. Iwashyna TJ, Curlin FA, Christakis NA. Racial, ethnic, and affluence differences in elderly patients' use of teaching hospitals. *J Gen Intern Med*. (2002) 17:696–703. doi: 10.1046/j.1525-1497.2002.01155.x

5. Glinskaya EE, Feng Z. Options for aged Care in China: Building an efficient and sustainable aged care system (English). Washington, D.C: World Bank Group (2018).

6. China National Health Accounts Report 2018. China National Health Accounts Report 2018. Beijing: China National Health Development Research Center (2019).

7. Yip W, Fu H, Chen AT, Zhai T, Jian W, Xu R, et al. 10 years of health-care reform in China: progress and gaps in universal health coverage. *Lancet*. (2019) 394:1192–204. doi: 10.1016/s0140-6736(19)32136-1

8. de Meijer C, Wouterse B, Polder J, Koopmanschap M. The effect of population aging on health expenditure growth: a critical review. *Eur J Ageing*. (2013) 10:353–61. doi: 10.1007/s10433-013-0280-x

9. Lopreite M, Zhu Z. The effects of ageing population on health expenditure and economic growth in China: a Bayesian-VAR approach. *Soc Sci Med*. (2020) 265:113513. doi: 10.1016/j.socscimed.2020.113513

10. Li L, Du T, Hu Y. The effect of population aging on healthcare expenditure from a healthcare demand perspective among different age groups: Evidence from Beijing City in the People's Republic of China. *Risk Manag Healthc Policy*. (2020) 13:1403–12. doi: 10.2147/rmhp.S271289

11. OECD. Health at a Glance 2021 (2021). Available at: https://www.oecd-ilibrary.org/content/publication/ae3016b9-en

12. Meng G, Yue B, Qianhui S, Junfeng C. Population ageing and the diseases economic burden in China. *Med Philos*. (2015) 36:32–4.

13. De Foor J, Senterre C, Leclercq P, Martins D, Pirson M. Profile of hospitalised elderly patients in Belgium-analysis of factors affecting hospital costs. *J Econ Ageing*. (2020) 15:100209. doi: 10.1016/j.jeoa.2019.100209

14. Zhang A, Nikoloski Z, Mossialos E. Does health insurance reduce out-of-pocket expenditure? Heterogeneity among China's middle-aged and elderly. *Soc Sci Med*. (2017) 190:11–9. doi: 10.1016/j.socscimed.2017.08.005

15. Wang L, Wang A, Zhou D, FitzGerald G, Ye D, Jiang Q. An empirical analysis of rural-urban differences in out-of-pocket health expenditures in a low-income Society of China. *PLoS One*. (2016) 11:e0154563. doi: 10.1371/journal.pone.0154563

16. Banerjee S. Determinants of rural-urban differential in healthcare utilization among the elderly population in India. *BMC Public Health*. (2021) 21:939. doi: 10.1186/s12889-021-10773-1

17. Ziyi Y, Jing O, Xiaoling L. Hospitalization cost influencing factors analysis of elderly inpatients participating new rural cooperative medical system in Xinjiang urban-rural fringe from 2012 to 2015. *Chin Med Rec*. (2017) 18:78–81. doi: 10.3969/j.issn.1672-2566.2017.03.028

18. Tang XW, Xie XX, Rao ZX, Zheng ZQ, Hu CC, Li SS, et al. Spatial analysis and comparison of the economic burden of common diseases: an investigation of 5.7 million rural elderly inpatients in Southeast China, 2010-2016. *Front Public Health*. (2021) 9:774342. doi: 10.3389/fpubh.2021.774342

19. Yanghe L, Yuewei L, Peng Z, Tianjing H, Guo L, Hongping C, et al. Analysis on medical expense of the elderly with chronic diseases in a Hospital in Haikou City. *Med Soc*. (2015) 28:13–5. doi: 10.13723/j.yxysh.2015.09.005

20. Yueqi WB. An empirical study on the impact of population aging on medical expenses[in Chinese]. *Money China*. (2019) 5:159–62. doi: 10.16266/j.cnki.cn11-4098/f.2019.03.115

21. Liu Q, Liu J, Sui S. Public medical insurance and healthcare utilization and expenditures of older with chronic diseases in rural China: evidence from NRCMS. *Int J Environ Res Public Health*. (2020) 17:683. doi: 10.3390/ijerph17207683

22. Chen J, Qian Z, Yang L, Liu T, Sun M, Yu H, et al. The risk factors for Chinese medical economic burden of aging: a cross-sectional study based on Guangdong Province. *Biomed Res Int*. (2021) 2021:6680441. doi: 10.1155/2021/6680441

23. Chen J, Zhao M, Zhou R, Ou W, Yao P. How heavy is the medical expense burden among the older adults and what are the contributing factors? A literature review and problem-based analysis. *Front Public Health*. (2023) 11:1165381. doi: 10.3389/fpubh.2023.1165381

24. Zhao Y, Hu Y, Smith JP, Strauss J, Yang G. Cohort profile: the China health and retirement longitudinal study (CHARLS). *Int J Epidemiol*. (2014) 43:61–8. doi: 10.1093/ije/dys203

25. Rongfei X, Shuo L, Lingzhong X, Xiaolong Y, Shanke YL. Analyzing the characteristics of outpatient and hospitalized service utilization in different provinces in China in 2010. *Chin Health Serv Manag*. (2012) 29:4. doi: 10.3969/j.issn.1004-4663.2012.11.003

26. Wisdom N, Aibing Q, Chuning G. Spatial distribution and influencing factors of per capita hospitalization expenses in China. *J Nanjing Med Univ*. (2022) 22:6. doi: 10.7655/nydxbss20220213

27. O'Brien RM. A caution regarding rules of thumb for variance inflation factors. *Qual Quant*. (2007) 41:673–90. doi: 10.1007/s11135-006-9018-6

28. Xin-dong X, Xiao-jing J. A review on the effects of health insurance on health status. *Chin J Health Policy*. (2015) 8:41–5. doi: 10.3969/j.issn.1674-2982.2015.02.007

29. Feng H, Li G. Excess demand or appropriate demand? Health Insurance,Medical care and mortality of the elderly in urban China. *Econ Res J*. (2010) 45:105–19.

30. Xu S, Fu-Ling C. The impact of the public pension program on the elderly's medical expenditures: a regression discontinuity approach. *J Appl Econ*. (2022) 25:178–96. doi: 10.1080/15140326.2021.2021748

31. Guagliardo MF. Spatial accessibility of primary care: concepts, methods and challenges. *Int J Health Geogr*. (2004) 3:3. doi: 10.1186/1476-072x-3-3

32. Kaufman BG, Thomas SR, Randolph RK, Perry JR, Thompson KW, Holmes GM, et al. The rising rate of rural hospital closures. *J Rural Health*. (2016) 32:35–43. doi: 10.1111/jrh.12128

33. Mohr NM, Harland KK, Shane DM, Ahmed A, Fuller BM, Ward MM, et al. Rural patients with severe Sepsis or septic shock who bypass rural hospitals have increased mortality: an instrumental variables approach*. *Crit Care Med*. (2017) 45:85–93. doi: 10.1097/ccm.0000000000002026

34. Ellis RP, Fiebig DG, Johar M, Jones G, Savage E. Explaining health care expenditure variation: large-sample evidence using linked survey and health administrative data. *Health Econ*. (2013) 22:1093–110. doi: 10.1002/hec.2916

35. Ning-Ning MA, Yong LI. Empirical analysis of influence factors on aged Population's health expenditures in China. *Chin J Drug Eval*. (2016). 33:188–192. doi: 10.3969/j.issn.2095-3593.2016.03.017

36. Baker DW, Gazmararian JA, Williams MV, Scott T, Parker RM, Green D, et al. Functional health literacy and the risk of hospital admission among Medicare managed care enrollees. *Am J Public Health*. (2002) 92:1278–83. doi: 10.2105/ajph.92.8.1278

37. Smith KV, Goldman N. Socioeconomic differences in health among older adults in Mexico. *Soc Sci Med*. (2007) 65:1372–85. doi: 10.1016/j.socscimed.2007.05.023

38. Kaur R, Bhardwaj A, Gupta S. Cancer treatment therapies: traditional to modern approaches to combat cancers. *Mol Biol Rep*. (2023) 50:9663–76. doi: 10.1007/s11033-023-08809-3

39. Kasuya Y, Hargett JL, Lenhardt R, Heine MF, Doufas AG, Remmel KS, et al. Ventilator-associated pneumonia in critically ill stroke patients: frequency, risk factors, and outcomes. *J Crit Care*. (2011) 26:273–9. doi: 10.1016/j.jcrc.2010.09.006

40. Ma C, Qian AS, Nguyen NH, Stukalin I, Congly SE, Shaheen AA, et al. Trends in the economic burden of chronic liver diseases and cirrhosis in the United States: 1996-2016. *Am J Gastroenterol*. (2021) 116:2060–7. doi: 10.14309/ajg.0000000000001292

41. Evans M, Lewis RD, Morgan AR, Whyte MB, Hanif W, Bain SC, et al. A narrative review of chronic kidney disease in clinical practice: current challenges and future perspectives. *Adv Ther*. (2022) 39:33–43. doi: 10.1007/s12325-021-01927-z

42. Chan KH, Wright N, Xiao D, Guo Y, Chen Y, Du H, et al. Tobacco smoking and risks of more than 470 diseases in China: a prospective cohort study. *Lancet Public Health*. (2022) 7:e1014–26. doi: 10.1016/S2468-2667(22)00227-4

43. Giskes K, Kunst AE, Benach J, Borrell C, Costa G, Dahl E, et al. Trends in smoking behaviour between 1985 and 2000 in nine European countries by education. *J Epidemiol Community Health*. (2005) 59:395–401. doi: 10.1136/jech.2004.025684

44. Kunz JL. Alcohol use and reported visits to health professionals: an exploratory study. *J Stud Alcohol*. (1997) 58:474–9. doi: 10.15288/jsa.1997.58.474

45. Baumeister SE, Meyer C, Carreon D, Freyer J, Rumpf HJ, Hapke U, et al. Alcohol consumption and health-services utilization in Germany. *J Stud Alcohol*. (2006) 67:429–35. doi: 10.15288/jsa.2006.67.429

46. Anzai Y, Kuriyama S, Nishino Y, Takahashi K, Ohkubo T, Ohmori K, et al. Impact of alcohol consumption upon medical care utilization and costs in men: 4-year observation of National Health Insurance beneficiaries in Japan. *Addiction*. (2005) 100:19–27. doi: 10.1111/j.1360-0443.2004.00874.x

47. Chou Y, Zhang Z. Research on anti-poverty alleviation in medical protection in minority ethnic areas of Guizhou[in Chinese]. *J Chin Acad Gov*. (2016) 3:7. doi: 10.14063/j.cnki.1008-9314.2016.03.012

48. Zhao D, Zhou Z, Shen C, Zhai X, Zhao Y, Cao D, et al. The effect of health check-ups on health among the elderly in China: evidence from 2011-2018 longitudinal data. *Int J Public Health*. (2022) 67:1604597. doi: 10.3389/ijph.2022.1604597

49. Jana A, Chattopadhyay A. Prevalence and potential determinants of chronic disease among elderly in India: rural-urban perspectives. *PLoS One*. (2022) 17:e0264937. doi: 10.1371/journal.pone.0264937

50. Su B, Li D, Xie J, Wang Y, Wu X, Li J, et al. Chronic disease in China: geographic and socioeconomic determinants among persons aged 60 and older. *J Am Med Dir Assoc*. (2023) 24:206–12.e5. doi: 10.1016/j.jamda.2022.10.002

51. Meng Q, Fang H, Liu X, Yuan B, Xu J. Consolidating the social health insurance schemes in China: towards an equitable and efficient health system. *Lancet*. (2015) 386:1484–92. doi: 10.1016/S0140-6736(15)00342-6

52. Yuan L, Cao J, Wang D, Yu D, Liu G, Qian Z. Regional disparities and influencing factors of high quality medical resources distribution in China. *Int J Equity Health*. (2023) 22:8. doi: 10.1186/s12939-023-01825-6

53. Shi B, Fu Y, Bai X, Zhang X, Zheng J, Wang Y, et al. Spatial pattern and spatial heterogeneity of Chinese elite hospitals: a country-level analysis. *Front Public Health*. (2021) 9:710810. doi: 10.3389/fpubh.2021.710810

54. Wang L, Chen Y. Determinants of China's health expenditure growth: based on Baumol's cost disease theory. *Int J Equity Health*. (2021) 20:213. doi: 10.1186/s12939-021-01550-y

frontiers | Frontiers in Public Health

TYPE Original Research
PUBLISHED 27 August 2024
DOI 10.3389/fpubh.2024.1369568

OPEN ACCESS

EDITED BY
Ali Sheidaei,
Tehran University of Medical Sciences, Iran

REVIEWED BY
Kimiya Gohari,
Tarbiat Modares University, Iran
Gui Jin,
China University of Geosciences Wuhan, China

*CORRESPONDENCE
Li Huang
✉ lh2015@sina.com

†These authors have contributed equally to this work and share first authorship

RECEIVED 17 January 2024
ACCEPTED 29 July 2024
PUBLISHED 27 August 2024

CITATION
Wang T, Zhou T, Zhou L, He Y, Wang J, Wang Y and Huang L (2024) Equity and efficiency of health resource allocation in the Chengdu–Chongqing Economic Circle of China.
Front. Public Health 12:1369568.
doi: 10.3389/fpubh.2024.1369568

Equity and efficiency of health resource allocation in the Chengdu–Chongqing Economic Circle of China

Tianqi Wang[1†], Ting Zhou[1†], Leming Zhou[2], Yunfei He[3], Jian Wang[4], Yonghong Wang[5] and Li Huang[3]*

[1]School of Public Health, Chongqing Medical University, Chongqing, China, [2]College of Computer Science and Technology, Chongqing University of Posts and Telecommunications, Chongqing, China, [3]Department of Personnel, The First Affiliated Hospital of Chongqing Medical University, Chongqing, China, [4]Department of Pathophysiology, Chongqing Medical University, Chongqing, China, [5]Department of Clinical Laboratory, Chongqing Qianjiang Central Hospital, Chongqing, China

Objective: This study aimed to evaluate the fairness and efficiency of health resource allocation (HRAE) in Chengdu-Chongqing Economic Circle after the new healthcare reform. This study also aimed to identify existing problems, providing empirical evidence for the government to formulate regional health plans scientifically and reasonably.

Methods: The fairness of health resource allocation was analyzed using the Gini coefficient, Theil index, and agglomeration degree from population and geographical area perspectives. The three-stage data envelopment analysis and the Malmquist productivity index were used to analyze HRAE from static and dynamic perspectives.

Results: The Gini coefficient for population allocation in Chengdu-Chongqing Economic Circle was 0.066–0.283, and the Gini coefficient for geographical area allocation was 0.297–0.469. The contribution rate within a region was greater than that between regions, and health resources were mainly concentrated in economically developed core areas. The overall fairness of Chengdu Economic Circle was relatively better than that of Chongqing Economic Circle. Moreover, the adjusted mean technical efficiency was 0.806, indicating room for HRAE improvement in Chengdu-Chongqing Economic Circle. Stochastic Frontier Analysis found that different environmental variables have varying degrees of impact on HRAE. The adjusted mean total factor productivity change (Tfpch) was 1.027, indicating an overall upward trend in HRAE since the new healthcare reform. However, scale efficiency change (Sech) (0.997) limited the improvement of Tfpch.

Conclusion: The fairness of health resources allocated by population was better than that allocated by geographical area. The unfairness of health resources mainly stemmed from intra-regional differences, with considerable health resources concentrated in core areas. Over the past 13 years, HRAE has improved but exhibited spatial heterogeneity and Sech-hindered productivity improvement. The study recommends strengthening regional cooperation and sharing to promote the integrated and high-quality development of the health and well-being in Chengdu–Chongqing Economic Circle.

KEYWORDS

Chengdu–Chongqing Economic Circle, health resource allocation, equity, three stage DEA, Malmquist productivity index

1 Introduction

The rapid growth of the global economy and society has brought about tremendous challenges. These include an aging population, the transformation of diseases, and an increase in chronic disease patients (1). China initiated a critical and demanding healthcare reform in 2009 to tackle these challenges and fulfill the public's evolving health needs (2, 3). This reform recognizes the imbalanced development of regional medical and health undertakings and unreasonable resource allocation in the medical and health field (4). It proposes to strengthen regional health planning and encourage co-construction and sharing, pointing out the development direction for optimizing the allocation of regional health resources.

The Chengdu-Chongqing Economic Circle is located at the intersection of the Belt and Road and the Yangtze River Economic Belt. Since China's 11th Five-Year Plan (5), the development of the Chengdu-Chongqing Economic Circle has been at the core of the national development strategy, making a significant contribution to the country's overall progress. The Chengdu-Chongqing Economic Circle Development Plan Outline (Planning Outline), released in 2021, particularly emphasizes the optimization of medical resource allocation. The Chengdu-Chongqing Economic Circle is not only the most densely populated area in Western China (6), but also faces the challenge of an aging population. The demand for medical and health services among residents is rapidly increasing in a diversified and multi-level manner. With support from national policies, it has achieved specific results in allocating health resources, which continue to grow. For example, it has established an alliance for the development of Traditional Chinese Medicine, accelerated the construction of national regional medical center projects, and built a cancer prevention and control community. However, the vast geographical area and complex mountainous terrain have to some extent limited the effective flow of health resources (7). Faced with these challenges, the Chengdu-Chongqing Economic Circle still has many issues in the balance of supply and demand of health resources, including the imbalance of resource allocation and insufficient allocation efficiency. Therefore, the rational allocation of limited medical and health resources has become particularly critical in promoting the development of the Chengdu-Chongqing Economic Circle. An efficient health resource allocation system not only forms the cornerstone of regional development but also provides a solid medical guarantee for attracting and retaining key personnel. Improving the equity, accessibility, and utilization rate of health resources (8) is the core goal pursued by health decision-makers and health systems (9, 10). This is conducive to achieving a balance of supply and demand for medical services, jointly building and sharing basic public health services, meeting people's needs for medical resources, improving public health literacy, promoting the comprehensive development of the Chengdu-Chongqing Economic Circle, and advancing the construction of a healthy China (11). Through scientific planning and precise investment, the allocation of medical and health resources in the Chengdu-Chongqing Economic Circle will be further improved, providing strong support for the region's sustained prosperity and the health and well-being of the people.

Previous research on health resource allocation has mainly focused on the national level or particular provinces or cities, and the research content is limited to a single aspect of fairness or efficiency. Liu et al. (12) analyzed the trends and equity of health resource allocation in primary-level medical and health institutions in China during the 13th Five-Year Plan period, finding that equity in health resource allocation in primary-level medical institutions in the eastern, central, and western regions of China has been continuously improving, but there are still differences. Wang et al. (13) used the Lorenz curve, Gini coefficient, and Theil index to evaluate the equity of health resource allocation in China by population and geography in 2019, discovering that the equity of health resources allocated by geographical area was much lower than that allocated by population, and that internal inequity within various regions is the main factor affecting the equity of health resource allocation in China. Fan et al. (14) against the backdrop of the construction of a tiered diagnostic and treatment system, evaluated the efficiency of health service resource allocation in Shandong Province, using the DEA-TOPSIS method for static analysis of health service resource allocation efficiency, and the DEA-Malmquist model for dynamic analysis. From 2012 to 2022, the average Malmquist Index in Shandong Province was 0.970, the average technical efficiency change index was 1.012, and the average technological progress index was 0.958, indicating that the decline in the Malmquist Index was mainly influenced by the technological progress index.

Only a few existing studies take regions as research subjects and combine equity and efficiency for comprehensive analysis. For instance, Zang et al. (15) conducted a study on the equity and efficiency of health resource allocation in the Yangtze River Delta region, using the Gini coefficient and Theil index to evaluate the equity of health resource allocation and a three-stage DEA model to assess efficiency. They found that the equity of health resource allocation by population in the Yangtze River Delta was better than by geography, with Shanghai's geographical allocation being in an unfair state. The overall efficiency of health resource allocation in the region is relatively high, but there are inter-regional differences. Wen et al. (16) analyzed the equity and efficiency of health resource allocation among the city clusters in the Guangdong-Hong Kong-Macao Greater Bay Area and found that from 2010 to 2020, the level of inequity in health resource allocation in the city clusters of the Greater Bay Area continued to improve, although there were regional differences in allocation efficiency, with technological regression being the main reason for the decline in total factor productivity. Zhou et al. (17) used the entropy weight TOPSIS method and the rank-sum ratio method to conduct a comprehensive evaluation of health resource allocation in the Chengdu-Chongqing Economic Circle. They discovered that there were significant regional differences in health resource allocation within the circle, with the Sichuan area showing a more balanced allocation and the Chongqing area showing a more polarized allocation. However, the study did not conduct an in-depth analysis of the equity and efficiency of health resource allocation, and the robustness of the research findings, as well as the causes of the health resource allocation issues, require further exploration.

This study takes the Chengdu–Chongqing Economic Circle as the research object and comprehensively analyzes the fairness and efficiency of health resource allocation in Chengdu–Chongqing Economic Circle from 2009 to 2021. A series of research methods such as Gini coefficient, Theil index, and agglomeration degree are used to evaluate the fairness of health resource allocation from the perspectives of population and geography. This study also employs the three-stage data envelopment analysis (three-stage DEA) model and Malmquist productivity index (MPI) to evaluate the HRAE from static and dynamic perspectives. Additionally, the factors affecting HRAE are analyzed. Our research aims to provide scientific reference for promoting high-quality and balanced development of medical services in Chengdu–Chongqing Economic Circle.

2 Methods

2.1 Data sources and regional distribution

This study utilized panel data from 44 districts in Chengdu-Chongqing Economic Circle from 2009 to 2021 for empirical analysis. The data originates from the healthcare reform in 2009 and continues until the beginning year of the 14th Five-Year Plan. This duration was a critical period for promoting the construction of a healthy China and advancing medical and health system reform, including the Chengdu-Chongqing Economic Circle in the National Five-Year Plan, underscoring the importance of promoting coordinated development of Chengdu-Chongqing Economic Circle at the national level. The data sources for this study include the Sichuan Health Statistical Yearbook, Sichuan Statistical Yearbook, Chongqing Health Statistical Yearbook, and Chongqing Statistical Yearbook, and selected statistical yearbooks from various districts and counties in Chongqing.

This article referred to the distribution range of Chengdu-Chongqing Economic Circle proposed in the Planning Outline. And taking into account the availability of indicator data and the accuracy of research results, the study area is divided into 2 regions and 44 districts. One was that Chengdu Economic Circle included 15 prefecture-level cities such as Chengdu, Zigong, Mianyang, Suining, Luzhou, Deyang, Nanchong, Meishan, Neijiang, Leshan, Guang'an, Yibin, Ya'an, Dazhou, and Ziyang. Another was Chongqing Economic Circle, which consisted of 29 districts and counties including Wanzhou, Fuling, Yuzhong, Shapingba, Jiulongpo, Dadukou, Jiangbei, Changshou, Jiangjin, Nan'an, Beibei, Yubei, Qijiang, Dazu, Qianjiang, Ba'nan, Hechuan, Yongchuan, Nanchuan, Bishan, Tongliang, Tongnan, Rongchang, Liangping, Fengdu, Zhongxian, Dianjiang, Kaizhou, and Yunyang. The districts of Ya'an, Dazhou, Mianyang, Yunyang, and Kaizhou constituted the entire region. ArcGIS 10.8 software was used to create a regional distribution map of Chengdu-Chongqing Economic Circle (Figure 1).

2.2 Measuring tools

2.2.1 Gini coefficients

The Gini coefficient is commonly used to evaluate the fairness of health resource allocation. Internationally, the Gini coefficient is conventionally defined between 0 and 1, and different values of Gini coefficient represent varying degrees of fairness: $G<0.2$ represents absolute fairness, $0.2<G<0.3$ represents comparative fairness, $0.3<G<0.4$ signifies relative rationality, 0.4 is the warning line for judging whether health resource allocation is fair, $0.4<G<0.5$ indicates relative unfairness, and $G>0.5$ signifies serious unfairness (18). The Gini coefficient calculation formula (Equation 1) is as follows:

$$G = 1 - \sum_{i=1}^{k} \left(X_{i+1} - X_i\right)\left(Y_{i+1} + Y_i\right) \qquad (1)$$

where G represents the Gini coefficient value, X_i is the cumulative percentage of population or geographical area of the *ith* district in Chengdu-Chongqing Economic Circle, and Yi is the cumulative percentage of health resources (5 indicators to measure equity) of the *ith* district in Chengdu-Chongqing Economic Circle. k represents the total number of districts in Chengdu-Chongqing Economic Circle.

2.2.2 Theil index

Compared to the Gini coefficient, one advantage of the Theil index is that it can analyze the sources of overall inequity. Like the

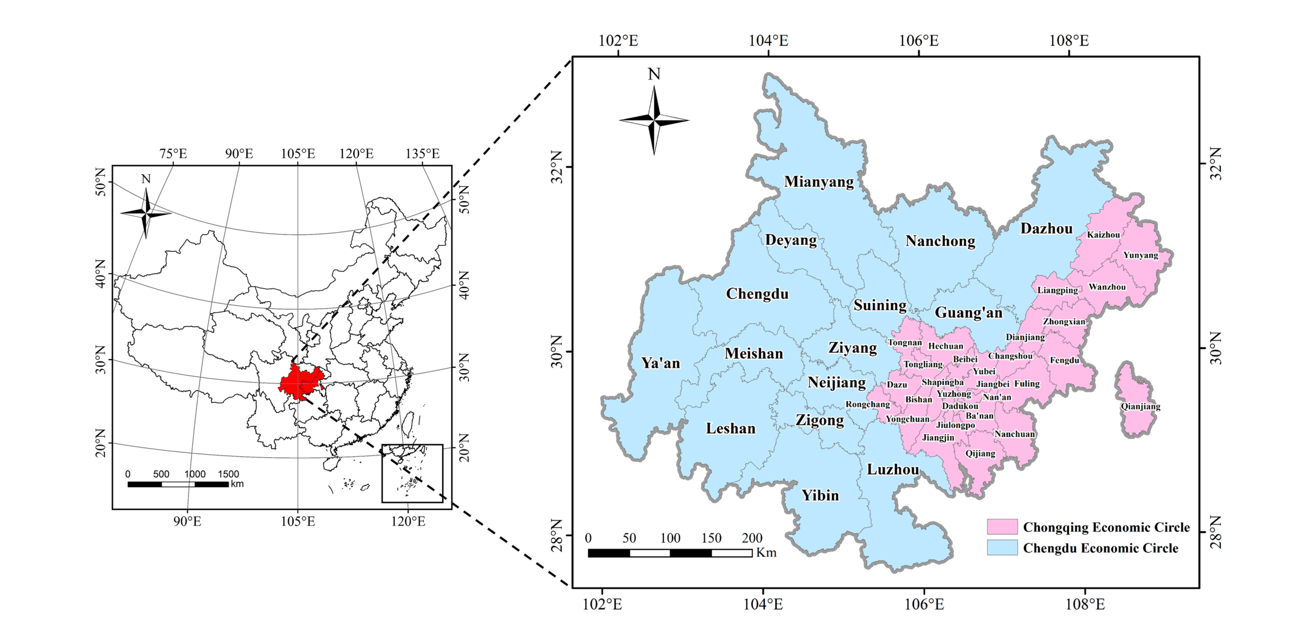


FIGURE 1
Regional distribution range of Chengdu–Chongqing Economic Circle.

Gini coefficient, the Theil index ranges from 0 to 1, and the lower the value, the better the equity of health resource allocation (19). The formula (Equation 2) for calculating the Theil index is as follows:

$$T = \sum_{i=1}^{k} P_i \log \frac{P_i}{D_i} \tag{2}$$

where T signifies the Theil index value, and P_i indicates the proportion of population of the *ith* district in Chengdu-Chongqing Economic Circle. D_i represents the proportion of health resources in the *ith* district of the Chengdu-Chongqing Economic Circle, and k denotes the total number of districts in Chengdu-Chongqing Economic Circle. The Theil index (Equation 3) can be further decomposed into intra-regional (Equation 5) Theil and inter-regional Theil (Equation 4) (18, 20), with the following decomposition formula:

$$T = T_{inter} + T_{intra} \tag{3}$$

$$T_{inter} = \sum_{j=1}^{n} P_j \log \frac{P_j}{D_j} \tag{4}$$

$$T_{intra} = \sum_{j=1}^{n} P_j T_j \tag{5}$$

where T_{inter} signifies the differences in health resources between the two regions of the Chengdu-Chongqing Economic Circle (Chengdu Economic Circle and Chongqing Economic Circle), whereas T_{intra} represents the differences in health resources within the two regions of the Chengdu-Chongqing Economic Circle. P_j is the proportion of population in the jth region, and D_j is the proportion of health resources in the jth region. T_j shows the Theil index of the two regions, and n shows the number of regions.

2.2.3 Health resource agglomeration degree

The health resource agglomeration degree (HRAD) is a new indicator proposed by scholars like Suwei Y to evaluate the equity of health resource allocation. It can comprehensively reflect the influence of population and geographical factors on the fairness of health resource allocation. The agglomeration degree of health resources refers to the proportion of health resources concentrated in a certain area that accounts for 1% of the geographical area of the upper-level region (21, 22). The calculation formula (Equation 6) for the agglomeration degree of health resources is as follows:

$$HRAD_j = \frac{\left(\frac{HR_j}{HR_k}\right) \times 100\%}{\left(\frac{A_j}{A_k}\right) \times 100\%} = \frac{\frac{HR_j}{A_j}}{\frac{HR_k}{A_k}} \tag{6}$$

Population agglomeration (PAD) refers to the proportion of population aggregated in a certain area, which occupies 1% of the geographical area of the upper-level region. The calculation formula (Equation 7) for population agglomeration is as follows:

$$PAD_j = \frac{\left(\frac{P_j}{P_k}\right) \times 100\%}{\left(\frac{A_j}{A_k}\right) \times 100\%} = \frac{P_j / A_j}{P_k / A_k} \tag{7}$$

where $HRAD_j$ indicates the concentration of health resources in the jth district, HR_j signifies the number of health resources in the jth district, and HR_k denotes the number of health resources in the upper-level region. A_j represents the geographical area of the jth district, and A_k signifies the geographical area of the upper-level region. PAD_j shows the population concentration of the jth district, P_j signifies the population number of the jth district, and P_k shows the population number of the upper-level region.

We usually use $HRAD_j/PAD_j$ to evaluate the fairness of population allocation, where $HRAD_j/PAD_j = 1$ shows absolute fairness in health resources allocated by population in the district, $HRAD_j/PAD_j > 1$ indicates that an excess of health resources relative to the population in the district, and $HRAD_j/PAD_j < 1$ signifies that the health resources in the district are relatively insufficient compared to the population. Similarly, $HRAD_j = 1$ indicates absolute equity in the allocation of health resources in the district based on geographical area, $HRAD_j > 1$ shows an excess of health resources allocated by geographical area in the district, and $HRAD_j < 1$ signifies that a shortage of health resources allocated by geographical area in the district.

2.2.4 Three-stage DEA model

Fried proposed the three-stage DEA model in 2002, aiming to eliminate the impact of environmental variables and random disturbances on efficiency. In this paper, the three-stage DEA model was used to analyze the HRAE of the Chengdu-Chongqing Economic Circle. The model comprised of three stages, and the calculation steps are as follows:

In the first stage, DEAP 2.1 software was employed to calculate each district's efficiency values and slack variables in Chengdu-Chongqing Economic Circle through a BCC model with variable returns to scale. The technical efficiency (TE) can be decomposed into scale efficiency (SE) and pure technical efficiency (PTE), and TE equals the product of SE and PTE (TE = SE × PTE) (23). TE = 1 suggests that the district is in a DEA valid state, TE < 1, and SE or PTE = 1 signifies that the district is in a weak DEA efficient state, and other situations indicate that the district is in a DEA invalid state (24).

In the second stage, Frontier 4.1 software was used, with six environmental variables as independent variables and the slack values of four input indicators as dependent variables, Equation (8) for Stochastic Frontier Analysis (SFA) model can be written as:

$$S_{mk} = f\left(Z_k; \beta_m\right) + v_{mk} + \mu_{mk} \\ k = 1, 2, \cdots, 44; m = 1, 2, 3, 4 \tag{8}$$

In the above formula, S_{mk} represents the slack value of the *kth* district in the *mth* input indicator, and $f(Z_k; \beta_m)$ indicates the impact of environmental factors on S_{mk}. v_{mk} shows random perturbation, μ_{mk} represents management inefficiency, and the sum of the two is a mixed error term. Equation (9) for calculating the adjusted investment indicators is as follows:

$$X_{mk}^{A} = X_{mk} + \left[\max\left(f\left(Z_k ; \hat{\beta}_m \right) \right) - f\left(Z_k ; \hat{\beta}_m \right) \right] + \left[\max\left(v_{mk} \right) - v_{mk} \right] \quad k = 1,2,\cdots,44; m = 1,2,3,4 \tag{9}$$

where X_{mk} and X_{mk}^{A} are the input indicators before and after adjustment, respectively (25). $\left[\max\left(f\left(Z_k ; \hat{\beta}_m \right) \right) - f\left(Z_k ; \hat{\beta}_m \right) \right]$ signifies placing the 44 districts under the same external environment, and $\left[\max\left(v_{mk} \right) - v_{mk} \right]$ represents placing the 44 districts under the same random error.

In the third stage, the DEAP 2.1 software was used to calculate the adjusted efficiency values of various districts in Chengdu-Chongqing Economic Circle through the BCC model, reflecting the true situation of HRAE in Chengdu-Chongqing Economic Circle.

2.2.5 Malmquist productivity index(MPI)

The MPI can dynamically evaluate the efficiency changes of decision-making units over many years. The total factor productivity change (Tfpch) can be decomposed into changes in technical efficiency (Effch) and technological progress (Techch), and Effch can be further decomposed into pure technical efficiency change (Pech) and scale efficiency change (Sech) (26). This article used DEAP 2.1 software to calculate the Tfpch value of the Chengdu-Chongqing Economic Circle in the past 13 years. The specific calculation formula (Equations 10–13) is as follows:

$$\text{Tfpch} = \text{Techch} \times \text{Effch} = \text{Techch} \times \text{Pech} \times \text{Sech} \tag{10}$$

$$Tfpch = \left(x^t, y^t, x^{t+1}, y^{t+1} \right) = \left[\frac{E^t\left(x^{t+1}, y^{t+1} \right)}{E^t\left(x^t, y^t \right)} \times \frac{E^{t+1}\left(x^{t+1}, y^{t+1} \right)}{E^{t+1}\left(x^t, y^t \right)} \right]^{\frac{1}{2}} \tag{11}$$

$$Effch = \frac{E^{t+1}\left(x^{t+1}, y^{t+1} \right)}{E^t\left(x^t, y^t \right)} \tag{12}$$

$$Techch = \left[\frac{E^t\left(x^{t+1}, y^{t+1} \right)}{E^{t+1}\left(x^{t+1}, y^{t+1} \right)} \times \frac{E^t\left(x^t, y^t \right)}{E^{t+1}\left(x^t, y^t \right)} \right]^{\frac{1}{2}} \tag{13}$$

In the above formula, (x^t, y^t) and (x^{t+1}, y^{t+1}) represent the input and output indicators for the periods t and $t+1$ respectively, while E^t and E^{t+1} show the distance functions for the periods t and $t+1$, respectively. Each efficiency change value = 1 indicates that the efficiency remains unchanged, each efficiency change value >1 suggests an improvement in efficiency, and each efficiency change value <1 shows a decrease in efficiency (27).

2.3 Indicator selection

Based on the principles of representativeness, correlation, and availability selected by DEA indicators. After consulting with experts and reviewing prior research (28–30), in order to fully reflect the allocation of health resources in Chengdu-Chongqing Economic Circle, the number of medical and health institutions (MHI), actual number of beds (AB), number of practicing (assistant) physicians (PAP), and number of registered nurses (RN) were selected as input indicators. And the number of diagnoses and treatments (DT), number of surgeries performed (SP), and number of discharged patients (DP) were selected as output indicators. Considering the impact of environmental factors such as economy, finance, population, education, and society on HRAE, gross domestic product (GDP), health expenditure (HE), number of permanent residents (PR), number of primary and secondary school teachers (FTPS), urbanization rate (UR), and general public budget revenue (GPBR) were selected as environmental variables. A significant difference has been observed between the maximum and minimum values of various indicator data in the past 13 years. Among the input indicators, the standard deviation of AB was the largest at 18,701.15. In the output indicators, DT had the highest standard deviation of 1873.41. Among environmental variables, the FTPS standard deviation was the highest at 17,139.75 (Table 1). MHI, AB, number of health workers (HW), PAP, and RN were selected for fairness analysis.

3 Results

3.1 Current situation of health resource allocation in Chengdu–Chongqing Economic Circle

From 2009 to 2021, although the number of MHI decreased in 2016, 2020, and 2021, it showed an overall growth trend. The number of AB, HW, PAP, and RN were increasing each year. The average annual growth rates of MHI, AB, HW, PAP, and RN were 2.24, 7.98, 6.51, 5.65, and 10.79%, respectively. Apart from MHI, there has been an annual increase in AB, HW, PAP, and RN per thousand population and per square kilometer (Table 2).

3.2 The equity of health resource allocation in Chengdu–Chongqing Economic Circle

From 2009 to 2021, according to population allocation, the Gini coefficient of various health resources in Chengdu-Chongqing Economic Circle showed a fluctuating downward trend, indicating that the fairness of health resources has improved after the new medical reform. The evolution trend of the Gini coefficient of HW showed an "inverted V-shape," reaching its peak in 2017 at 0.239. In contrast, the Gini coefficient of AB displayed a "V-shaped" trend, reaching a trough of 0.066 in 2016. The Gini coefficient of most health resources allocated by population was less than 0.2, suggesting absolute equity. From a regional perspective, the Gini coefficients of various health resources in Chengdu Economic Circle ranged from 0.044 to 0.265. Except for RN, the Gini coefficients of all other health resources were less than 0.2. For Chongqing Economic Circle, the Gini

TABLE 1 Descriptive analysis of input–output and environmental variables.

Primary indicators	Secondary indicators	Abbreviation	Mean	SD	Min	Max
Input indicators	Medical and health institutions (unit)	MHI	1761.50	2134.82	71.00	12497.00
	Actual beds (number)	AB	12810.35	18701.15	616.00	160833.00
	Practicing (assistant) physicians (person)	PAP	4958.04	8261.34	568.00	80002.00
	Registered nurses (person)	RN	5310.34	9970.34	333.00	100742.00
Output indicators	Number of diagnoses and treatments (10,000 person times)	DT	1134.90	1873.41	67.20	16451.64
	Number of surgeries performed (10,000 person times)	SP	8.72	16.12	0.60	172.13
	Discharged patients (10,000 persons)	DP	39.84	56.67	2.22	479.34
Environment variables	Gross domestic product (100 million yuan)	GDP	992.24	1811.03	65.71	19916.98
	Health expenditure (100 million yuan)	HE	15.23	19.40	0.55	187.64
	Permanent residents (10,000 persons)	PR	214.92	260.10	27.72	2119.20
	Full-time teachers in primary and secondary schools (person)	FTPS	15608.28	17139.75	1773.00	125365.00
	Urbanization rate (%)	UR	57.83	19.35	28.89	100.00
	General public budget revenue (100 million yuan)	GPBR	67.92	162.35	2.54	1697.63

coefficients of various health resources ranged from 0.102 to 0.315. Except for 2009, the Gini coefficients of MHI, AB, and HW were less than 0.2 (Figures 2A–C).

When configured by geographical area, the Gini coefficients of AB and RN in Chengdu-Chongqing Economic Circle have shown an overall downward trend in the past 13 years, while the Gini coefficients of MHI, HW, and PAP have shown an overall upward trend. Moreover, the Gini coefficients of most health resources ranged from 0.3 to 0.5, which was between relatively reasonable and relative inequity. From 2009 to 2010, MHI experienced a greater decrease in its Gini coefficient than other health resources, with a decrease of 0.079. The fairness of RN was even worse. From a regional perspective, the Gini coefficients of various health resources in Chengdu Economic Circle did not change much, with MHI, AB, HW, and PAP having Gini coefficients ranging from 0.277 to 0.400, while the Gini coefficients of RN ranged from 0.401 to 0.440. The Gini coefficient values of various health resources in Chongqing Economic Circle ranged from 0.306 to 0.542. Furthermore, the decline in various health resources was larger from 2009 to 2010, but remained relatively stable in other periods (Figures 2D–F).

The Theil index and Gini coefficient of health resource allocation in Chengdu-Chongqing Economic Circle showed a generally consistent evolution trend (31). Further analysis of the sources of unfairness revealed that the main reason for the inequity in health resource allocation in Chengdu-Chongqing Economic Circle was intra-regional differences. From 2009 to 2021, the contribution rates of AB, HW, PAP, and RN within the region were greater than those between regions, and the intra-regional contribution rates exceeded 94%. Except for the relatively small intra-regional contribution rate of MHI in 2009, the intra-regional contribution rate of MHI in all other years was greater than the inter-regional contribution rate (Table 3).

We further decomposed the intra-regional differences. From 2009 to 2021, the contribution rate of differences in MHI allocation in Chengdu Economic Circle showed an upward trend, whereas the contribution rate of differences in the allocation of other health resources showed an overall downward trend. The Chongqing Economic Circle was the opposite. Before 2018, the internal differences in Chongqing Economic Circle contributed more to the differences in MHI allocation. However, the internal differences in Chengdu Economic Circle have contributed more to the differences in MHI allocation since 2018. The internal differential contribution rates of AB, HW, PAP, and RN allocation in Chongqing Economic Circle were greater than 71, 72, 67, and 62% respectively, indicating that the inequity of AB, HW, PAP, and RN mainly comes from Chongqing Economic Circle (Table 4).

The agglomeration degree of various health resources in Chengdu-Chongqing Economic Circle from 2009 to 2021 exceeded 2.140. This result denotes that the fairness of health resource allocation based on geographical area is relatively high. The agglomeration degree of RN was the highest, while MHI's was the lowest but greater than 1, which indicates that RN is more concentrated compared to other health resources. From a regional perspective, the HRAD of Chengdu Economic Circle exceeded 2.360, higher than the average level, showing a relative surplus of health resources. The HRAD in Chongqing Economic Circle exceeded 1.300, indicating a relative concentration of health resources (Figures 3A–C).

The agglomeration ratios of various health resources in Chengdu-Chongqing Economic Circle were relatively stable, with the ratios of AB, HW, PAP, and RN basically greater than 1, while the ratios of MHI were all less than 1. The results suggest that apart from MHI, most health resources are allocated fairly by population. The trend of changes in the ratio of various health resources in Chengdu Economic Circle was the same as that in Chengdu-Chongqing Economic Circle, whereas the overall ratios of various health resources in Chongqing Economic Circle exhibited a downward trend. The ratio of MHI of Chongqing Economic Circle decreased from 1.034 in 2009 to 0.968 in 2021, and the ratio of AB fluctuated around 1, while the ratios of other health resources were all greater than 1. This suggests that the health human resources in Chongqing Economic Circle are sufficient relative to the population (Figures 3D–F).

Looking at different districts, in terms of MHI, the agglomeration degree of most districts (63.64%) was below 1.224. The agglomeration degree of 10 districts including Chengdu and Tongliang ranged from 1.224 to 1.933. The agglomeration degree of six main urban districts

TABLE 2 Health resource allocation in Chengdu–Chongqing Economic Circle from 2009 to 2021.

Year	MHI			AB			HW			PAP			RN		
	/1000 persons	$/km^2$	Total	/1000 persons	$/km^2$	Total	/1000 persons	$/km^2$	Total	/1000 persons	$/km^2$	Total	/1000 persons	$/km^2$	Total
2009	0.6740	0.3061	62,459	3.3315	1.5128	308,734	5.1413	2.3347	476,453	1.6736	0.7600	155,099	1.1654	0.5292	107,995
2010	0.7947	0.3560	72,659	3.8068	1.7055	348,056	5.8630	2.6267	536,055	1.8051	0.8087	165,040	1.3777	0.6172	125,961
2011	0.8077	0.3626	74,199	4.2199	1.8942	387,638	6.3070	2.8310	579,351	1.8975	0.8518	174,306	1.5785	0.7085	145,000
2012	0.8071	0.3584	74,473	4.8634	2.1599	448,777	6.8137	3.0260	628,746	2.0137	0.8943	185,822	1.8145	0.8058	167,438
2013	0.8421	0.3774	78,207	5.3260	2.3870	494,614	7.3107	3.2764	678,924	2.1311	0.9551	197,912	2.0155	0.9033	187,172
2014	0.8450	0.3807	78,897	5.7045	2.5704	532,624	7.6750	3.4583	716,610	2.1952	0.9891	204,964	2.2407	1.0096	209,210
2015	0.8415	0.3824	79,236	6.0543	2.7511	570,065	7.9508	3.6129	748,642	2.2306	1.0136	210,029	2.4234	1.1012	228,186
2016	0.8307	0.3806	78,876	6.4052	2.9350	608,174	8.2446	3.7778	782,818	2.2850	1.0470	216,957	2.6261	1.2033	249,351
2017	0.8317	0.3837	79,511	6.8828	3.1756	658,026	8.6716	4.0009	829,041	2.4025	1.1085	229,692	2.8695	1.3239	274,333
2018	0.8460	0.3926	81,352	7.2743	3.3757	699,493	9.1127	4.2289	876,276	2.5586	1.1874	246,036	3.1147	1.4454	299,509
2019	0.8634	0.4029	83,496	7.6353	3.5635	738,402	9.6467	4.5023	932,928	2.7594	1.2878	266,856	3.3889	1.5816	327,736
2020	0.8392	0.3993	82,743	7.6833	3.6560	757,569	9.8760	4.6994	973,774	2.8737	1.3674	283,346	3.5110	1.6707	346,184
2021	0.8254	0.3932	81,470	7.8550	3.7422	775,347	10.2922	4.9034	1,015,923	3.0387	1.4477	299,940	3.7427	1.7831	369,439

in Chongqing Economic Circle, including Yuzhong and Dadukou, was greater than 3, with Yuzhong reaching a high of 42.825. Regarding AB, the agglomeration degree in most districts (61.36%) was below 1.133. The agglomeration degree of eight districts including Chengdu and Shapingba was greater than 2.142, especially in Yuzhong, which was as high as 188.722. Regarding human resources, the agglomeration degree of PAP and RN in over half of the districts was below 0.931. The agglomeration degree of human resources in nine districts including Chengdu and Yubei was greater than 2.031. PAP and RN agglomeration degrees in Yuzhong were 229.133 and 316.347, respectively. These results suggest the health resources in Chengdu-Chongqing Economic Circle are concentrated in the core areas, showing a significant disparity in the distribution of health resources among different districts (Figures 3G–J).

3.3 HRAE in Chengdu–Chongqing Economic Circle

3.3.1 Efficiency analysis based on the traditional DEA model in the first stage

Research has shown that the average TE, SE, and PTE of the Chengdu-Chongqing Economic Circle from 2009 to 2021 were 0.841, 0.920, and 0.914, respectively. Compared to 2009, the TE of the Chengdu-Chongqing Economic Circle in 2021 has increased. The Chengdu Economic Circle has increased by 0.409, and the Chongqing Economic Circle has increased by 0.091, which denotes more room for improvement in Chengdu Economic Circle than in Chongqing Economic Circle. Compared with the 12th Five-Year Plan period, the TE of the Chengdu-Chongqing Economic Circle increased during the 13th Five-Year Plan period by 0.036 in Chengdu Economic Circle and 0.021 in Chongqing Economic Circle. In 2021, 12 districts, including Deyang and Yuzhong, were in a DEA effective state, 12 districts, including Chengdu and Dadukou, were in a DEA weakly effective state, and 20 districts, including Suining and Fuling, were in a DEA ineffective state. Among the 15 districts in Chengdu Economic Circle, 2 districts (13.33%) had DEA effectiveness, 8 districts (53.33%) had DEA weak effectiveness, and 5 districts (33.33%) had DEA inefficiency. Among the 29 districts in Chongqing Economic Circle, 10 districts (34.48%) had DEA effectiveness, 4 districts (13.79%) had weak DEA effectiveness, and 15 districts (51.72%) had DEA inefficiency (Appendix Table 1).

From 2009 to 2021, TE, SE, and PTE in Chengdu-Chongqing Economic Circle showed a fluctuating upward trend, with a more significant increase from 2009 to 2010. The trend of SE and TE changes was generally consistent, indicating that SE is the main factor affecting TE changes. Looking at different districts, from 2009 to 2021, the TE of most districts (61.36%) was less than 0.875, whereas the TE of eight districts, including Deyang and Tongnan, was greater than 0.945. Yuzhong and Qianjiang reached the DEA effective state. A second stage SFA regression analysis is required to obtain the true HRAE (Figures 4A–D).

3.3.2 Analysis of results based on the SFA regression model in the second stage

This article used Frontier 4.1 to construct the SFA regression model with environmental variables as independent variables and input slack values as dependent variables. All four input slack variables

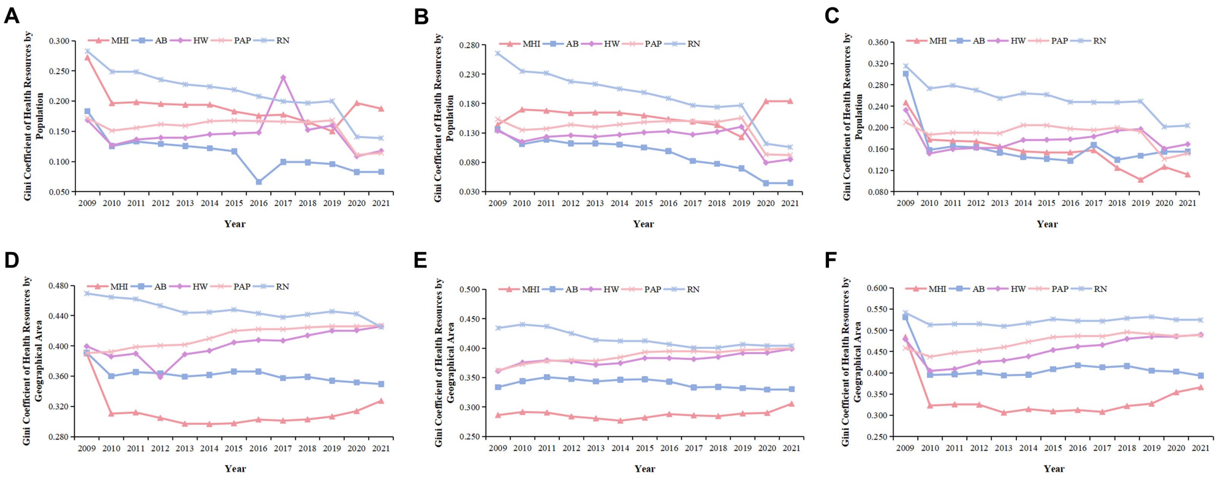


FIGURE 2
Gini coefficient of health resource allocation in Chengdu–Chongqing Economic Circle from 2009 to 2021. **(A,D)** Are the Gini coefficients of health resources in Chengdu-Chongqing Economic Circle allocated by population and geographical area, respectively. **(B,E)** Are the Gini coefficients of health resources in Chengdu Economic Circle allocated by population and geographical area, respectively. **(C,F)** Are the Gini coefficients of health resources in Chongqing Economic Circle allocated by population and geographical area, respectively.

TABLE 3 Theil index of health resource allocation in Chengdu-Chongqing Economic Circle.

Year	Theil index					Contribution rate of intra-region(%)					Contribution rate of inter-region(%)				
	MHI	AB	HW	PAP	RN	MHI	AB	HW	PAP	RN	MHI	AB	HW	PAP	RN
2009	0.0569	0.0272	0.0237	0.0225	0.0614	29.63	99.53	94.65	98.79	99.66	70.37	0.47	5.35	1.21	0.34
2010	0.0262	0.0135	0.0154	0.0186	0.0490	79.47	99.98	100.00	99.85	99.77	20.53	0.02	0.00	0.15	0.23
2011	0.0265	0.0146	0.0177	0.0199	0.0497	76.64	99.71	99.63	98.95	99.99	23.36	0.29	0.37	1.05	0.01
2012	0.0259	0.0133	0.0183	0.0205	0.0456	76.08	98.48	99.20	97.91	100.00	23.92	1.52	0.80	2.09	0.00
2013	0.0254	0.0125	0.0182	0.0204	0.0420	75.92	99.38	98.67	97.34	99.97	24.08	0.62	1.33	2.66	0.03
2014	0.0255	0.0118	0.0199	0.0233	0.0414	72.76	99.48	98.95	98.04	99.99	27.24	0.52	1.05	1.96	0.01
2015	0.0226	0.0110	0.0211	0.0237	0.0402	77.20	99.91	99.83	98.91	99.98	22.80	0.09	0.17	1.09	0.02
2016	0.0210	0.0104	0.0213	0.0231	0.0361	77.17	99.97	99.99	99.50	99.96	22.83	0.03	0.01	0.50	0.04
2017	0.0216	0.0087	0.0215	0.0229	0.0347	72.66	99.71	99.89	99.38	100.00	27.34	0.29	0.11	0.62	0.00
2018	0.0184	0.0089	0.0227	0.0229	0.0336	72.14	99.56	99.97	99.99	99.82	27.86	0.44	0.03	0.01	0.18
2019	0.0153	0.0085	0.0245	0.0235	0.0348	64.99	99.26	99.88	100.00	99.93	35.01	0.74	0.12	0.00	0.07
2020	0.0264	0.0089	0.0161	0.0136	0.0221	78.85	98.27	99.80	100.00	99.92	21.15	1.73	0.20	0.00	0.08
2021	0.0246	0.0087	0.0174	0.0141	0.0220	82.30	97.91	99.21	99.72	99.96	17.70	2.09	0.79	0.28	0.04

passed the LR test at the 1% level, and the corresponding σ^2 and γ also passed the t-test at the 1% level. Therefore, removing environmental variables and random disturbances is reasonable (16). Additionally, $\gamma \geq 0.68$ exhibits that HRAE is mainly affected by management inefficiency (32) (Table 5).

The impact coefficients of PR were all positive and significant at least under the 5% significance level. Such values indicate that the HRAE of the Chengdu-Chongqing Economic Circle decreases as PR increases. This means that increasing PR will drive the demand for medical services among residents, increasing redundant investment in health workforce and material resources and negatively affecting HRAE. The regression coefficients of UR were all negative and passed the t-test at the 5% level, indicating that the improvement of UR has a promoting effect on HRAE. The reason may be that districts with higher UR are more likely to have high-quality medical resources and services, and people can avail high-quality and convenient medical services more. The impact coefficients of HE to medical and health human and material input slack variables were all negative, and the impact coefficients to AB and PAP slack variables were significant under the 1% significance level. The results denote that an increase in HE will reduce the redundancy of health resource investment and improve HRAE. After investigating the reasons, local governments have continuously emphasized the optimization of health resource allocation (33) and increased funding and regulatory efforts in the health field since the new healthcare reform, promoting the improvement of HRAE. The regression coefficients of GPBR to

TABLE 4 Proportion of disparities in contribution between Chengdu Economic Circle and Chongqing Economic Circle.

Year	MHI		AB		HW		PAP		RN	
	Chengdu Economic Circle	Chongqing Economic Circle	Chengdu Economic Circle	Chongqing Economic Circle	Chengdu Economic Circle	Chongqing Economic Circle	Chengdu Economic Circle	Chongqing Economic Circle	Chengdu Economic Circle	Chongqing Economic Circle
2009	24.03	75.97	15.41	84.59	22.34	77.66	28.67	71.33	37.43	62.57
2010	43.73	56.27	22.85	77.15	27.05	72.95	26.23	73.77	35.96	64.04
2011	43.60	56.40	24.96	75.04	26.74	73.26	25.97	74.03	33.48	66.52
2012	42.49	57.51	24.43	75.57	26.99	73.01	28.93	71.07	31.77	68.23
2013	45.37	54.63	26.99	73.01	25.16	74.84	27.71	72.29	33.08	66.92
2014	48.01	51.99	28.04	71.96	23.91	76.09	25.22	74.78	30.44	69.56
2015	48.33	51.67	27.39	72.61	24.61	75.39	27.37	72.63	29.70	70.30
2016	47.13	52.87	24.78	75.22	24.54	75.46	29.52	70.48	29.25	70.75
2017	44.48	55.52	18.90	81.10	21.88	78.12	29.85	70.15	26.33	73.67
2018	54.71	45.29	15.54	84.46	22.49	77.51	28.74	71.26	26.45	73.55
2019	55.56	44.44	12.67	87.33	24.09	75.91	32.11	67.89	26.67	73.33
2020	66.35	33.65	4.95	95.05	8.75	91.25	15.64	84.36	13.32	86.68
2021	70.05	29.95	5.38	94.62	9.54	90.46	14.99	85.01	11.82	88.18

10.3389/fpubh.2024.1369568

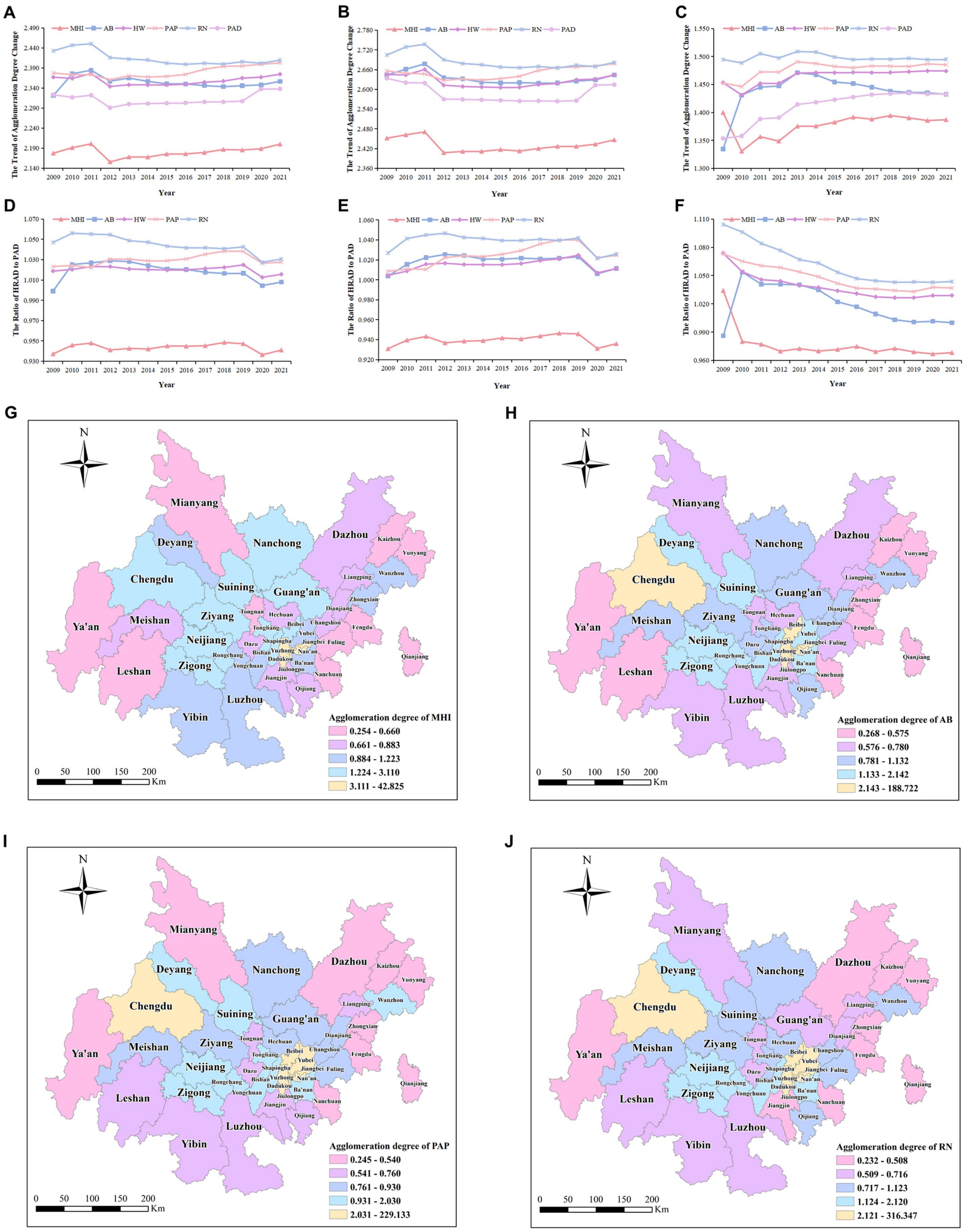


FIGURE 3
Agglomeration degree in Chengdu-Chongqing Economic Circle from 2009 to 2021. **(A–C)** represent the HRAD and PAD in Chengdu-Chongqing Economic Circle, Chengdu Economic Circle, and Chongqing Economic Circle, respectively. **(D–F)** Represent the ratios of HRAD to PAD in Chengdu-Chongqing Economic Circle, Chengdu Economic Circle, and Chongqing Economic Circle, respectively. **(G–J)** represent the agglomeration degree of MHI, AB, PAP, and RN in various districts of Chengdu-Chongqing Economic Circle.

various input slack variables were all negative, and the regression coefficients of GPBR to PAP and RN slack variables were significant, at least under the 5% level. That is, the increase in GPBR will positively impact HRAE. A possible reason is that local governments with more GPBR are more likely to arrange fiscal expenditures reasonably based on the health needs of residents (34). The increase in FTPS will reduce

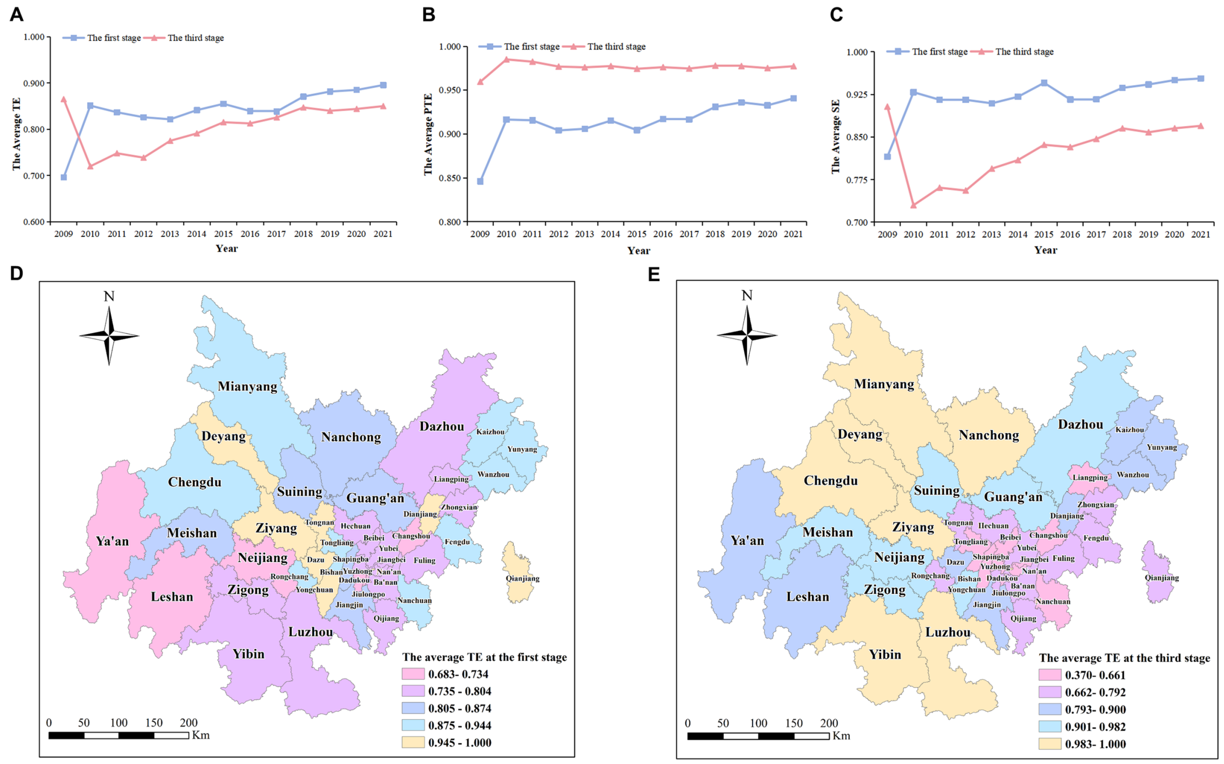


FIGURE 4
Comparison of HRAE in the first and third stages of Chengdu-Chongqing Economic Circle from 2009 to 2021. **(A–C)** signify the average TE, PTE, and SE of health resource allocation in Chengdu-Chongqing Economic Circle at stage 1 and stage 3, respectively. **(D,E)** Signify the average TE of each district in Chengdu-Chongqing Economic Circle at stage 1 and stage 3, respectively.

TABLE 5 Analysis of regression results based on SFA model at the second stage.

Variables	MHI slack		AB slack		PAP slack		RN slack	
	Coefficient	*T*-value	Coefficient	*T*-value	Coefficient	*T*-value	Coefficient	*T*-value
Constant term	55.38***	3.97	426.81**	2.03	175.16*	1.74	139.23*	1.76
GDP	0.01	0.33	0.17	1.16	0.18**	2.57	0.12*	1.91
HE	−1.57	−1.57	−13.19***	−3.41	−6.55***	−3.61	−3.88**	−2.43
PR	0.56**	2.26	2.99***	2.71	1.38***	2.81	1.16**	2.48
FTPS	−62.08*	−1.70	−316.31*	−1.82	−153.71*	−1.99	−141.31*	−1.94
UR	−1.34***	−2.94	−7.37**	−2.14	−3.26**	−2.05	−2.64**	−2.08
GPBR	−0.25	−0.64	−2.32	−1.47	−2.04***	−2.82	−1.48**	−2.23
σ^2	96180.95***	96173.59	1956769.20***	1942256.90	386615.78***	382302.98	373468.85***	368561.41
γ	0.68***	34.30	0.76***	50.87	0.74***	44.87	0.78***	57.13
LR-value	248.15***		334.12***		298.66***		361.28***	

*, **, and *** Denote significance at 10, 5, 1% significance levels, respectively.

the slack values of each input variable and improve HRAE. The strengthening of the teaching staff may promote the development of education and broaden the coverage of the population receiving education, which enable people to make more reasonable use of health resources and thereby improve the utilization rate of health resources. Moreover, the increase in GDP negatively impacts HRAE, and the impact coefficient of GDP to PAP slack variable was significant at the 5% level. Considering the continuous promotion of the construction of the Chengdu-Chongqing Economic Circle, the economy has been continuously developing. At the same time, people's purchasing power has been constantly improving, and investment in healthcare has been increasing, leading to resource waste.

3.3.3 Efficiency analysis after adjusting investment indicators in the third stage

Research has shown that the average values of TE, SE, and PTE after the adjustment of the Chengdu-Chongqing Economic Circle from 2009 to 2021 were 0.806, 0.825, and 0.976, respectively. TE and SE decreased by 0.035 and 0.095 respectively, whereas PTE increased by 0.062. Thus, the low SE is the main reason for the low TE. After three-stage DEA adjustment, the TE of the Chengdu-Chongqing Economic Circle in 2021 decreased by 0.015 compared to 2009. The Chengdu Economic Circle increased by 0.031, whereas the Chongqing Economic Circle decreased by 0.038. The TE of the Chengdu-Chongqing Economic Circle during the 12th Five-Year Plan period and the 13th Five-Year Plan period decreased by 0.062 and 0.029, respectively. The TE of the 13th Five-Year Plan period was higher than that of the 12th Five-Year Plan period. Thus, not considering the external environment will overestimate the TE of these two periods. In terms of various districts, in 2021, TE increased in 17 districts including Luzhou and Jiangjin, decreased in 22 districts including Yubei and Changshou, and remained unchanged in 5 districts including Deyang and Kaizhou. After adjustment, seven districts including Bishan and Tongnan were no longer at the forefront of technology. In contrast, three new districts, including Chengdu, Mianyang, and Meishan, were at the forefront of technology (Appendix Table 1).

From 2009 to 2021, the adjusted TE and SE showed a trend of first decreasing and then increasing, whereas PTE showed a trend of first increasing and then steadily decreasing. TE and SE experienced a greater decline from 2009 to 2010, and their trends were generally consistent, further indicating that SE is the main influencing factor of TE changes. PTE experienced a greater increase from 2009 to 2010 and peaked in 2010. Looking at different districts, from 2009 to 2021, the TE of eight districts including Luzhou and Nanchong was greater than 0.983. The efficiency values of Chengdu and Yuzhong were all 1, reaching the DEA effective state. The rise in Neijiang and Dazhou was more pronounced, whereas the decline in Dadukou and Qianjiang was more pronounced. This indicates that environmental factors have a greater impact on these districts (Figures 4A–C,E).

3.4 Productivity of health resource allocation in Chengdu–Chongqing Economic Circle

Based on the adjusted input indicators and original output indicator data, the dynamic HRAE of the Chengdu-Chongqing Economic Circle was calculated again using DEAP 2.1 software. The Tfpch of the Chengdu-Chongqing Economic Circle from 2009 to 2021 was 1.027, except for 2017–2018 and 2019–2020, and the Tfpch of all other periods was greater than 1. The results show that the HRAE has shown an overall upward trend since the new healthcare reform, with an average annual increase of 2.7%. At the same time, Techch had an average annual growth of 2.8%, whereas Effch had an average annual decrease of 0.1%, indicating that the improvement of Tfpch is mainly because of the improvement of Techch. From 2009 to 2010, the Tfpch was 1.135, with a significant annual increase, which is due to the government's high attention and determination to deepen the reform of the medical and health system, which has led to a rapid increase in Techch and thereby driven the improvement of Tfpch. From 2019 to 2020, Tfpch was 0.899, with a large average annual decline. A possible reason is that, due to the impact of COVID-19 in this period, the work focused on the prevention and control of infectious diseases, which slowed down the improvement speed of Techch, and then led to the decline of Tfpch. The frequency distribution shows that the Tfpch in 39 districts was greater than 1 from 2020 to 2021, indicating that the HRAE was developing in a good trend at the beginning of the 14th Five-Year Plan. Compared to 2009–2010, the frequency distribution of Effch (score > 1) from 2020 to 2021 was higher, while the frequency distribution of Techch (score > 1) was lower (Table 6).

In terms of Tfpch, except for the three districts of Jiangjin, Hechuan, and Tongnan where Tfpch was less than 1 and Fengdu where the Tfpch was equal to 1, the Tfpch in all other districts was greater than 1. Tfpch in Qianjiang was the highest at 1.071, whereas Tfpch in Jiangjin was the lowest at 0.983. In terms of Effch, 16 districts (36.36%) had an Effch greater than 1, 25 districts (56.82%) less than 1, and 3 districts (6.82%) had it equal to 1. In terms of Techch, except for the three districts of Jiangjin, Tongnan, and Zhongxian, where Techch was less than 1, all other districts were greater than 1 (Appendix Table 2).

4 Discussion

Since the new healthcare reform in 2009, how to allocate health resources reasonably has been a hot topic of discussion. The Planning Outline attaches great importance to the development of the Chengdu-Chongqing Economic Circle, placing it at an important level with the Yangtze River Delta, the Guangdong-Hong Kong-Macao Greater Bay Area, and the Beijing-Tianjin-Hebei at the national strategic level. It also emphasizes the importance of promoting the sinking of high-quality medical resources and improving the two-way referral mechanism. Optimizing the allocation of medical resources is an important connotation of promoting integrated health and hygiene

TABLE 6 Dynamic HRAE and frequency distribution in Chengdu-Chongqing Economic Circle.

Year	Effch	Techch	Pech	Sech	Tfpch
2009–2010	0.797	1.424	1.028	0.776	1.135
2010–2011	1.048	1.004	0.997	1.051	1.052
2011–2012	0.991	1.124	0.994	0.997	1.114
2012–2013	1.060	0.961	0.999	1.061	1.018
2013–2014	1.028	0.985	1.002	1.027	1.012
2014–2015	1.037	0.968	0.997	1.040	1.004
2015–2016	0.996	1.011	1.002	0.994	1.007
2016–2017	1.017	1.015	0.998	1.019	1.033
2017–2018	1.027	0.954	1.003	1.024	0.980
2018–2019	0.991	1.032	0.999	0.991	1.023
2019–2020	1.009	0.891	0.997	1.011	0.899
2020–2021	1.009	1.057	1.002	1.007	1.067
Mean	0.999	1.028	1.002	0.997	1.027
Frequency distribution (2009–2010)					
>1	12	44	23	7	23
1	3	0	12	5	0
<1	29	0	9	32	21
Frequency distribution(2020–2021)					
>1	21	43	15	19	39
1	6	0	20	6	0
<1	17	1	9	19	5

development in Chengdu-Chongqing Economic Circle. However, equity and efficiency are very important and difficult to balance when allocating medical resources. Therefore, this study empirically analyzes the health resource allocation-related issues encountered in constructing the Chengdu-Chongqing Economic Circle.

Since the new healthcare reform, the total amount of health resources in Chengdu-Chongqing Economic Circle, as well as health resources per thousand people and per square kilometer, have steadily increased over the past 13 years. Compared to other health resources, the growth rate of MHI is relatively small. Given the changes in the development mode of public hospitals and the allocation of health resources in recent years, the expansion of the scale of public hospitals has been limited to some extent (35). Simultaneously, as a critical component of MHI, public hospitals have also affected the growth rate of MHI. This study uses the Gini coefficient, Theil index, and agglomeration degree to study the fairness of health resource allocation in Chengdu-Chongqing Economic Circle. The empirical results show that the Gini coefficient range of each health resource in Chengdu-Chongqing Economic Circle according to population allocation is 0.066–0.283, while the Gini coefficient range for geographical area allocation is 0.297–0.469. The results denote that the fairness of health resources allocated by geographical area is worse than that allocated by population, which is consistent with existing research results (36). Possible reasons for this situation include the government's goal of fulfilling residents' health service needs and the impact of economic disparities in different districts of the Chengdu-Chongqing Economic Circle on the health resource allocation. The distance between residents and MHI should not be ignored as it can affect their convenience and enthusiasm for seeking medical treatment. Therefore, when formulating health plans, the government should comprehensively consider population and geographical area factors (9, 37). At the same time, the Gini coefficient of health resources allocated by population in Chengdu-Chongqing Economic Circle shows a downward trend. The equity of population allocation is constantly improving, which is closely related to the government's emphasis on health resource allocation, and may also be related to changes in population structure and the health needs of residents. For the older adult and those with chronic diseases, the service capacity of primary-level medical and health institutions should be strengthened to make basic medical and health services more fair and accessible.

The research results indicate that intra-regional differences are the main reason for the unfair allocation of health resources in Chengdu-Chongqing Economic Circle. The contribution rate of internal differences in the allocation of most health resources in Chongqing Economic Circle is greater than that in Chengdu Economic Circle, which means larger internal differences are found in the allocation of health resources in Chongqing Economic Circle. Further analysis reveals that the reasons for the differences in the allocation of health resources in different regions include the level of economic development and the geographical distribution of MHI. Economically developed regions usually provide more medical resources and higher quality medical services, while remote areas have a weak attraction to health talents, resulting in insufficient high-quality medical resources and lower medical service capabilities. We must first solve the problem of unequal distribution of health resources in Chongqing Economic Circle, and lay a good foundation for scientific expansion of high-quality medical resources and regional balanced distribution of high-quality medical resources in Chengdu-Chongqing Economic Circle. The government should pay attention to the internal differences in the allocation of health resources in Chongqing Economic Circle, provide financial support to economically underdeveloped and remote areas such as Qianjiang, and promote the construction of close county-level medical communities. This suggestion aims to enhance the accessibility of high-quality medical resources, establish a high-quality and efficient integrated medical and health service system, and meet the health needs of residents in remote areas.

The fairness of most health resources in Chengdu-Chongqing Economic Circle based on population and geographical area allocation is good, but the fairness of MHI based on population allocation needs to be further improved. This result is similar to that of Yixin et al. (38). Research has shown that the regional agglomeration of health resources has been observed in Chengdu-Chongqing Economic Circle, with health resources mainly concentrated in economically developed core areas, consistent with existing research results basically (39, 40). Considering the region's small geographical area and relatively developed economy, health resources are tilted toward the region, presenting a "Matthew effect" in terms of health resource allocation (41). Additionally, the characteristics of health resource allocation are largely consistent with the trend of urbanization, spreading from the core area outwards (42). Thus, it's necessary to expand the radiation scope and enhance the core areas' driving role in health resource allocation. This will boost health resource supply in less developed areas like Yunyang and Ya'an. Simultaneously, learn relevant experiences from Beijing-Tianjin-Hebei. Districts with relatively scarce health resources can precisely connect high-quality medical resources in core areas through collaborative construction and technological exchange.

From the perspective of HRAE in Chengdu-Chongqing Economic Circle, after removing the influence of environmental factors and random interference, the HRAE in most districts of the Chengdu-Chongqing Economic Circle changed. A three-stage DEA model for efficiency analysis must be used to obtain the actual efficiency value. The efficiency analysis results showed that the adjusted average TE value of the Chengdu-Chongqing Economic Circle was 0.806 from 2009 to 2021, which was higher than India (0.655) (43), Shanxi (0.675), and Inner Mongolia (0.730) (44) but lower than the national average (0.838) (45), Iraq (0.910) (46), and the Yangtze River Delta region (0.961) (47). Before and after the adjustment, the TE during the 13th Five-Year Plan period was higher than that during the 12th Five-Year Plan period, which resulted from the government's reforms over the years. Moreover, we found that the overall HRAE of Chengdu Economic Circle was higher than that of Chongqing Economic Circle, and the resource allocation of Chongqing Economic Circle needs further optimization. Although the government continues to promote the integrated development of health and hygiene in Chengdu-Chongqing Economic Circle, the effectiveness of the cross-regional allocation of medical resources is not significant. Further improvement of relevant supporting systems and implementation of relevant measures should be carried out. We also found that 6 districts (40.00%) in Chengdu Economic Circle, including Luzhou and Nanchong, should reduce their scale, whereas 26 districts (89.66%) in Chongqing Economic Circle, including Fuling and Jiangbei, should increase their scale. Hence, the Chengdu-Chongqing Economic Circle should establish specialized alliances and strengthen the construction of closely-integrated urban medical groups to achieve differentiated development among institutions. In addition, the Yangtze River Delta region has taken the lead in making beneficial explorations in "Internet plus healthcare." The Chengdu-Chongqing Economic Circle should actively learn from its experience in telehealth and intelligent hospital construction and address the uneven distribution of health resources through the development of telehealth. For example, by providing online paid diagnostic and treatment services through a telemedicine platform, this measure can moderately reduce the medical burden on patients, and also reduce the service pressure of offline hospitals and the diagnostic and treatment pressure on doctors (48). Online paid diagnosis and treatment can divert excessive medical resources, allowing patients in remote areas to enjoy high-quality medical services. In addition, through cross-regional medical information sharing, doctors can make accurate diagnoses more quickly, reduce repeated examinations, save time and costs, and to some extent alleviate the gap in urban and rural medical levels (49). Health managers, by analyzing patient data, can better understand the health status and needs of various groups in different areas, thereby optimizing the allocation of medical resources (50).

Research has found spatial heterogeneity in efficiency within and between regions in Chengdu-Chongqing Economic Circle. The government should implement localized and targeted strategies for each district, considering the actual conditions of different districts to make scientific assessments. Districts such as Dadukou, where low efficiency in scale results in overall inefficiency, should be provided with preferential policies with district's characteristics, fiscal support, and a rational expansion of scale to reduce the differences between districts. The study also found that environmental variables have a certain impact on HRAE. HE, FTPS, UR, and GPBR positively impact efficiency, whereas GDP and PR negatively impact efficiency. Therefore, these influencing factors should be comprehensively considered, and multiple measures should be adopted to improve HRAE. Regarding productivity, the HRAE has shown an overall upward trend since the new healthcare reform, and the improvement of Techch has driven the improvement of Tfpch. Furthermore, the Tfpch and Techch in most districts were greater than 1, whereas Effch was less than 1. Further decomposition confirms that low Sech leads to low Effch, indicating room for improvement in the Sech of the Chengdu-Chongqing Economic Circle. Therefore, MHI needs to anchor the demand of the medical service market accurately based on the local population size, economic level, and disease spectrum (51), allocate health resources scientifically and reasonably, and improve the utilization rate of health resources.

5 Conclusion

The Chengdu-Chongqing Economic Circle faces issues such as the need for further improvement in HRAE and Sech, imbalances in health resource allocation between regions and within different areas of the region, and significant differences in HRAE. Overall, due to Chongqing being a mega-city that integrates large urban areas, rural areas, mountainous areas, and reservoir areas, and Chengdu having advantages as a provincial capital and geographical benefits of the Chengdu Plain, the Chengdu Economic Circle has relatively better equity compared to the Chongqing Economic Circle, which is consistent with the results of the efficiency analysis. To address these issues, regional cooperation and sharing should be strengthened to improve the equity and efficiency of regional health resource allocation.

5.1 Limitations

Our study has certain limitations. First, this study included representative indicators of human and material resources but did not include indicators of financial resources. As a result, our findings might not completely reflect the aggregate status of health resources in Chengdu-Chongqing Economic Circle. Second, given the unavailability of the Chongqing Health Statistical Yearbook before 2009, relevant research on the early stage of the Eleventh Five-Year Plan was not conducted. Finally, our research methods mainly explored the fairness of health resources from the dimensions of population and geographical area, without fully considering the impact of the economic factors on equity. Moreover, the three-stage DEA model cannot rank DEA-efficient decision-making units, which has certain limitations.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

TW: Data curation, Supervision, Writing – original draft, Writing – review & editing. TZ: Data curation, Writing – original draft. LZ: Data curation, Writing – review & editing. YH: Writing – review & editing. JW: Data curation, Writing – review & editing. YW: Writing – review & editing. LH: Supervision, Writing – review & editing.

Funding

The author(s) declare financial support was received for the research, authorship, and/or publication of this article This manuscript was supported by the National Social Science Foundation Project (16XRK004), Chongqing Science and Health Joint Medical Research Project (2021MSXM011), and the Social Science Planning Project of Chongqing (2020WT06).

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2024.1369568/full#supplementary-material

References

1. Tian Y, Peng J, Liu Y, Huang J. Efficiency trends of essential public health services and possible influencing factors since the new round health reform in China: a case study from Hainan Province. *Front Public Health*. (2023) 11:1269473. doi: 10.3389/fpubh.2023.1269473

2. Yip W, Fu H, Chen AT, Zhai T, Jian W, Xu R, et al. 10 years of health-care reform in China: progress and gaps in universal health coverage. *Lancet*. (2019) 394:1192–204. doi: 10.1016/S0140-6736(19)32136-1

3. Tao W, Zeng Z, Dang H, Li P, Chuong L, Yue D, et al. Towards universal health coverage: achievements and challenges of 10 years of healthcare reform in China. *BMJ Glob Health*. (2020) 5:e002087. doi: 10.1136/bmjgh-2019-002087

4. Li Z, Yang L, Tang S, Bian Y. Equity and efficiency of health resource allocation of Chinese medicine in mainland China: 2013-2017. *Front Public Health*. (2020) 8:579269. doi: 10.3389/fpubh.2020.579269

5. Wu S, Deng X, Qi Y. Factors driving coordinated development of urban green economy: an empirical evidence from the Chengdu-Chongqing economic circle. *Int J Environ Res Public Health*. (2022) 19:6107. doi: 10.3390/ijerph19106107

6. Han D, Chen L, Wu H, Wang X, Xiao Y, Yang H, et al. Evaluation on coupling coordinated development of population economy and eco-geological environment in the twin-city economic circle of Chengdu-Chongqing region. *Sci Rep*. (2023) 13:13459. doi: 10.1038/s41598-023-40352-w

7. Wei L, Fangjuan D, Ou R. Geographical detection of the allocation and influencing factors of different healthcare resources: take the main city of Guiyang as an example. *Bull Surveying Mapping*. (2022) 116-120:125. doi: 10.13474/j.cnki.11-2246.2022.0366

8. Pu L. Fairness of the distribution of public medical and health resources. *Front Public Health*. (2021) 9:768728. doi: 10.3389/fpubh.2021.768728

9. Sun J, Luo H. Evaluation on equality and efficiency of health resources allocation and health services utilization in China. *Int J Equity Health*. (2017) 16:127. doi: 10.1186/s12939-017-0614-y

10. Zhou Z, Zhu L, Zhou Z, Li Z, Gao J, Chen G. The effects of China's urban basic medical insurance schemes on the equity of health service utilisation: evidence from Shaanxi Province. *Int J Equity Health*. (2014) 13:23. doi: 10.1186/1475-9276-13-23

11. Zhang T, Xu Y, Ren J, Sun L, Liu C. Inequality in the distribution of health resources and health services in China: hospitals versus primary care institutions. *Int J Equity Health*. (2017) 16:42. doi: 10.1186/s12939-017-0543-9

12. Muzi L, Xiaoyuan Q, Yanli Z, Yuanna Z, Zhihui L. Analysis of the equity of health resource allocation in grassroots health care institutions in China during the 13th five-year plan period. *Chin Hospitals*. (2023) 27:22–5. doi: 10.19660/j.issn.1671-0592.2023.02.06

13. Xiaoyu W, Qianqian W, Jingju X, Yuzhuo L, Zichen X, Chao X, et al. Fairness of health resource allocation. *China Modern Prevent Med*. (2022) 49:845–50.

14. Zhixin F, Peng Y, Chao Z, Ting W, Jia Y, Qiang S, et al. Evaluation on the health service resources allocation efficiency in Shandong Province under hierarchical diagnosis and treatment. *Chinese Health Econ*. (2024) 43:42–6.

15. Mengliu Z, Qiaohui D, Qi D, Yue X, Jing W, Yi X. Research on the equity and efficiency of health resource allocation in the Yangtze River Delta region. *Med Soc*. (2024) 37:96. doi: 10.13723/j.yxysh.2024.04.011

16. Jiaying W, Kainuo L, Qiu Z, Yuqi Z, Baoyi Z, Siyuan X. Equity and efficiency of health resources allocation in the Greater Bay Area. *China J Pharmaceut Econ*. (2023) 18:33. doi: 10.12010/j.issn.1673-5846.2023.08.004

17. Zhou M. Regional differences in health resource allocation: a longitudinal study in the Chengdu-Chongqing economic circle. *China. BMJ Open*. (2024) 14:e082721. doi: 10.1136/bmjopen-2023-082721

18. Zhang Y, Wang Q, Jiang T, Wang J. Equity and efficiency of primary health care resource allocation in mainland China. *Int J Equity Health*. (2018) 17:140. doi: 10.1186/s12939-018-0851-8

19. Yang C, Cui D, Yin S, Wu R, Ke X, Liu X, et al. Fiscal autonomy of subnational governments and equity in healthcare resource allocation: evidence from China. *Front Public Health*. (2022) 10:989625. doi: 10.3389/fpubh.2022.989625

20. Wang Y, Li Y, Qin S, Kong Y, Yu X, Guo K, et al. The disequilibrium in the distribution of the primary health workforce among eight economic regions and between rural and urban areas in China. *Int J Equity Health*. (2020) 19:28. doi: 10.1186/s12939-020-1139-3

21. Suwei Y, Fengqing W, Wenwei L, Zhe Z, Jin M. Methodology discussion of health resource allocation equity evaluation based on agglomeration degree. *Chin Hosp Manag*. (2015) 35:3–5.

22. Dai G, Li R, Ma S. Research on the equity of health resource allocation in TCM hospitals in China based on the Gini coefficient and agglomeration degree: 2009-2018. *Int J Equity Health*. (2022) 21:145. doi: 10.1186/s12939-022-01749-7

23. Mohd Hassan NZA, Bahari MS, Aminuddin F, Kunusagaran MNS, Zaimi NA, Mohd Hanafiah AN, et al. Data envelopment analysis for ambulance services of different service providers in urban and rural areas in Ministry of Health Malaysia. *Front Public Health*. (2023) 10:959812. doi: 10.3389/fpubh.2022.959812

24. Wang X, Luo H, Qin X, Feng J, Gao H, Feng Q. Evaluation of performance and impacts of maternal and child health hospital services using data envelopment analysis in Guangxi Zhuang autonomous region, China: a comparison study among poverty and non-poverty county level hospitals. *Int J Equity Health*. (2016) 15:131. doi: 10.1186/s12939-016-0420-y

25. Yao S, Wu G. Research on the efficiency of green agricultural science and technology innovation resource allocation based on a three-stage DEA model-a case study of Anhui Province, China. *Int J Environ Res Public Health*. (2022) 19:13683. doi: 10.3390/ijerph192013683

26. Wang C, Zeng J, Zhong H, Si W. Scientific research input and output efficiency evaluation of universities in Chengdu-Chongqing economic circle based on data envelopment analysis. *PLoS One*. (2023) 18:e0287692. doi: 10.1371/journal.pone.0287692

27. Liu W, Xia Y, Hou J. Health expenditure efficiency in rural China using the super-SBM model and the Malmquist productivity index. *Int J Equity Health*. (2019) 18:111. doi: 10.1186/s12939-019-1003-5

28. Cheng J, Kuang X, Zeng L. The impact of human resources for health on the health outcomes of Chinese people. *BMC Health Serv Res*. (2022) 22:1213. doi: 10.1186/s12913-022-08540-y

29. Lee KS, Chun KH, Lee JS. Reforming the hospital service structure to improve efficiency: urban hospital specialization. *Health Policy*. (2008) 87:41–9. doi: 10.1016/j.healthpol.2007.10.003

30. Yang CC. Measuring health indicators and allocating health resources: a DEA-based approach. *Health Care Manag Sci*. (2017) 20:365–78. doi: 10.1007/s10729-016-9358-2

31. Li Q, Wei J, Jiang F, Zhou G, Jiang R, Chen M, et al. Equity and efficiency of health care resource allocation in Jiangsu Province. *China Int J Equity Health*. (2020) 19:211. doi: 10.1186/s12939-020-01320-2

32. Yi M, Peng J, Zhang L, Zhang Y. Is the allocation of medical and health resources effective? Characteristic facts from regional heterogeneity in China. *Int J Equity Health*. (2020) 19:89. doi: 10.1186/s12939-020-01201-8

33. Dong E, Liu S, Chen M, Wang H, Chen LW, Xu T, et al. Differences in regional distribution and inequality in health-resource allocation at hospital and primary health Centre levels: a longitudinal study in Shanghai. *China BMJ Open*. (2020) 10:e035635. doi: 10.1136/bmjopen-2019-035635

34. Zhikun C, Yan Z. Fiscal decentralization and efficiency of medical and health expenditure: as the example of Jiangsu Province. *Finance Trade Res*. (2018) 29:76–84. doi: 10.19337/j.cnki.34-1093/f.2018.09.007

35. Su W, Du L, Fan Y, Wang P. Equity and efficiency of public hospitals' health resource allocation in Guangdong Province, China. *Int J Equity Health*. (2022) 21:138. doi: 10.1186/s12939-022-01741-1

36. Yixin B, Hang Z, Mingying G, Hao W, Chuan P. Study on the current situation and equity of health resource allocation in Chengdu-Chongqing economic circle. *Chin Hospitals*. (2023) 27:14–7. doi: 10.19660/j.issn.1671-0592.2023.04.04

37. Huang M, Luo D, Wang Z, Cao Y, Wang H, Bi F, et al. Equity and efficiency of maternal and child health resources allocation in Hunan Province. *China BMC Health Serv Res*. (2020) 20:300. doi: 10.1186/s12913-020-05185-7

38. Yixin B, Mingying G, Chuan P. Distribution characteristics and prediction of health resources in Chengdu-Chongqing economic circle. *Chin Rural Health Serv Admin*. (2023) 43:650–6. doi: 10.19955/j.cnki.1005-5916.2023.09.008

39. Xu R, Mu T, Liu Y, Ye Y, Xu C. Trends in the disparities and equity of the distribution of traditional Chinese medicine health resources in China from 2010 to 2020. *PLoS One*. (2022) 17:e0275712. doi: 10.1371/journal.pone.0275712

40. Yaqing L, Haoran N, Xiangyang T, Meicheng Z, Feng J, Yutong Q, et al. Research on equity of medical resource allocation in Yangtze River Economic Belt under healthy China strategy. *Front Public Health*. (2023) 11:1175276. doi: 10.3389/fpubh.2023.1175276

41. Zhaofei Z, Lei H, Qi C, Bo G, Shujuan Y, Xu L, et al. Comprehensive evaluation on the level of primary medical and health services, Sichuan. *Modern Preventive Medicine*. (2021) 17:3161.

42. Gui J, Xiangzheng D, Xiaodong Z, Baishu G, Jun Y. Spatiotemporal patterns in urbanization efficiency within the Yangtze River Economic Belt between 2005 and 2014. *J Geogr Sci*. (2018) 28:1113–26. doi: 10.1007/s11442-018-1545-2

43. De P, Dhar A, Bhattacharya BN. Efficiency of health care system in India: an inter-state analysis using DEA approach. *Soc Work Public Health*. (2012) 27:482–506. doi: 10.1080/19371918.2012.672261

44. Zheng Y, Xiang Z. Studying on the efficiency measurement of medical resources in the Yellow River Economic Belt under the 14th five-year plan based on DEA and SFA. *Chin Health Serv Manag*. (2022) 39:81–4.

45. Zhao N, Chen K. Equity and efficiency of medical and health service system in China. *BMC Health Serv Res*. (2023) 23:33. doi: 10.1186/s12913-023-09025-2

46. Seddighi H, Nejad FN, Basakha M. Health systems efficiency in eastern Mediterranean districts: a data envelopment analysis. *Cost Eff Resour Alloc*. (2020) 18:22. doi: 10.1186/s12962-020-00217-9

47. Dexian B, Hongyan L. Efficiency of health resource allocation in the Yangtze River Delta: a data envelopment analysis.Chinese medical. *Manag Sci*. (2023) 13:32–9.

48. Xue Y, Chengjue W, Yu T, Nan Z. Spillover effects of online paid medical treatment services on improving offline medical treatment services. *Manag Sci*. (2023) 3:66–80. doi: 10.3969/j.issn.1672-0334.2023.03.005

49. Goh JM, Gao GG, Agarwal R. The creation of social value: can an online health community reduce rural-urban health disparities? *MIS Q*. (2016) 40:247–63. doi: 10.25300/MISQ/2016/40.1.11

50. Shi J, Yuan R, Yan X, Wang M, Qiu J, Ji X, et al. Factors influencing the sharing of personal health data based on the integrated theory of privacy calculus and theory of planned behaviors framework: results of a cross-sectional study of Chinese patients in the Yangtze River Delta. *J Med Internet Res*. (2023) 25:e46562. doi: 10.2196/46562

51. Zhang X, Zhao L, Cui Z, Wang Y. Study on equity and efficiency of health resources and services based on key indicators in China. *PLoS One*. (2015) 10:e0144809. doi: 10.1371/journal.pone.0144809

frontiers | Frontiers in Public Health

TYPE Original Research
PUBLISHED 24 September 2024
DOI 10.3389/fpubh.2024.1425716

Check for updates

OPEN ACCESS

EDITED BY
Xiaozhen Lai,
Peking University, China

REVIEWED BY
Naib Alakbarov,
University Usak, Türkiye
Alexandre Morais Nunes,
University of Lisbon, Portugal

*CORRESPONDENCE
Rui-xue Zhang
✉ ww8796@126.com

RECEIVED 30 April 2024
ACCEPTED 27 August 2024
PUBLISHED 24 September 2024

CITATION
Li H-y and Zhang R-x (2024) Analysis of the structure and trend prediction of China's total health expenditure.
Front. Public Health 12:1425716.
doi: 10.3389/fpubh.2024.1425716

Analysis of the structure and trend prediction of China's total health expenditure

Hong-yan Li and Rui-xue Zhang*

School of Management, Shanghai University of Engineering Science, Shanghai, China

Background: In the context of rapid economic and social development, there has been a continuous intensification of population aging, transformation of disease patterns, and wide application of new medical technologies. As a result, health expenditures in various countries have sharply soared. How to utilize limited medical resources to maximize the improvement of health levels has become a hot and challenging issue related to the well-being of all humanity. The relevant indicators of total health expenditure play a crucial role in monitoring and evaluating the fairness of health financing and health security in the region.

Objective: This study explores the changes in the main expenses that constitute China's total health expenditure and uses indicators related to health expenditure to observe the changes and future development trends of China's health expenditure. Based on this, the utilization of China's health expenditure is monitored to identify possible problems, and thereby targeted suggestions for promoting the development of China's health and wellness cause are put forward.

Methods: Based on the comparison of previous literature, this paper analyzes the changes and future development trends in China's health expenditure by using the relevant indicators of China's health expenditure through the structural variation analysis method and the gray prediction model.

Results: The results show that the scale of government, social, and out-of-pocket health expenditures has continuously expanded, with social health expenditures becoming the main funding source for total health expenditures. The burden of medical expenditures on individuals has been further reduced. In the institutional method of total health expenditures, hospital expenditures account for about 60% of the total and are the main component. The expenditures of health administration and medical insurance management institutions are the main driving force behind the growth of total health expenditures. However, the proportion of health expenditures in China's GDP is relatively low, so more investment is needed in the healthcare sector, and the burden of individual medical expenses also needs to be continuously reduced.

Discussion: In the future, China should further increase its investment in the medical and health sector. Specifically, the government should persist in investing in fundamental medical and health services. Simultaneously, efforts should be made to establish a scientific cost control mechanism for pharmaceuticals and broaden financing channels for healthcare, such as accelerating the development of commercial health insurance.

KEYWORDS

total health expenditure, trend prediction, China, structural variation, gray prediction model, residents' medical burdens

1 Introduction

In China, the total health expenditure pertains to the value of economic resources expended by the entire society for the provision of medical and health services within a specific period (typically 1 year) in a country or region. It represents a significant indicator for gauging the financing level of health care and its utilization degree (1). It mirrors the degree of attention accorded by the government, society, and individual residents toward health under certain economic and social circumstances, the level of medical and healthcare costs borne, and the fairness and rationality of health financing. Therefore, this study aims to track the processes of fundraising, allocation, and usage of funds in the health system. It provides important data support for evaluating the sufficiency and sustainability of health fundraising, as well as the efficiency of fund usage. Additionally, it aims to measure the economic burden of medical treatment for the population. It is of great significance for optimizing the allocation of medical and health resources, ensuring the affordability of medical treatment for the masses, enhancing the fairness and accessibility of health services, and promoting the achievement of universal health. In recent years, China has initiated several relevant plans regarding health expenses. The "Healthy China 2030" Outline explicitly stipulates that by 2030, the proportion of out-of-pocket health expenditure in the total health expenditure will decline to approximately 25% (2). The "14th Five-Year Plan for National Medical Security" outlines the development goals of achieving a fairer and more inclusive basic medical security system, ensuring a more balanced burden-sharing among all parties, establishing guaranteed scope and standards that are better aligned with the level of economic and social development, and providing more accessible public services (3). The World Health Organization has even proposed that the proportion of total health expenditure in Gross Domestic Product (GDP) should be no less than 5%, and the proportion of out-of-pocket health expenditure in total health expenditure should range from 15 to 20% (4).

Due to the increasing demands for residents' health, changes in population structure, and the rise in drug expenses, China's total health expenditure has been continuously increasing. In 2022, China's total health expenditure reached 8,532.749 billion yuan (equivalent to 1,268.603 billion US dollars at the current exchange rate), accounting for 7.05% of GDP. The *per capita* total health expenditure in China was 6,044.09 yuan (or 898.60 US dollars) (5). Among China's total health expenditure, the proportion of individual health expenditure in the total health expenditure decreased to 26.89%, and the proportion of social health expenditure in the total health expenditure continued to ascend. Simultaneously, the government's financing role for health has continuously strengthened. Despite the increase in total government health expenditures, the expenditure structure remains inadequately rational, and there has been no fundamental reversal of the situation where public medical and health resources are skewed toward treatment (6). In 2022, the proportion of health expenditure in the US GDP amounted to 16.63%. The proportion of health expenditure in the GDP of major OECD countries such as Japan, Germany, and the United Kingdom has exceeded 10% in the past few years (7). The medical and health expenditures in these countries are mainly derived from the government and society, accounting for approximately 90%, while out-of-pocket expenditures merely make up about 10%. In contrast to developed economies, the proportion of government health expenditures in China is excessively low and the proportion of out-of-pocket expenditures is relatively high, leaving the burden of residents' medical expenses rather heavy.

Health expenditure has consistently been a topic of global preoccupation. In recent years, scholars across the world have predominantly centered their research on total health expenditure in terms of accounting outcomes, trend projections, and the analysis of influencing factors. In the majority of developed countries, health care expenditure has witnessed a sharp increase. Among them, the *per capita* expenditure on healthcare in the United States is twice that of any other developed country worldwide (8). Among the member states of the European Union, health expenditure is also one of the items with the fastest growth rate, and GDP and out-of-pocket health expenditure have been identified as the critical drivers of public health expenditure (9). However, as states in the United States are more homogeneous in terms of medical technology, consumer preferences, health policies, and the structure and general characteristics of the healthcare system, the convergence of healthcare costs among states in the United States might be quicker than among the European Union or OECD countries (8). Public health and health expenditures are significant for both developed and developing countries, but they are even more vital for the latter (10). For instance, Africa aspires to enhance health outcomes on the continent by increasing public health expenditure (11). Indian scholars contend that the ratio of public health expenditure to the country's gross domestic product is a positively substantial predictor of healthcare infrastructure and human resources in rural areas of India (12). Health expenditures can result in the improved provision of healthcare opportunities, thereby reinforcing human capital, augmenting productivity, and boosting economic performance (10). In an economic environment featuring high levels of household consumption, employee wages, and physical capital investment, public health expenditure will considerably contribute to economic growth (13). Other scholars' research has discovered that in the control of COVID-19, higher public health expenditure can shorten the time to reach the peak level of infection in the local area (14). Nevertheless, except the United States, all economies under examination have insufficient expenditures on healthcare. The insufficiency of expenditures is particularly acute in China, India, and the Russian Federation (15). So health expenditure is associated with the investment in medical care, the allocation of funds for health expenditure, and the equity of people's health. There is a positive correlation between health expenditure and healthcare outcomes, but it is projected that in the upcoming years, health expenditure will further pose a challenge to financial sustainability (16).

Some studies show that the OECD's System of Health Accounts (SHA) is commonly used as a basis for determining the measurement scope internationally (17). According to the International Classification for Health Accounts (ICHA) of the Statistical Abstract of the United States (SHA), total health expenditures can be divided into three categories: general government expenditure on health (GGHE), private expenditure on health (PHE), and the rest of the world, where the latter mainly refers to foreign aid expenditures, which usually come from international organizations, and the World Health Organization (WHO) generally includes it in the general government expenditure category (18). There are two ways to calculate the total health expenditures in China. One is the institutional approach, which defines total health expenditures as the sum of expenditures from public health institutions, health administration and pharmaceutical insurance management institutions, outpatient clinics, hospitals, pharmacies, and other sectors (19). The other is the source approach, which consists of government health expenditures, social health expenditures, and out-of-pocket health expenditures (20). According to the OECD classification of total health expenditures and the classification of total health expenditures in China, China's total health expenditures can be classified as shown in Figure 1.

2 Materials and methods

2.1 Source of information

The data are sourced from *China Statistical Yearbook*, *Research Report on China's Total Health Expenditure in 2020*, and *Statistical Bulletin on the Development of China's Health and Wellness Undertakings in 2022*, and data such as China's total health expenditure, government health expenditure, social health expenditure, out-of-pocket health expenditure, GDP, and health expenditure flowing to institutions like hospitals are extracted. Based on these data, structural variation analysis and trend prediction are carried out. Extract the specific composition data of diverse health expenses from the *Research Report on China's Health Expenditure in 2020* as well as the personal health expenditure and drug expenses of certain developed countries, providing a reference basis for comparing with China's health expenses and conducting in-depth analyses of the reasons for the structural variations of China's health expenses.

The *China Statistical Yearbook* is an informative annual publication compiled and printed by the National Bureau of Statistics of China, comprehensively reflecting the economic and social development situation of China. It mainly includes a large amount of statistical data on the economy and society of the whole country, provinces, autonomous regions, and municipalities directly under the Central Government in the previous year collected in a certain year's statistical yearbook, as well as the main statistical data of the country in important historical years and the past two decades. It is published by the National Bureau of Statistics every year and is China's most comprehensive and authoritative comprehensive statistical yearbook. This article mainly selects the data on health expenditures and GDP in the *China Statistical Yearbook* from 2012 to 2022. *Research Report on China's Total Health Expenditure in 2020* includes the main data of China's total health expenditure from 1990 to 2019, the accounting results of health expenditure for each province, and briefly lists some historical materials since 1978 and foreign total health expenditure data. The *Statistical Bulletin on the Development of China's Health and Wellness Undertakings in 2022* mainly describes the conditions of health resources and other aspects.

2.2 Methods

2.2.1 Structural variation analysis method

As a dynamic data processing method, the structural change analysis method was mostly applied in resident consumption research in the early stage. It is also commonly used in the analysis of medical income and expense structure. It can comprehensively reflect the internal composition changes of medical expense structure and the overall characteristics of medical expense changes. This paper employs the method of structural variation analysis to study the measurement indicators of the structure of China's total health expenditures, including the Value of Structure Variation (VSV), Degree of Structure Variation (DSV), Contribution rate of structural variation (CRSV), and driving force (21).

The Value of Structure Variation (VSV): $VSV = X_{i1} - X_{i0}$. During a certain period, subtract the composition ratio at the beginning of each project from that at the end. If VSV > 0, the proportion of a certain project's cost in the total cost increases, and this is a positive change; if VSV < 0, it is a negative change, and the situation is reversed.

Degree of Structure Variation (DSV): $DSV = |X_{i1} - X_{i0}|$. This value always fluctuates between 0 and 1, reflecting the comprehensive change in the composition ratio of each project within a certain period. The size of the value reflects the degree of structural change; the larger the value, the greater the degree of change.

Contribution rate of structural variation (CRSV): $CRSV = |X_{i1} - X_{i0}| / DSV \times 100\%$. This value reflects the degree of influence of the changes in the proportion of each project in the overall on the overall cost structure; the larger the value, the greater the degree of influence.

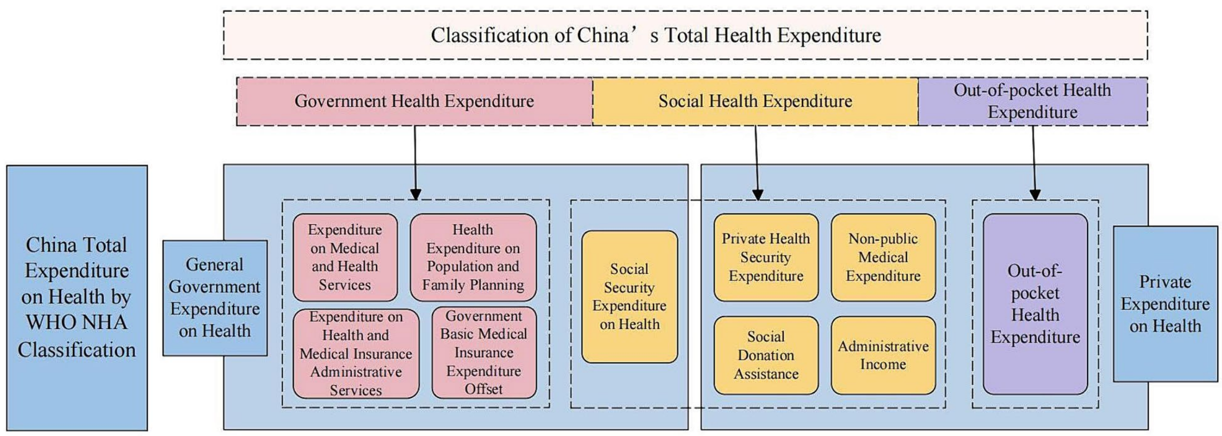


FIGURE 1
Classification of China's total health expenditures.

Driving force = *CRSV* × *Project Growth Rate* × 100%. This value is to analyze the driving force of each item on the overall cost growth in combination with the direction of structural changes. The larger the value, the greater the driving force.

Among them, *i* represents the serial number of the expense item, 0 represents the beginning, 1 represents the end, X_{i0} represents the composition ratio of a certain expense item to the total expense at the beginning, and X_{i1} represents the composition ratio of a certain expense item to the total expense at the end.

2.2.2 Gray prediction model

The gray prediction model is based on past and present known or uncertain information to construct a gray model (GM) and generate a hierarchical solution to obtain the generation function, thereby establishing a numerical sequence prediction for the target sequence (22). By forecasting the future trends of the system, it provides a basis for planning and decision-making. This forecasting method is designed for analyzing and modeling gray processes with limited information, sparse data, and concealed system laws. It has unique functions by generating and processing the original data sequence to weaken the randomness of the original data sequence and reveal the actual development laws of the system, thereby achieving the goal of forecasting.

This paper first analyzes the current situation and variations in China's total health expenditures, and then, based on the initial time series of China's total health expenditures from 2012 to 2022, it uses the gray system theory to establish a GM (1,1) model and conducts a test to predict and analyze the dynamic trend of China's total health expenditures. The modeling process is as follows:

The original value sequence of total health expenditure for the constructed series is shown in Equation 1.

$$X^{(0)} = \left\{X^{(0)}(1), X^{(0)}(2), \cdots\cdots, X^{(0)}(N)\right\} \tag{1}$$

The cumulative value of total health expenditures is shown in Equations 2 and 3.

$$X^{(1)} = \left\{X^{(1)}(1), X^{(1)}(2), \cdots\cdots, X^{(1)}(N)\right\} \tag{2}$$

$$X^{(1)}(N) = \left\{\begin{array}{l} X^{(0)}(1), N = 1) \\ X^{(1)}(N-1+X^{(0)}(N), N = 2,3,\cdots,N \end{array}\right\} \tag{3}$$

Formulate the cumulative predictive equation for total health expenditures (Equation 4).

$$\hat{X}^{(1)}(t) = \left(X^{(0)}(1) - \frac{u}{a}\right)e^{-a(t-1)} + \frac{u}{a} \tag{4}$$

In Equation 4, *a* and *u* are the unknown parameters to be determined, which can be obtained from the gray parameter matrix:

$$\hat{a} = \begin{bmatrix} a \\ u \end{bmatrix} = \left(B^T B\right)^{-1} B^T Y_n \tag{5}$$

In Equation 5, the sliding average matrix (*B*) and the data vector (*Yn*) are, respectively, defined in Equations 6 and 7. By substituting the obtained *a* and *u* into Equation 4, we get the equation expression of the cumulative predicted value of total health expenditure, and then by reducing it iteratively, we obtain the equation of the predicted value of total health expenditure for the "*t*" year, which is Equation 8.

$$\begin{bmatrix} -\frac{1}{2}\left(X^{(1)}(2) + X^{(1)}(2)\right) \\ -\frac{1}{2}\left(X^{(1)}(2) + X^{(1)}(3)\right) \\ \vdots \\ -\frac{1}{2}\left(X^{(1)}(N-1) + X^{(1)}(N)\right) \end{bmatrix} \tag{6}$$

$$Y_n = \begin{bmatrix} X^{(0)}(2) \\ X^{(0)}(3) \\ \vdots \\ X^{(0)}(N) \end{bmatrix} \tag{7}$$

$$\hat{X}^{(0)}(t) = \left\{\begin{array}{l} \hat{X}^{(0)}(t), t = 1 \\ \hat{X}^{(1)}(t) - \hat{X}^{(1)}(t-1), t \geq 2 \end{array}\right\} \tag{8}$$

Check the residuals and the relative error is given by Equation 9.

$$\Delta(\varepsilon) = \left|\frac{X^{(0)}(t) - \hat{X}^{(0)}(t)}{X^{(0)}(t)}\right| \tag{9}$$

Average relative error $\bar{\Delta}(\varepsilon) = \frac{1}{n}\sum_{t=1}^{n}\Delta(\varepsilon)$. When the average relative error is less than or equal to 0.2, the model passes the residual test. The model is diagnosed using the posterior difference test (23). Calculate the mean square errors of $X^{(0)}$ and $\varepsilon^{(0)}(t)$ separately, denoted as S_1 and S_2, respectively. The posterior ratio $C = S_1/S_2$ is then calculated. The small error probability $p < 0.6745S_1$ is also calculated.

This research examines China's aggregate health expenditure structure, its trajectory, and forthcoming patterns through structural variation analysis and a gray prediction model. Currently, the application of structural variation analysis in China's health expenditures primarily focuses on examining the composition of outpatient and inpatient expenses (24–26) and analyzing the distribution of health expenditures across different provinces and cities (27–29). Research on China's health expenditures is limited to accounting-based analysis, without delving into a deeper understanding through structural variation analysis. The gray prediction model has found widespread utility for projecting health expenditure and anticipating future trends related to medical insurance funds within China.

3 Results

3.1 The composition of total health expenditure

3.1.1 China total expenditure on health by source

The total health expenditure in China has generally demonstrated an upward tendency. Among the total health expenditure, the proportion of social health expenditure is the largest, while that of individual health expenditure has further decreased (Table 1). The total health expenditure has increased by 203% from 2012 to reach 85327.49 billion yuan, while the government health expenditure has increased by 15608.91 billion yuan, an increase of 185%. The social health expenditure has increased the most, rising to 38345.67 billion yuan. Out-of-pocket health expenditure has also increased, but the increase is the smallest, at 138%. The total health expenditure in China has shown an upward trend from 2012 to 2022, with the proportion of government health expenditure in total health expenditures declining from 29.99 to 28.17%. Although government health expenditure has shown a continuous growth trend, its proportion in total health expenditures has fluctuated within a small range. The proportion of social health expenditure in total health expenditures has shown an increasing trend, while the proportion of out-of-pocket health expenditure in total health expenditures has declined from 31.34 to 26.89%, reaching and falling below the 27% requirement mentioned in the "14th Five-Year Plan for National pharmaceutical Insurance."

Over the past decade, China's total health expenditures have been fluctuating, with "increase and decrease" reflecting the warm process of meeting people's needs and showcasing the solid steps toward building a healthy China. In the past decade, China's total health expenditure as a percentage of GDP has increased from 5.22 to 7.05%, exceeding the WHO's recommendation for medium-low income countries in 2010 (5–7%) and continuing to move toward a target of more than 7%.

3.1.2 China total expenditure on health by provider

The total health expenditure in China is primarily allocated to hospitals, with a slight shortage of funding for primary care facilities (Table 2). In 2022, the total health expenditure (institutional method) in China directed 48,548.93 billion yuan toward hospital expenditures, accounting for 61.41% of the total expenditure. This figure was 0.74 percentage points lower than that in 2012, indicating overall fluctuations in funding allocation over the years. The expenditure directed toward public health institutions amounted to 502.568 billion yuan, accounting for 6.36% of the total expenditure. This percentage showed a consistent decrease from 2012 to 2019, followed by a slight increase to 6.56% in 2020 before declining once again. The proportion of expenditures in outpatient institutions is expected to remain stable within the range of 6–8%. The proportion of pharmacy retail expenditures has exhibited a slight downward trend, currently standing at 9.01%, while the proportion of expenditures in other institutions continues to rise within the total health expenditures. The proportion of expenditures flowing to hospitals has been relatively stable during the period from 2012 to 2022, with urban hospitals accounting for about 60% of the total expenditures and county hospitals about 20%. The expenditures of other primary health institutions account for a relatively small proportion (Figure 2).

3.1.3 China pharmaceuticals expenditure

Outpatient and retail pharmaceutical expenditures account for an increasing share of total health expenditures, while the share of hospital pharmaceutical expenditures has a downward trend. In 2022, the total expenditure on pharmaceuticals in China decreased by 13.46 percentage points to 21,275.81 billion yuan, accounting for 26.91% of the total health expenditure (institutional method). Of which, the retail pharmaceutical expenditure was 7,123.98 billion yuan, accounting for one-third of the total pharmaceutical expenditure. In 2020, retail pharmaceutical expenditures accounted for the largest share, but in 2021, they fell back to 30.91%, with the overall trend being an upward one for the proportion of retail pharmaceutical expenditures in total pharmaceutical expenditures.

TABLE 1 Composition of total health expenditures in China from 2012 to 2022.

Year	Total health expenditure (billion yuan)	Government health expenditure		Social health expenditure		Out-of-pocket expenditure		Total health expenditure as share of GDP (%)
		Expenditure (billion yuan)	Share (%)	Expenditure (billion yuan)	Share (%)	Expenditure (billion yuan)	Share (%)	
2012	28119.00	8431.98	29.99	10030.70	35.67	9656.32	31.34	5.22
2013	31668.95	9545.81	30.14	11393.79	35.98	10729.34	33.88	5.34
2014	35312.40	10579.23	29.96	13437.75	38.05	11295.41	31.99	5.49
2015	40974.64	12475.28	30.45	16506.71	40.29	11992.65	29.27	5.95
2016	46344.88	13910.31	30.01	19096.68	41.21	13337.90	28.78	6.21
2017	52598.28	15205.87	28.91	22258.81	42.32	15133.60	28.77	6.32
2018	59121.91	16399.13	27.74	25810.78	43.66	16911.99	28.61	6.43
2019	65841.39	18016.95	27.36	29150.57	44.27	18673.87	28.36	6.67
2020	72175.00	21941.90	30.40	30273.67	41.94	19959.43	27.65	7.10
2021	76844.99	20676.06	26.91	34963.26	45.50	21205.67	27.60	6.72
2022	85327.49	24040.89	28.17	38345.67	44.94	22940.94	26.89	7.05

The data in the table is derived from the China Statistical Yearbook from 2012 to 2022 and the Research Report on China's Total Health Expenditure in 2020.

TABLE 2 Institutional distribution of total health expenditures in China, 2012–2022 (%).

Year	Hospitals	Outpatient clinics	Pharmaceutical retail institutions	Public health facilities	Health administration and medical insurance management authorities	Others
2012	62.15	8.00	12.28	7.49	2.27	7.82
2013	62.33	7.43	12.45	7.38	2.29	8.12
2014	61.52	6.84	12.38	7.02	3.63	8.61
2015	61.73	6.74	12.47	6.56	3.34	9.15
2016	61.90	6.45	12.54	6.05	3.48	9.57
2017	62.59	6.64	11.73	5.85	3.20	9.98
2018	62.91	6.76	11.60	5.58	3.21	9.93
2019	63.55	6.91	11.67	5.47	3.34	9.05
2020	60.13	6.69	11.73	6.56	5.35	9.55
2021	63.67	6.92	8.86	6.40	4.49	9.65
2022	61.41	6.99	9.01	6.36	5.94	10.29

Source: The data in the table is derived from the Research Report on China's Total Health Expenditure in 2020 and the Statistical Bulletin on the Development of China's Health and Wellness Undertakings in 2022.

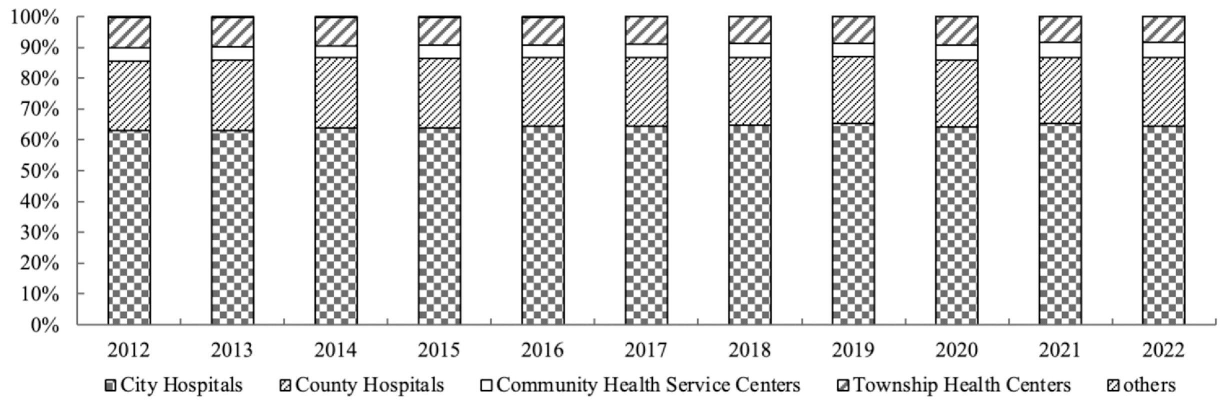


FIGURE 2
The share of expenditures for each institution in hospital organizations (2012–2022).

In 2022, the expenditures for outpatient pharmaceuticals and hospital pharmaceuticals were 8303.04 billion yuan and 5,848.79 billion yuan, respectively, accounting for 39.03 and 27.49% of the total pharmaceutical expenditures. Outpatient pharmaceutical expenditures have been increasing steadily, with the proportion of total pharmaceutical expenditures declining in 2013 and then rising again in subsequent years (Table 3). In contrast, inpatient pharmaceutical expenditures have fluctuated up and down, and the proportion of total pharmaceutical expenditures has been declining steadily, dropping by 7.68 percentage points compared to 2012.

3.2 Analysis of variation in the structure of China's total health expenditure

3.2.1 Analysis of structural variations of China's total health expenditure by source

The total health expenditure in China has been increasing steadily, with individuals' medical burdens further reduced. The variation in the structure of health expenditure sources in China (Table 4) indicates that, on the whole, government health expenditures and out-of-pocket expenditures have experienced negative variations, while social health expenditures have experienced positive variations. The overall structural variation in health expenditures is 15.54%. The structural variation in social health expenditures has the highest contribution rate, at 59.65%. On the other hand, out-of-pocket expenditures exhibit the smallest value of structural variation, while government health expenditures show the lowest contribution rate of structural variation. This indicates that out-of-pocket expenditures are decreasing, medical burdens are being alleviated to some extent, and the proportion of government health expenditures is showing a downward trend.

From the value of structure variation, government health expenditures had positive variations in 2012–2013, 2014–2015, 2019–2020, and 2021–2022, while the overall structural variation value was negative. Social health expenditures had a negative structural variation value in 2019–2020 and 2021–2022, while

TABLE 3 The composition of total pharmaceutical expenditure in China from 2012 to 2022.

Year	Pharmaceutical expenditure (billion yuan)	Outpatient pharmaceutical expenditure		Hospital pharmaceutical expenditure		Retail pharmaceutical expenditure		Pharmaceutical expenditure as share of THE (%)
		Expenditure (billion yuan)	Share (%)	Expenditure (billion yuan)	Share (%)	Expenditure (billion yuan)	Share (%)	
2012	11860.45	4082.74	34.42	4171.31	35.17	3606.40	30.41	40.37
2013	13307.70	4102.65	30.83	5043.48	37.90	4161.57	31.27	39.80
2014	13925.00	4203.43	30.19	5086.89	36.53	4634.67	33.28	37.20
2015	16166.34	5065.84	31.34	5674.11	35.10	5426.39	33.57	37.16
2016	17602.44	5471.30	31.08	6053.59	34.39	6077.55	34.53	36.32
2017	18203.00	5959.95	32.74	6037.84	33.17	6205.21	34.09	34.42
2018	19148.98	6286.22	32.83	6074.27	31.72	6788.50	35.45	32.37
2019	21116.82	7227.06	34.22	6490.30	30.74	7399.46	35.04	33.31
2020	20699.90	7093.89	34.27	5769.35	27.87	7836.66	37.86	30.98
2021	20395.63	7848.64	38.48	6242.58	30.61	6304.41	30.91	28.67
2022	21275.81	8303.04	39.03	5848.79	27.49	7123.98	33.48	26.91

Source: The data in the table is derived from the Research Report on China's Total Health Expenditure in 2020 and the Statistical Bulletin on the Development of China's Health and Wellness Undertakings in 2022.

TABLE 4 Variations in the funding structure of total health expenditures in China (%).

Year	Government health expenditure		Social health expenditure		Out-of-pocket expenditure		DSV
	VSV	CRSV	VSV	CRSV	VSV	CRSV	
2012–2013	0.15	5.00	0.31	10.33	2.54	84.67	3.00
2013–2014	−0.18	4.35	2.07	50.00	−1.89	45.65	4.14
2014–2015	0.49	8.99	2.24	41.10	−2.72	49.91	5.45
2015–2016	−0.44	23.78	0.92	49.73	−0.49	26.49	1.85
2016–2017	−1.10	49.55	1.11	50.00	−0.01	0.45	2.22
2017–2018	−1.17	43.82	1.34	50.19	−0.16	5.99	2.67
2018–2019	−0.38	30.65	0.61	49.19	−0.25	20.16	1.24
2019–2020	3.04	50.00	−2.33	38.32	−0.71	11.68	6.08
2020–2021	−3.49	49.15	3.56	50.14	−0.05	0.70	7.10
2021–2022	1.26	49.80	−0.56	22.13	−0.71	28.06	2.53
2012–2022	−1.82	11.71	9.27	59.65	−4.45	28.64	15.54

they had a positive structural variation value in the other years. Out-of-pocket expenditures have shown a negative trend overall. From the perspective of the contribution rate of structural variations, it was observed that in 2012–2013, out-of-pocket expenditures made the largest contribution to structural variations, followed by social health expenditures. Government health expenditures were found to have the smallest contribution rate. The contribution rate of the structural change in social health expenditures has fluctuated, experiencing a decrease in 2014–2015. However, overall, there has been a gradual increasing trend compared to 10 years ago. This increase is on par with, or even slightly higher than, government health expenditures. In contrast, the contribution rate of out-of-pocket expenditures has steadily decreased over time.

3.2.2 Analysis of structural variations in China's total health expenditure by provider

The allocation of health expenditures is uneven, and there is still room for improvement in the expenditures of primary healthcare institutions. Overall, the structural variations in the allocation of healthcare expenditures in China indicate that the largest values of structural variation and contribution rates were observed in health administrative and insurance management institutions, at 3.67 and 29.86%, respectively, during the period from 2012 to 2022 (Table 5). The structural variation value of pharmaceutical retail institutions was the smallest, while the contribution rate of hospitals was the smallest. The degree structure variation of the allocation of healthcare expenditures in China was 12.29%, with the largest overall changes occurring in 2020–2021 and the smallest changes occurring in 2017–2018.

TABLE 5 Variations in the institutional flow structure of China's total health expenditures.

Year	Hospitals		Outpatient clinics		Pharmaceutical retail institutions		Public health facilities		Health administration and medical insurance management authorities		Others		DSV
	VSV	CRSV	VSV	CRSV	VSV	CRSV	VSV	CRSV	VSV	CRSV	VSV	CRSV	
2012–2013	0.18	13.33	−0.57	42.22	0.17	12.59	−0.11	8.15	0.02	1.48	0.30	22.22	1.35
2013–2014	−0.81	22.13	−0.59	16.12	−0.07	1.91	−0.36	9.84	1.34	36.61	0.49	13.39	3.66
2014–2015	0.21	12.43	−0.10	5.92	0.09	5.33	−0.46	27.22	−0.29	17.16	0.54	31.95	1.69
2015–2016	0.17	10.63	−0.29	18.13	0.07	4.37	−0.51	31.88	0.14	8.75	0.42	26.25	1.6
2016–2017	0.69	26.74	0.19	7.36	−0.81	31.40	−0.20	7.75	−0.28	10.85	0.41	15.89	2.58
2017–2018	0.32	35.56	0.12	13.33	−0.13	14.44	−0.27	30.00	0.01	1.11	−0.05	5.56	0.9
2018–2019	0.64	32.32	0.15	7.58	0.07	3.54	−0.11	5.56	0.13	6.57	−0.88	44.44	1.98
2019–2020	−3.42	46.85	−0.22	3.01	0.06	0.82	1.09	14.93	2.01	27.53	0.50	6.85	7.3
2020–2021	−2.02	11.58	−1.31	7.51	−0.55	3.15	−0.93	5.33	3.08	17.66	−9.55	54.76	7.76
2021–2022	−2.26	49.02	0.07	1.52	0.15	3.25	−0.04	0.87	1.45	31.45	0.64	13.88	4.61
2012–2022	−0.74	6.02	−1.01	8.22	−3.27	26.61	−1.13	9.19	3.67	29.86	2.47	20.10	12.29

Regarding the value of structural variation, it was observed that public health institutions generally exhibited negative values, except a positive trend from 2019 to 2020. These institutions showed minimal fluctuations in expenditures. In contrast, health administration and medical insurance management institutions demonstrated predominantly positive structural variation values, accompanied by substantial expenditure variations. The proportion of expenditures allocated to hospitals showed a positive trend from 2012–2013 to 2014–2019, but exhibited a negative trend from 2019 to 2022, resulting in an overall small structural variation in the negative direction. On the other hand, the proportion of expenditures directed toward outpatient institutions displayed a negative structural variation value from 2012–2016 and 2019–2021, while showing positive trends in other years. However, the overall structural variation value remained negative. From the contribution rate of structural variations, the contribution rates of various expenditures to structural variations have fluctuated in 2012–2015, and in 2017–2022, the impact of hospitals and other institutions on the overall structural variations has been the largest. Additionally, by referring to Figure 2 and Table 3, we can see that the allocation of health funding in China is primarily concentrated in urban large hospitals, while there is a slight lack of resources allocated to grassroots healthcare institutions.

3.2.3 Analysis of structural variations in China's total health expenditure by provider

The fluctuation in hospital pharmaceutical expenditures has a significant impact on total health expenditures. On the whole, the structural variation values of pharmaceutical expenditures in China (Table 6) indicate that the structural variation value of outpatient pharmaceutical expenditures is the largest, at 4.61%, while the structural variation value of inpatient pharmaceutical expenditures is the smallest. However, the structural pharmaceutical contribution rate of inpatient pharmaceutical expenditures is the largest, while the structural variation contribution rate of retail pharmaceutical expenditures is the smallest. The structural variation degree of total pharmaceutical expenditures in China is 15.36%, and the overall variations in pharmaceutical expenditures for 2020–2021 are the largest, while the variations for 2015–2016 are the smallest.

From the perspective of structural variation values, the structural variation values of outpatient pharmaceutical expenditures and retail pharmaceutical expenditures are mostly positive, and the structural variation values in pharmaceutical total expenditures are larger. From the perspective of the contribution rate of structural variation, it is evident that there have been significant changes in the contribution rates of each expenditure during this period. Of particular note is the substantial impact of hospital pharmaceutical expenditures on the overall structure, while outpatient pharmaceutical expenditures have

TABLE 6 Variations in the structure of pharmaceutical expenditures in China (%).

Year	Outpatient pharmaceutical expenditure		Hospital pharmaceutical expenditure		Retail pharmaceutical expenditure		DSV
	VSV	CRSV	VSV	CRSV	VSV	CRSV	
2012–2013	−3.59	50.00	2.73	38.02	0.86	11.98	7.18
2013–2014	−0.64	15.92	−1.37	34.08	2.01	50.00	4.02
2014–2015	1.15	40.07	−1.43	49.83	0.29	10.10	2.87
2015–2016	−0.26	13.47	−0.71	36.79	0.96	49.74	1.93
2016–2017	1.66	50.00	−1.22	36.75	−0.44	13.25	3.32
2017–2018	0.09	3.10	−1.45	50.00	1.36	46.90	2.90
2018–2019	1.39	50.00	−0.98	35.25	−0.41	14.75	2.78
2019–2020	0.05	0.87	−2.87	50.00	2.82	49.13	5.74
2020–2021	4.21	30.29	2.74	19.71	−6.95	50.00	13.9
2021–2022	0.55	8.81	−3.12	50.00	2.57	41.19	6.24
2012–2022	4.61	30.01	−7.68	50.00	3.07	19.99	15.36

TABLE 7 The driving force for health expenditures from various expenditures from 2012 to 2022 (%).

Project	Growth rate	Contribution rate of structural variation	Driving force
Government health expenditure	11.05	11.73	129.57
Social health expenditure	14.35	59.83	858.60
Out-of-pocket expenditure	9.04	28.44	257.06
Hospitals	12.00	6.02	72.27
Outpatient clinics	7.78	8.22	63.91
Pharmaceutical retail institutions	12.36	26.61	328.88
Public health facilities	9.43	9.19	86.72
Health administration and medical insurance management authorities	17.04	29.86	508.76
Others	15.06	20.10	302.73
Outpatient pharmaceutical expenditure	7.36	30.01	220.79
Hospital pharmaceutical expenditure	3.44	50.00	171.89
Retail pharmaceutical expenditure	7.04	19.99	140.80

had the smallest impact on the overall structure of total pharmaceutical expenditures.

3.3 The driving force for health expenditures from various expenditures

3.3.1 The driving force of health expenditures by source

Social health expenditures have become the predominant component of total health expenditures, with government health expenditures demonstrating strong emergency response capabilities. Analysis of the driving forces behind health expenditure from various financing sources (Table 7) reveals that all factors contribute positively to the growth of total health expenditure. Among these factors, social health expenditure serves as the primary driving force, while government health expenditure plays a relatively smaller role. This indicates that social health expenditure has the greatest impact on the growth of total health expenditure, whereas government health expenditure makes the smallest contribution.

The contribution rate of government health expenditure structure variations has been growing steadily in recent years, with a particularly large increase after 2015, despite the continuous expansion of government health expenditures. The proportion of health expenditures has changed little and has shown a downward trend, mainly consisting of expenditures on healthcare services and health insurance subsidies, which together account for about 95%. The proportion of government expenditures on healthcare services has decreased from 52.01% in 2015 to 49.63% in 2019 and then increased to 58.22% in 2022. The proportion of government expenditures on health insurance subsidies has increased from 47.99% in 2015 to 50.37% in 2019 and then decreased to 41.78% in 2022. As a result, the government's expenditure structure has changed (30). This shows that the government health expenditures can adjust its allocation proportion promptly to actively respond to major public health events.

The contribution rate of social health expenditure to total health expenditure has been increasing steadily, and it has a powerful driving

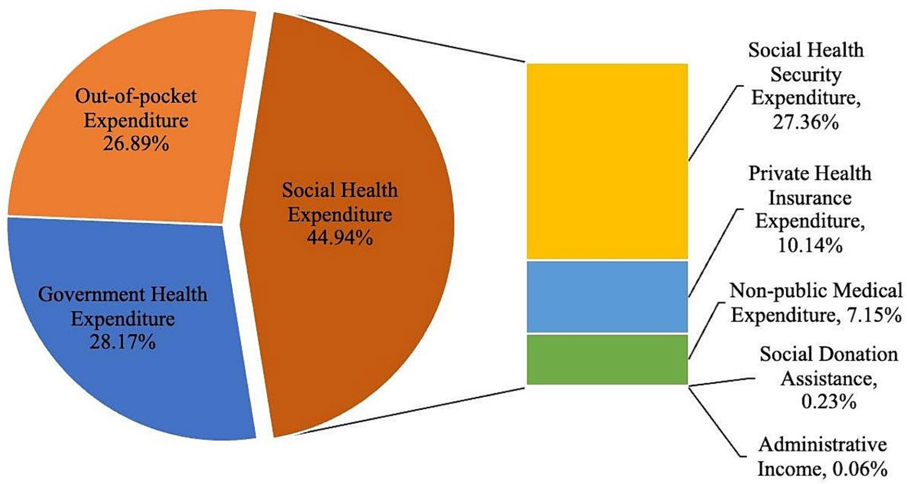


FIGURE 3
The composition of total health expenditures in China in 2020.

force for the growth of total health expenditure. Among social health expenditures, social security expenditures constitute half of the total health expenditures. Social security expenditures mainly denote the funds collected by various social medical insurance projects in the current year and do not incorporate government input (Figure 3). The funds collected are relatively large, so they also account for the largest share of social health expenditure. At the same time, due to the government's robust support for commercial health insurance and the public's growing awareness of healthcare, there has been a steady increase in premium income for commercial health insurance. This increase has contributed to social health expenditure and has enhanced the role of commercial health insurance in providing reimbursements, thereby increasing its share in total health expenditure. Meanwhile, social medical expenditure also plays a crucial role, making a significant contribution to the growth of total health expenditure. Direct investments from all sectors of society in various levels and types of healthcare institutions have driven the increase in social health expenditure. As a result, there has been a rising share of social health expenditure in total health expenditure.

3.3.2 The driving force of health expenditures by provider

The growth of total health expenditure in institutional law is mainly driven by the expenditures of health administration and medical insurance management agencies. The various expenditures in the institutional flow have certain driving effects on the growth of total health expenditures (Table 7). The health administrative and medical insurance management institutions can raise more funds for medical insurance and other funds, and their expenditures have a greater driving force compared to other departments' expenditures. At the same time, outpatient institutions primarily offer diagnosis and treatment services for outpatients and community family health care services. Due to their specific functions, the funds raised by these institutions are relatively less compared to other healthcare facilities. As a result, the expenditures of outpatient institutions have the smallest impact on driving force. Furthermore, the market scale of retail pharmaceutical institutions is continuously expanding and diversifying its development under the premise of standardized management, multi-channel circulation, and increasing chain rate year by year. As a result, their driving force for expenditures is substantial, enabling them to provide convenient pharmaceutical services for individuals or families in various regions. This can be explained by the fact that China's medical insurance cause is experiencing rapid development, with a focus on strengthening the synergy between the medical, insurance, and pharmaceutical sectors. This development aims to promote the reform of the health and medical system in response to the needs of the people, ensuring that their demand for health services is consistently met.

3.3.3 The driving force of pharmaceuticals expenditure

The outpatient department remains the mainstream for purchasing pharmaceuticals, and there is still considerable room for the development of retail pharmaceuticals. The pharmaceutical expenditures of various institutions have a strong driving effect on total health expenditures (Table 7). Among these factors, the driving effect of outpatient pharmaceutical expenditures is the most significant, while the impact of inpatient pharmaceutical expenditures on the structure of pharmaceutical expenditures is also substantial. On the other hand, retail pharmaceutical expenditures have the smallest driving effect. Although inpatient pharmaceutical expenditures have the largest impact on the structure of pharmaceutical expenditures, their driving effect is not as significant as that of outpatient pharmaceutical expenditures. This shows that outpatient pharmaceutical expenditures play an important role in the growth of total pharmaceutical expenditures, while the contribution of retail pharmaceutical expenditures to the growth of total pharmaceutical expenditures is small. Some scholars have found that the annual growth rate of pharmaceutical expenditures in China is 4.20%, far lower than the pharmaceutical expenditures growth rate during the "Thirteenth Five-Year Plan" period (31). The proportion of pharmaceutical expenditures in total health expenditures has also declined significantly, indicating that the era of "relying on pharmaceuticals to support medical services" is coming to an end.

TABLE 8 Establishment and verification of GM (1,1) model.

Predictive indicators	GM (1,1) model	*C*	*P*	Result
Government health expenditure	$99982.37e^{0.0967(t-1)} - 91550.39$	0.1580	1	Excellent
Social health expenditure	$101479.15e^{0.1221(t-1)} - 91448.45$	0.1234	1	Excellent
Out-of-pocket expenditure	$113692.50e^{0.0886(t-1)} - 104036.18$	0.0927	1	Excellent
GDP	$7233636.83e^{0.0794(t-1)} - 6695057.83$	0.0824	1	Excellent

TABLE 9 Projections of health expenditures and financing structures.

Year	THE (billion yuan)	Government health expenditure		Social health expenditure		Out-of-pocket expenditure		GDP (billion yuan)	The Share of THE to GDP (%)
		Expenditure (billion yuan)	Share (%)	Expenditure (billion yuan)	Share (%)	Expenditure (billion yuan)	Share (%)		
2023	96939.02	26680.58	27.52	44689.89	46.10	25568.56	26.38	1323708.42	7.32
2024	107820.96	29388.53	27.26	50494.01	46.83	27938.43	25.91	1433157.49	7.52
2025	119951.20	32371.32	26.99	57051.93	47.56	30527.95	25.45	1551656.22	7.73
2026	133475.92	35656.86	26.71	64461.58	48.29	33357.48	24.99	1679952.85	7.95
2027	148558.69	39275.86	26.44	72833.55	49.03	36449.28	24.54	1818857.53	8.17
2028	165382.65	43262.17	26.16	82292.84	49.76	39827.65	24.08	1969247.35	8.40
2029	184152.87	47653.07	25.88	92980.65	50.49	43519.14	23.63	2132071.95	8.64
2030	205098.97	52489.63	25.59	105056.55	51.22	47552.79	23.19	2308359.49	8.89

However, pharmaceutical income is still the largest item of outpatient income for public hospitals, and efforts need to be continued to control pharmaceutical expenditures. Controlling pharmaceutical expenditures should still be one of the important tasks for adjusting outpatient expenditure structure. In particular, within the outpatient population, patients with chronic diseases who require long-term medication often do not receive treatments and laboratory tests beyond regular checkups. Therefore, reducing pharmaceutical expenditures remains a crucial approach to controlling patients' medical costs (32).

3.4 Projections for China's total health expenditures

3.4.1 Predict the overall expenditure on health in our nation

The total health expenditure and its share in GDP will continue to rise, with a gap remaining with developed countries. Using the four expenditures listed in Table 8 as predictor variables, after calculating the predicted values of the expenditures, this model passed the test, and the prediction results are scientific and reasonable. Finally, the ratios of government health expenditures, social health expenditures, and personal health expenditures to total health expenditures are calculated, and the ratio of total health expenditures to GDP is calculated through the model (Table 8). According to the results of the GM (1,1) model (Table 9), the government, social, and out-of-pocket health expenditures of all three sides have been continuously increasing, so the total health expenditures have been continuously increasing. It is expected that the total health expenditures in China will reach 205098.97 billion yuan by 2030. The proportion of out-of-pocket health expenditures to total health expenditures is expected to drop to 23.19%, achieving the goal set in the "Healthy China 2030" planning outline, which is 25%. Combining Table 5 shows that the proportion of government health expenditures and personal health expenditures is almost the same, and both are constantly decreasing, while the proportion of social health expenditures is gradually becoming the largest component of total health expenditures. In addition, it is expected that the proportion of total health expenditures to GDP will be 8.89% in 2030.

The proportion of out-of-pocket health expenditure in China has been steadily decreasing. However, there still exists a significant disparity when compared to the WHO's initiative, which aims to reduce out-of-pocket health expenditure to 15% of the total health expenditure. This reduction is intended to minimize and eliminate catastrophic health expenditure and poverty resulting from illness. Meanwhile, in contrast to some developed countries of the OECD, the proportion of personal health expenditure in China relative to total health expenditure remains comparatively high. The proportion of out-of-pocket health expenditure in the majority of developed countries has been beneath 20%, and the proportion of total health expenditure to GDP in numerous developed countries has presently exceeded 10% (Figure 4). Hence, it becomes evident that the attention and investment in health expenditure still require further enhancement.

3.4.2 Predict the pharmaceuticals expenditure on health in our nation

The share of pharmaceutical expenditure in total health expenditure has decreased, but further efforts are needed to effectively control expenditures. The proportion of out-of-pocket health expenditures in China has been declining since 2015, mainly due to the

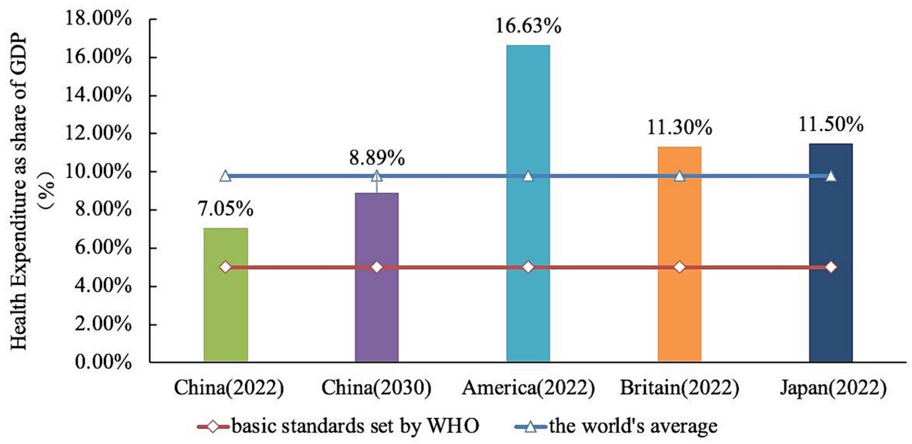


FIGURE 4
Comparison of healthcare expenditure as a percentage of GDP between some developed countries and China.

TABLE 10 Predicted share of pharmaceutical expenditures in total health expenditures.

Year	Pharmaceutical expenditure (billion yuan)	Total health expenditures (billion yuan)	The share of pharmaceutical expenditures in total health expenditures
2023	23528.40	92069.52	25.56
2024	24696.45	101328.73	24.37
2025	25922.50	111519.12	23.24
2026	27209.40	122734.33	22.17
2027	28560.20	135077.43	21.14
2028	29978.06	148661.85	20.17
2029	31466.30	163612.41	19.23
2030	33028.43	180066.53	18.34

deep reform of China's medical and health system, which abolished pharmaceutical margins and adjusted medical service prices (33). The reform has achieved significant results. In 2017, China comprehensively launched the reform of public hospitals, and all public medical institutions abolished pharmaceutical margins (34), which has achieved significant breakthroughs in the pharmaceutical and healthcare system reform. Through forecasting, it can be seen that the proportion of pharmaceutical expenditures in total health expenditures will drop to 19.34% by 2030, and the effect of reducing residents' medical expenditures through controlling pharmaceutical expenditures will be further manifested (Table 10). In addition, the "Guiding Opinion on Pilot Reform of Urban Public Hospitals" issued in 2015 proposed that the proportion of pharmaceuticals (excluding Chinese herbal pharmaceutical decoctions) in pilot city public hospitals should be reduced to around 30% in 2017 (35). However, the limited regulatory role of simply abolishing pharmaceutical margins in controlling medical expenditure, and the possibility of being offset by an increase in pharmaceutical, can only play a certain alleviating role. Controlling the pharmaceutical ratio at the same time will ensure sufficient price adjustment flexibility. In many developed countries, the proportion of healthcare costs spent on drugs has already fallen below 20% (Figure 5). This suggests that there is still significant potential for China to reduce its healthcare expenditures. Therefore, it is imperative to implement targeted measures aimed at cost control and alleviating patients' financial burdens to achieve further reductions in healthcare costs.

4 Conclusion

The continuous expansion of total health expenditure presents both a challenge and an opportunity for healthcare system reform in China. Firstly, as indicated by the above analysis, there is a rising trend in total health expenditure in China. Factors such as GDP and urbanization influence the growth of health expenditure in OECD countries, while improvements in health status, decline in mortality rate, and extended life expectancy have contributed to increased total health expenditure in Asian countries but reduced it in OECD countries (36). GDP, urbanization, and an aging population are also important factors contributing to the growth of health expenditures in China, a conclusion that has been confirmed by many scholars (37, 38). Furthermore, the out-of-pocket health expenditure among Chinese residents is on a decreasing trend. This can be attributed to the increasing contribution of social health expenditure to the total health expenditure. The shift toward social health expenditure as the primary contributor is a result of continuous improvements and advancements in China's medical insurance system. These efforts are aimed at reducing the financial burden of medical expenses on residents. Despite increasing government health expenditure, greater fiscal input into the healthcare sector is still required in China, particularly for rural and grassroots healthcare.

Secondly, hospital expenses account for the majority of total health expenditures in China. Large urban hospitals have ample funds to equip themselves, possibly due to fiscal input, leading to the

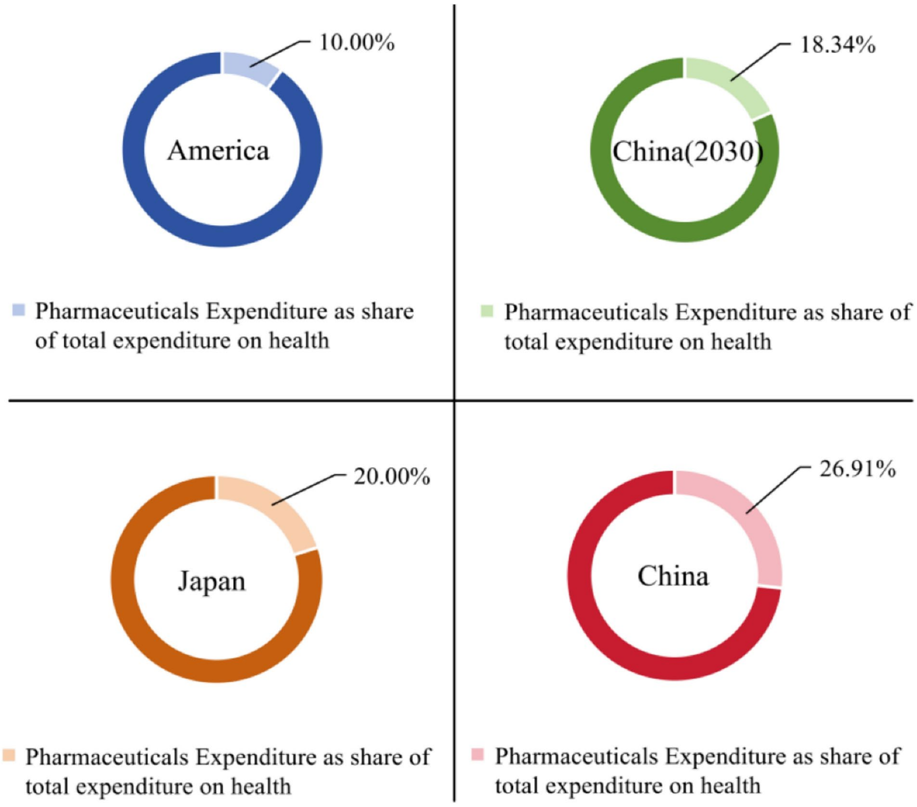


FIGURE 5
Comparison of the proportion of pharmaceutical expenditures in healthcare expenditures between China and selected developed countries.

expansion of hospital scale. This results in increased medical expenses through higher numbers of hospitalizations and an increase in the average payment willingness of patients. And the subsidy from medical insurance will also raise medical expenses (39). Consequently, the funds allocated to the primary medical and health institutions are relatively less, and their expense growth rate is lower, and the proportion also shows a downward trend. If there are phenomena of excessive medical treatment in medical institutions, it will further lead to the unreasonable growth of medical expenses. Analysis of total health expenditure reveals that changes in expenses related to health administrative and medical insurance management institutions have the most significant impact on overall health expenditure. These changes are expected to drive the growth of health expenditure. The impact of hospital expenses and outpatient institution expenses on the overall changes in health expenditure is the smallest. Therefore, the function played by medical insurance is crucial, which can not only provide economic help to patients but also meet the adequacy of health expenditure financing in China.

Moreover, pharmaceutical expenses constitute a substantial portion of healthcare outlays for Chinese patients and significantly influence overall healthcare spending. They also contribute significantly to individual financial burdens associated with medical care. An examination reveals that pharmaceutical expenses in China have increased over time. However, their share relative to total healthcare expenditure has decreased due to regulatory measures introduced in 2016. These measures mandate pricing based on actual procurement cost plus a maximum markup limit set at 15% (35). These measures have curbed reliance on medications as a means to offset medical bills and facilitated rationalization of medical service charges through comprehensive healthcare reforms. Changes in hospital-based pharmaceutical expenses exert notable influence on overall variations in medication outlays while increases in outpatient fees drive aggregate pharmaceutical spending upwards. As a result, both outpatient and hospital-based medications play crucial roles. However, greater efforts are needed compared to developed nations to reduce reliance on medications for covering medical expenses. This leaves ample room for further development within the retail pharmacy sector.

Finally, the proportion of total health expenditures in GDP, which serves as the primary indicator for measuring the coordination between health expenditures and the national economy (40), reflects the level of social investment in healthcare and the degree of attention paid to residents' healthcare. From the analysis of the results, it can be seen that the proportion of total health expenditures in GDP in China has been increasing steadily, and it has now entered the "7%" stage. It can also be predicted that the proportion of total health expenditures in GDP in China will continue to grow in the future. According to the data released by the World Health Organization (WHO), in 2021, the proportion of total health expenditures in GDP in China ranked 90th in descending order among WHO member countries (41), which still has development potential compared to the world average level.

5 Discussion

Firstly, it is necessary to clarify the policy areas covered by the health expenditure accounting results and determine the key tasks or priority problems to be addressed by policy analysis. Based on this, strike at the crux of the matter and set reasonable standards for the proportion of expenditure. The World Health Organization advocates that the broad government health expenditure ratio should be no less than 5% of GDP and the proportion of personal health cash expenditure in the total health expenditure of the country should be between 15 and 20% (42). If the proportion of personal health expenditure is lower than 15%, few families will suffer from catastrophic health expenditure (43). Therefore, it is recommended that the aforementioned international advisory indicators be established as the ultimate development goal. Suitable standards should be set for each stage, with a fluctuation range to address sudden public health emergencies. Efforts should also be made to ensure adequate investment in health and healthcare.

Secondly, the government should increase its financial support for preventive health services even further. It should also rapidly expand and balance medical resources, strengthen policies on talent training and salary incentives, and enhance the health management capacity of grassroots healthcare institutions. Additionally, efforts should be made to raise individual self-care levels in resisting diseases. The key to implementing the "Healthy China 2030" strategy is to shift the focus of investment from "disease treatment-centered" to "people-centered health," and strengthen the service level and efficiency of grassroots healthcare institutions, to maximize the health benefits of government preventive spending. The reimbursement ratio for medical insurance can be moderately increased to reduce individual medical expenditures (44). However, it is important to consider the potential negative impact this may have on personal health investment, as well as the issues related to rising healthcare expenditure and fiscal reliance on medical insurance funds. Then, harmful health products such as alcohol, tobacco, and sugary drinks could be subjected to taxation or higher taxes. The revenue generated from these taxes can be allocated for health investment purposes, not only to address immediate health funding needs but also to mitigate long-term spending requirements by improving overall health conditions.

Moreover, China is a large country of generic pharmaceuticals, with about 95% of chemical pharmaceuticals being generics (45). However, due to the relatively backward development of China's pharmaceutical industry, its generic pharmaceuticals compared with original research pharmaceuticals have a huge gap in quality and effect. Therefore, generic pharmaceuticals must pass the evaluation of consistency, be consistent with original research pharmaceuticals in terms of effective ingredients, dosage, safety, efficacy, and other aspects, and be allowed to be sold on the market. The level of consistency evaluation directly relates to the quality and therapeutic effect of the use of generic pharmaceuticals by patients, and stricter implementation of relevant policy opinions is needed to strictly control the entry threshold and ensure the effectiveness and safety of pharmaceuticals. Accelerating the pace of selection is necessary to improve the supply level of generic pharmaceuticals. There are still gaps in the targeted pharmaceuticals for certain diseases in China. It is essential to monitor the expiration dates of patented pharmaceuticals and expedite the process of updating the recommended list to encourage the production of generic pharmaceuticals, to meet the needs of patients. Promoting the assessment of consistency in generic pharmaceuticals aims to ensure that many generic drugs provide the same therapeutic effects and cost advantages as original research products. This will enable people to access high-quality and affordable medications, thereby reducing the economic burden of pharmaceutical use for residents.

Finally, the government should clarify its responsibilities, rationally control its financial input into the healthcare sector, and make adjustments based on real-time dynamics, ensuring the rationality of its input ratio. Encouraging active participation from all sectors of society in financing the healthcare sector and expanding social healthcare financing channels is crucial. Social healthcare financing plays a key role in ensuring the sustainable funding of China's healthcare sector, and drawing on international experience can help promote diversified fundraising to meet the diverse healthcare service needs of different groups within the population. Accelerate the development of commercial health insurance and increase its proportion in total healthcare expenditures to increase the total social healthcare financing. Meanwhile, it is important to rationally allocate healthcare resources and stimulate the vitality of grassroots medical and health institutions. This can be achieved by promoting the principle of tiered medical treatment and building a pattern of "treating minor illnesses in communities, major illnesses in hospitals, and rehabilitation back in communities." These efforts will lead to a continuous reduction in the proportion of out-of-pocket health expenditures in total healthcare expenditures, ultimately alleviating residents' medical burdens.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

H-yL: Conceptualization, Data curation, Formal analysis, Writing – original draft, Writing – review & editing. R-xZ: Conceptualization, Data curation, Writing – review & editing.

Funding

The author(s) declare that financial support was received for the research, authorship, and/or publication of this article. This research was supported by the National Social Science Fund of China (24BSH096, Research on the Policy Effect and the Overall Governance of Coordinated Development on Multi level Medical Security).

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

References

1. Shu-qi L, Hai-yu X, Jia-yu Q, Li-ming L, Jing-fei Y, Yu-run Y, et al. Analysis on the correlation between aging, economic status and health expenditure. *Chinese Health Econ*. (2022) 41:7–9.

2. Wei F, Shu-li Z, Yu-hui Z, Pei-pei C, Goss J. Research in health policy making in China: out-of-pocket payments in healthy China 2030. *Brit Med J*. (2018) 360:k234. doi: 10.1136/bmj.k234

3. The State Council of the People's Republic of China. Notice on the 14th Five-Year Plan for National Medical Insurance. (2021). Available at: http://www.nhsa.gov.cn/art/2021/9/29/art_37_6137.html (Accessed October 30, 2023)

4. World Health Organization. The world health report. Geneva: WHO (2010).

5. Pei-pei C, Yan L, Tie-min Z, Feng G, Xiao-guang F, Yu-hui Z, et al. Results and analysis of national health accounts of China in 2022. *Health Econ Res*. (2024) 41:14–9. doi: 10.14055/j.cnki.33-1056/f.2024.01.020

6. Chuang D. Fiscal investment, incentive compatibility and reform of China's disease prevention and control system. *J World Econ*. (2023) 46:3–31. doi: 10.19985/j.cnki.cassjwe.2023.01.001

7. Heng-yuan Zhu. What is the total investment made by China in healthcare? Caixin Weekly (2017). Available at: http://mis.sem.tsinghua.edu.cn/ueditor/jsp/upload/file/20171222/1513916505001017331 (Accessed July 02, 2024).

8. Clemente J, Lázaro-Alquézar A, Montanñés A. US state health expenditure convergence: a revisited analysis. *Econ Model*. (2019) 83:210–20. doi: 10.1016/j.econmod.2019.02.011

9. Piscopo J, Groot W, Pavlova M. Determinants of public health expenditure in the EU. *PLoS One*. (2024) 19:e0299359. doi: 10.1371/journal.pone.0299359

10. Raghupathi V, Raghupathi W. Healthcare expenditure and economic performance: insights from the United States data. *Front Public Health*. (2020) 8:156. doi: 10.3389/fpubh.2020.00156

11. Oladosu AO, Chanimbe T, Anaduaka US. Effect of public health expenditure on health outcomes in Nigeria and Ghana. *Health Policy Open*. (2022) 3:100072. doi: 10.1016/j.hpopen.2022.100075

12. Das T, Guha P. The puzzle of public health expenditure and healthcare infrastructure in India: an empirical investigation. *Reg Sci Policy Pract*. (2023):1–37. doi: 10.1111/rsp3.12710

13. Hu Q, Wang L. Economic growth effects of public health expenditure in OECD countries: An empirical study using the dynamic panel threshold model. *Heliyon*. (2024) 10:684. doi: 10.1016/j.heliyon.2024.e25684

14. Acharya A, Wolfson C, Matta S, Cardona C, Lamba S, Bishai D. The role of public health expenditures in COVID-19 control: evidence from local governments in England. *SSM Populat Health*. (2021) 15:861. doi: 10.1016/j.ssmph.2021.100861

15. Si-Miao C, Kuhn M, Prettner K, Bloom DE, Wang C. Macro-level efficiency of health expenditure: estimates for 15 major economies. *Soc Sci Med*. (2021) 287:114270. doi: 10.1016/j.socscimed.2021.114270

16. Christopoulos K, Eleftheriou K. The fiscal impact of health care expenditure: evidence from the OECD countries. *Econ Anal Policy*. (2020) 67:195–202. doi: 10.1016/j.eap.2020.07.010

17. Feng-hua Y, Jian W, jing-jie S. Discussing the basic theoretical framework of sub-national total health cost accounting research sampled with Shandong province of China. Chinese health. *Serv Manag*. (2011) 28:4-5–4-17. doi: 10.3969/j.issn.1674-29822011.11.009

18. Feng-Hua Y, Qing-Yue M, Jian W, Yan-hua L, Zhen, W. The comparative study on the accounting indicators caliber between chinese and international total health expenditure, *Chin Health Econ* (2010) 29:67–70.

19. Qiao L, Li-qing L. Development trend and future prospects of total expenditure on health in China. *Chin General Pract*. (2017) 20:859–64. doi: 10.3969/j.issn.1007-9572.2017.07.019

20. Ai-tan Y, Li-hua W, Dong-fu Q. Comparative research on total expenditure on health and its composition between China and other countries. *Chin Health Econ*. (2005) 24:5–8.

21. Meng-zhe Y, Jie D, Xin-hua Z, Yu-hui Z. Analysis of average outpatient expenditure per visit of public hospitals in Hainan province of China based on degree of structure variation. *Med Soc*. (2023) 36:109–14. doi: 10.13723/j.yxysh.2023.09.019

22. Cui-cui J, Wan-chu L. Construction and application of GM (1,1) model in mathematical modeling. *Stud College Mathemat*. (2023) 26:31–3. doi: 10.3969/j.issn.1008-1399.2023.04.010

23. Lan-yi W, Wang Q. Prediction of basic medical insurance fund balance in China based on GM (1,1) model. *Chin Health Econ*. (2021) 40:33–8.

24. Hao D, Jing F, Yan L, Tie-min Z, Quan W. Research on the effect of compensation mechanism reform in public hospitals in Hebei Province based on degree of structure variation. *Chin Health Econ*. (2024) 43:1–8.

25. Xiao-meng F, Hong-mei J. Current situation of medical resource allocation and service utilization in Chinese hospitals based on structural variation analysis, modern. *Hospitals*. (2024) 24:664–9. doi: 10.3969/j.issn.1671-332X.2024.05.002

26. Dong-ling X, Xiao-wei M, Yi-xin W. Analysis of hospitalization expenses for four types of malignant tumors in Sichuan Province of China based on grey correlation and structural variation. *Chin Med Record*. (2024) 25:75–9.

27. Teng-yan W, Zi-xian H. Analysis of financing level and structure of total health expenditure from 2011 to 2020 in Guangxi province of China. *Soft Sci Health*. (2023) 37:69–74. doi: 10.3969/j.issn.1003-2800.2023.09.014

28. Xie Li-fang X, Ai-jun Q X-b. Financing of total health expenditure in Fujian province of China during 2009-2018 from the perspective of structural variation. *Chin Rural Health Ser Admin*. (2022) 42:390–4. doi: 10.19955/j.cnki.1005-5916.2022.06.002

29. Ning W, Chun-yu L, Yun-que B, Meng-jun Z, Si-qiu Y. Structural variation analysis and trends of total expenditure on health in Tianjin province of China. *Chin J Med Manag Sci*. (2023) 13:26–32. doi: 10.3969/j.issn.2095-7432.2023.06.005

30. Yan, L, Yu-hui, Z, Quan, W, Xiao-guang, F, Tie-min, Z, Pei-pei, C, et al. Review and prospect of national health accounts in China. Chinese. *Health Econ*. (2022) 41:9–11.

31. Yan, L, Yu-hui, Z, Quan, W, Xiao-guang, F, Tie-min, Z, Pei-pei, C, et al. Results and analysis of National Health Accounts in 2020 in China. *Health Econ Res*. (2022) 39:2–6.

32. Xin L, Hong-li Z, Li-tao G, Qing-xi G. Evaluation of the impact of drug reform on the average cost of outpatients based on the structural variation analysis and the grey relevancy analysis and policy discussion. *Drugs Clinic*. (2021) 36:1056–60. doi: 10.7501/j.issn.1674-5515.2021.05.040

33. The State Council of the People's Republic of China. Summary of the work of deepening the reform of the medical and health system in 2014 and notice of key tasks in 2015. (2015). Available at: https://www.gov.cn/zhengce/zhengceku/2015–05/09/content_9716.htm (Accessed October 30, 2023)

34. Li-juan Y, Yu-qing Z, Li-fang Z, Jian-cun Z. Study on the influencing factors of drug rational pricing. *Chin Hospit*. (2018) 22:23–5. doi: 10.19660/j.issn.1671-0592.2018.10.07

35. The State Council of the People's Republic of China. Guiding opinions on the pilot comprehensive reform of urban public hospitals. (2015). Available at: https://www.gov.cn/zhengce/zhengceku/2015–05/17/content_9776.htm (Accessed October 30, 2023)

36. Paitoon K. Factors determining health expenditure in the Asian and the OECD countries. *J World Eco*. (2017) 5:407–17. doi: 10.1787/eco_studies-2014-5jz0v44s66nw

37. Shi-yu LI, Jun-xin F. Re-measuring the impact of demographic structure on health costs in China: an estimate based on an improved factor decomposition method. *Populat Econ*. (2023) 3:100–16. doi: 10.3969/j.issn.1000-4149.2023.00.031

38. Analysis on the impact of urbanization. Aging, government health expenditure on China's total health expenditure. *Chin Health Econ*. (2019) 9:42–6.

39. Heng-peng Z, Yang Y, Ji X. Effects of public expenditures on health care cost in China. *J World Econ*. (2021) 12:149–67.

40. Zhao-mei Z, Xiao-ming C. A study on the law between health expenditure and economy development in China and OECD countries. *Chin Hospit Manag*. (2006) 26:14–7.

41. World Health Organization. Global health expenditure database. (2023) Available at: http://apps.who.int/nha/database/Select/Indicators/en (Accessed December 29, 2023).

42. Jian C. On health equity. *Chin Rural Health Ser Admin*. (2022) 42:2–9. doi: 10.19955/j.cnki.1005-5916.2022.01.001

43. Quan W, Tao L, Pei-pei C, Feng G, Xiao-guang F, Tie-min Z, et al. Study on monitoring and evaluation of the share of out-of-pocket payment in total health expenditure in China and its prediction. *Chin Health Econ*. (2021) 40:33–6.

44. Shu-sen W, Cheng-yu Y. Government health expenditure, individual health investment and welfare n China. *Econ Res J*. (2023) 58:190–208.

45. Li Dong D, Hong-jin ZY. Analysis and discussion of generic drug consistency evaluation in NMPA and relevant drug policies in FDA and PMDA. *Chin J New Drugs*. (2021) 30:1164–7.

frontiers | Frontiers in Public Health

TYPE Original Research
PUBLISHED 02 October 2024
DOI 10.3389/fpubh.2024.1407568

Check for updates

OPEN ACCESS

EDITED BY
Xiaozhen Lai,
Peking University, China

REVIEWED BY
Eduardo Fernandez,
University of Salamanca, Spain
Sivabaskari Pasupathy,
University of Adelaide, Australia

*CORRESPONDENCE
Franz Haertel
✉ Franz.Haertel@med.uni-jena.de

RECEIVED 26 March 2024
ACCEPTED 27 August 2024
PUBLISHED 02 October 2024

CITATION
Haertel F, Montag C, Kraeplin T, Lauer B, Memisevic N, Moebius-Winkler S, Schulze PC and Otto S (2024) Management of myocardial infarction with non-obstructive coronary arteries (MINOCA) in Germany: a single-center study on hospital resources and healthcare economics.
Front. Public Health 12:1407568.
doi: 10.3389/fpubh.2024.1407568

Management of myocardial infarction with non-obstructive coronary arteries (MINOCA) in Germany: a single-center study on hospital resources and healthcare economics

Franz Haertel[1]*, Carolin Montag[1], Thomas Kraeplin[1], Bernward Lauer[1], Nedim Memisevic[1], Sven Moebius-Winkler[1], P. Christian Schulze[1] and Sylvia Otto[1,2]

[1]Klinik für Innere Medizin I, Kardiologie, Universitaetsklinikum Jena, Jena, Germany, [2]Herz - und Gefäßpraxis Gera, Gera, Germany

Background: Patients with myocardial infarction with non-obstructive coronary arteries (MINOCA) present as a main feature ≤50% stenosis upon angiography despite clinical symptoms and biomarker elevation related to acute coronary syndrome. Due to broad availability of high sensitivity troponin testing as well as invasive and non-invasive imaging, this clinical entity receives increasing clinical awareness.

Objective: We aimed to investigate the in-hospital work flow and economic impact of MINOCA vs. MICAD (myocardial infarction with obstructive coronary artery disease) patients and related clinical outcomes in a single-center patient collective of a large university heart center in Germany.

Methods: We retrospectively screened and analyzed all patients who were admitted to our hospital under the suspicion of an acute coronary syndrome within a 12-month period (2017–2018) for further diagnostics and treatment. All included patients showed a pathological troponin elevation and received invasive coronary angiography for acute coronary syndrome. Associated in-hospital costs, procedural and various clinical parameters as well as timelines and parameters of work-flow were obtained.

Results: After screening of 3,021 patients, we included 660 patients with acute coronary syndrome. Of those, 118 patients were attributed to the MINOCA-group. 542 patients presented with a "classical" myocardial infarction (MICAD group). MINOCA patients were less frail, more likely female, but showed no relevant difference in age or other selected comorbidities except for fewer cases of diabetes. In-hospital mortality (11% vs. 0%; $p < 0.001$) and 30-day mortality (17.3% vs. 4.2%; $p < 0.001$) after the index event were significantly higher in the "classical" myocardial infarction group (MICAD)- Despite a shorter overall length of hospital stay (9.5 ± 8.7 days vs. 12.3 ± 10.5 days, $p < 0.01$) with a significantly shorter duration of high care monitoring (intensive/intermediate care or chest pain units) (2.4 ± 2.1 days vs. 4.7 ± 3.3 days, $p < 0.01$) MINOCA patients consumed a relevant contingent of hospital resources. Thus, in a 12-months period a total sum of almost 300 days was attributed to high care monitoring for MINOCA patients with a mean difference of approximately 50% compared to patients with classical myocardial infarction. With average and median costs of 50% less per index, MINOCA treatment costs were lower compared to the MICAD group in the hospital reimbursement system of Germany. Consequently, MINOCA treatment was not associated with a relevant profit for these expanses and a relevant share of nearly 40% of the total costs was generated due to high care monitoring.

Conclusion: In light of lower mortality than MICAD and growing scarcity of staff, financial and capacity resources the clinical symptom complex of MINOCA should be put under particular consideration for refining care concepts and resource allocation.

KEYWORDS

MINOCA, hospital resources, ACS, high care monitoring, intensive care, intermediate care

Introduction

Myocardial infarction with non-obstructive coronary artery disease (MINOCA) is a clinical entity characterized by acute myocardial infarction (AMI) fulfilling the universal AMI criteria (1), the absence of significant coronary artery disease (CAD; stenosis ≥50%) in any coronary artery determined by invasive angiography and no clinically overt specific cause for acute presentation (2).

The prevalence of MINOCA may vary (3). MINOCA has been reported to occur in approximately 6% of patients with AMI (4), other estimates range from a mere 3.5% to a relevant share of up to 25% (2, 5–8) depending on the population being studied and the criteria used to define MINOCA. Consensus statements defining MINOCA by applying specific criteria and diagnostic algorithms have been published in the past years by the European and American cardiac societies (2, 5, 9). However, epicardial and microvascular causes or associated risk factors are overlapping, and establishment of a definite diagnosis can be challenging in clinical practice.

Despite an almost exclusively conservative treatment for MINOCA patients (7, 10–12), this disease entity still utilizes financial and capacity resources including high care monitoring and an in-hospital treatment (13).

At the moment, a health care expenditure discourse is emerging in the western world, particularly in high-income countries such as Germany (14). Recent data clearly show higher than ever growing health care costs *per capita* in Germany that do not translate to longevity advantages (14). On the contrary, an economically strong country like Germany can be viewed as a "poor performer" compared to other nations regarding health care outcomes (14). This discrepancy between rising health care costs *per capita* and no added benefit or even a decrease in life expectancy in Germany is creating a growing awareness for a more cautious resource allocation (14).

In light of this context, data on in-hospital resource management and economic aspects for the clinical entity of MINOCA are scarce and new insights are strongly needed.

Aim of the study

The present study aimed to investigates clinical characteristics, prognosis, in-hospital workflow, and consequently economic impact of MINOCA patients compared to "classical" AMI patients [myocardial infarction with obstructive coronary artery disease (MICAD)], and analyses potential implications for hospital resource management of MINOCA.

Materials and methods

Study design

At the University Hospital Jena, Germany, a "MINOCA database" was established in April 2017 as the foundation for the data used in this study. The study received approval from the medical faculty's ethics commission at the Friedrich-Schiller University Jena (registry number: 2018-11-35-Daten). This study is a single-center, retrospective study that analyzed data from a one-year period (April 2017 to May 2018) and was conducted in accordance with the Declaration of Helsinki.

Patient population

The study screened in a first step all patients who received invasive coronary diagnostics for a working diagnosis of acute coronary syndrome (ACS), including ST-elevation myocardial infarction (STEMI) and non-ST elevation myocardial infarction (NSTEMI) as well as elevated troponin levels with no or indistinct signs of myocardial ischemia. From this population, patients were selected further for suspected MINOCA. Cases were assessed using a specific diagnostic algorithm designed to distinguish MINOCA from other causes involving non-ischemic mechanisms in line with a previous study (9).

Patients who received a coronary angiography for other indications such as elective or preoperative diagnostics or who had normal cTn levels were excluded from the study.

We used the "Universal definition of myocardial infarction (UDMI)" from 2018 for elevation of cTn levels to define AMI (1): "detection of an elevated cTn value above the 99th percentile upper reference level (URL) is defined as myocardial injury." For an acute injury, cTn values had to elevated and/or rise. Additionally, a clinical constellation compatible with acute myocardial injury (typical ischemic symptoms, new ischemic electrocardiogram (ECG) – changes or new pathological Q-waves, imaging evidence of loss of viable myocardium or new regional wall abnormalities, or detection of intracoronary thrombus) was necessary. For evaluation of the clinical constellation, the working diagnosis of in-hospital course was considered and reevaluated in the aforementioned process.

Definition of MINOCA diagnosis

Definition of MINOCA was based on current consensus and guidelines (2, 9, 15). First, the working diagnosis of MINOCA was established on the initial presentation of the patient and all relevant information using the hospital information system upon coronary angiography, if the following criteria were fulfilled: universal AMI criteria, non-obstructive coronary arteries <50% in any potentially infarct-related artery and no clinically overt specific cause for the acute presentation during initial work-up and upon decision for coronary angiography.

All included cases were retrospectively reviewed and reanalyzed regarding the final diagnosis of MICAD or MINOCA using all available information from the hospital information system (e.g., laboratory values, imaging results, angiographic results). In case of incongruent findings, final diagnosis was established by clinical consensus reading by two investigators (C.M. and S.O.).

Due to the retrospective nature of this study, patients with a specific alternative diagnosis such as pulmonary embolism, sepsis, Tako-Tsubo syndrome, myocarditis or other non-cardiac cTn elevation [e.g., stroke, acute respiratory distress syndrome (ARDS)] were excluded.

In addition, radiological findings were analyzed to determine if and which imaging was performed (cardiac magnetic resonance imaging (MRI), coronary computed tomography (CT) angiography, myocardial scintigraphy).

Troponin test

cTn testing was conducted utilizing the Cobas e 801© module, a component of the Roche Cobas 8,000© system by Roche© employing the ElectroChemiLuminescence Immunoassay (ECLIA) methodology. The reference values at our study site for normal troponin levels were established as <9 pg./mL for women and < 16.8 pg./mL for men. Notably, concentrations of cTn exceeding the 99th centile of the URL were considered elevated as mentioned above.

Data management

Various demographic, clinical and procedural parameters, as well as laboratory parameters and diagnostic work-up were collected and anonymously registered using the SAP® electronic patient management system (SAP®, Walldorf, Germany). Also, emergency medical protocols (obtained from emergency medical services (EMS) and the emergency department) were used for confirming the initial working diagnosis MINOCA. We determined in-hospital and 30-day mortality as both all-cause and cardiovascular mortality.

The electronic documentation system of the cardiac catheterization laboratory, cardWorks® (Schwarzer Cardiotek GmbH, Heilbronn, Germany), and coronary angiography findings were reviewed and provided specific clinical parameters such as ejection fraction, heart rate, and blood pressure, as well as information on the interventions performed, percutaneous coronary intervention (PCI), and intracoronary imaging [optical coherence tomography (OCT) or intravascular ultrasound (IVUS)]. The degree of stenosis in diagnosed CAD (exclusion, mild CAD with stenosis <50%; manifest CAD with stenosis ≥50%) were determined.

In-hospital workflow data

We collected logistical data that were obtained from specific time points that every patient underwent within the hospital from first presentation to diagnostics and to discharge. Relevant parameters and measurements that we investigated were: primary point of contact with the hospital (e.g., emergency department), rate of admission to high-care monitoring, time interval between admission to the hospital and arrival in the catheterization laboratory, length of in-hospital stay, length of high care monitoring, mode and time of admission to the hospital and seasonal distribution of admission among others.

Economic data

Costs associated with the studied patients were derived from the German health care insurance reimbursement system. In Germany, hospital costs/health care services are classified and reimbursed through the so-called Diagnosis Related Groups (DRG) system. It operates on a case-based payment model, assigning a fixed reimbursement amount for each patient case, considering factors like diagnosis, procedures, age, and gender. This system aims to streamline billing processes, enhancing transparency and efficiency in healthcare services.

Key features of the German DRG system include:

Case-Based Payments: Hospitals receive a predetermined reimbursement for each case, covering all associated costs related to a specific condition or procedure.

Patient Classification: Patients are categorized into specific DRGs based on diagnoses and procedures, with each DRG having an associated base rate that is adjusted based on factors such as age and comorbidities.

Grouping Criteria: The classification of patients into DRGs relies on standardized criteria, including primary and secondary diagnoses, procedures, age, and other relevant factors.

Coding System: Accurate coding of diagnoses and procedures using the international classification of diseases (ICD) and operational and procedural system (OPS) coding systems is crucial for correct DRG assignment.

Transparent Reimbursement: The DRG system provides transparency by specifying in advance the reimbursement amount for each case, enabling hospitals to make informed decisions about resource allocation and budgeting.

Updates and Adjustments: Periodic updates ensure the DRG system remains current, reflecting changes in medical practices, technology, and healthcare policies.

To characterize the economic impact of MINOCA, the costs (in EUR) were categorized as follows: (1) procedures, which included invasive angiography and additional intravascular imaging if necessary, (2) high-care monitoring such as intensive care unit (ICU), intermediate care unit (IMC), and chest pain unit (CPU), including costs for medical supplies, care, medication, ventilation, dialysis, and extracorporeal circulatory support, (3) regular ward, which included costs for medical supplies, care, and medication, and (4) total cost.

Statistical analysis

Analyses were done using SPSS Statistics (version 27.0, SPSS Inc., IBM, Armonk, New York). A p-value less than 0.05 was considered statistically significant, a p-value <0.1 was considered a trend. Baseline parameters are presented descriptively including whole integers and percentages. The data was analyzed by Kolmogorov-Smirnov test for normal distribution and the appropriate statistical tests were applied. The frequency of nominally scaled parameters was compared using Pearson's chi-squared test. Variables are expressed as mean ± standard deviation (Mean ± SD) and the t-test for independent samples and one-way analysis of variance were used for mean comparisons. Non-normally distributed data were expressed as median with interquartile range (Median [IQR: 25th percentile–75th percentile]) and compared using the Mann-Whitney U-test. The diagrams depicted were generated using SPSS Statistics.

Results

Study population and clinical characteristics

In the time frame of 12 months, 3,021 patients were screened. A total of 660 patients were included in the study. Of those, 542 patients (82%) were attributed to the MICAD group and 118 patients (18%) formed the MINOCA group (Figure 1). Table 1 summarizes the baseline characteristics for the entire study population. The prevalence of MINOCA was 18% in our study population of patients presenting with ACS symptoms.

The total study population included 62.6% men (413 patients) and 37.4% women (247 patients). The age at presentation ranged from 25 to 96 years, with a mean of 68.8 ± 12.8 and a median of 72 [60–79] years. MINOCA patients were more likely female (59.3% vs. 32.7% $p < 0.001$), but showed no difference in age compared to the MICAD group.

A better left ventricular ejection fraction (56.1 ± 15.6% vs. 41.8 ± 14.9%; $p < 0.001$) and more hypertensive blood pressure values

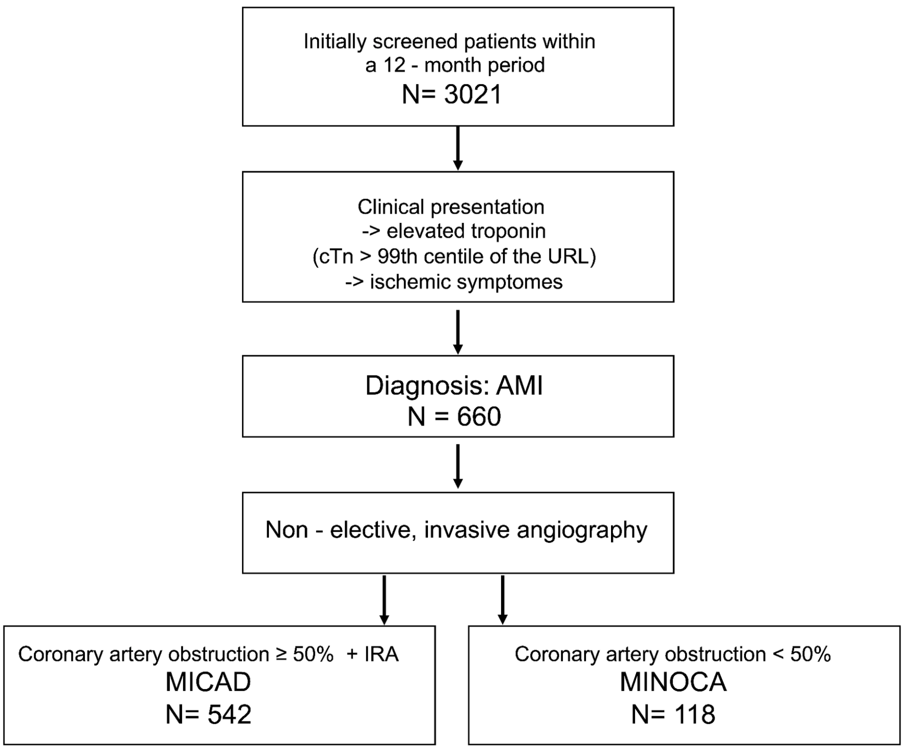


FIGURE 1
Flow chart of the patient selection for this study. MINOCA, myocardial infarction with non-obstructive coronary arteries; MICAD, myocardial infarction with obstructive coronary artery disease [ST elevation myocardial infarction (STEMI) and non-ST elevation myocardial infarction (NSTEMI)]; N, absolute number; cTn, cardiac troponin; URL, upper reference level; AMI, acute myocardial infarction; IRA, infarct related artery.

TABLE 1 Baseline characteristics.

	Total study population (n = 660)	MICAD [n = 542 (82%)]	MINOCA [n = 118 (18%)]	p-value*
Demographics				
Age [years – mean ± SD]	68.8 ± 12.8	68.8 ± 12.8	69.8 ± 12.7	n.s.
Male [n (%)]	413 (62.6)	365 (67.3)	48 (40.7)	<0.001
Female [n (%)]	247 (37.4)	177 (32.7)	70 (59.3)	<0.001
BMI [kg/m^2 – mean ± SD]	28.3 ± 5.2	28.4 ± 5.1	27.5 ± 5.4	n.s.
Charlson comorbidity index [mean ± SD]	4.78 ± 1.8	4.87 ± 1.8	3.9 ± 1.7	<0.001
All-cause mortality				
In-hospital [n (%)]	59 (9)	59 (11)	0 (0)	<0.001
30-day [n (%)]	99 (15)	94 (17.3)	5 (4.2)	<0.001
Cardiovascular mortality				
In-hospital [n (%)]	39 (5.9)	39 (7.2)	0 (0)	<0.001
30-day [n (%)]	58 (8.8)	54 (9.9)	4 (3.3)	<0.001
Echocardiographic parameters				
LVEF [% – mean ± SD]	49.5 ± 15.2	41.8 ± 14.9	56.1 ± 15.6	<0.001
Hemodynamic parameters				
Systolic blood pressure [mmHg – mean ± SD]	141.5 ± 36.1	139.6 ± 35.4	151.9 ± 38.1	<0.001
Heart rate [bpm – mean ± SD]	79.5 ± 22.4	79.7 ± 22.3	78.7 ± 23.1	n.s.
Biomarkers				
Troponin [pg/ml–median [IGR]]	4165.1 [569.2–26519.3]	6761.6 [729.5–35908.5]	821.1 [197.1–3642.4]	<0.001
CK [pg/ml–median [IGR]]	4.8 [2.4–15.4]	5.8 [2.7–18.6]	2.5 [1.8–4.7]	<0.001
Creatinine [µmol/l – mean ± SD]	115.2 ± 88.4	115.9 ± 89.3	111.5 ± 83.7	n.s.
Organizational work-flow and resources				
Admission via ED [n (%)]	515 (78)	431 (79.5)	84 (71.2)	n.s.
High-care monitoring [n (%)]	560 (84.8)	487 (89.9)	73 (61.9)	<0.01
CABG [n (%)]	51 (7.7)	50 (9.2)	0 (0)	< 0.01
Interval admission ED-catheterization laboratory [h–median [IQR]]	11.3 [1.5–65.5]	9.1 [1.1–59.9]	43.1 [10.4–117.6]	<0.001
Time of admission				
Morning [n (%)]	204 (30.9)	184 (33.9)	29 (24.5)	n.s.
Afternoon [n (%)]	314 (47.6)	267 (49.2)	64 (54.1)	n.s.
Night [n (%)]	110 (16.7)	91 (16.8)	25 (21.4)	n.s.
On-hours [n (%)]	404 (61.2)	333 (61.4)	71 (60.4)	n.s.
Off-hours [n (%)]	256 (38.8)	209 (38.6)	47 (39.6)	n.s.
Weekend [n (%)]	117 (17)	107 (19.7)	10 (8.5)	0.01
Comorbidities				
Hypertension [n (%)]	497 (75.3)	419 (77.3)	78 (66.1)	n.s.
Heart failure [n (%)]	277 (42)	232 (42.8)	45 (38.1)	n.s.
PAD [n (%)]	46 (7.0)	40 (7.4)	6 (5.1)	n.s.
Stroke [n (%)]	23 (3.5)	22 (4.1)	1 (0.8)	n.s.
Dementia [n (%)]	15 (2.5)	13 (2.4)	2 (1.7)	n.s.
COPD [n (%)]	45 (6.8)	35 (6.4)	13 (11.2)	n.s.
Diabetes [n (%)]	226 (34.2)	287 (36)	27 (22.9)	0.037

$p < 0.05$ = statistically significant; * MICAD vs. MINOCA; MICAD, myocardial infarction with obstructive coronary artery disease; MINOCA, myocardial infarction with non-obstructive coronary arteries; ED, emergency department; SD, standard deviation, BMI, body mass index; ICU, intensive care unit; CABG; coronary artery bypass graft; h, hours; PAD, peripheral artery disease; COPD, chronic obstructive pulmonary disease; CAD, coronary artery disease; n.s., not significant; IQR, Interquartile range; CK, creatinine kinase.

(151.9 ± 38.1 mmHg vs. 139.6 ± 35.4 mmHg; $p < 0.001$) prior to the angiography were found in MINOCA patients.

In general, the presence of diabetes mellitus, hypertension or multimorbidity seem to be important co-factors for the occurrence of cardiovascular diseases in both groups (Table 1).

Biomarkers

Upon presentation, MINOCA patients showed lower cardiac biomarkers (troponin: 821.1 pg. / ml [197.1–3642.4] vs. 6761.6 pg. / ml [729.5–35908.5]; $p < 0.001$; CK: 2.5 pg. / ml [1.8–4.7] vs. 5.8 pg./mL [2.7–18.6]; $p < 0.001$) (Table 1). All but two patients in the MINOCA-cohort, and all patients in the MICAD-cohort had a clear troponin elevation >5 x URL.

There was no statistically significant difference in the minimal hemoglobin levels between the two groups (7.03 ± 1.48 mmoL/L vs. 6.79 ± 1.63 mmoL/L; $p < 0.238$). The leukocyte count was found to be significantly higher in the MICAD group compared to the MINOCA group (14.29 ± 6.67 Gpt/l vs. 12.83 ± 13.68 Gpt/l; $p < 0.001$). Moreover, maximal CRP levels were significantly higher in the MICAD group compared to the MINOCA group (84.70 ± 106.18 mg/L vs. 66.24 ± 91.99 mg/L; $p < 0.004$). Although there was no statistically significant difference in the GFR (65.64 ± 24.68 mL/min vs. 67.26 ± 26.74 mL/min; $p = 0.482$) and serum creatinine levels (106.3 ± 83.45 µmoL/L vs. 110.88 ± 84.21 µmoL/L; $p = 0.173$) between the two groups at admission, the serum creatinine levels in the MICAD group were significantly higher than in the MINOCA group during the follow-up period (93.92 ± 68.81 µmoL/L vs. 109.62 ± 86.56 µmoL/L; $p = 0.003$) (Table 1).

Mortality and outcomes

The total study population had a 30-day all-cause mortality rate of 15% (99 patients). Compared to the MINOCA group, the MICAD group had significantly higher rates of all-cause in-hospital mortality (11% vs. 0%, $p < 0.001$) and all-cause 30-day mortality (17.3% vs. 4.2%, $p < 0.001$) following the clinical index event (Table 1). The majority of both in-hospital and 30-day mortality cases were attributed to cardiovascular causes.

Organizational work-flow and in-hospital resources

The emergency department was the primary point and most common mode of hospital admission for >70% of the entire patient cohort with no difference between MICAD and MINOCA patients (Table 1). Approximately 50% of the patients arrived in the afternoon but still within regular working hours on a weekday. MINOCA patients were less present during the weekend [compared to MICAD patients (8.5% vs. 19.7%; $p = 0.01$, Table 1)]. With regard to potential seasonal fluctuations of these entities, both MINOCA and MICAD cases showed a similar pattern with two peaks in late spring and late fall (Figure 2).

MINOCA patients were more likely to receive coronary angiography later after admission (43.1 h [10.4–117.6] vs. 9.1 h [1.1–59.9]; $p < 0.001$) (Table 1).

Overall, both MINOCA and MICAD required relevant, approximately one-week long in-hospital treatment. However, length-of-hospital stay (mean: 9.5 ± 8.7 days vs. 12.5 ± 10.5 days; $p < 0.01$; median: 8.0 days (5–14) vs. 7.0 days (4–11); $p = 0.023$) was significantly shorter in the MINOCA group compared to MICADs.

Demands for high care monitoring (ICU, IMC, CPU), showed significant differences for admission rates (61.9% vs. 89.9%; $p < 0.01$) and length of stay in these units (mean: 2.4 ± 2.1 days vs. 4.7 ± 3.3 days; $p < 0.01$; median: 1.9 days [1.1–4.4] vs. 1.5 days [0.4–2.7]; $p = 0.01$) between MINOCA and MICAD patients. Nevertheless, a total sum of 298.4 days was utilized solely by MINOCA patients for high care monitoring in a 12-months period (Figure 3).

Analyses of in-hospital costs and reimbursement

With average and median costs of 6871.5 ± 5670.8 EUR and 3585.2 [3461.4–10167.2] EUR per index, MINOCA treatment costs were lower compared to the MICAD group (mean: 13045.9 ± 7896.9 EUR; $p = 0.02$; median: 5958.9 [4682.7–16654.9] EUR; $p < 0.01$) with a mean difference of approximately 6,000–7,000 EUR. However, MINOCA treatment was not associated with a relevant profit for these expanses (mean: 198.1 ± 4329.2 EUR//median: 0 (−1702.6–1405.1) EUR) in the German health care system.

For MINOCA patients, 36.2% of the total costs were attributed to high care monitoring and 41.5% to regular ward care, in comparison, these expenditures for MICAD patients were 24.8 and 22.6%, respectively (Figure 4).

Discussion

The aim of this study was to investigate the procedural and economic impact of MINOCA patients compared to those with "true myocardial" infarction and related clinical outcomes in a single-center patient collective of a large university heart center in Germany. Our results showed that MINOCA patients had lower cardiac biomarkers, a better and mostly preserved left ventricular ejection fraction, and showed no differences in age, very low in-hospital and 30-day mortality.

Although MINOCA patients had shorter hospital stays and spent less time in high care units, they still required significant in-hospital resources over a 12-month period. Treatment costs were lower for MINOCA patients but did not result in significant profit from the German diagnosis-related group (DRG) system. These findings underscore the importance of distinguishing between MINOCA and MICAD in patient management and resource allocation, especially in the context of limited resources.

Classification and prevalence of MINOCA

The diagnosis of MINOCA was made based on the initial presentation of the patient together with criteria adapted from Agewall et al. (2) from European Society of Cardiology (ESC) working group position paper on myocardial infarction with non-obstructive coronary arteries.

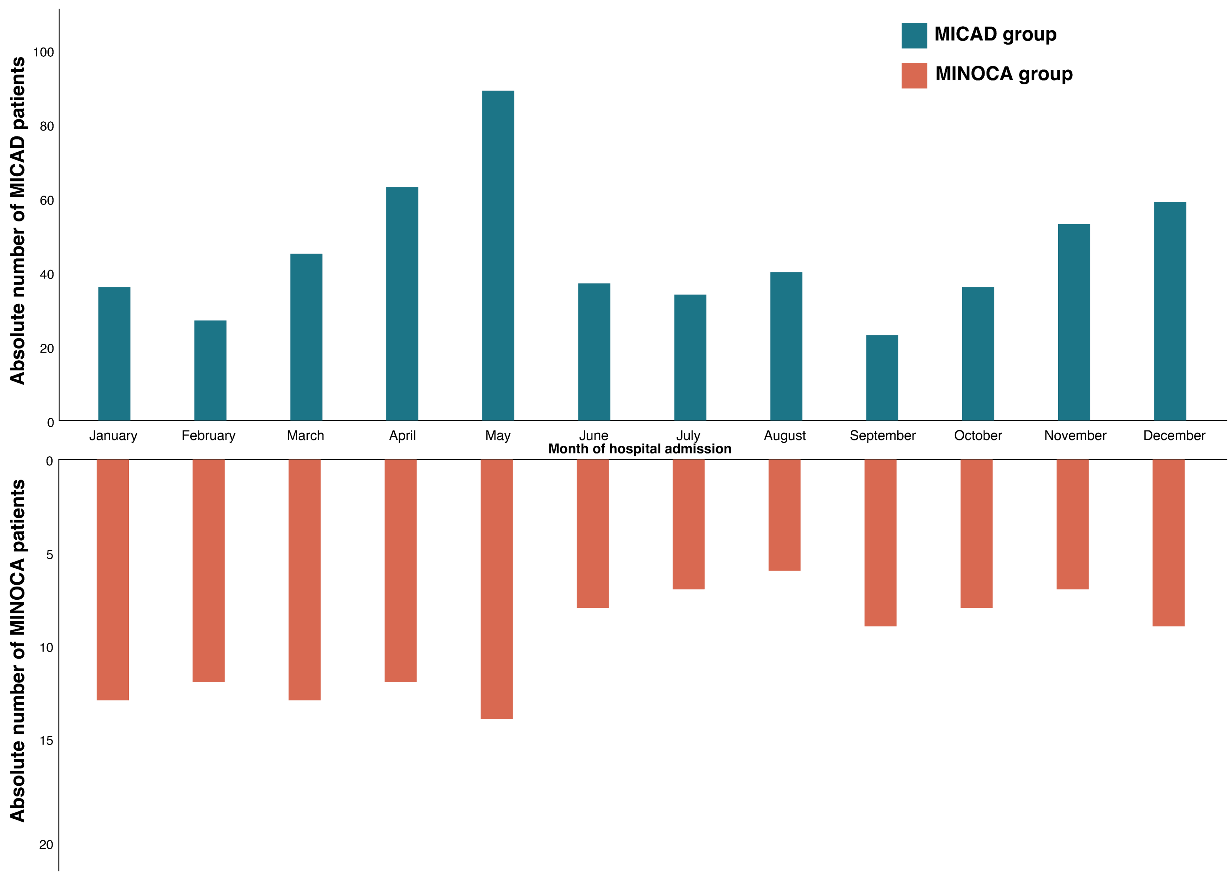


FIGURE 2
Seasonal distribution of the study population. Comparison of MINOCA (orange) vs. MICAD (blue); MINOCA, myocardial infarction with non-obstructive coronary arteries. MICAD, myocardial infarction with obstructive coronary artery disease [ST elevation myocardial infarction (STEMI) and non-ST elevation myocardial infarction (NSTEMI)].

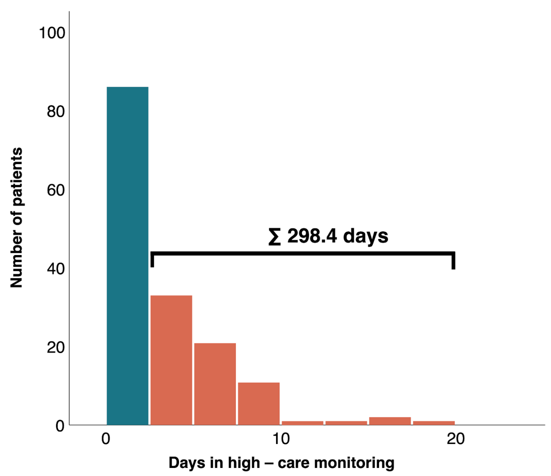


FIGURE 3
Absolute number of days of MINOCA patients in high care monitoring (orange) and without high-care monitoring (blue). MINOCA, myocardial infarction with non-obstructive coronary arteries.

Recently, there has been further refinement of terminology based on pathophysiology of MINOCA. The term *MINOCA* should be reserved for patients with evidence of ischemia-related myocardial necrosis, and thus is suggestive for an epicardial cause of AMI such as coronary dissection, coronary artery spasm or coronary plaque (rupture or erosion). Whereas the novel term *TpNOCA* (Troponin-positive with non-obstructive coronary arteries) was formed and refers to normal or regional wall abnormalities with a microvascular pattern (e.g., Tako-Tsubo-Syndrome, myocarditis, coronary microvascular spasm or coronary embolism) (6).

Per definition MINOCA is used as a "working diagnosis" and should not be considered after a specific cardiac (coronary or non-coronary) or extra-cardiac condition has been identified. However, current consensus (6, 15, 16) also utilizes "unclassified MINOCA" (= MINOCA-working diagnosis vs. unclassified MINOCA) as a specific cardiac condition after additional investigation such as vascular function tests. Non-invasive and intracoronary imaging, as well as extra-cardiac work-up. After this diagnostic process, an alternative diagnosis (e.g., sepsis, pulmonary embolism, cardiac contusion) or cardiac/coronary diagnosis (e.g., Tako-Tsubo syndrome, myocarditis, coronary dissection or thrombus) can be established.

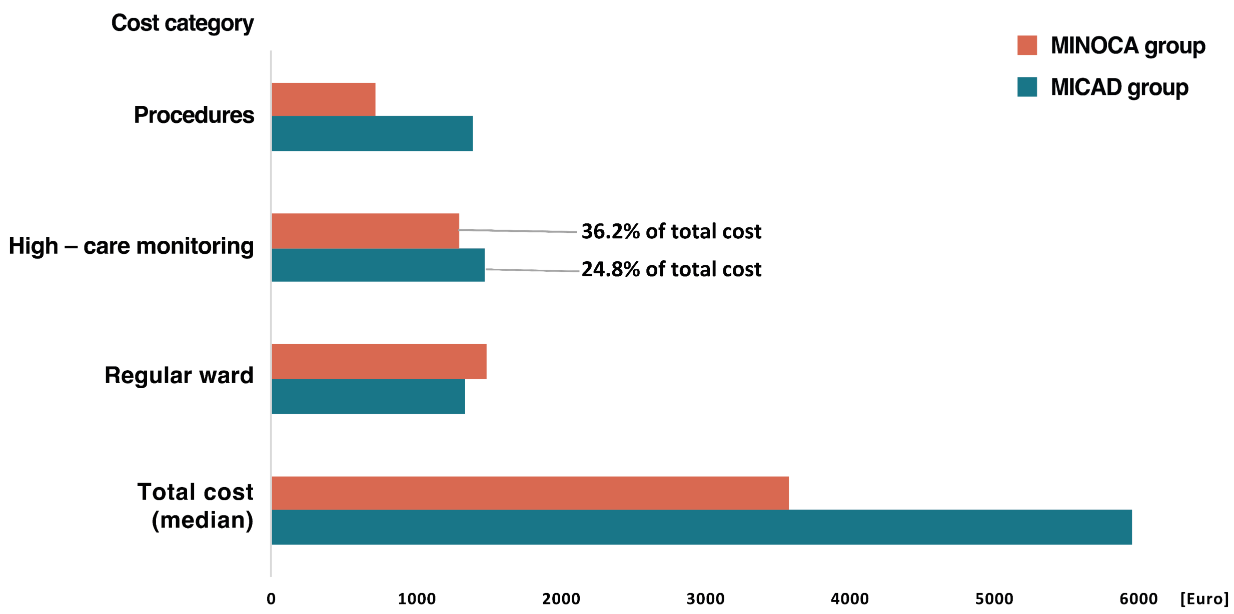


FIGURE 4
Median total hospital cost per index for MICAD and MINOCA patients and the respective cost category in group comparison. Definition: Procedures = invasive angiography including additional intravascular imaging if necessary. High-care monitoring = intensive care unit (ICU), intermediate care unit (IMC), and chest pain unit (CPU) including costs for medical supplies, care, medication, ventilation, dialysis, and extracorporeal circulatory support. Regular ward = regular admission including costs for medical supplies, care, and medication. MINOCA, myocardial infarction with non-obstructive coronary arteries; MICAD, myocardial infarction with obstructive coronary artery disease.

However, since our work is a retrospective analysis, patients correctly attributed to the MINOCA group remained MINOCA patients but the final, specific diagnosis (if established) was determined and documented in our database. One could argue, if an alternative diagnosis such as sepsis or pulmonary embolism should even be considered as a MINOCA working diagnoses or if the clinical context was misjudged or not overtly present during the initial patient assessment. Furthermore, MINOCA or TpNOCA terminology should solely be attributed to epicardial or myocardial pathophysiological causes of myocardial injury. This however, is an ongoing debate (6, 15–18). Despite its many advantages, it must also be said that the use of hs-cTnT test themselves might "produce" the diagnosis of MINOCA as the reliability of positive values is challenged by noncoronary causes and thus contributes to over-diagnosis and over-investigation (19, 20).

With a share of 18%, MINOCA patients make up a significant proportion of all myocardial infarctions in the analyzed patient population. Regarding the prevalence of MINOCA, there have been many discrepancies and no clear statements in recent years due to the lack of a uniform definition: The term "MINCA" was already described in 2000, encompassing myocardial infarctions in patients without atherosclerosis of the epicardial vessels (21). According to the study conducted at that time, these patients had a lower cardiovascular risk profile and an "excellent" prognosis (21). The term MINCA was replaced by MINOCA by John Beltrame et al. (22, 23), so that patients with angiographic stenosis between 1 and 50% were also included (23).

The position paper of the ESC states the prevalence of MINOCA to be 1–13% of all patients with acute myocardial infarction (2) and a systematic review by Pasupathy et al. (4) based on 28 publications reveals a prevalence of approximately 6% of patients presenting with ACS symptoms. A prospective multicenter large-scale cohort study by Lawless et al. (24) with 13.202 patients determined a 10.9% prevalence of MINOCA patients in this collective and two very recent studies, one prospective by Bergamaschi et al. (5) and one retrospective meta-analysis by Mileva et al. (25) reported 6 and 22%, respectively.

Our own study findings corroborate a comparable percentage of 17.9% within an ACS collective despite its retrospective nature and excluding diagnosis like pulmonary embolism or sepsis. This might be due to improvement of early screening methods, the use of high-sensitive troponin assays, and possibly a higher awareness of MINOCA as an ACS entity (26).

Intracoronary imaging such as IVUS or OCT was performed in only 16 patients (2.4%) of the entire study cohort, which is rather low. However, we believe it reflects the true real-life situation and might be a bit higher today (5 years forward) due to the increasing evidence and clear guideline recommendations. The strength of our work is the angiography that was carried out for all patients and is not required in all ACS patients regarding current guidelines. Therefore, one could speculate that in an ACS cohort of patients without 100% invasive diagnostic the prevalence of MINOCA might be even higher.

Comorbidities, high-sensitivity troponin assays and mortality

The gender distribution in this study is in slight favor for women (59.3%). With a median of 74 years [60–79] and average age of 69.8 ± 12.7 years, there were no significant differences in terms of age between the two groups. This is consistent with the work published in 2022 by published in 2022 by Lopez-Pais et al. (26). Here, an average age of 64.6 ± 14.9 years or 66.7 ± 13.5 years was described (26). In the VIRGO study, MINOCA was more often found in younger patients;

these patients were more likely to have an NSTEMI and fewer traditional cardiac risk factors than patients with MICAD (27). Contrary to the VIRGO study, the MINOCA patients in the described collective were not significantly younger, which contradicts the assumption that MINOCA is supposedly a disease of younger people.

Comorbidities and cardiovascular risk factors were evenly distributed in the study cohort; and without differences between MICAD and MINOCA patients with the exception of a preexisting type 2 diabetes, which was more often seen in the MICAD group.

Troponin is considered an important prognostic marker (15). MINOCA patients have significantly lower concentrations of cardiac necrosis markers as opposed to classical myocardial infarction where the massive release of hs-cTnT (high sensitive cardiac troponin T) occurs as a result of significant damage to the supplied myocardial area due to the immediate total or subtotal occlusion of a coronary artery (15, 28). Moreover, an acute troponin elevation of >5 x URL has a very high positive predictive value for myocardial ischemia compared to troponin elevation ≤3 x URL (8, 9, 29).

Since this is not the case in MINOCA, it can be assumed that there is a lower release of troponin.

This could partially explain why MINOCA patients had a lower mortality rate. Although the MINOCA group had no in-hospital deaths, their 30-day mortality rate of 4.2% was significantly lower than the 17.3% observed in the classic myocardial infarction group. However, this mortality rate should still be regarded as substantial and clinically relevant. The study by Lawless et al. (24) mentioned earlier, which compared female and male MINOCA patients, reported an in-hospital mortality of 2.1 to 3.2%; a 1-year mortality of 6.9 to 9.2% and long-term mortality 11.2 to 14.2%. A more recent study by Bergamaschi et al. (5) reports a mean mortality rate of 8.1% (over a period of 33.7 ± 12.0 months).

Left ventricular ejection fraction at admission was better in the MINOCA group, which could potentially speak for a better long-term prognosis for MINOCA patients. However, it is extremely difficult to make a specific statement about long-term prognosis due to the large heterogeneity of available registries. For example, Lopez-Pais et al. (26) describe similar complications such as reinfarction, severe bleeding, stroke, pulmonary edema, or shock in 13.8% of MINOCA patients vs. 17.6% in MICAD ($p = 0.335$).

Economic aspects and in-hospital resource management

While the DRG system promotes standardization and transparency, critics argue that it may incentivize hospitals to increase case volume to maximize revenue. Concerns also exist about potential underpayment for complex cases requiring more resources.

In 2020, healthcare expenditure in Germany amounted to 13.1% of GDP (Federal Statistical Office of Germany). Ischemic heart diseases and acute myocardial infarction accounted for 10.8 billion Euros (73.8% attributed to ischemic heart, 26.2% acute myocardial infarction), which is a 15.3% increase from 2015. As the population ages and risk factors increase, these costs are likely to continue to rise. It is worth mentioning that Germany has already the highest *per capita* expenditures annually for cardiovascular diseases and with more than 900 Euros per person, Germany is also the unchallenged leader in cardiovascular disease expenditures in Europe (average costs 630 EUR/person/year) (14, 30).

Therefore, accurately differentiating between real AMIs and MINOCAs is essential for effective resource allocation and management of costs.

The true costs of treatment and management for patients with MINOCA with regard to high care monitoring, such as in an ICU, are currently unknown and can only be approximated based on the known costs of ICU patients with underlying cardiovascular diseases.

In the context of cost considerations, our research shows a variability within the data, indicating that there may be outliers or a high degree of heterogeneity within the MINOCA and MICAD patient population. In our analysis, this variability can be attributed to differences in patient demographics, comorbidities, and the severity of conditions within the MINOCA and MICAD groups that required different length of stay in hospital and in a high care unit expressed through varying health care cost expenditures. The variability in costs and resource utilization underscores the need for personalized approaches in managing MINOCA and MICAD patients, as standardized protocols may not adequately address the diverse needs of the patient population. It is important to recognize that our cost analysis is based on healthcare resource data specific to Germany, and may not be fully applicable to other countries, including those within Europe. Nevertheless, factors such as in-hospital treatment, duration of high care monitoring or total length of stay offer valuable insights into resource utilization and are comparable for different health care systems.

Whether a patient with MINOCA should receive high care monitoring or a normal admission may depend on the severity of their condition and their overall prognosis. Some patients with MINOCA may be able to receive care on a normal hospital ward, while others may require more intensive care or a specialized cardiac unit. A non-existing in-hospital and significantly lower 30-day mortality in the MINOCA group after the clinical index event speak for a generally more favorable course compared to "true infarctions."

Given limited personnel and financial resources and the obligation to be economically viable, it would be advisable to establish an effective treatment path at the first contact with the patient, which occurs in over 70% via the emergency department, in order to make organizational and administrative processes as efficient as possible. One approach could be the consistent application of the 1 h algorithm recommended by the ESC (31). A faster "rule-in" allows infarction patients to be treated earlier, avoiding long-term complications and mortality due to delayed diagnosis; and ultimately reduces resource consumption and costs (31).

The early use of computed tomography (CT) to rule out CAD might allow a step-down approach, e.g., early discharge or admission to a regular ward for further diagnostic work-up for patients who generally carry a low to intermediate risk, and would avoid an overuse of high care monitoring capacities (32, 33).

Another way to diagnose MINOCA is through cardiac MRI or invasive coronary imaging and vascular function tests such as IVUS, OCT or pressure wire (2, 17, 18). These methods provide additional information that can help differentiate MINOCA from other types of heart disease (2, 17, 18). It is important to note that these diagnostic tests should not be performed in an outpatient setting. Rather, they require specialized expertise and infrastructure available at a hospital or specialized center.

However, further research is needed to better understand different causes of MINOCA, and ultimately formulate recommendations for risk stratification and management of MINOCA.

Limitations

This is a single-center and retrospective study with associated limitations and missing data in some cases. A potential bias cannot be excluded. The study was conducted at a large university heart center in Germany. Therefore, economic analysis and derived implications can only be formulated for the German health care system.

The presence of wide standard deviations suggests that while our mean estimates provide a central tendency of expenditure for MINOCA, there is a substantial variability that needs to be considered when interpreting the results. Clinicians should be aware of the variability of the costs and consider individual patient characteristics and contextual factors when applying our study findings.

Other aspects that should be considered as limitations but can be the focus of future studies include: the rate of readmissions/ medication compliance /medication rate/quality of life of MICAD vs. MINOCA patients.

Conclusion

Despite MINOCA requiring an almost exclusively conservative treatment it utilizes relevant financial and medical resources including experienced personal, an interdisciplinary team, high care monitoring and an in-hospital treatment of relevant length. Regarding scarcity of structural and personnel resources, this entity should be put under particular consideration for refining care concepts and identification of patients suitable for early discharge and outpatient care.

Data availability statement

The datasets presented in this article are not readily available because the data presented in this study are not publicly available due to local legal restrictions on data safety. Requests to access the datasets should be directed to Franz.Haertel@med.uni-jena.de.

Ethics statement

The studies involving humans were approved by Friedrich-Schiller University Jena, Germany. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

FH: Conceptualization, Data curation, Formal analysis, Investigation, Visualization, Writing – original draft, Writing – review & editing. CM: Data curation, Writing – review & editing. TK: Data curation, Writing – review & editing. BL: Writing – review & editing. NM: Data curation, Writing – review & editing. SM-W: Writing – review & editing. PCS: Resources, Writing – review & editing. SO: Investigation, Methodology, Project administration, Resources, Supervision, Writing – review & editing.

Funding

The author(s) declare financial support was received for the research and authorship. For publication, the author(s) acknowledge support by the German Research Foundation (Project-Nr. 512648189), the open access publication fund of the Thueringer Universitaets - und Landesbibliothek Jena and the publication fund of the Thueringer Universitaets - und Landesbibliothek Jena.

Acknowledgments

We thank all the medical and nursing staff in the Department of Cardiology and Intensive Care, University Hospital Jena, who assisted with the conduction of this study.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

References

1. Thygesen K, Alpert JS, Jaffe AS, Chaitman BR, Bax JJ, Morrow DA, et al. Fourth universal definition of myocardial infarction (2018). *J Am Coll Cardiol*. (2018) 72:2231–64. doi: 10.1016/j.jacc.2018.08.1038

2. Agewall S, Beltrame JF, Reynolds HR, Niessner A, Rosano G, Caforio AL, et al. ESC working group position paper on myocardial infarction with non-obstructive coronary arteries. *Eur Heart J*. (2017) 38:143–53. doi: 10.1093/eurheartj/ehw149

3. Tamis-Holland JE, Jneid H. Myocardial infarction with nonobstructive coronary arteries (MINOCA): It's time to face reality! *J Am Heart Assoc*. (2018) 7:e009635. doi: 10.1161/JAHA.118.009635

4. Pasupathy S, Air T, Dreyer RP, Tavella R, Beltrame JF. Systematic review of patients presenting with suspected myocardial infarction and nonobstructive coronary arteries. *Circulation*. (2015) 131:861–70. doi: 10.1161/CIRCULATIONAHA.114.011201

5. Bergamaschi L, Foà A, Paolisso P, Renzulli M, Angeli F, Fabrizio M, et al. Prognostic role of early cardiac magnetic resonance in myocardial infarction with nonobstructive coronary arteries. *JACC Cardiovasc Imaging*. (2024) 17:149–61. doi: 10.1016/j.jcmg.2023.05.016

6. Scalone G, Niccoli G, Crea F. Editor's choice-pathophysiology, diagnosis and management of MINOCA: an update. *Eur Heart J Acute Cardiovasc Care*. (2019) 8:54–62. doi: 10.1177/2048872618782414

7. Smilowitz NR, Mahajan AM, Roe MT, Hellkamp AS, Chiswell K, Gulati M, et al. Mortality of myocardial infarction by sex, age, and obstructive coronary artery disease status in the ACTION registry-GWTG (acute coronary treatment and intervention outcomes network registry-get with the guidelines). *Circ Cardiovasc Qual Outcomes*. (2017) 10:e003443. doi: 10.1161/CIRCOUTCOMES.116.003443

8. Thygesen K, Alpert JS, Jaffe AS, Chaitman BR, Bax JJ, Morrow DA, et al. Fourth universal definition of myocardial infarction (2018). *Eur Heart J*. (2019) 40:237–69. doi: 10.1093/eurheartj/ehy462

9. Collet JP, Thiele H, Barbato E, Barthélémy O, Bauersachs J, Bhatt DL, et al. 2020 ESC guidelines for the management of acute coronary syndromes in patients presenting

without persistent ST-segment elevation. *Eur Heart J*. (2021) 42:1289–367. doi: 10.1093/eurheartj/ehaa575

10. Abdu FA, Liu L, Mohammed AQ, Luo Y, Xu S, Auckle R, et al. Myocardial infarction with non-obstructive coronary arteries (MINOCA) in Chinese patients: clinical features, treatment and 1 year follow-up. *Int J Cardiol*. (2019) 287:27–31. doi: 10.1016/j.ijcard.2019.02.036

11. Bainey KR, Welsh RC, Alemayehu W, Westerhout CM, Traboulsi D, Anderson T, et al. Population-level incidence and outcomes of myocardial infarction with non-obstructive coronary arteries (MINOCA): insights from the Alberta contemporary acute coronary syndrome patients invasive treatment strategies (COAPT) study. *Int J Cardiol*. (2018) 264:12–7. doi: 10.1016/j.ijcard.2018.04.004

12. Williams MJA, Barr PR, Lee M, Poppe KK, Kerr AJ. Outcome after myocardial infarction without obstructive coronary artery disease. *Heart*. (2019) 105:524–30. doi: 10.1136/heartjnl-2018-313665

13. Ballesteros-Ortega D, Martínez-González O, Blancas Gómez-Casero R, Quintana-Díaz M, de Miguel-Balsa E, Martín-Parra C, et al. Characteristics of patients with myocardial infarction with nonobstructive coronary arteries (MINOCA) from the ARIAM-SEMICYUC registry: development of a score for predicting MINOCA. *Vasc Health Risk Manag*. (2019) 15:57–67. doi: 10.2147/VHRM.S185082

14. Jasilionis D, van Raalte AA, Klüsener S, Grigoriev P. The underwhelming German life expectancy. *Eur J Epidemiol*. (2023) 38:839–50. doi: 10.1007/s10654-023-00995-5

15. Tamis-Holland JE, Jneid H, Reynolds HR, Agewall S, Brilakis ES, Brown TM, et al. Contemporary diagnosis and Management of Patients with Myocardial Infarction in the absence of obstructive coronary artery disease: a scientific statement from the American Heart Association. *Circulation*. (2019) 139:e891–908. doi: 10.1161/CIR.0000000000000670

16. Pasupathy S, Tavella R, Beltrame JF. Myocardial infarction with nonobstructive coronary arteries (MINOCA): the past, present, and future management. *Circulation*. (2017) 135:1490–3. doi: 10.1161/CIRCULATIONAHA.117.027666

17. Ibanez B, James S, Agewall S, Antunes MJ, Bucciarelli-Ducci C, Bueno H, et al. 2017 ESC guidelines for the management of acute myocardial infarction in patients presenting with ST-segment elevation: the task force for the management of acute myocardial infarction in patients presenting with ST-segment elevation of the European Society of Cardiology (ESC). *Eur Heart J*. (2018) 39:119–77. doi: 10.1093/eurheartj/ehx393

18. Niccoli G, Scalone G, Lerman A, Crea F. Coronary microvascular obstruction in acute myocardial infarction. *Eur Heart J*. (2016) 37:1024–33. doi: 10.1093/eurheartj/ehv484

19. Doust J, Glasziou P. High-sensitivity troponin highlights the need for new methods to evaluate diagnostic tests. *Circ Cardiovasc Qual Outcomes*. (2018) 11:e004468. doi: 10.1161/CIRCOUTCOMES.117.004468

20. Slagman A, von Recum J, Möckel M, Holert F, Meyer zum Büschenfelde D, Müller C, et al. Diagnostic performance of a high-sensitive troponin T assay and a troponin T point of care assay in the clinical routine of an emergency department: a clinical cohort study. *Int J Cardiol*. (2017) 230:454–60. doi: 10.1016/j.ijcard.2016.12.085

21. Ammann P, Kraus M, Angehrn W, Rickli H, Marschall S, Schmid L, et al. Characteristics and prognosis of myocardial infarction in patients with normal coronary arteries. *Chest*. (2000) 117:333–8. doi: 10.1378/chest.117.2.333

22. Beltrame JF. Assessing patients with myocardial infarction and nonobstructed coronary arteries (MINOCA). *J Intern Med*. (2013) 273:182–5. doi: 10.1111/j.1365-2796.2012.02591.x

23. Pelliccia F, Marzilli M, Boden WE, Camici PG. Why the term MINOCA does not provide conceptual clarity for actionable decision-making in patients with myocardial infarction with no obstructive coronary artery disease. *J Clin Med*. (2021) 10:4630. doi: 10.3390/jcm10204630

24. Lawless M, Appelman Y, Beltrame JF, Navarese EP, Ratcovich H, Wilkinson C, et al. Sex differences in treatment and outcomes amongst myocardial infarction patients presenting with and without obstructive coronary arteries: a prospective multicentre study. *Eur Heart J Open*. (2023) 3:oead033. doi: 10.1093/ehjopen/oead033

25. Mileva N, Paolisso P, Gallinoro E, Fabbricatore D, Munhoz D, Bergamaschi L, et al. Diagnostic and prognostic role of cardiac magnetic resonance in MINOCA: systematic review and Meta-analysis. *JACC Cardiovasc Imaging*. (2023) 16:376–89. doi: 10.1016/j.jcmg.2022.12.029

26. Lopez-Pais J, Izquierdo Coronel B, Galán Gil D, Espinosa Pascual MJ, Alcón Durán B, Martinez Peredo CG, et al. Clinical characteristics and prognosis of myocardial infarction with non-obstructive coronary arteries: a prospective single-center study. *Cardiol J*. (2022) 29:798–806. doi: 10.5603/CJ.a2020.0146

27. Safdar B, Spatz ES, Dreyer RP, Beltrame JF, Lichtman JH, Spertus JA, et al. Presentation, clinical profile, and prognosis of young patients with myocardial infarction with nonobstructive coronary arteries (MINOCA): results from the VIRGO study. *J Am Heart Assoc*. (2018) 7:e009174. doi: 10.1161/JAHA.118.009174

28. Hjort M, Lindahl B, Baron T, Jernberg T, Tornvall P, Eggers KM. Prognosis in relation to high-sensitivity cardiac troponin T levels in patients with myocardial infarction and non-obstructive coronary arteries. *Am Heart J*. (2018) 200:60–6. doi: 10.1016/j.ahj.2018.03.005

29. Agewall S, Giannitsis E, Jernberg T, Katus H. Troponin elevation in coronary vs. non-coronary disease. *Eur Heart J*. (2011) 32:404–11. doi: 10.1093/eurheartj/ehq456

30. Luengo-Fernandez R, Walli-Attaei M, Gray A, Torbica A, Maggioni AP, Huculeci R, et al. Economic burden of cardiovascular diseases in the European Union: a population-based cost study. *Eur Heart J*. (2023) 44:4752–67. doi: 10.1093/eurheartj/ehad583

31. Ambavane A, Lindahl B, Giannitis E, Roiz J, Mendivil J, Frankenstein L, et al. Economic evaluation of the one-hour rule-out and rule-in algorithm for acute myocardial infarction using the high-sensitivity cardiac troponin T assay in the emergency department. *PLoS One*. (2017) 12:e0187662. doi: 10.1371/journal.pone.0187662

32. Dewey M, Rief M, Martus P, Kendziora B, Feger S, Dreger H, et al. Evaluation of computed tomography in patients with atypical angina or chest pain clinically referred for invasive coronary angiography: randomised controlled trial. *BMJ*. (2016) 355:i5441. doi: 10.1136/bmj.i5441

33. DISCHARGE Trial GroupMaurovich-Horvat P, Bosserdt M, Kofoed KF, Rieckmann N, Benedek T, et al. CT or invasive coronary angiography in stable chest pain. N Engl J Med. (2022) 386:1591–602. doi: 10.1056/NEJMoa2200963,

frontiers | Frontiers in Public Health

TYPE Original Research
PUBLISHED 18 November 2024
DOI 10.3389/fpubh.2024.1442304

Check for updates

OPEN ACCESS

EDITED BY
Xiaozhen Lai,
Peking University, China

REVIEWED BY
Emanuel Orozco,
National Institute of Public Health, Mexico
Umit Cirakli,
Izmir Bakircay University, Türkiye

*CORRESPONDENCE
Josue Mbonigaba
✉ mbonigaba@ukzn.ac.za

RECEIVED 01 June 2024
ACCEPTED 16 October 2024
PUBLISHED 18 November 2024

CITATION
Dlamini M and Mbonigaba J (2024) The impact of regional poverty on public health expenditure efficacy across South Africa's provinces: investigating the influence of historical economic factors on health. *Front. Public Health* 12:1442304. doi: 10.3389/fpubh.2024.1442304

The impact of regional poverty on public health expenditure efficacy across South Africa's provinces: investigating the influence of historical economic factors on health

Msawenkosi Dlamini and Josue Mbonigaba*

Department of Economics, University of KwaZUlu-Natal, Durban, South Africa

Introduction/objectives: More than half of South Africa's population lives in poverty, with significant health disparities across different regions. This study investigates the effects of regional poverty and historical economic factors on the efficacy of public health expenditure to understand how socioeconomic contexts influence overall public health outcomes.

Methods: Our study utilized annual data from 2005 to 2019 for 9 provinces, drawing from the General Household Survey, Health Systems Trust database, and National Treasury's Intergovernmental Fiscal Review. The primary health outcome was life expectancy at birth, while public health expenditure *per capita* was the main independent variable. We developed the Provincial Index of Multiple Deprivation to assess poverty, incorporating dimensions such as health, education, and living standards. We employed a two-way fixed effects model to examine the complex relationships between regional poverty, public health spending, and health outcomes.

Results: The study found that poverty levels moderate the impact of public health spending on health outcomes, as evidenced by varying results across different provincial regions. Health outcomes in poorer provinces were less influenced by public health spending than wealthier regions. Additionally, the study established that income *per capita*, along with its lagged values and the lagged values of public health expenditure *per capita*, did not significantly affect health outcomes as measured by life expectancy.

Conclusion/recommendations: The impact of health expenditure in South Africa is influenced by regional poverty levels. To maximize the effectiveness of health spending, equitable, region-specific interventions tailored to address the unique health challenges of each area should be implemented.

KEYWORDS

regional, poverty, health, expenditure, South Africa

1 Introduction

Poverty is a significant challenge in South Africa that profoundly affects the well-being and quality of life of a large portion of the population. Based on the upper-middle income poverty line of R1,499 per person per month, the World Bank estimates the country's poverty rate at 62.2% (1). Furthermore, the extent and severity of poverty vary widely across different regions. These disparities reflect the nation's historical and structural inequalities, particularly affecting rural and underdeveloped areas.

The apartheid system, designed to segregate Black and White populations, was largely responsible for the significant socioeconomic disparities closely tied to regional inequalities in South Africa (2). During apartheid, Black South Africans were forcibly relocated to underdeveloped rural areas known as homelands or Bantustans, while white South Africans resided in well-developed urban centers (3). Consequently, wealthier provinces were predominantly home to white populations, while most black South Africans resided in poorer provinces. Urban areas benefited from extensive infrastructure and resources. However, the demand for labor in cities led to the creation of informal urban settlements for Black workers, as apartheid laws prohibited racial integration in urban residential neighborhoods (4). In rural regions, land governance varied: Some areas were controlled by traditional chiefs, where land was communally held and private ownership was restricted (5); other rural areas followed conventional governance systems, allowing for private ownership of key assets such as land (5). This divergence in governance structures contributed to stark differences in socioeconomic development across rural regions. These regional and socioeconomic disparities, deeply rooted in apartheid policies, have persisted post-apartheid, maintaining an uneven distribution of wealth and resources across different municipalities and provinces in South Africa (6).

Widespread poverty creates significant health challenges, limiting access to essential items such as proper nutrition, sanitation, and healthcare. This deprivation heightens vulnerability to infectious diseases, chronic conditions, and the hazards associated with violence and accidents (7). Poverty also shapes health behaviors, often resulting in low awareness and diminished demand for healthcare and preventive services (8). As a result, poverty exacerbates health problems and hinders the achievement of optimal health outcomes.

In this context, public health expenditure is vital in influencing health outcomes. However, its effectiveness varies across South Africa's diverse socioeconomic landscape, with regional poverty levels and other factors affecting the demand for and the supply of health services (9). This raises important questions about the equitable distribution and impact of public health resources in these regions.

Bidzha analyzed data from the South African Demographic and Health Survey to examine the impact of public health expenditure on health outcomes at the provincial level between 2002 and 2012 (10). The study focused on four key health indicators: the infant mortality rate, the child and maternal mortality ratios, and life expectancy at birth. The study employed pooled OLS fixed effects (FE) and random effects (RE) models to examine these relationships. The findings revealed a significant relationship between public health expenditure and only two health outcomes: infant mortality rate and life expectancy at birth.

Hlafa et al. employed data from the Health Systems Trust (HST) to investigate the relationship between public health expenditure and health outcomes across South Africa's nine provinces from 2002 to 2016 (9). The study measured health outcomes using the under-five mortality rate and life expectancy at birth. The authors employed fixed effects (FE) and random (RE) estimation techniques to analyze the data, accounting for time effects and provincial heterogeneity. The results revealed a positive relationship between public health expenditure and health outcomes, although the strengths of these outcomes varied across provinces.

Makuta and O'Hare (11) carried out a comparative analysis of the relationship between public health expenditure and health outcomes in sub-Saharan Africa from 1996 to 2011, utilizing data sources such as the World Bank, United Nations Development Program, and the World Health Organization. Health outcomes were measured through life expectancy at birth and the mortality rate of those under five. The analysis employed two-stage least squares, controlling for income and education. The study also investigated the interaction between public health expenditure and governance quality to assess whether governance moderated the impact of health expenditure on health outcomes. The findings revealed that public health expenditure positively and significantly affected health outcomes, with improved governance further amplifying this effect.

Similarly, Bunyaminu et al. investigated how health expenditure affects life expectancy in a panel of 43 African countries from 2000 to 2018 (12). The study used data from various sources, such as the World Bank, the United Nations Development Program, and the World Health Organization, to measure health expenditure, life expectancy, and government effectiveness. A dynamic panel generalized method of moments(GMM) estimation technique was applied to control for unobserved heterogeneity and endogeneity in the panel model. The researchers found that health expenditure positively impacts life expectancy. The findings revealed that health expenditure positively affected life expectancy, with government effectiveness further enhancing this relationship.

A common limitation of these studies is the lack of a detailed analysis of regional poverty levels and their impact on public health expenditure's efficacy. They also overlook historical economic factors, such as past income levels and investments, which shape current health outcomes through access to healthcare, education, sanitation, and housing.

Our argument is supported by Francis and Webster's study, which explored the interplay between historical economic factors and health outcomes in South Africa by analyzing how poverty, inequality, and health are interconnected and influenced by historical elements like colonialism and apartheid (13). These factors have not only exacerbated poverty and inequality but also impacted health, creating a mutually reinforcing cycle that has worsened over time. However, the study's limitation lies in its methodology: it employed a qualitative and historical approach utilizing broad historical categories for analysis rather than a multivariate analysis to pinpoint the specific impacts of these historical economic factors on health outcomes.

Our study aims to address these gaps by investigating the impact of regional poverty on the relationship between public health expenditure and health outcomes across South Africa's provinces. We also explore the potential delayed effects of public health spending and income *per capita*, offering a more nuanced understanding of the factors influencing health in South Africa.

2 Theoretical foundation

2.1 The Grosman model

Our study builds on the Grossman model (14) to examine the complex relationship between public health expenditure, health, and poverty, focusing on South Africa's provinces. The model is a pivotal contribution to the economic analysis of health and healthcare, as it treats health as both a consumption and an investment good. It posits that individuals demand healthcare to increase their stock of health capital, enhancing their utility and productivity.

The model assumes that health capital depreciates over time and that individuals can invest in health through medical care and other inputs to maintain or improve their health status (15). It also implies that the optimal level of health depends on the individual's preferences, income, and the prices of health inputs.

2.2 Limitations of the Grossman model

However, the Grossman model has some limitations and challenges, especially when applied to a developing country like South Africa. First, the model is based on a micro-level perspective that focuses on individual choices and outcomes, ignoring the macro-level factors that affect the supply and quality of health services, such as public health expenditure, health system performance, and governance. Second, it does not account for the heterogeneity and diversity of the population and regions, such as differences in income, poverty, and health needs across the provinces.

Third, the model does not consider economic factors' dynamic and lagged effects on health outcomes, such as the impact of past income and public health expenditure on current health status through various intermediary factors. Therefore, a more comprehensive and nuanced theoretical framework is needed to address these limitations and challenges and capture the multifaceted relationship between public health expenditure, health, and poverty in South Africa.

2.3 Theoretical framework and hypotheses

Our study aimed to develop a framework by adapting and extending the Grossman model from its original micro-level focus to a broader macro-level approach. This adaptation was tailored to South Africa, incorporating additional variables and mechanisms. We shifted the focus from individual health outcomes to the provincial level, assessing the aggregate and comparative effects of public health expenditure and poverty across South Africa's nine provinces, as captured by Equation 1:

$$\textit{Health outcome} = h\left(\begin{array}{l}\text{income, public health expenditure, poverty,}\\ \text{public health expenditure} * \text{poverty,}\\ \text{lagged public health expenditure,}\\ \text{lagged income}\end{array}\right) \quad (1)$$

Increased provincial income levels could significantly advance human development and economic growth in South Africa. Higher-income levels could lead to increased consumer spending, investment in local businesses, and improved access to education and healthcare (16). Enhanced economic activity and development could foster improved living conditions, create more employment opportunities, and increase public health funding. Collectively, these factors would thus contribute to improved overall health and well-being by providing access to essential health services, reducing health issues, and improving living standards.

Central to our framework is considering public health expenditure as a crucial variable influencing health outcomes alongside income. Public health expenditure reflects the government's *per capita* investment in health services, which is crucial to improving the availability, accessibility, and quality of healthcare. This investment directly affects the provision of healthcare services. It indirectly influences health outcomes by shaping the overall health system. Such expenditure contributes to developing and maintaining medical facilities, training healthcare professionals, and implementing public health initiatives. Improving these areas leads to more effective medical care, better preventive measures, enhanced health education, and a stronger healthcare infrastructure, all essential to improving the population's health.

Our study also analyzed regional poverty levels in our adapted model, as these are indicators of various socioeconomic and environmental factors that significantly impact health in different provinces, including nutrition, sanitation, living conditions, and pollution. The multifaceted nature of poverty often leads to a challenging cycle of adverse health outcomes (8). Due to their exposure to adverse socioeconomic and environmental conditions, individuals living in poverty are typically more susceptible to a range of diseases and health complications.

A key aspect of our study is how regional poverty levels might influence the relationship between public health expenditure and health outcomes. This is particularly relevant as impoverished areas will likely have higher healthcare needs than wealthier regions. For example, in poorer regions such as the Eastern Cape, where poverty rates are high, there may be increased demand for public health services like basic healthcare and infectious disease management. Conversely, regions like Gauteng, with higher average income levels, might have different health priorities and expenditure patterns, such as a greater focus on preventive care and chronic disease management. Given these contrasting scenarios, analyzing the interaction between poverty levels and public health expenditure is crucial, as this significantly shapes each province's health needs and outcomes.

Furthermore, our study integrated an analysis of the potential delayed effects of public health expenditure and income on health outcomes in our model. This is based on the understanding that the impact of these economic factors might not manifest immediately but could be mediated over time through various factors (17). These intermediary factors act as channels through which past economic activities may influence current health outcomes.

Based on our theoretical framework, which is illustrated in Figure 1 below, our study aimed to test the following hypotheses:

> *H*1: Poverty levels reduce the effect of public health expenditure on health outcomes.

The hypothesis is formulated based on the observation that regions with higher poverty levels could experience more adverse

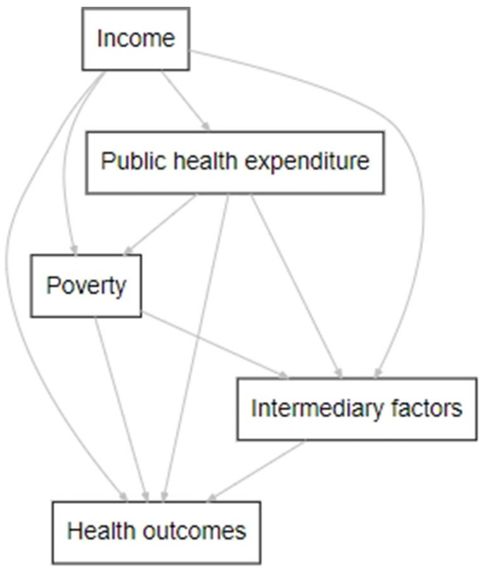


FIGURE 1
The relationship between public health expenditure, health, and poverty. This figure represents the main variables (nodes) and hypothesized effects (egde) and is the author's work. It was created using DiagrammeR in R. The direction and strength of these effects will be tested empirically.

health outcomes due to poverty compared to wealthier regions, potentially negatively affecting health spending. Consequently, we anticipated variations in this influence across South Africa's diverse provinces and sought to empirically assess how these differing poverty levels interact with public health expenditure.

> *H2*: Historical economic factors, measured by the lag values of income *per capita* and public health expenditure *per capita*, differently impact regional health outcomes.

This hypothesis stemmed from the assumption that economic conditions and health investment in previous years could have lasting effects on the current health status of a population (17).

The following section outlines the empirical approach to test these hypotheses, providing deeper insights into the relationship between public health expenditure, health, and poverty in South Africa.

3 Materials and methods

3.1 Data

Our study utilized annual data from 2005 to 2019, sourced from various databases, including the General Household Survey (GHS), the Health Systems Trust (HST), and annual reports such as the National Treasury's Intergovernmental Fiscal Reviews. Table 1 presents the relevant variables and their description. After collecting the necessary information for each province, we merged the data into a single dataset and analyzed the provincial level.

Throughout the analysis, our dependent variable was life expectancy at birth, and the primary independent variable under consideration was public health expenditure *per capita*. We opted for public health expenditure *per capita* over total public health expenditure because our dependent variable was life expectancy. As explained in the table above, public health expenditure *per capita* represents the average monetary amount allocated to healthcare for each individual within a population. Consequently, higher *per capita* public health expenditure can lead to improved health outcomes and an increase in the population's life expectancy. This measure establishes a direct link between the healthcare resources available for each person and their corresponding health outcomes, as indicated by life expectancy.

The next section outlines the methodology used to examine how regional poverty levels affect public health expenditure and influence health outcomes across South Africa's provinces.

3.2 Empirical methods of estimation

This study builds on the methodological approaches of Hlafu et al. (9) by introducing three distinct models, all of which use life expectancy at birth as the dependent variable. The first model focuses on developing the PIMD, drawing inspiration from Noble et al. (18). we employed data from the GHS from 2005 to 2019. The PIMD was designed to capture various dimensions of deprivations faced by individuals, encompassing five critical domains: health, education, standard of living, income, and material deprivation.

Traditional poverty measures, such as income or expenditure, are effective for measuring absolute poverty but fail to capture its multifaceted nature. The PIMD provide a more comprehensive assessment of poverty levels across South Africa's provinces, transcending conventional money-based metrics. Our primary goal in constructing the PIMD was to capture deprivation consistently over time by selecting indicators from the GHS available from 2005 to 2019.

For example, in the health domain, we used the variable indicating whether an individual receives a disability grant. This measure was chosen because receiving the grant requires a significant health impairment, reflecting the prevalence of health-related deprivation. Households were considered deprived in this domain if at least one member received a disability grant.

In line with the study's objectives, which mirror the domains in the South African Multidimensional Poverty Index (SAMPI), we incorporated another indicator in the standard of living: the type of fuel used for cooking. This indicator assesses poverty levels by identifying households that rely on basic and potentially hazardous materials such as wood, coal, paraffin, or animal dung for cooking. Dependence on these fuels signals a lower standard of living and limited access to modern amenities, qualifying such a household as deprived in this domain. Table 2 presents a comprehensive overview of all the domains, indicators, and thresholds we employed in constructing the PIMD, ensuring a thorough and nuanced measurement of poverty. The deprivation headcounts for each indicator, calculated using GHS data for each province from 2005 to 2019, are presented in Supplementary material (Tables 17–25).

Also integral to this specification is the weighting stage, a crucial aspect of our process that determines the relative importance of each dimension and indicator in assessing the poverty experienced by households in these provinces. In line with the methodology used in the SAMPI and acknowledging

TABLE 1 Description of variables used in the study.

Variable	Description	Categories/values	Used in PIMD
Life expectancy at birth	Represents the average number of years a newborn can expect to live based on current mortality rates.	Life expectancy values for both sexes across all provinces in South Africa.	NO
Provinces	Refers to the different administrative regions within South Africa.	Eastern Cape, Free State, Gauteng, KwaZulu-Natal, Limpopo, Mpumalanga, Northern Cape, North-West, Western Cape.	YES
Public Health Expenditure	Represents total government spending on healthcare services per province.	Continuous	NO
Public Health Expenditure *per capita*	Calculated as total public health expenditure divided by the population of the province.	Continuous	NO
Income *per capita*	Calculated as the GDP in constant prices of each province divided by the size of each province's population	Continuous	NO
Population Growth rate	Calculated as the percentage difference between the current and previous population.	Continuous	NO
HIV Prevalence	Represents the percentage of the population aged 15–49 estimated to be HIV-positive per province.	Continuous	NO
Female literacy Rate	It represents the percentage of women aged 15 and above who can read and write a short, simple statement with understanding per province.	Continuous	NO
Disability Grant	Indicates whether individuals reported receiving a disability grant.	1: Yes, 2: No	YES
The highest level of education attained	Represents the highest level of education attained by individuals.	Levels of education range from primary (0–8) to high school (8–18), and post-high school qualification (19–24).	YES
Access to Electricity	Indicates whether a household has access to electricity.	1: Yes, 2: No	YES
Fuel for cooking	Represents the type of fuel households use for cooking.	1: Electricity from mains, 2: Electricity from generator, 3: Gas, 4: Paraffin, 5: Wood, 6: Coal, 7: Animal dung, 8: Solar energy.	YES
Access to water	Indicates whether households have access to piped water.	1: Yes, 2: No	YES
Sanitation type	Represents the type of toilet facility used by households.	This ranges from flush toilets (connected to mains or septic tanks) to chemical toilets, pit latrines (with or without ventilation), and bucket toilets. Each can be located in the dwelling, on-site, or offsite.	YES
Housing quality	Represents the type of region in which households reside.	1: Urban formal, 2: Urban informal, 3: Traditional areas, 4: Rural formal.	YES
Asset ownership	A composite variable of several asset variables, including a radio, refrigerator, television, telephone, and car, determines a household's asset ownership.	1: radio, 2: refrigerator, 3: television, 4: telephone, 5: car.	YES
Unemployment	The official criteria define the unemployment rate per province.	Continuous	YES

that, despite their unique characteristics and challenges, the provinces share fundamentally similar socioeconomic structures, our study implemented a nested weighting system. This entails weighing all domains equally and assigning equal weights to the indicators within each domain.

Table 3 summarizes the details of the weighting structure we employed. The Health and Education indicators are each assigned a weight of 1/4, underscoring their critical role in comprehending the poverty landscape across the provinces. Furthermore, aligned with the SAMPI approach, our study introduced an additional income and material deprivation indicator. This is represented by the Unemployment indicator, which carries a weight of 1/8. Its inclusion is particularly pertinent given its significant impact on income deprivation and material hardship. It thus enhances the index's robustness and sensitivity, providing a more thorough depiction of poverty's multifaceted nature.

Considering that, we multiplied the calculated rates (see Tables 17–25 in Supplementary material) by their respective weights and combined them to compute a composite score for each province each year. The final step in our specification was to standardize these combined scores, assigning values within a range of 0 to 10. On this scale, zero indicates the least deprived area, and 10 indicates the most deprived area. This facilitates a clear, scaled representation of deprivation levels across the provinces.

TABLE 2 Domains, associated indicators, and thresholds of deprivation in the PIMD.

Domain	Indicator	Threshold
Health	Disability Grant	A household is considered deprived in this dimension if at least one member receives a disability grant due to his/her inability to work.
Education	The highest level of education attained	Individuals with less than 5 years' (Grade 4) formal schooling are considered deprived.
Standard of living	Access to Electricity	Households marked as 'No' for having electricity are considered deprived.
	Fuel for cooking	Households using wood, coal, paraffin, or animal dung for cooking are considered deprived.
	Access to water	Households without access to piped water in the dwelling are considered deprived.
	Sanitation type	Households without a flush toilet in the dwelling are considered deprived.
	Housing quality	Households living in informal areas or traditional authority areas are considered deprived.
Income and material deprivation	Asset ownership	A household that does not own more than one radio, refrigerator, television, telephone, or car is considered deprived.
	Unemployment	Households are considered deprived if all adults (aged 15 to 64) are unemployed.

In the second specification, we utilized the PIMD figures derived from the previous specification to explore whether regional poverty levels affect the relationship between public health expenditure and overall health across South Africa's provinces. The study employed the two-way FE model and the subsequent specification to accomplish this. The use of this model is advantageous in this context as it enables control over time-invariant regional characteristics and common time effects. This methodological choice ensures a more nuanced and precise analysis of the intricate interplay between public health spending, regional poverty, and health outcomes.

To implement this approach, our two-way FE model was estimated using Equation 2:

$$\begin{aligned} LE_{it} &= \beta_0 + \beta_1 \ln\left(\frac{PHE}{pop}\right)_{1it} + \beta_3 \ln\left(PIMD\right)_{3it} \\ &+\beta_4 \ln\left(GDP\ per\ capita\right)_{4it} + \beta_5 \ln\left(PGR\right)_{5it} \\ &+\beta_6 \ln\left(FLR\right)_{6it} + \beta_7 \ln\left(\text{HIV}\right)_{7it} + \beta_8\left(GP * \frac{PHE}{pop} * PIMD\right)_{8it} \\ &+\beta_9\left(WC * \frac{PHE}{pop} * PIMD * \frac{PHE}{pop} * PIMD\right)_{9it} \\ &+\beta_{10}\left(NW * \frac{PHE}{pop} * PIMD\right)_{10it} + \beta_{11}\left(KZN * \frac{PHE}{pop} * PIMD\right)_{11it} \\ &+\beta_{12}\left(MP * \frac{PHE}{pop} * PIMD\right)_{12it} + \beta_{13}\left(LP * \frac{PHE}{pop} * PIMD\right)_{13it} \\ &+\beta_{14}\left(FS * \frac{PHE}{pop} * PIMD\right)_{14it} + \beta_{15}\left(NC * \frac{PHE}{pop} * PIMD\right)_{15it} \\ &+f_t + \varepsilon_{it} \end{aligned} \tag{2}$$

In Equation 2, life expectancy at birth is the dependent variable, measured for each province (i) at time (*t*). The independent variables include the logarithms of the following: public health expenditure *per capita*, GDP *per capita* to estimate income, the population growth rate, the female literacy rate, and the HIV prevalence rate, all specific to each province. Utilizing logarithmic transformations for these variables linearizes their relationships with life expectancy. This creates a more interpretable model that translates effects into percentage changes, accounting for potential skewness in the data distributions.

The PIMD is also included in its original form, specific to each province and period, providing a nuanced view of poverty. Furthermore, Equation 2 included variables to capture time effects (f_t), which is crucial as it allows the model to account for temporal trends and variations, thereby improving the accuracy and relevance of the findings in a dynamic socioeconomic context (Imai and Kim).

A significant aspect of Equation 2 includes an interaction term between *per capita* public health expenditure, the PIMD, and the provincial dummy variables. This was crucial as it provided insight into how regional poverty levels influenced changes in provincial public health expenditure between 2005 and 2019, compared to the changes experienced by the reference category, namely the Eastern Cape province. It was essential to understand the varying impacts of poverty levels across provinces.

The final specification involved re-estimating Equation 2, but with a key difference: it used lagged values of public health expenditure *per capita* and GDP *per capita* as explanatory variables. This modification was designed to test the possibility that past economic activity could significantly impact the current health status of the population. To conduct this Analysis, we employed an equation similar in structure to Equation 3, adapting it to reflect the influence of these historical economic factors.

$$\begin{aligned} LE_{it} &= \beta_1 \ln\left(GDP\ per\ capita\right)_{i,t-1} + \beta_2 \ln\left(GDP\ per\ capita\right)_{i,t-2} \\ &+\beta_3 \ln\left(\frac{PHE}{pop}\right)_{i,t-1} + \beta_4 \ln\left(\frac{PHE}{pop}\right)_{i,t-2} + +\beta_5 \ln\left(GDP\ per\ capita\right)_{5it} \\ &+\beta_6 \ln\left(PGR\right)_{6it} + \beta_7\left(FLR\right)_{7it} + \beta_8 \ln\left(\text{HIV prevalence}\right)_{8it} \\ &+\beta_9\left(PIMD * \frac{PHE}{pop} * PIMD\right)_{9it} + \beta_{10}\left(GP * \frac{PHE}{pop} * PIMD\right)_{10it} \\ &+\beta_{11}\left(WC * \frac{PHE}{pop} * PIMD\right)_{11it} + \beta_{12}\left(NW * \frac{PHE}{pop} * PIMD\right)_{12it} \\ &+\beta_{13}\left(KZN\right)_{13it} + \beta_{14}\left(MP\right)_{14it} + \beta_{15}\left(LP * \frac{PHE}{pop} * PIMD\right)_{15it} \\ &+\beta_{16}\left(FS * \frac{PHE}{pop} * PIMD\right)_{16it} + \beta_{17}\left(NC * \frac{PHE}{pop} * PIMD\right)_{17it} \\ &+f_t + \varepsilon_{it} \end{aligned} \tag{3}$$

Researchers such as Schultz et al. and Ullah et al. posited that incorporating two lags of the independent variables is sufficient to account for the delayed effects of income and public health expenditure (17, 19). Considering this, we included two lags of each variable in our Analysis, as indicated in Equation 3. This allows us to examine the potential impact of past economic activity on population health, providing a more comprehensive understanding of the temporal dynamics.

Lastly, when interpreting the results from a two-way FE model, it is essential to understand that the process involves more than just determining the direction of the coefficients; their magnitude is equally important as it quantifies the extent and significance of the impact of each variable (20). This provides crucial insights into these variables' practical and measurable influence on the dependent variable. We used R software as the primary computational tool to facilitate this Analysis.

We present a detailed discussion of the statistical findings considering these methodological considerations.

TABLE 3 Indicators and their weights.

Domain	Indicator	Weight
Health	Disability Grant	1/4
Education	The highest level of education attained	1/4
Standard of Living	Access to Electricity	1/20
	Fuel for cooking	1/20
	Access to water	1/20
	Sanitation type	1/20
	Housing quality	1/20
Income and material deprivation	Asset ownership	1/8
	Unemployment	1/8

4 Results

4.1 Descriptive statistics

This section describes the study's main variables: public health expenditure, public health expenditure *per capita*, life expectancy, income *per capita*, and poverty. We use different methods to compare these variables across South Africa's nine provinces and examine their trends over time.

4.1.1 Public health expenditure

There has been a significant increase in South Africa's public health expenditure over the past decade, primarily focusing on improving access to healthcare among previously disadvantaged populations. This is evident in the data presented in Figure 2, which shows a clear and consistent increase across all provinces and years. Gauteng and KwaZulu-Natal consistently emerge as the top spenders during these 14 years. In 2005, Gauteng allocated R11.12 billion, and KwaZulu-Natal spent R11.66 billion, reflecting substantial financial commitments. By 2019, Gauteng's expenditure had surged to R50.67 billion, while KwaZulu-Natal's had risen to R45.23 billion.

Mpumalanga occupies a middle ground in terms of growth. From health expenditure of R3.013 billion in 2005, it experienced steady growth, reaching R14.259 billion in 2019, representing an increase of approximately R11.246 billion over 14 years. While not as substantial as the growth in provinces like Gauteng or KwaZulu-Natal, this signifies a significant commitment to enhancing public healthcare services in Mpumalanga. At the other end of the spectrum, the Northern Cape showed consistently lower levels of public health

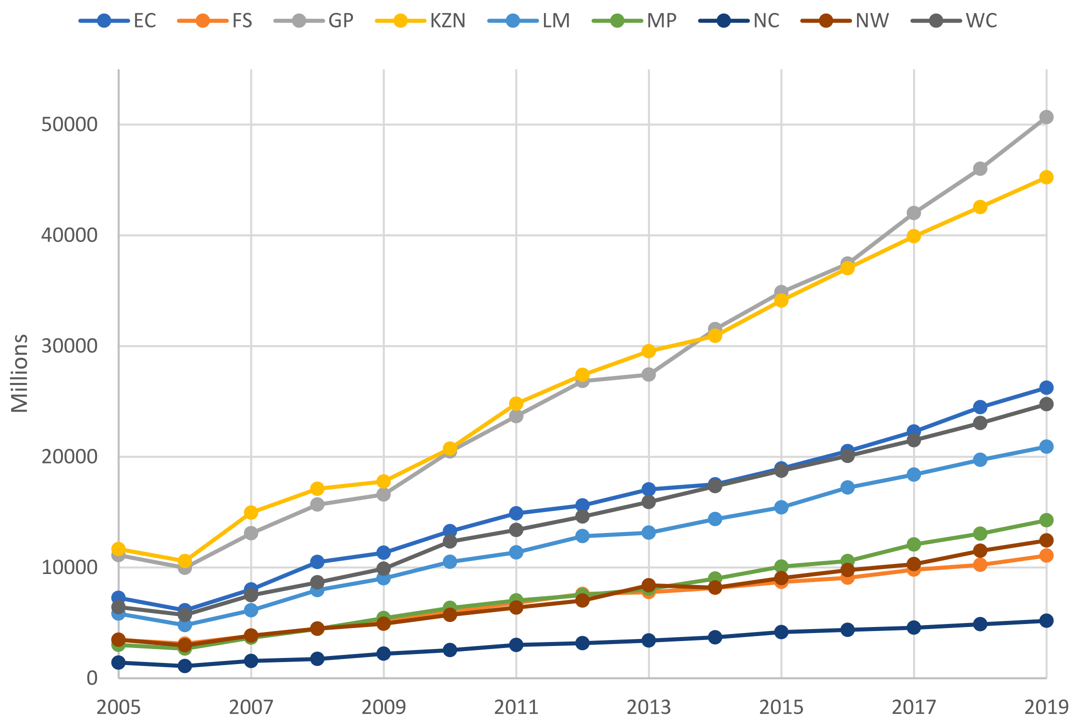


FIGURE 2
Trends in public health expenditure by province (2005–2019). *This figure is the author's work and was compiled using the National Treasury's provincial database data.

expenditure. From 2005 to 2019, its spending on healthcare remained relatively stable yet modest compared to other provinces. The budget allocation started at R1.41 billion in 2005 and increased to R5.18 billion in 2019, indicating a modest growth trajectory.

The increase in public health expenditure across South Africa's provinces indicates an upward trend in healthcare funding. This may have implications for health outcomes, warranting further exploration. In subsequent analysis, we investigate the potential impact of these expenditure patterns on life expectancy across various provinces, examining the data to discern any correlations or trends.

4.1.2 Life expectancy trends across provinces

Building on our understanding of public health expenditure trends, we now shift our focus to the corresponding changes in life expectancy, where, as illustrated in Figure 3, we observe distinct patterns across the provinces.

The Western Cape maintained the highest life expectancy, increasing from 64 to 65 years between 2005 and 2019. While this is a modest increase, it indicates improved healthcare and living conditions in the Western Cape. Notably, this province's life expectancy aligns with its position among the top provinces regarding public health expenditure (see Figure 2).

Gauteng saw a notable increase in life expectancy, from 57 years in 2005 to 62 years in 2019. This positions it among the top three provinces in terms of life expectancy by around 2018, closely following the Western Cape and Limpopo. The increase in Gauteng's life expectancy over this period indicates progress in healthcare and overall living conditions within the province.

Despite recording the lowest public health expenditure among all the provinces, the Northern Cape has achieved one of the highest increase in life expectancies, from 53 to 61 years between 2005 and 2019, surpassing five other provinces. In contrast, KwaZulu-Natal, the second-largest spender on public health, recorded the lowest life expectancy. In 2005, life expectancy in this province was 48 years, increasing to 57 years by 2019. This intriguing disparity between provinces' expenditure and life expectancy outcomes suggests that factors beyond public health expenditure significantly influence life expectancy in these regions.

The life expectancy data for South Africa's provinces over 14 years reveal notable disparities in health outcomes. While some provinces, such as the Northern Cape, showed significant improvement, others experienced only marginal increases. These variations suggest a complex pattern rather than a uniformly clear upward trend, reflecting diverse levels of improvement in healthcare and living conditions. This nuanced picture underscores the ongoing need for targeted efforts to address regional disparities in access to quality healthcare, ensuring equitable health improvements across all provinces.

Closer examination is required to enhance our understanding of the connection between public health expenditure and life expectancy. The following section presents summary statistics on these variables, offering a deeper perspective on this relationship.

4.1.3 Summary statistics of life expectancy and public health expenditure *per capita*

To deepen our analysis, this section presents a comprehensive summary of statistical data on life expectancy and public health expenditure *per capita* across the provinces. The remainder of the analysis focuses on public health expenditure *per capita*, as it provides a more accurate reflection of individual resource allocation and its impact than aggregate spending.

Table 4 presents the summary statistics of each province's life expectancy and public health expenditure *per capita*. The table shows life expectancy's average, minimum, maximum, and standard deviation. The data highlights significant disparities in average life expectancy, ranging from 53 years in KwaZulu-Natal to 64 years in the Western Cape.

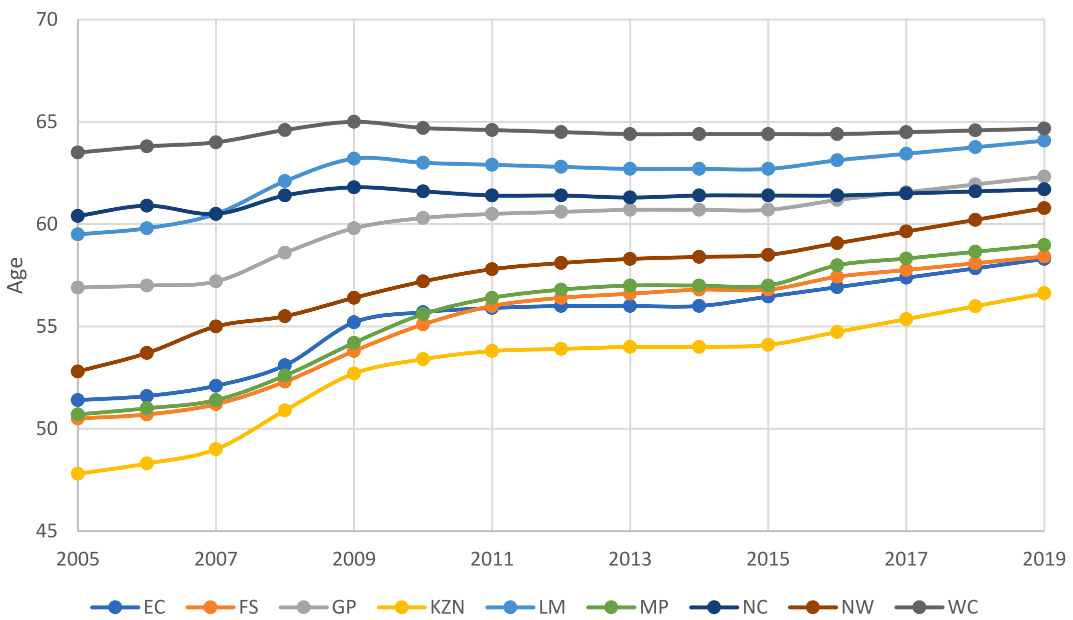


FIGURE 3
Trends in Life Expectancy by province (2005–2019). *This figure is the author's work and was compiled using data from the Health Barometers published by the Health Systems Trust.

These disparities underscore the substantial variations in health outcomes among provinces, with standard deviations indicating the degree of variability within each region. While the Western Cape reports the highest average life expectancy, it also displays the lowest standard deviation, suggesting a more consistent life expectancy distribution. Conversely, provinces like KwaZulu-Natal exhibit lower average life expectancy and higher standard deviations, signaling greater variations in health outcomes. These findings are supported by Figure 3 above.

An analysis of public health expenditure *per capita* reveals significant diversity across provinces. Gauteng leads with an average expenditure of R3,084 (see Figure 2), closely followed by the Western Cape at R3,423. In contrast, despite ranking second in aggregate expenditure, KwaZulu-Natal falls fifth in public expenditure *per capita*. This discrepancy can be attributed to the province's distinct health needs and the fact that it is the second-largest province in South Africa (21).

On the lower end of the scale, the Eastern Cape and Mpumalanga report the lowest average public health expenditure *per capita*, at R2,888 and R2,291, respectively. This contrasts with their rankings based on aggregate expenditure. Similar to KwaZulu-Natal, larger populations and distinct health needs in these provinces could explain the discrepancies observed between Figure 2 and Table 4. Furthermore, the range of public health expenditure *per capita* across provinces is substantial. For example, Gauteng's maximum *per capita* allocation reached R4,910, while the Eastern Cape's minimum spending was as low as R2,054 between 2005 and 2019. This wide variation is also reflected in the standard deviation, highlighting disparities in resource allocation among the provinces.

This section explored summary statistics of life expectancy and public health expenditure by province, revealing disparities in resource allocation. The following section examines (YOY) percentage changes to investigate the impact of economic factors on health status and deepen our understanding of these relationships.

4.1.4 Annual trends in health and economic indicators

This section examines annual health and economic indicators trends across various provinces, using year-on-year percentage changes (YoY). These proved a valuable analytical tool, providing insights into the dynamic relationship between historical economic factors such as public health expenditure and income *per capita* and the overall health status within these regions. Our objective was to determine the nature of the relationship between these variables and life expectancy at birth, specifically whether it was non-existent, positive, or negative.

To maintain clarity and focus within the primary results section, we provide the YoY percentage change for provinces with the highest (Gauteng), median (Limpopo), and lowest (Northern Cape) public health expenditure. Detailed data for the other provinces can be found in Supplementary material.

Table 5 presents the annual trends in life expectancy, *per capita* public health expenditure, and *per capita* income in Gauteng, highlighting the YoY percentage changes. The changes reveal the interconnectedness of these factors and their potential impact on health outcomes. Gauteng has consistently improved life expectancy, mainly reflecting positive YoY changes. However, a noteworthy observation in this table is the substantial increase in life expectancy in 2008, marked by a YoY change of 2.45%. This shift suggests that investment in public health expenditure and income in the preceding year may have positively influenced health outcomes, emphasizing the importance of consistent healthcare spending in enhancing life expectancy.

The data highlights varying trends in public health expenditure *per capita* over time, with a significant rise of 18.19% in 2006. Interestingly, the same year marked the highest annual increase in *per capita* income, showing a remarkable surge of 592.73%. Such variations in these economic factors could influence the accessibility and quality of healthcare services, potentially impacting life expectancy in this province.

However, it is important to note that these economic fluctuations did not immediately reflect in the YOY percentage change in life expectancy for that year or the subsequent one. As noted previously, the effect primarily became evident in 2008. This might suggest a two-year lag in the influence of economic factors working through the intermediaries mentioned earlier, or other factors could have contributed to the surge in life expectancy in 2008.

Moving to Table 6, which shows annual trends in life expectancy, public health expenditure *per capita*, and income *per capita* in the Northern Cape, a notable observation is substantial fluctuations in life

TABLE 4 Summary statistics of life expectancy and public health expenditure by province.

	Average life expectancy	Min life expectancy	Max life expectancy	Std dev life expectancy	Average public health expenditure *per capita*	Min public health expenditure *per capita*	Max public health expenditure *per capita*	Std dev public health expenditure *per capita*
EC	55	51	58	2.23	2,888	2054	4,137	680.85
FS	55	51	58	2.78	3,047	1,192	4,790	1156.13
GP	60	57	62	1.76	3,084	1,385	4,910	1122.02
KZN	53	48	57	2.74	2,982	1,591	4,436	922.64
LP	62	60	64	1.38	2,450	1,186	3,667	792.02
MP	56	51	59	2.87	2,291	1,231	3,376	677.84
NC	61	60	62	0.41	3,353	862	5,839	1583.09
NW	57	53	61	2.33	2,338	949	3,659	866.81
WC	64	64	65	0.38	3,423	1,515	5,333	1207.26

*These categorizations are calculated using our data sourced from publications by the National Treasury and the Health Systems Trust.

TABLE 5 Annual trends in life expectancy and public health expenditure in Gauteng.

Year	YoY change in life expectancy	YoY change in public health expenditure *per capita*	YoY change in income *per capita*
2005			
2006	0,18	18,19	592,73
2007	0,35	15,39	−42,22
2008	2,45	13,34	−32,32
2009	2,05	11,77	44,01
2010	0,84	4,10	90,26
2011	0,33	15,74	−91,24
2012	0,17	5,24	−8,98
2013	0,17	0,46	4,93
2014	0,00	9,52	−0,17
2015	0,00	16,96	39,62
2016	0,79	6,45	−26,97
2017	0,62	6,06	32,89
2018	0,62	5,71	17,60
2019	0,61	5,41	12,69

*The author's data was used to calculate YOY percentage changes, following the formula: percentage difference between the current and previous year's values, divided by the previous year's value, multiplied by 100.

TABLE 6 Annual trends in life expectancy and public health expenditure in Northern Cape.

Year	YoY change in life expectancy	YoY change in public health expenditure *per capita*	YoY change in income *per capita*
2005			
2006	0,83	41,25	−92,48
2007	−0,66	29,20	518,29
2008	1,49	22,60	−30,67
2009	0,65	18,43	37,31
2010	−0,32	17,77	92,46
2011	−0,32	14,57	−13,86
2012	0,00	10,09	−8,13
2013	−0,16	8,04	−89,59
2014	0,16	7,50	973,15
2015	0,00	12,10	37,52
2016	0,00	8,05	−28,39
2017	0,16	7,43	33,70
2018	0,16	6,91	−88,23
2019	0,16	6,47	11,79

*The author's data was used to calculate YOY percentage changes, following the formula: percentage difference between the current and previous year's values, divided by the previous year's value, multiplied by 100.

expectancy. In 2007, a sharp negative YoY change of −0.66% indicates a decline in life expectancy. However, in 2008, the Northern Cape experienced the highest positive YoY percentage change, with a figure of 1.49%, suggesting that investment in public health or income in that year or the preceding year(s) may have positively influenced health outcomes, akin to the findings for Gauteng.

Furthermore, the YoY changes in public health expenditure *per capita* reveal considerable volatility, especially in 2007 (29.20%) and 2008 (22.60%), reflecting instability in the allocation of healthcare resources, which can influence healthcare investment for the population in this province.

Regarding *per capita* income in the Northern Cape, 2014 is particularly notable for its extraordinary surge, showing a YOY change of 973.15%. While this indicates improved economic conditions, the data does not readily reveal its immediate impact on life expectancy. Further Analysis may be needed to understand why this specific change in income *per capita* did not translate into improved health in that year or the subsequent year.

Lastly, Table 7 shows the annual trends in life expectancy, public health expenditure *per capita*, and income *per capita* in Limpopo province. Similar to the patterns observed earlier, the most notable increase occurred in 2008, with a substantial YoY change of 2.64%, implying that economic factors in that particular year, along with historical ones, may have played a role in fostering consistent improvements in life expectancy across most of South Africa's provinces.

As corroborated by Figure 3, public health expenditure *per capita* in Limpopo remains relatively stable compared to the Northern Cape and Gauteng. However, the data also reveals extreme YoY changes in income *per capita*, especially in 2011, where an exceptional positive change of 797.21% was observed.

Interestingly, this substantial increase in income *per capita* does not translate into improved life expectancy, as reflected in the negative −0.16% YoY percentage change in life expectancy for that year and the subsequent one. This disconnection between a significant increase in income and its failure to translate into improved life expectancy highlights the multifaceted nature of this relationship, warranting further examination.

These findings highlight the importance of understanding how extreme income and public health expenditure fluctuations can affect access to healthcare and overall well-being. However, this Analysis does not comprehensively depict the complex relationship between economic factors and individuals' health in these regions. While there are instances where improvements follow an increase in economic factors in life expectancy, the relationship is not consistently observed. Consequently, the following section delves into the results of a multivariate analysis to gain deeper insight into these complex dynamics.

4.2 Results of the provincial index of multiple deprivation

Before examining the results of the multivariate Analysis, it is essential to explore the outcome of the initial specification, which generated the PIMD for each province. This is crucial to understanding the deprivation variations across South Africa's provinces. Table 8 presents an overview of the PIMD scores by province in South Africa from 2005 to 2019, ranging from 0 to 10. Lower scores indicate less deprivation, while higher scores denote greater deprivation. Analysis of this measure uncovers several significant findings and trends.

First, we observe substantial variation in deprivation levels across provinces. In 2005, the Eastern Cape had the highest level of deprivation, with a score of 3.24, while the Western Cape had the lowest at 1.60. These disparities persisted over the years, with the Eastern Cape consistently having the highest deprivation scores and the Western Cape maintaining its position as the least deprived province.

Second, the data reveals fluctuations in deprivation levels within each province over time. While some provinces like Gauteng show relatively stable scores over the years, others, such as KwaZulu-Natal and Limpopo, experience more variability. KwaZulu-Natal, for example, exhibits a notable decrease in deprivation from 3.42 in 2005 to 1.73 in 2019.

Third, the data shows a consistent decrease in deprivation scores across all provinces, suggesting enhanced living conditions. However, it is crucial to note that the rate of improvement varies. For example, KwaZulu-Natal has the highest annual improvement rate at 0.100, whereas Gauteng has the lowest at 0.034. This indicates that while progress is being made, it is unevenly distributed, highlighting the need for targeted interventions in areas lagging.

The variations in deprivation scores have significant implications for our analysis of how poverty affects the effectiveness of public health expenditure, using the PIMD scores as a measure of poverty. These results are presented in the following section.

TABLE 7 Annual trends in life expectancy and public health expenditure in Limpopo.

Year	YoY change in life expectancy	YoY change in public health expenditure *per capita*	YoY change in income *per capita*
2005			
2006	0,50	14,93	−28,72
2007	1,17	12,99	−39,79
2008	2,64	11,50	−29,32
2009	1,77	10,31	55,83
2010	−0,32	11,56	−80,44
2011	−0,16	11,97	797,21
2012	−0,16	8,11	−6,53
2013	−0,16	2,27	6,86
2014	0,00	8,02	−0,40
2015	0,00	4,63	42,47
2016	0,67	5,99	−24,73
2017	0,51	5,65	36,22
2018	0,50	5,35	21,05
2019	0,50	5,08	13,63

*The author's data was used to calculate YOY percentage changes, following the formula: percentage difference between the current and previous year's values, divided by the previous year's value, multiplied by 100.

4.3 Two-way fixed effects regression results: analysis of the base model

The results from the two-way FE model provide insights into the relationship between public health expenditure, regional poverty levels, and life expectancy across South Africa's provinces.

As anticipated, the coefficient for the logarithm of income *per capita* is positive, signifying that a 1% increase in income *per capita* corresponds to a modest increase of 0.0523 units (years) in life expectancy. However, it is important to note that this coefficient is statistically insignificant, implying no substantial statistical relationship with the dependent variable.

Interestingly, the negative coefficient for the logarithm of public health expenditure *per capita* indicates that a 1% increase in public health expenditure *per capita* leads to an approximate decrease of 2.64 years in life expectancy. This counterintuitive finding suggests that increased public health spending does not directly translate to improved life expectancy. However, this variable is statistically significant at all conventional levels, signifying a significant statistical relationship with the dependent variable. Therefore, further investigation into this relationship is warranted.

The negative coefficient for the PIMD suggests that an increase in poverty levels by one unit corresponds to a decrease in life expectancy by approximately 3.22 units. The substantial magnitude of the PIMD coefficient underscores the significant and direct impact of poverty on life expectancy, indicating that higher poverty levels correlate with considerably reduced life expectancy across South Africa's provinces. This observation aligns with expectations and reinforces the well-established link between poverty and lower life expectancy. Notably, this variable is statistically significant at all conventional levels, suggesting a robust relationship with the dependent variable (Table 9).

TABLE 8 Index of multiple deprivation by province in South Africa (2005–2019).

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
EC	3,24	3,16	3,07	3,21	2,73	2,60	2,55	2,46	2,40	2,35	2,34	2,28	2,30	2,29	2,28
FS	2,36	2,23	2,18	2,13	1,56	1,41	1,31	1,37	1,35	1,38	1,44	1,42	1,42	1,37	1,41
GP	1,70	1,71	1,66	1,49	1,21	1,16	1,12	1,15	1,10	1,10	1,20	1,16	1,16	1,16	1,21
KZN	3,42	3,21	3,07	2,57	1,95	1,83	1,91	1,84	1,99	1,97	1,95	1,91	1,90	1,82	1,73
LP	3,29	3,19	3,11	3,19	2,51	2,40	2,30	2,27	2,42	2,36	2,28	2,28	2,28	2,26	2,22
MP	3,00	2,96	2,91	2,81	2,17	1,97	1,89	1,81	1,91	1,97	1,99	1,97	1,92	1,85	1,93
NC	2,19	2,37	2,36	2,23	1,82	1,73	1,84	1,73	1,69	1,68	1,70	1,69	1,69	1,56	1,49
NW	2,75	2,78	2,64	2,66	2,02	1,94	1,85	1,83	1,83	1,86	2,00	1,88	1,83	1,83	1,86
WC	1,60	1,58	1,56	1,36	1,04	0,95	0,90	0,81	0,86	0,84	0,90	0,90	0,89	0,86	0,80

*The content presented here, including calculating deprivation scores using the first specification, is the author's original work.

TABLE 9 Two-way fixed effects model results.

Variables	Coefficients	Std. error
The logarithm of Income *per Capita*	0.0523	0.0671
The logarithm of the Population Growth Rate	0.0680	0.0896
The logarithm of the Female Literacy Rate	−0.2172	2.1069
The logarithm of Public Health Expenditure *per Capita*	−2.6415***	0.8303
Logarithm of HIV Prevalence (Ages 15–49)	−1.1772	1.2709
PIMD	−3.2160***	0.7876
Interaction Term: Public Health Expenditure, PIMD, and Free State	0.0010***	0.0002
Interaction Term: Public Health Expenditure, PIMD, and Gauteng	0.0006**	0.0003
Interaction Term: Public Health Expenditure, PIMD, and KwaZulu-Natal	0.0005**	0.0002
Interaction Term: Public Health Expenditure, PIMD, and Limpopo	−0.0003	0.0002
Interaction Term: Public Health Expenditure, PIMD, and Mpumalanga	0.0009***	0.0002
Interaction Term: Public Health Expenditure, PIMD, and North-West	0.0007**	0.0002
Interaction Term: Public Health Expenditure, PIMD, and Northern Cape	−0.0002	0.0002
Interaction Term: Public Health Expenditure, PIMD, and Western Cape	−0.0011***	0.0004

*Equation 2 presents the results presented here. Coefficients marked with * indicate significance at the 10% level, those marked with ** denote significance at the 5% level, and coefficients with *** represent a high significance level at the 1% level.

The analysis of the interaction term between public health expenditure *per capita*, poverty, and the respective provinces yields notable results. Considering regional poverty rates in the Free State, Gauteng, KwaZulu-Natal, Mpumalanga, and North-West, a 1% increase in public health expenditure is linked to increased life expectancy. Specifically, the increases are approximately 0.0010, 0.0006, 0.0005, 0.0009, and 0.0007 years, respectively, compared to the Eastern Cape. These variables were found to be statistically significant, indicating that they have a statistical relationship with life expectancy.

In contrast, the Western Cape was the only province demonstrating a significant negative relationship between *per capita* public health expenditure and life expectancy. Here, a 1% increase in public health expenditure *per capita* is associated with a reduction of 0.0011 years in life expectancy compared to the Eastern Cape. However, it is important to note that the coefficients for these interaction variables are relatively small compared to those for variables like *per capita* public health expenditure and the PIMD. This suggests that the influence of these interaction term variables on life expectancy is comparatively modest.

These results highlight the complex interplay between public health expenditure, poverty levels, and life expectancy across different provinces in South Africa and how these relationships differ from one province to another. The following section examines whether historical economic factors influence life expectancy.

4.4 Two-way fixed effects regression results: analysis of past economic activities

The findings presented in Table 10, which include lagged effects of past economic activities, align with those in the base model discussed in the previous section.

Regarding the lagged variables of income *per capita*, the coefficient for the one-year lag is 0.0000, implying that in this context, income from a year ago does not significantly impact life expectancy. This variable is also statistically insignificant. In contrast, the two-year lag of income *per capita* suggests that a 1% increase in this variable corresponds to a 0.0001-year reduction in life expectancy. However, the magnitude of this variable is close to zero and insignificant, suggesting that, in this context, income *per capita* from a year and 2 years ago does not significantly impact life expectancy.

Lastly, the one- and two-year lagged public health expenditure *per capita* values show identical magnitudes. This implies that a 1% increase in public health expenditure *per capita* from one and 2 years ago results in a 0.0004-year reduction in life expectancy. However, these values are near zero, and both lagged variables are statistically insignificant. This indicates that, in this context, public health expenditure *per capita* from 1 and 2 years ago does not significantly impact life expectancy.

In conclusion, our findings indicate that while public health expenditure *per capita* significantly affects life expectancy, income *per capita*, its lagged values, and its lagged variables do not influence life expectancy. This conclusion is drawn from the fact that income *per capita* and its lagged values are statistically insignificant, as are the lagged values of public health expenditure *per capita*.

5 Discussion

Health spending is widely regarded as a key policy tool, with calls for increased investment as part of the global effort to achieve universal access to healthcare. The rationale is straightforward: more spending leads to expanded health services and infrastructure for the population. These initiatives align with global goals, particularly the Sustainable Development Goals (SDGs). The positive impact of health spending on health outcomes has been well-established. However, evidence suggests that the effects of health spending vary across regions with different development levels (22). In low-development areas, spending often has more immediate and tangible benefits, though inefficiencies and inadequate infrastructure frequently hamper its effectiveness. Since socioeconomic status is a crucial determinant of health, high poverty levels—common in less developed regions—can undermine the potential benefits of health spending. In South Africa, research indicates that these challenges persist, with poverty exacerbating the limitations of public health expenditure in underdeveloped areas.

This study examined the intricate interplay between public health expenditure, regional poverty levels, and health outcomes across South Africa's provinces. Our findings reveal a nuanced and complex relationship significantly shaped by the varying poverty levels as measured by the PIMD.

We established the the provincial index of multiple deprivation (PIMD) for each of the nine provinces, covering the period from 2005 to 2019. This index revealed significant variations in poverty levels across

TABLE 10 Two-way fixed effects model results.

Variables	Coefficients	Std. error
The logarithm of Income *per Capita*	0.0208	0.0731
The logarithm of the Population Growth Rate	0.1587*	0.0968
The logarithm of the Female Literacy Rate	−2.4690	2.5333
The logarithm of Public Health Expenditure *per Capita*	−2.4519*	1.1736
Logarithm of HIV Prevalence (Ages 15–49)	−3.4625*	1.4236
PIMD	−4.2100***	1.0910
Interaction Term: Public Health Expenditure, PIMD, and Free State	0.0011***	0.0002
Interaction Term: Public Health Expenditure, PIMD, and Gauteng	0.0006*	0.0003
Interaction Term: Public Health Expenditure, PIMD, and KwaZulu-Natal	0.0007***	0.0002
Interaction Term: Public Health Expenditure, PIMD, and Limpopo	−0.0003	0.0002
Interaction Term: Public Health Expenditure, PIMD, and Mpumalanga	0.0009***	0.0003
Interaction Term: Public Health Expenditure, PIMD, and North-West	0.0006*	0.0003
Interaction Term: Public Health Expenditure, PIMD, and Northern Cape	−0.0001	0.0002
Interaction Term: Public Health Expenditure, PIMD, and Western Cape	−0.0003	0.0004
One-year Lag of Public Health Expenditure *per Capita*	−0.0004	0.0005
Two-year Lag of Public Health Expenditure *per Capita*	−0.0004	0.0004
One-year Lag of Income *per Capita*	0.0000	0.0001
Two-year Lag of Income *per Capita*	−0.0001	0.0001

*Equation 3 presents the results presented here. Coefficients marked with * indicate significance at the 10% level, those marked with ** denote significance at the 5% level, and coefficients with *** represent a high significance level at the 1% level.

the provinces. For instance, in 2005, the Eastern Cape had the highest deprivation score at 3.24, in stark contrast with the Western Cape's score of 1.60. these disparities, initially observed in 2005, persisted throughout the study period. Analyzing the PIMD alongside the Human Development Index (HDI) from the Global Data Lab (1990–2021) (23) and the South African multidimensional poverty index (SAMPI) from Stats SA (based on 2001 and 2011 census data), we identified consistent patterns of poverty variation between the two provinces over time.

After estimating the two-way FE model of the base model, many variables displayed the anticipated signs; however, contrary to expectations, our results indicated that for every 1% increase in public health expenditure *per capita*, life expectancy was projected to decrease by 2.6415 years. This unexpected outcome necessitated further exploration, as it implies that investment in healthcare services per person does not yield the expected life expectancy improvements. This may signal inefficiencies, misallocation of funds, systemic issues, and poor healthcare governance (23), as higher healthcare spending should ideally lead to better health outcomes and longer life expectancy. Indeed, studies found that government effectiveness moderated the impact of public health expenditure on health outcomes in different African contexts (11, 12).

Another possible explanation for these unexpected results is the principle of health persistence discussed by Miller, who posits that regions with lower life expectancy often necessitate increased healthcare spending to address poor health outcomes (24). This scenario is particularly relevant in South Africa, where more than half the population lives in poverty. Longstanding health challenges compromise the efficacy of current public health expenditure in economically disadvantaged areas. Consequently, the observed negative correlation might not imply that higher spending leads to shorter lifespans. Rather, it could indicate that areas with lower life expectancy must invest more in public health, primarily in response to persistent health issues. This finding contrasts with Hlafu et al., who reported a positive relationship between life expectancy and public health expenditure *per capita* in the Western Cape (9). However, it is important to acknowledge that Hlafu et al. did not account for regional poverty levels in their study (9).

A consistent observation emerged in our analysis of historical economic factors, which we measured using one- and two-year lags for public health expenditure and income *per capita*. Both the lag variables for public health expenditure exhibited the same negative coefficient of 0.0004, close to zero. Moreover, these variables were statistically insignificant, implying that historical public health expenditure did not significantly influence life expectancy. Instead, only immediate health expenditure *per capita* appears to impact the dependent variable.

This finding is particularly intriguing when contrasted with research by Ullah et al. that identified a significant relationship between the lagged values of public health expenditure *per capita* and health outcomes (25). However, although significant, their observed effects were relatively small and tended to diminish with increased lags. This difference highlights the complexity and variability of the factors influencing health outcomes over time.

A similar trend emerged with lagged income *per capita*. The one-year lag had no effect, and the two-year lag's coefficient was close to zero, both statistically insignificant. This contradicts Sharmar's findings of a positive relationship between income lags and life expectancy, likely due to differing institutional efficiencies in advanced economies (26).

The varying poverty levels across South Africa's provinces have significant implications for the impact of public health spending on health outcomes. While health spending is crucial for providing and treating adverse health conditions (27), it does not address the underlying socioeconomic factors contributing to poor health outcomes. A recent study reported, for example, that participants with lower educational and income levels had higher healthcare expenditure and used more healthcare compared to participants with the highest educational and income levels, signifying the adverse socioeconomic conditions in propelling the need for healthcare spending (22). Poorer regions benefit more from additional health spending, but overall health outcomes remain relatively low, highlighting the need for more specific, targeted interventions. This type of intervention is in line with the fact that to narrow gaps in heath developing nations would benefit more from increased health spending than the developed world, highlighting that improvement in health expenditure has been part of the solution to address social disparities in health. These interventions should consider the unique health challenges of each region. If implemented alongside socioeconomic initiatives, such targeted health spending would likely be more effective than current allocation practices, achieving better results and delivering greater benefits (22).

In summary, the analysis demonstrates the varied ways poverty influences the effectiveness of public health expenditure in improving people's health across various provinces, confirming the validity of our first hypothesis. Furthermore, the effects of historical economic factors were insignificant, leading us to reject our second hypothesis that the lagged values of income *per capita* and public health expenditure *per capita* would impact the dependent variable.

6 Conclusion and recommendations

This study explored the intricate relationships between regional poverty levels, public health expenditure, and population health outcomes in South Africa, particularly focusing on the role of historical economic factors. Using data from 2005 to 2019 sourced from the GHS, HST database, and National Treasury's Intergovernmental Fiscal Review (28, 29), we developed the PIMD. This index was then analyzed using a two-way FE model to examine these complex relationships thoroughly.

The study revealed a surprising negative correlation between life expectancy at birth and public health expenditure *per capita*. This contradicts the conventional assumption that higher healthcare spending improves health outcomes, suggesting possible inefficiencies or misallocation of resources within South Africa's healthcare system. One possible reason for this is health persistency, where regions with historically lower life expectancy demand more public health spending to address longstanding health issues without significant health improvements.

To address these inefficiencies, the study recommends that the South African government review its healthcare spending to optimize resource allocation. This review should focus on improving healthcare distribution and ensuring that funding is effectively targeted, particularly in regions with historically low life expectancy. A health persistency-focused strategy, which directs resources to areas with enduring health challenges, could help reduce health disparities and improve overall life expectancy.

The study also examined the relationship between public health expenditure, regional poverty, and life expectancy across provinces. It found that increased health spending modestly improved life expectancy when adjusted for poverty in provinces like the Free State, Gauteng, and KwaZulu-Natal. However, in the Western Cape, a paradox emerged, with higher health spending linked to a decline in life expectancy, highlighting the limitations of a uniform national health policy across diverse regions. The study calls for region-specific health policies, especially in regions like the Western Cape, where socioeconomic disparities might reduce the effectiveness of increased health spending.

Data availability statement

Data used in this manuscript are included in Supplementary material. All queries relating to data must be directed to the first author of the paper.

Author contributions

MD: Formal analysis, Writing – review & editing, Conceptualization, Writing – original draft. JM: Formal analysis, Writing – review & editing.

Funding

The author(s) declare that no financial support was received for the research, authorship, and/or publication of this article.

Acknowledgments

Authors acknowledge the help of the AI (chat.openai.com) in improving the language of the manuscript.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2024.1442304/full#supplementary-material

References

1. World Bank. South Africa MPO - public documents. Available at: https://thedocs.worldbank.org/en/doc/bae48ff2fefc5a869546775b3f010735-0500062021/related/mpo-zaf.pdf [Accessed 10 December 2023]. (2022).

2. Mtapuli O, Partson T. From apartheid to democracy. *Southern African J Demography*. (2021) 21:104–33. doi: 10.2307/27125725

3. Marais L, Cloete J. Patterns of territorial development and inequality from South Africa's periphery: Evidence from the Free State Province. Rimisp, Santiago, Chile: (2016).

4. Berman F. Sotuh Africa: a study of apartheid law and its neforcement. *Touro J Transitional law*. (1991) 2:1–66.

5. Ivanovich M. The role of traditional authorities in rural tourism development in South Africa: the case of the kingdom of the rain queen. *African J Physical Health Educ, Recreation and Dance*. (2015) 21:37–54.

6. David A, Guilbert N, Hamaguchi N, Higashi Y, Hino H. Spatial poverty and inequality in South Africa: a municipality level analysis. Cape Town: SALDRU, UCT (2018).

7. Marais L, Cloete J. *Patterns of territorial development and inequality from South Africa's periphery: evidence from the Free State Province*. Rimisp, Santiago, Chile: Working Paper Series N° 188. (2016).

8. Sherry K. Disability and rehabilitation: essential considerations for equitable, accessible and poverty-reducing health care in South Africa. *South African Health Rev*. (2014) 1:89–99.

9. Hlafa B, Sibanda K, Hompashe DM. The impact of public health expenditure on health outcomes in South Africa. *Int J Environ Res Public Health*. (2019) 16:2993–296. doi: 10.3390/ijerph16162993

10. Bidzha ML. The effectiveness of public health spending in South Africa (Doctoral dissertation, University of Johannesburg, South Africa. (2015).

11. Makuta I, O'Hare B. Quality of governance, public spending on health and health status in sub Saharan Africa: a panel data regression analysis. *BMC Public Health*. (2015) 15:1–11. doi: 10.1186/s12889-015-2287-z

12. Bunyaminu A, Mohammed I, Yakubu IN, Shani B, Abukari AL. The effect of health expenditure on average life expectancy: does government effectiveness play a moderating role? *Int J Health Gov*. (2022) 27:365–77. doi: 10.1108/IJHG-03-2022-0027

13. Francis D, Webster E. Poverty and inequality in South Africa: critical reflections. *Dev South Afr*. (2019) 36:788–802. doi: 10.1080/0376835X.2019.1666703

14. Grossman HI. A choice-theoretic model of an income-investment accelerator. *Am Econ Rev*. (1972) 62:630–41.

15. Zweifel P. The Grossman model after 40 years. *Eur J Health Econ*. (2012) 13:677–82. doi: 10.1007/s10198-012-0420-9

16. Rogerson CM, Rogerson JM. Improving the business environment for local economic development in South Africa. *J Public Adm*. (2011) 46:994–1004.

17. Ullah S, Akhtar P, Zaefarian G. Dealing with endogeneity bias: the generalized method of moments (GMM) for panel data. *Ind Mark Manag*. (2018) 71:69–78. doi: 10.1016/j.indmarman.2017.11.010

18. Noble M, Barnes H, Wright G, Roberts B. Small area indices of multiple deprivation in South Africa. *Soc Indic Res*. (2010) 95:281–97. doi: 10.1007/s11205-009-9460-7

19. Schult EL, Tan DT, Walsh KD. Endogeneity and the corporate governance-performance relation. *Aust J Manag*. (2010) 35:145–63. doi: 10.1177/0312896210370079

20. Imai K, Kim IS. On the use of two-way fixed effects regression models for causal inference with panel data. *Polit Anal*. (2021) 29:405–15. doi: 10.1017/pan.2020.33

21. Statistics South Africa. The south African MPI: creating a multidimensional poverty index using census data. Pretoria: statistics South Africa. Available at: https://www.statssa.gov.za/publications/Report-03-10-08/Report-03-10-082014.pdf (Accessed: 10 December 2023). (2014).

22. Loef B, Meulman I, Herber G-CM, Kommer GJ, Koopmanschap MA, Kunst AE, et al. Socioeconomic differences in healthcare expenditure and utilization in the Netherlands. *BMC Health Serv Res*. (2021) 21:1–17. doi: 10.1186/s12913-021-06694-9

23. Mbonigaba J, Oumar SB. The relative efficiency of south African municipalities in providing public health care. *Afr J Econ Manag Stud*. (2016) 7:346–65. doi: 10.1108/AJEMS-04-2014-0028

24. Global Data Lab. Human development index figures from the global data lab (1990-2021). Available at: https://globaldatalab.org/shdi/ (Accessed: 10 December 2023). (2021).

25. Ullah I, Ullah A, Ali S, Poulova P, Akbar A, Haroon S, et al. Public health expenditures and health outcomes in Pakistan: evidence from quantile autoregressive distributed lag model. Risk management and healthcare. *Policy*. (2021) 14:3893–909. doi: 10.2147/RMHP.S316844

26. Sharma R. Health and economic growth: evidence from dynamic panel data of 143 years. *Public Libr Sci*. (2018) 13:e0204940. doi: 10.1371/journal.pone.0204940

27. Bein MA, Unlucan D, Olowu G, Kalifa W. Healthcare spending and health outcomes: evidence from selected east African countries. *Afr Health Sci*. (2017) 17:247–54. doi: 10.4314/ahs.v17i1.30

28. National Treasury. Intergovernmental fiscal review 2009. Pretoria: National Treasury. Available at:https://www.treasury.gov.za/publications/igfr/2009/prov/04.%20Chapter%204%20-%20Health.pdf (Accessed: 3 November 2023). (2009).

29. National Treasury. Intergovernmental fiscal review 2015. Pretoria: National Treasury. Available at:https://www.treasury.gov.za/publications/igfr/2015/prov/04.%20Chapter%204%20-%20Health.pdf (Accessed: 3 November 2023). (2015).

frontiers | Frontiers in Public Health

TYPE Original Research
PUBLISHED 03 December 2024
DOI 10.3389/fpubh.2024.1322327

Check for updates

OPEN ACCESS

EDITED BY
Xiaozhen Lai,
Peking University, China

REVIEWED BY
Giulia Caggiu,
University of Milano-Bicocca, Italy
Mark Attridge,
Attridge Consulting, Inc., United States

*CORRESPONDENCE
Clara Oliveras
✉ coliveras@clinic.cat

RECEIVED 20 November 2023
ACCEPTED 14 October 2024
PUBLISHED 03 December 2024

CITATION
Oliveras C, Bruguera P, Cordero-Torres I, Millán-Hernández A, Pons-Cabrera MT, Guzmán Cortez PR, Gómez-Ramiro M, Vázquez M, Borràs R, Asenjo-Romero M, Vieta E, Gual A, López-Pelayo H and Balcells-Oliveró M (2024) Effects of alcohol-related problems on the costs of frequent emergency department use: an economic analysis of a case–control study in Spain.
Front. Public Health 12:1322327.
doi: 10.3389/fpubh.2024.1322327

Effects of alcohol-related problems on the costs of frequent emergency department use: an economic analysis of a case–control study in Spain

Clara Oliveras[1,2,3,4]*, Pol Bruguera[1,2,3,4], Imanol Cordero-Torres[5], Andrea Millán-Hernández[3], Maria Teresa Pons-Cabrera[1,2,3], Pablo Rodrigo Guzmán Cortez[1,2,3], Marta Gómez-Ramiro[2,5,6,7,8], Mireia Vázquez[2,5], Roger Borràs[9], Maria Asenjo-Romero[5], Eduard Vieta[2,6,10], Antoni Gual[1,2,3,4], Hugo López-Pelayo[1,2,3,4] and Mercè Balcells-Oliveró[1,2,3,4]

[1]Addictions Unit, Psychiatry and Psychology Service, ICN, Hospital Clinic Barcelona, Barcelona, Spain, [2]Department of Psychiatry and Clinical Psychology, Hospital Clínic de Barcelona, Barcelona, Spain, [3]Health and Addictions Research Group, Institut d'Investigacions Biomèdiques August Pi i Sunyer (IDIBAPS), Barcelona, Spain, [4]Red de Investigación en Atención Primaria de Adicciones (RIAPAd), Madrid, Spain, [5]Emergency Department, Hospital Clínic de Barcelona, Barcelona, Spain, [6]Centro de Investigación en Red de Salud Mental (CIBERSAM), Madrid, Spain, [7]Barcelona Clínic Schizophrenia Unit, Institute of Neuroscience, Hospital Clínic, University of Barcelona, IDIBAPS, Barcelona, Spain, [8]Psychiatry Service, Complejo Hospitalario Universitario de Vigo, SERGAS, Translational Neuroscience Research Group, Galicia Sur Health Research Institute (IISGS), Vigo, Spain, [9]Institute of Neuroscience and Medical Statistics Core Facility, Hospital Clínic de Barcelona, Barcelona, Spain, [10]Bipolar and Depressive Disorders Unit, Institute of Neuroscience, Hospital Clínic, University of Barcelona, IDIBAPS, Barcelona, Spain

Introduction: Alcohol-related problems increase the probability of frequent emergency department (ED) use. In this study, we compared the direct healthcare expenses incurred during a single visit among frequent and non-frequent ED users and analyzed the impact of alcohol-related issues in healthcare costs arising from ED usage.

Methods: The study relied on secondary analyses of economic data from a 1:1 matched case–control study with the primary aim of identifying the clinical characteristics of hospital ED frequent users in a Mediterranean European environment with a public, universal, and tax-funded health system. The participants ranged in age from 18 to 65 years and underwent ED visits at a high-complexity Spanish hospital (cases ≥5 times, controls <5) from December 2018 to November 2019. Each case was matched to a control with the same age, gender, and date of attendance at the ED. Clinical data and direct healthcare costs for a single ED visit were obtained by a retrospective review of the first electronic medical register. Costs and duration of stay were compared between cases and controls using paired-samples *t*-tests, and ED users with and without alcohol-related problems were compared using bivariate (independent-samples *t*-tests, one-way analysis of variance, Chi square tests, and multiple linear regression) and multivariate analyses (multiple linear regression models with backward stepwise selection algorithm, and dependent variable: total mean direct costs).

Results: Among 609 case–control pairs (total $n = 1218$), mean total healthcare direct costs per ED visit were 22.2% higher among frequent compared with non-frequent users [mean difference 44.44 euros; 95% confidence interval (CI) 13.4–75.5; $t(608) = 2.811$; $p = 0.005$]. Multiple linear regression identified length of stay, triage level, ambulance arrival, and the specialty discharging the patient as associated with total healthcare costs for frequent users. In bivariate analyses, a history of alcohol-related problems was associated with a 32.5% higher mean total healthcare costs among frequent users [mean difference 72.61 euros; 95% confidence interval 25.24–119.97; $t(320.016) = 3.015$; $p = 0.003$].

Conclusion: The findings confirm the high cost of frequent ED use among people with alcohol-related problems, suggesting that costs could be reduced through implementation of intervention protocols.

KEYWORDS

healthcare costs, alcohol, psychiatry, emergency department, frequent users

1 Introduction

Most patients use emergency departments (EDs) sporadically for isolated pathologies, but some patients use these services frequently, representing a disproportionate amount of healthcare costs (1). Although definitions of frequent ED use vary (2), a common definition is five or more visits annually (3). In high-income countries, the percentage of frequent users (FUs) of ED is between 0.3 and 8% of all patients who present to emergency services, representing up to 28% of all ED visits (4). FUs are not only heavy users of acute services, but they also frequently use other health services (5), which suggests that they are sicker and more vulnerable. This is supported by a higher-than-expected mortality (6). These factors are likely to increase healthcare system costs.

Drug use-related disorders and other psychiatric diseases seem to increase the probability of frequent ED use (7, 8), which is especially true for alcohol addiction (9).

From 1990 to 2017, there was a global increase in individual alcohol consumption, prevalence of current drinkers, and proportion of episodic heavy drinkers among adults, whereas the proportion of lifetime abstinence declined. These trends are anticipated to continue in the coming years (10). Patients with alcohol-related problems (ARPs) are less likely to use primary care services than the rest of the population (11), but they are more likely to use emergency services (12). Furthermore, alcohol-related ED visits seem to be increasing in frequency, duration, and resource consumption (13). For instance, patients with emergency department visits related to drug use are more likely to receive diagnostic tests, such as toxicology screenings (14).

As described for other psychiatric illnesses (15), ARPs predict higher costs, not only in the ED (16), but also in the entire healthcare network (17).

Currently, the majority of studies describing the characteristics of FUs have been conducted in English-speaking countries, such as the United States, Canada, Australia, or the United Kingdom (18–20), with fewer studies available from other regions (21). Globally, healthcare costs associated with frequent ED use have received less attention (2).

This manuscript presents the secondary analyses of economic data obtained from a case–control study with the primary objective of outlining the clinical characteristics of hospital ED FUs in a Mediterranean European country (Spain). The results of that study indicated that a history of ARPs [adjusted odds ratio = 1.82 (95% confidence interval [CI] 1.26–2.64), $p = 0.001$] increased the probability of frequent utilization of emergency services (22). The main aims of the secondary analyses presented in this manuscript were to compare direct healthcare costs of a single urgent visit between frequent and non-frequent users of hospital emergency services and to explore the role of ARPs in direct healthcare costs of frequent ED use in a universal, public, tax-financed national health system. A secondary objective was to investigate the factors influencing the direct costs of ED utilization among individuals who are non-frequent users.

2 Methods

2.1 Study design and setting

A retrospective matched case–control study was conducted to characterize the clinical profile of ED FUs at a tertiary hospital located in a metropolitan city (Barcelona) in Spain.

The ED is responsible for treating internal medicine, psychiatric, trauma, and surgical emergencies. Electronic health records are used to track all healthcare encounters within the center and provide access to clinical care data. The ED is located in a specific building of the hospital, and different levels of acute care are assigned to different floors. The Spanish healthcare system is public, universal, and free of charge (tax-financed; Beveridge model (23)).

The study adhered to the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) Statement Checklist for case–control studies (24) (Supplementary material 1).

The main objective of the study was to determine the significance of alcohol-related issues in the frequent utilization of an ED at a general hospital in a European Mediterranean society with a public, universal, tax-funded healthcare system (Spain). Another objective was to investigate the influence of other drug use-related disorders on frequent ED use in this environment. The hypothesis for the main study was that a history of alcohol-related problems and other drug use-related disorders would increase the probability of frequent attendance at the ED.

In this article, the secondary analyses of economic data from the aforementioned study (22) are reported.

The local Ethics Committee for Clinical Research at the Hospital Clinic of Barcelona has granted ethical approval (HCB/2019/0717). The investigation was conducted in accordance with the guidelines on Good Clinical Practice (CPMP/ICH/135/95) and with the ethical principles stated in the Declaration of Helsinki 1964, as revised at the 64th World Medical Association General Assembly held in Fortaleza, Brazil, in October 2013.

2.2 Participant selection

All cases (FUs) were all adults (ages 18 to 65 years) who had at least five visits to the hospital ED from 1 December 2018 to 30 November 2019. Each case was matched by age, gender, and date of ED attendance to one control (a non-frequent user with <5 yearly ED visits during that period).

During the study period, the ED received 103,668 visits from 75,410 patients. As in previous studies (4), the initial ED attendance recorded in the electronic register from 1 December 2018 to 30 November 2019 was utilized to match, by date of presentation to the ED, each case with a control of the same age and gender, extract clinical characteristics, and calculate direct healthcare costs per urgent visit.

After electronically applying inclusion and exclusion criteria, we have identified 698 case–control pairs. Of these, 89 pairs were manually excluded, including 14 instances of duplicate cases and 75 instances of absence of a medical note. A final list of 609 case–control pairs was generated, giving a total sample size of 1218 (Figure 1).

Before data extraction started, sample size calculations were performed based on estimates from previous studies (25). Assuming that 12% of controls would have a history of ARP, to detect a minimum odds ratio of 1.6 for emergency department frequent use with a power of 80% and a type I error of 0.5, a minimum of 567 case–control pairs with one matched control per case was needed, for a total sample size of 1158.

2.3 Methods of measurement

The variables obtained from each participant in the main case–control study are the following:

Outcome: frequent use of ED (≥5 visits to the ED from 1 December 2018 to 30 November 2019).

Exposures of interest include the history of any alcohol-related issues, as well as reports of other drug use-related disorders.

Covariates: age, gender, residence near the hospital, number of visits to the ED during a year, length of stay in the ED per visit (in minutes), night admission to the ED, ambulance arrival, report of other psychiatric comorbidity, report of organic comorbidity, report of alcohol drinking pattern, psychiatric assessment in the ED, social assessment in the ED, assessment by a non-psychiatric medical specialty in the ED, triage level at admission to the ED, type of specialty that discharged the patient from the ED, month of attendance at the ED, time of day at admission, type of psychiatric comorbidity, type of other drug use, situation at discharge.

To elaborate on a "Yes" in the variable "history of any alcohol-related problem," the medical report had to include the history of diagnoses according to the International Classification of Diseases, Tenth Revision (ICD-10) (26) and the Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (DSM-5) (27), given in the table included in Supplementary material 2. The presence in the medical report of clinical

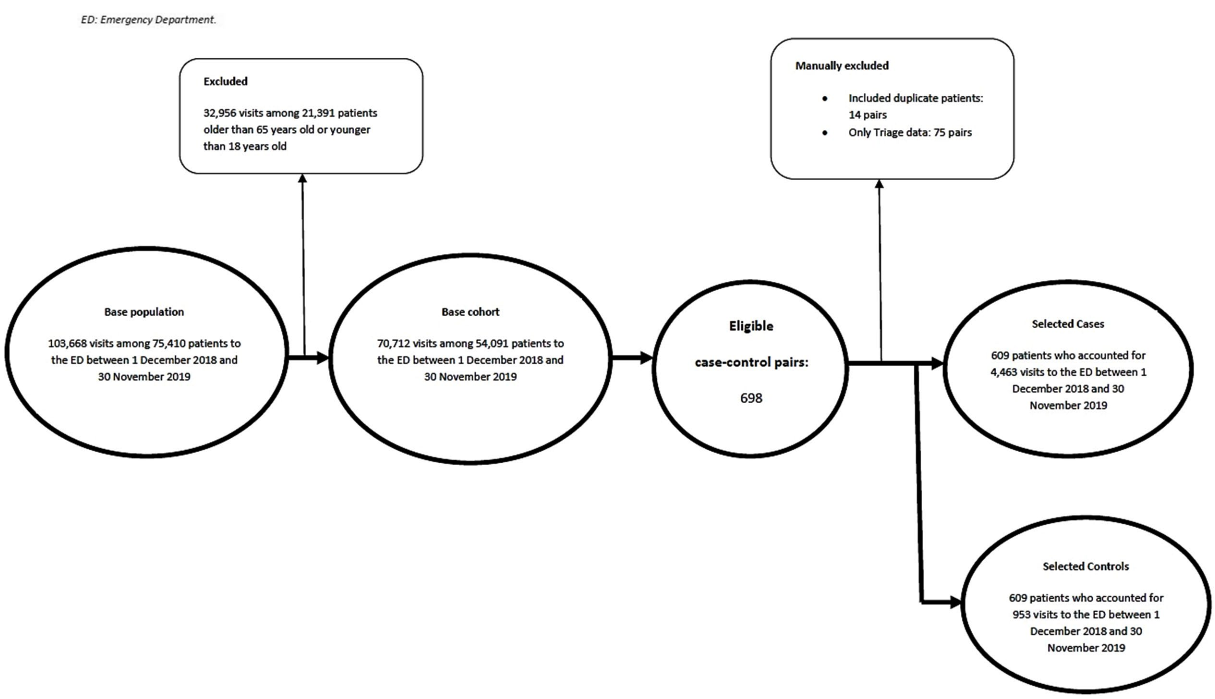


FIGURE 1
Flowchart of participant selection.

presentations compatible with these pathologies, even if they were not coded through a standardized disease classification system, was also considered affirmative for the presence of ARPs. The reporting of other clinical conditions, such as accidents and trauma, when clearly related to alcohol use was also included as ARPs.

The following variables were automatically provided by the electronic health record system (SAP® software): age, gender, triage level at admission to the ED, month of attendance at the ED, time of day at admission, and length of stay (LoS). For other variables, in accordance with the general recommendations for this particular methodology (28), three team members conducted a chart data extraction. Two are psychiatrists specialized in addictions (CO and MTPC), and one is a nurse specialized in mental health (AMH). Prior to the commencement of extraction, all abstractors attended a meeting with the corresponding author (CO) to train in chart review methodology. If a condition was not mentioned, the abstractors documented that the condition was not present. Before formally beginning the extraction process, they reviewed 20 sample cases to assess reliability. This was confirmed by a Fleiss multi-rater Kappa statistic >0.6 for all variables. Throughout the extraction period, chart abstractors and senior researchers (AG, MB-O, HL-P) regularly met to resolve disputes and review coding rules.

Further details on the data extraction criteria are described elsewhere (22).

For the secondary analyses presented in this article, financial data on direct medical costs (in euros, €) per ED visit were obtained from the hospital's financial department (Supplementary material 3).

2.4 Data analysis

The statistical analyses were performed using SPSS version 23.0 (IBM Corp., Armonk, NY, United States) and Stata 14 (StataCorp LLC, College Station, TX, United States). Data were summarized with descriptive analyses: continuous quantitative variables with total numbers, mean (M), and standard deviation (SD) and categorical variables with counts and percentages. To compare the costs and LoS between cases and controls, Student's *t*-tests for paired samples were used.

Subsequently, the subgroups of frequent and non-frequent users were analyzed separately to ascertain which patient characteristics and professional interventions influence direct total costs per ED visit within each subgroup. ED users with ARPs were compared to users without ARPs using bivariate analyses (independent-samples *t*-tests, one-way analysis of variance, Chi-square tests, and multiple linear regression). In multivariate analyses, multiple linear regression models were used with total direct costs per ED visit as the dependent variable. Variables deemed clinically relevant and that were statistically significant ($p < 0.05$) for the dependent variable in bivariate analyses were incorporated into adjusted models employing a backward stepwise selection algorithm.

3 Results

3.1 Descriptive analyses

The sample included 609 case–control pairs ($N = 1218$; Tables 1–3). During the one-year period (1 December 2018 to 30 November 2019), controls accounted for 953 visits to the ED, whereas FUs accounted for 4,463 visits. The FUs visited the ED a mean of 7.34 (SD = 4.16) times per year (minimum of 5 and maximum of 42; 88.8% visited the ED ≤10 times during the study period). Controls presented a mean of 1.56 (SD = 0.87) times per year to the ED. The mean total direct expenses per ED visit were 244.87 € (SD = 268.86) among ED FUs and 200.43€ (SD = 310.12) among controls. There were no missing data.

3.2 Bivariate analyses

During the comparison of cases and controls in bivariate analyses, the mean total healthcare direct costs per ED visit were higher for FUs compared with non-frequent users [mean difference, 44.44 euros; 95% CI 13.4–75.5; $t(608) = 2.811$; $p = 0.005$]. The mean healthcare human resources costs for ED FU visits were higher by 55.97€ (95% CI 33.39–78.56) compared to costs for non-frequent users [$t(608) = 4.868$; $p < 0.0005$]. Mean LoS was longer for FUs by 142.117 minutes (95% CI 81.55–202.68) compared to non-frequent users [$t(608) = 4.608$, $p = 0.0005$].

In the bivariate analysis comparing ED FUs with and without ARPs and controls with and without ARPs, the mean total costs, healthcare human resources costs, and structural costs were higher, and the mean LoS was longer in the ARP groups from both FUs and non-frequent ED users (Table 4).

3.3 Multivariate analyses

In a multiple linear regression model (Table 5) analyzing total costs per ED visit among FUs, we found that LoS, triage level, ambulance arrival, and the specialty that discharged the patient were significant predictors of direct costs. Longer LoS and ambulance arrival predicted higher costs per ED visit among FUs.

Among non-frequent ED users (Table 6), the significant predictors identified in multivariate analysis were LoS, triage level, ambulance arrival, specialty that discharged the patient, and receiving assessment by a non-psychiatric medical specialty in the ED. The longer duration of LoS, ambulance arrival, and receiving assessment by a non-psychiatric medical specialty in the ED predicted higher costs per ED visit.

4 Discussion

To our knowledge, this investigation is one of the few to focus on understanding the influence of ARPs on healthcare costs related to frequent use of hospital emergency services in a public, universal, free-of-charge national health system.

In this secondary analysis, the mean direct total healthcare costs of a single ED visit in a general hospital were 22.2% more expensive among ED FUs compared to controls. It is clear that ED FUs present for emergency services much more frequently than do other patients and that, as a result, the total healthcare costs of this frequent use will be greater over time, as reported previously. A study conducted in the United States showed that, after a year, the global costs of attendance to emergency services were $10,465,216.07 among ED FUs compared with $1,012,610.21 among non-frequent ED users. However, past studies also pointed out that healthcare costs were similar for each ED visit between ED FUs and other users (29). Our results suggest that healthcare costs associated with ED frequent use are higher not only because of

TABLE 1 Patient characteristics (clinical and sociodemographic data) of ED FUs (cases) vs. non-frequent users (controls): descriptive statistics.

	ED FUs (n = 609)	ED FUs with ARPs (n = 182)	ED FUs without ARPs (n = 427)	Controls (n = 609)	Controls with ARPs (n = 86)	Controls without ARPs (n = 523)
Age (years)	M = 44.57 SD = 13.7	M = 46.84 SD = 12.236	M = 44.51 SD = 13.840	M = 44.57 SD = 13.7	M = 47.92 SD = 12.69	M = 44.02 SD = 13.50
Gender (Male)	346 (56.8%)	136 (74.7%)	210 (49.2%)	346 (56.8%)	57 (66.3%)	289 (55.3%)
Number of visits to the ED during a year	M = 7.34 SD = 4.16	M = 8.31 SD = 4.98	M = 6.92 SD = 3.69	M = 1.56 SD = 0.87	M = 1.57 SD = 0.902	M = 1.56 SD = 0.869
Month of Attendance at ED	January 102 (16.7%)	January 33 (18.1%)	January 69 (16.2%)	January 102 (16.7%)	January 18 (20.9%)	January 84 (16.1%)
	February 74 (12.2%)	February 28 (15.4%)	February 46 (10.8%)	February 74 (12.2%)	February 7 (8.1%)	February 67 (12.8%)
	March 71 (11.7%)	March 18 (9.9%)	March 53 (12.4%)	March 71 (11.7%)	March 5 (5.8%)	March 66 (12.6%)
	April 69 (11.3%)	April 19 (10.4%)	April 50 (11.7%)	April 69 (11.3%)	April 5 (5.8%)	April 64 (12.2%)
	May 39 (6.4%)	May 13 (7.1%)	May 26 (6.1%)	May 39 (6.4%)	May 6 (7.0%)	May 33 (6.3%)
	June 43 (7.1%)	June 8 (4.4%)	June 35 (8.2%)	June 43 (7.1%)	June 8 (9.3%)	June 35 (6.7%)
	July 18 (3.0%)	July 3 (1.6%)	July 15 (3.5%)	July 18 (3.0%)	July 2 (2.3%)	July 16 (3.1%)
	August 14 (2.3%)	August 2 (1.1%)	August 12 (2.8%)	August 14 (2.3%)	August 2 (2.3%)	August 12 (2.3%)
	September 14 (2.3%)	September 3 (1.6%)	September 11 (2.6%)	September 14 (2.3%)	September 3 (3.5%)	September 11 (2.1%)
	October 2 (0.3%)	October 0 (0%)	October 2 (0.5%)	October 2 (0.3%)	October 0 (0%)	October 2 (0.4%)
	November 3 (0.5%)	November 1 (0.5%)	November 2 (0.5%)	November 3 (0.5%)	November 0 (0%)	November 3 (0.6%)
	December 160 (26.3%)	December 54 (29.7%)	December 106 (24.8%)	December 160 (26.3%)	December 30 (34.9%)	December 130 (24.9%)
Triage Level at Admission	I 4 (0.7%)	I 0 (0%)	I 4 (0.9%)	I 7 (1.1%)	I 3 (3.5%)	I 4 (0.8%)
	II 133 (21.8%)	II 55 (30.2%)	II 78 (18.3%)	II 99 (16.3%)	II 31(36.0%)	II 68 (13.0%)
	III 336 (55.2%)	III 88 (48.4%)	III 248 (58.1%)	III 343 (56.3%)	III 43 (50.0%)	III 300 (57.4%)
	IV 107 (17.6%)	IV 32 (17.6%)	IV 75 (17.6%)	IV 144 (23.6%)	IV 9 (10.5%)	IV 135 (25.8%)
	V 29 (4.8%)	V 7 (3.8%)	V 22 (5.2%)	V 16 (2.6%)	V 0 (0.0%)	V 16 (3.1%)
Night admission (22 to 6 h) to the ED	94 (15.4%)	37 (20.3%)	57 (13.3%)	100 (16.4%)	18 (20.9%)	82 (15.7%)
Time of the day at admission	Evening and night (16:00 to 23:59 h) 240 (39.4%)	Evening and night (16:00 to 23:59 h) 70 (38.5%)	Evening and night (16:00 to 23:59 h) 170 (39.8%)	Evening and night (16:00 to 23:59 h) 211 (34.6%)	Evening and night (16:00 to 23:59 h) 32 (37.2%)	Evening and night (16:00 to 23:59 h) 179 (34.2%)
	Morning and afternoon (08:00 h to 15.59 h) 295 (48.4%)	Morning and afternoon (08:00 h to 15.59 h) 86 (47.3%)	Morning and afternoon (08:00 h to 15.59 h) 209 (48.9%)	Morning and afternoon (08:00 h to 15.59 h) 312 (51.2%)	Morning and afternoon (08:00 h to 15.59 h) 37 (43.0%)	Morning and afternoon (08:00 h to 15.59 h) 275 (52.6%)
	Early morning (00:00 to 07:59 h) 74 (12.2%)	Early morning (00:00 to 07:59 h) 26 (14.3%)	Early morning (00:00 to 07:59 h) 48 (11.2%)	Early morning (00:00 to 07:59 h) 86 (14.1%)	Early morning (00:00 to 07:59 h) 17 (19.8%)	Early morning (00:00 to 07:59 h) 69 (13.2%)
Lives near the hospital	390 (64%)	126 (69.2%)	264 (61.8%)	310 (50.9%)	49 (57.0%)	261 (49.9%)

(Continued)

TABLE 1 (Continued)

	ED FUs (*n* = 609)	ED FUs with ARPs (*n* = 182)	ED FUs without ARPs (*n* = 427)	Controls (*n* = 609)	Controls with ARPs (*n* = 86)	Controls without ARPs (*n* = 523)
History of Any Alcohol-Related Problem	182 (29.9%)			86 (14.1%)		
Report of Psychiatric Comorbidity	245 (40.2%)	91 (50.0%)	154 (36.1%)	112 (18.4%)	23 (26.7%)	89 (17.0%)
Type of Psychiatric Comorbidity	Psychotic Disorder 45 (18.4%)	Psychotic Disorder 17 (18.7%)	Psychotic Disorder 28 (18.2%)	Psychotic Disorder 14 (12.5%)	Psychotic Disorder 4 (17.4%)	Psychotic Disorder 10 (11.2%)
	Affective Disorder 70 (28.6%)	Affective Disorder 19 (20.9%)	Affective Disorder 51 (33.1%)	Affective Disorder 44 (39.3%)	Affective Disorder 8 (34.8%)	Affective Disorder 36 (40.4%)
	Personality Disorder 46 (18.8%)	Personality Disorder 25 (27.5%)	Personality Disorder 21 (13.7%)	Personality Disorder 14 (12.5%)	Personality Disorder 4 (17.4%)	Personality Disorder 10 (11.2%)
	Anxiety Disorder 47 (19.2%)	Anxiety Disorder 16 (17.6%)	Anxiety Disorder 31 (20.1%)	Anxiety Disorder 20 (17.9%)	Anxiety Disorder 5 (21.7%)	Anxiety Disorder 15 (16.9%)
	Others 37 (15.1%)	Others 14 (15.4%)	Others 23 (14.9%)	Others 20 (17.9%)	Others 2 (8.7%)	Others 18 (20.2%)
Report of other drug use-related disorders	276 (45.3%)	134 (73.6%)	142 (33.3%)	153 (25.1%)	46 (53.5%)	107 (20.5%)
Types of other drug use	Tobacco Use Disorders 169 (61.2%)	Tobacco Use Disorders 77 (57.5%)	Tobacco Use Disorders 92 (64.8%)	Tobacco Use Disorders 122 (79.7%)	Tobacco Use Disorders 36 (78.3%)	Tobacco Use Disorders 86 (80.4%)
	Cannabis Use Disorders 16 (5.8%)	Cannabis Use Disorders 3 (2.2%)	Cannabis Use Disorders 13 (9.2%)	Cannabis Use Disorders 12 (7.8%)	Cannabis Use Disorders 4 (8.7%)	Cannabis Use Disorders 8 (7.5%)
	Cocaine Use Disorders 17 (6.2%)	Cocaine Use Disorders 12 (9.0%)	Cocaine Use Disorders 5 (3.5%)	Benzodiazepine Use Disorders 6 (3.9%)	Benzodiazepine Use Disorders 1 (2.2%)	Benzodiazepine Use Disorders 5 (4.7%)
	Benzodiazepine Use Disorders 14 (5.1%)	Benzodiazepine Use Disorders 6 (4.5%)	Benzodiazepine Use Disorders 8 (5.6%)	Amphetamine Use Disorders 2 (1.3%)	Polysubstance Use Disorders 5 (10.9%)	Amphetamine Use Disorders 2 (1.9%)
	Amphetamine Use Disorders 6 (2.2%)	Amphetamine Use Disorders 3 (2.2%)	Amphetamine Use Disorders 3 (2.1%)	Opioid Use Disorders 1 (0.7%)		Opioid Use Disorders 1 (0.9%)
	Polysubstance Use Disorders 51 (18.5%)	Polysubstance Use Disorders 32 (23.9%)	Polysubstance Use Disorders 19 (13.4%)	Polysubstance Use Disorders 10 (6.5%)		Polysubstance Use Disorders 5 (4.7%)
	Others 3 (1.1%)	Others 1 (0.7%)	Others 2 (1.4%)			
Report of Organic Comorbidity	470 (77.2%)	144 (79.1%)	326 (76.3%)	378 (62.1%)	57 (66.3%)	321 (61.4%)

Data are reported as mean (M) with standard deviation (SD) for continuous variables or percentages (%) with counts for categorical variables unless otherwise specified. Lower levels of Triage imply higher acuity/clinical severity. ED, Emergency Department; ED FUs, Emergency Department Frequent Users; ARPs, Alcohol-Related Problems. Study period: from 1 December 2018 to 30 November 2019.

10.3389/fpubh.2024.1322327

TABLE 2 Professional interventions received in the ED by ED FUs (cases) vs. non-frequent users (controls): descriptive statistics.

	ED FUs (*n* = 609)	ED FUs with ARPs (*n* = 182)	ED FUs without ARPs (*n* = 427)	Controls (*n* = 609)	Controls with ARPs (*n* = 86)	Controls without ARPs (*n* = 523)
Length of Stay (minutes)	M = 519.68 SD = 615.72	M = 601.85 SD = 595.729	M = 495.04 SD = 619.512	M = 377.56 SD = 460.81	M = 644.99 SD = 715.107	M = 333.59 SD = 387.742
Ambulance Arrival	148 (24.3%)	57 (31.3%)	91 (21.3%)	97 (15.9%)	30 (34.9%)	67 (12.8%)
Type of specialty that discharged the patient from the ED	Surgical 124 (20.4%)	Psychiatry 42 (23.1%)	Psychiatry 63 (14.8%)	Surgical 136 (22.3%)	Psychiatry 5 (5.8%)	Psychiatry 25 (4.8%)
	Trauma 40 (6.6%)	Internal Medicine 104 (57.1%)	Internal Medicine 236 (55.3%)	Trauma 105 (17.2%)	Internal Medicine 53 (61.6%)	Internal Medicine 285 (54.5%)
	Internal Medicine 340 (55.8%)	Trauma 12 (6.6%)	Trauma 28 (6.6%)	Internal Medicine 338 (55.5%)	Trauma 20 (23.3%)	Trauma 85 (16.3%)
	Psychiatry 105 (17.2%)	Surgical 24 (13.2%)	Surgical 100 (23.4%)	Psychiatry 30 (4.9%)	Surgical 8 (9.3%)	Surgical 128 (24.5%)
Situation at Discharge	Discharge home 500 (82.1%)	Discharge home 144 (79.1%)	Discharge home 356 (83.4%)	Discharge home 508 (83.4%)	Discharge home 56 (65.1%)	Discharge home 452 (86.4%)
	Hospital Admission 86 (14.1%)	Hospital Admission 29 (15.9%)	Hospital Admission 57 (13.3%)	Hospital Admission 81 (13.3%)	Hospital Admission 24 (27.9%)	Hospital Admission 57 (10.9%)
	Transfer to another center 23 (3.8%)	Transfer to another center 9 (4.9%)	Transfer to another center 14 (3.3%)	Transfer to another center 20 (3.3%)	Transfer to another center 6 (7.0%)	Transfer to another center 14 (2.7%)
Report of Alcohol Drinking Pattern	50 (8.2%)	40 (22.0%)	10 (2.3%)	30 (4.9%)	21 (24.4%)	9 (1.7%)
Psychiatric Assessment in ED	123 (20.2%)	56 (30.8%)	67 (15.7%)	38 (6.2%)	10 (11.6%)	28 (5.4%)
Social Assessment in ED	13 (2.1%)	11 (6.0%)	2 (0.5%)	4 (0.7%)	0 (0.0%)	4 (0.8%)
Assessment by a non-psychiatric medical specialty in ED	179 (29.4%)	57 (21.3%)	122 (28.6%)	142 (23.3%)	39 (45.3%)	103 (19.7%)

Data are reported as mean (M) with standard deviation (SD) for continuous variables or percentages (%) with counts for categorical variables unless otherwise specified. ED, Emergency Department; ED FUs, Emergency Department Frequent Users; ARPs, Alcohol-Related Problems. Study period: from 1 December 2018 to 30 November 2019.

TABLE 3 Detailed healthcare costs per a single ED visit ED FUs (cases) vs. non-frequent users (controls): descriptive statistics.

	ED FUs (*n* = 609)	ED FUs with ARPs (*n* = 182)	ED FUs without ARPs (*n* = 427)	Controls (*n* = 609)	Controls with ARPs (*n* = 86)	Controls without ARPs (*n* = 523)
Human Resources Costs (€)	M = 197.29 SD = 236.57	M = 241.86 SD = 246.51	M = 178.29 SD = 229.88	M = 141.31 SD = 163.32	M = 233.97 SD = 230.72	M = 126.08 SD = 144.06
Costs of Diagnostic Tests (€)	M = 15.47 SD = 28.45	M = 17.55 SD = 30.13	M = 14.58 SD = 27.69	M = 31.22 SD = 221.29	M = 33.10 SD = 65.73	M = 30.91 SD = 237.35
Blood bank costs (€)	M = 2.15 SD = 20.77	M = 2.57 SD = 24.5	M = 1.98 SD = 18.99	M = 0.82 SD = 12.12	M = 3.55 SD = 24.15	M = 0.38 SD = 8.64
Pharmacy Costs (€)	M = 6.37 SD = 5.575	M = 6.70 SD = 4.87	M = 6.24 SD = 6.09	M = 5.92 SD = 7.10	M = 7.68 SD = 6.67	M = 5.63 SD = 7.14
Medical supplies costs (€)	M = 5.85 SD = 5.93	M = 5.79 SD = 4.39	M = 5.87 SD = 6.48	M = 6.53 SD = 8.14	M = 7.36 SD = 7.22	M = 6.40 SD = 8.28
Other Costs (€)	M = 0.65 SD = 0.42	M = 0.67 SD = 0.29	M = 0.65 SD = 0.47	M = 0.63 SD = 0.59	M = 0.74 SD = 0.51	M = 0.61 SD = 0.59
Structural Costs (€)	M = 17.08 SD = 18.75	M = 20.64 SD = 19.23	M = 15.57 SD = 18.37	M = 13.98 SD = 21.64	M = 21.48 SD = 18.54	M = 12.75 SD = 21.88
Total Costs (€)	M = 244.87 SD = 268.86	M = 295.77 SD = 275.66	M = 223.17 SD = 263.25	M = 200.43 SD = 310.12	M = 307.88 SD = 265.70	M = 182.76 SD = 315.55

Data are reported as mean (M) with standard deviation (SD) for continuous variables or percentages (%) with counts for categorical variables unless otherwise specified. ED, Emergency Department; ED FUs, Emergency Department Frequent Users; ARPs, Alcohol-Related Problems. Study period: from 1 December 2018 to 30 November 2019.

10.3389/fpubh.2024.1322327

10.3389/fpubh.2024.1322327

TABLE 4 Independent samples *t*-tests comparing ED FUs with and without ARP and non-frequent users of the ED with and without ARP.

	ED FUs with ARP and ED FUs without ARP			Controls with ARP and controls without ARP		
	Mean difference	95% CI of the difference	*p*-value	Mean difference	95% CI of the difference	*p*-value
Mean Total Costs (€)	**72.61**	**25.24–119.97**	**0.003***	**125.13**	**62.28–187.98**	**<0.0005***
Mean Healthcare Human Resources Costs (€)	**63.56**	**21.48–105.65**	**0.003***	**107.89**	**56.95–158.84**	**<0.0005***
Mean Structural Costs (€)	**5.07**	**1.76–8.37**	**0.003***	**8.73**	**4.34–13.12**	**<0.0005***
Mean Diagnostic Test Costs (€)	2.97	(−2.15)-8.10	0.255	2.19	(−48.43)-52.80	0.932
Mean Blood Bank Costs (€)	0.59	(−3.02)-4.20	0.749	3.17	(−2.06)-8.40	0.231
Mean Pharmacy Costs (€)	0.46	(−0.54)-1.46	0.362	**2.05**	**0.43–3.67**	**0.013***
Mean Medical Supplies Costs (€)	(−0.08)	(−1.11)-0.95	0.879	0.96	(−0.89)-2.82	0.310
Mean Other Costs (€)	0.03	(−0.46)-0.10	0.461	0.13	(−0.003)-0.264	0.055
LoS (minutes)	**134.71**	**28.12–241.30**	**0.013***	**311.40**	**154.63–468.18**	**<0.0005***

ED FUs: Emergency Department Frequent Users; LoS: Length of Stay; ARP: Alcohol-Related Problems; CI: Confidence Interval; * and bold text indicate statistically significant results ($p < 0.05$).

TABLE 5 Multiple linear regression models examining patient characteristics and professional interventions that influence direct total costs per ED visit among ED FUs.

	Unadjusted			Adjusted		
	B (95% CI)	*t*	*p*-value	B (95% CI)	*t*	*p*-value
Constant				112.837 (68.704, 156.969)	5.021	<0.0005
Age	3.070 (1.525, 4.614)	3.903	<0.0005			
LoS	0.397 (0.382, 0.411)	53.414	<0.0005	0.385 (0.370, 0.400)	50.256	<0.0005
Triage Level at Admission	−101.324 (−127.541, (−75.106))	−7.590	<0.0005	−19.427 (−31.355, (−7.500))	−3.199	0.001
Night admission	67.121 (8.093, 126.150)	2.233	0.026			
Ambulance arrival	138.693 (90.007, 187.379)	5.595	<0.0005	27.732 (3.008, 46.456)	2.236	0.026
Type of specialty that discharged the patient from the ED	−44.208 (−65.752, (−22.665))	−4.030	<0.0005	−11.401 (−20.661, (−2.142))	−2.418	0.016
History of any ARP	72.606 (26.186, 119.026)	3.072	0.002			
Other drug use-related disorders	43.272 (0.395, 86.150)	1.982	0.048			
Organic comorbidities	96.053 (45.610, 146.496)	3.740	<0.0005			
Situation at discharge	229.593 (190.423, 268.764)	11.511	<0.0005			
Report of alcohol drinking pattern	101.597 (24.015, 179.178)	2.572	0.010			
Assessed by a non-psychiatric medical specialty	212.888 (169.054, 256.723)	9.538	<0.0005			

Final adjusted Model: Adjusted $R2 = 83.1\%$; $F(4,604) = 747.716$; $p < 0.0005$. ED, Emergency Department; ED FUs, Emergency Department Frequent Users; LoS, Length of Stay; ARP, Alcohol- Related Problem; CI, Confidence Interval. For Triage, Level I was the reference category. Lower levels of Triage imply higher acuity/clinical severity. For the Type of specialty that discharged the patient from the ED, "Psychiatry" was the reference category. For Situation at discharge, "Discharge home" was the reference category.

10.3389/fpubh.2024.1322327

TABLE 6 **Multiple linear regression models examining patient characteristics and professional interventions that influence direct total costs per ED visit among non-frequent ED users.**

	Unadjusted			Adjusted		
	B (95% CI)	*t*	*p*-value	B (95% CI)	*t*	*p*-value
Constant				292.286 (178.830, 405.742)	5.059	<0.0005
Age	4.282 (2.510, 6.053)	4.747	<0.0005			
Gender	58.574 (8.928, 108.221)	2.317	0.021			
LoS	0.371 (0.326, 0.416)	16.280	<0.0005	0.282 (0.233, 0.332)	11.165	<0.0005
Triage Level at Admission	−146.885 (−178.413,(−115.357))	−9.149	<0.0005	−62.225 (−92.265, (−32.186))	−4.068	<0.0005
Ambulance arrival	250.625 (186.150, 315.099)	7.634	<0.0005	80.516 (21.143, 139.890)	2.663	0.008
Type of specialty that discharged the patient from the ED	−51.001 (−78.487, (−23.515))	−3.644	<0.0005	−24.160 (−46.780, (−1.541))	−2.098	0.036
History of any ARP	125.129 (54.906, 195.352)	3.499	0.001			
Other drug use-related disorders	172.113 (116.841, 227.385)	6.115	<0.0005			
Organic comorbidities	101.925 (51.673, 152.178)	3.983	<0.0005			
Situation at discharge	240.283 (191.847, 288.718)	9.743	<0.0005			
Report of alcohol drinking pattern	284.538 (172.680, 396.396)	4.996	<0.0005			
Assessment by a non-psychiatric medical specialty in ED	262.160 (207.612, 316.707)	9.439	<0.0005	84.785 (32.426, 137.144)	3.180	0.002

Final adjusted Model: Adjusted R2 = 35.7%; F (5,603) = 68.509; $p < 0.0005$. ED, Emergency Department; LoS, Length of Stay; ARP, Alcohol-Related Problem; CI, Confidence Interval. For Triage, Level I was the reference category. Lower levels of Triage imply higher acuity/clinical severity. For the Type of specialty that discharged the patient from the ED, "Psychiatry" was the reference category. For situation at discharge, "Discharge home" was the reference category.

frequency but also because each consultation entails greater complexity, as indicated by the 37.6% longer mean LoS and 39.6% higher mean healthcare human resources costs for ED FUs compared with controls.

Results of bivariate analyses suggest that a history of ARPs was associated with an increase in mean total direct costs per visit among all ED users, raising mean human resources costs and LoS to an even greater degree among non-frequent users compared with FUs. Among ED FUs, a history of ARPs was linked to a 32.5% higher mean direct total cost per visit. Compared to ED FUs without ARPs, FUs with ARPs exhibited a 21.6% longer mean LoS, and each ED visit was 35.7% more expensive in terms of human resources costs. Among non-frequent users, ARPs were associated with a 68.5% higher mean direct total cost per visit. Compared with controls without ARPs, non-frequent users with ARPs had a mean LoS that was 93.3% longer, and each ED visit was 85.6% more expensive in terms of human resources costs. These results that suggest increased healthcare costs for patients with ARPs are similar to previously reported findings. In a Canadian sample of people with chronic diseases, psychiatric illnesses significantly increased the use of healthcare resources and their associated costs, whereas alcohol use disorders and other addictions had the highest rates of presentation to emergency services (15). In an Australian study involving ED patients, those who need extensive specialized treatment for alcoholism and other addictions attended the ED more frequently and incurred higher costs per visit. In addition, their hospital stays were usually longer (16). In a Catalan sample of adult primary healthcare patients, alcohol consumption was associated with increased charges from the public medical care system, showing a positive dose–response relationship (17).

The mean total direct cost per ED visit among ED FUs with ARPs was 295.77€ (SD = 275.66) in our analysis. Previous research on how ARPs affect frequent ED use–related costs is scarce, but estimates reported so far of healthcare costs for alcohol use–related ED presentations are generally higher. For instance, among ED users in the Netherlands, the average total expenses per patient seeking treatment for acute alcohol intoxication at the ED amounted to €1070 (encompassing estimated costs for ambulance transportation, ED visits, and hospital admission) (30). In an investigation involving adult ED users of a Belgian high-complexity hospital during a single year who attended the ED due to inebriety, the average estimated treatment cost was €541.32 per patient (31). However, most available estimates of urgent care costs related to alcohol use are reported from different countries, with distinct health systems and different costs of living.

In multivariate analyses, LoS, triage level, ambulance arrival, and type of specialty that discharged the patient were associated with total direct costs per ED visit among ED FUs in our sample. These factors were also associated with total direct costs among non-frequent users, as was undergoing assessment by a non-psychiatric medical specialty in the ED. According to these results, the most robust predictors of healthcare direct costs per ED visit would be the LoS, triage level, ambulance arrival, and discharge type of specialty for all users. The findings of the LoS and the triage level as predictors of ED healthcare costs are consistent with previous literature (32). Patients arriving by ambulance to the ED were noted to experience extended stays in the emergency services and incurred higher average expenses (33). The type of specialty that discharges the patient is also a predictor of ED healthcare costs, which is congruous with earlier evidence, as different types of diseases have been associated with diverse healthcare costs (34). Undergoing assessment by a non-psychiatric medical specialty is a predictor of costs among non-frequent users and is also consistent with previous knowledge. Multimorbidity is associated with an increased use of healthcare services, with associated costs (35). Nonetheless, given that ARPs were likely underreported in the reviewed charts, these results may underestimate emergency department costs attributable to ARPs.

4.1 Limitations

Some limitations of the current investigation should be noted. The first involves the case–control design, as retrospective data provide limited-quality evidence (28). Also, due to the focus of the original study on the relationship between substance use disorders and frequent ED use, clinical complexity was more finely assessed for substance use disorders and other psychiatric comorbidities and not so much for organic (non-psychiatric) medical comorbidities. Researchers were not blind to the study objectives or to the status of study participants (28). Since this is a single-center study, our findings might not be applicable to different contexts. Furthermore, variables of interest for this study could have been underreported in the charts. The literature suggests that psychiatric disorders (36), and especially addictions (25), are underreported in emergency medical reports. Therefore, it is possible that the findings underestimate the ED costs attributable to ARPs. Also, the estimates reflect only direct medical costs incurred only in the ED of one hospital, and the costs of using other resources of the healthcare system were not studied.

Despite these constraints, the academic background of abstractors equipped them with the expertise needed to precisely comprehend the subtleties of clinical data in the charts they reviewed. Additionally, they received standardized training in variable extraction and attended regular meetings with senior researchers to address disputes and review coding rules. Although prospective longitudinal studies provide higher-quality evidence, the clinical and social complexity of ED frequent users often makes long-term follow-up challenging. Retrospective designs are a useful initial approach for exploring large samples of this kind of patient.

Above all, the current study contributes to the limited body of research investigating expenses associated with frequent ED visits.

5 Conclusion

In a high-complexity public hospital, each FU attended the ED between 5 and 42 times per year, with an average of around 7 ED visits per patient. The mean direct total healthcare costs of a single ED visit were 22.2% higher among ED FUs than among matched, non-frequent users of emergency services. Given the association between a history of ARPs and a significantly increased likelihood of repeated emergency service use within the same sample, we propose that implementing targeted intervention protocols in the emergency room to address these issues simultaneously could mitigate the high healthcare costs associated with frequent ED use.

Prior presentations

Some of the data included in this manuscript was previously presented as a short oral communication under the title “El precio de la hiperfrecuentación de urgencias hospitalarias: ¿qué papel juegan el uso de alcohol y otras drogas?” in the 4th International

Congress-XLIX Jornadas Nacionales Socidrogalcohol, which was held in Tenerife, Spain, between 6th and 8th October 2022, and as a short oral communication under the title "Influence of alcohol use and other addictive disorders in the costs of Emergency Department Frequent Use" in Lisbon Addictions 2022 (European Conference on Addictive Behaviors and Dependencies), which was held in Lisbon, Portugal, between 23rd and 25th November 2022.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary materials, further inquiries can be directed to the corresponding author.

Ethics statement

This study protocol was reviewed and approved by the local Ethics Committee for Clinical Research of Hospital Clinic de Barcelona, approval number HCB/2019/0717. The need for informed consent was waived by the Ethics Committee for Clinical Research of Hospital Clínic de Barcelona as the study consisted of a retrospective chart review of data routinely collected in daily clinical practice. This study was performed in accordance with the guidance on Good Clinical Practice (CPMP/ICH/135/95) and with the ethical principles stated in the Declaration of Helsinki 1964, as revised at the 64th World Medical Association (WMA) General Assembly in Fortaleza, Brazil, October 2013. The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation was not required from the participants or the participants' legal guardians/next of kin in accordance with the national legislation and institutional requirements.

Author contributions

CO: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Visualization, Writing – original draft, Writing – review & editing. PB: Conceptualization, Formal analysis, Investigation, Methodology, Supervision, Writing – review & editing. IC-T: Data curation, Software, Writing – review & editing. AM-H: Data curation, Investigation, Writing – review & editing. MTP-C: Data curation, Formal analysis, Investigation, Writing – review & editing. PRGC: Formal analysis, Writing – review & editing. MG-R: Formal analysis, Writing – review & editing. MV: Formal analysis, Writing – review & editing. RB: Formal analysis, Methodology, Supervision, Writing – review & editing. MAR: Writing – review & editing, Data curation, Software. EV: Writing – review & editing, Supervision. AG: Supervision, Writing – review & editing, Conceptualization, Methodology. HL-P: Conceptualization, Methodology, Supervision, Writing – review & editing, Formal analysis. MB-O: Conceptualization, Methodology, Supervision, Writing – review & editing.

Funding

The author(s) declare that financial support was received for the research, authorship, and/or publication of this article. MTP-C received funding by Contractes Clínic de Recerca "Emili Letang-Josep Font," granted by Hospital Clínic de Barcelona, outside the submitted work. Red de Investigación en Atención Primaria de Adicciones, RIAPAd (RICORS), which is a project (RD21/0009/0010) funded by the Carlos III Institute, the European Regional Development Fund, and the Recovery, Transformation, and Resilience Plan.

Acknowledgments

The authors are grateful to Grup de Recerca Emergent, 2021 SGR 01158, AGAUR.

Conflict of interest

CO has received travel grants from Lundbeck, which had no bearing on the research of this study. PB has received honoraria from Lundbeck and travel grants from Pfizer, Lundbeck and Camurus, all outside the work of this manuscript. MTPC has received financial support for CME activities and travel funds from Lundbeck, Pfizer, and Esteve, outside the submitted work. MG-R has received funding unrelated to the present work for research projects and/or honoraria as a consultant or speaker from the following entities: Angelini, Janssen, Lundbeck, Otsuka, Sanofi-Aventis and Spanish Ministry of Science and Innovation- Instituto de Salud Carlos III. EV has received grants and served as consultant, advisor or CME speaker for the following entities: ABBiotics, AbbVie, Angelini, Biogen, Boehringer-Ingelheim, Celon Pharma, Dainippon Sumitomo Pharma, Ferrer, Gedeon Richter, GH Research, Glaxo-Smith Kline, Janssen, Lundbeck, Novartis, Orion Corporation, Organon, Otsuka, Sage, Sanofi-Aventis, Sunovion, Takeda, and Viatris, outside the submitted work. AG has received honoraria, research grants and travel grants from Lundbeck and D&A Pharma, which had no bearing on the research of this study. HL-P has received honoraria and travel grants from Lundbeck, which had no bearing on the research of this study. MB-O has received travel grants from Lundbeck and Camurus and CME-related honoraria from Novo Nordisk, all outside the subject of this article.

The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

The author(s) declared that they were an editorial board member of Frontiers, at the time of submission. This had no impact on the peer review process and the final decision.

Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2024.1322327/full#supplementary-material

References

1. Williams RM. Frequent emergency department use in Sweden: implications for emergency medicine in the United States. *Ann Emerg Med*. (2001) 37:627–9. doi: 10.1067/mem.2001.115175

2. Pines JM, Asplin BR, Kaji AH, Lowe RA, Magid DJ, Raven M, et al. Frequent users of emergency department services: gaps in knowledge and a proposed research agenda. *Acad Emerg Med*. (2011) 18:e64–9. doi: 10.1111/j.1553-2712.2011.01086.x

3. Locker TE, Baston S, Mason SM, Nicholl J. Defining frequent use of an urban emergency department. *Emerg Med J*. (2007) 24:398–401. doi: 10.1136/emj.2006.043844

4. Bieler G, Paroz S, Faouzi M, Trueb L, Vaucher P, Althaus F, et al. Social and medical vulnerability factors of emergency department frequent users in a universal health insurance system. *Acad Emerg Med*. (2012) 19:63–8. doi: 10.1111/j.1553-2712.2011.01246.x

5. Byrne M, Murphy AW, Plunkett PK, McGee HM, Murray A, Bury G. Frequent attenders to an emergency department: a study of primary health care use, medical profile, and psychosocial characteristics. *Ann Emerg Med*. (2003) 41:309–18. doi: 10.1067/mem.2003.68

6. Hansagi H, Olsson M, Sjöberg S, Tomson Y, Göransson S. Frequent use of the hospital emergency department is indicative of high use of other health care services. *Ann Emerg Med*. (2001) 37:561–7. doi: 10.1067/mem.2001.111762

7. Meng X, Muggli T, Baetz M, D'Arcy C. Disordered lives: life circumstances and clinical characteristics of very frequent users of emergency departments for primary mental health complaints. *Psychiatry Res*. (2017) 252:9–15. doi: 10.1016/j.psychres.2017.02.044

8. Moe J, Kirkland S, Ospina MB, Campbell S, Long R, Davidson A, et al. Mortality, admission rates and outpatient use among frequent users of emergency departments: a systematic review. *Emerg Med J*. (2016) 33:230–6. doi: 10.1136/emermed-2014-204496

9. Gual A, Drummond C. Killing me softly: alcohol addiction today. *Eur Neuropsychopharmacol*. (2022) 57:30–2. doi: 10.1016/j.euroneuro.2021.12.008

10. Manthey J, Shield KD, Rylett M, Hasan OSM, Probst C, Rehm J. Global alcohol exposure between 1990 and 2017 and forecasts until 2030: a modelling study. *Lancet*. (2019) 393:2493–502. doi: 10.1016/S0140-6736(18)32744-2

11. Miquel L, Gual A, Vela E, Lligoña A, Bustins M, Colom J, et al. Alcohol consumption and inpatient health service utilization in a cohort of patients with alcohol dependence after 20 years of follow-up. *Alcohol Alcohol*. (2016) 52:227–33. doi: 10.1093/alcalc/agw075

12. Chabert J, Lambert C, Cabé J, Cherpitel CJ, Rolland B, Moustafa F, et al. Could reasons for admission help to screen unhealthy alcohol use in emergency departments? A multicenter French study. *Front. Psychiatry*. (2023) 14:1–11. doi: 10.3389/fpsyt.2023.1271076

13. Mullins PM, Mazer-Amirshahi M, Pines JM. Alcohol-related visits to US emergency departments, 2001-2011. *Alcohol Alcohol*. (2016) 52:119–25. doi: 10.1093/alcalc/agw074

14. Beckerleg W, Hudgins J. Substance use-related emergency department visits and resource utilization. *West J Emerg Med*. (2022) 23:166–73. doi: 10.5811/westjem.2022.1.53834

15. Sporinova B, Manns B, Tonelli M, Hemmelgarn B, Macmaster F, Mitchell N, et al. Association of mental health disorders with health care utilization and costs among adults with chronic disease. *JAMA Netw Open*. (2019) 2:1–14. doi: 10.1001/jamanetworkopen.2019.9910

16. Butler K, Reeve R, Arora S, Viney R, Goodall S, van Gool K, et al. The hidden costs of drug and alcohol use in hospital emergency departments. *Drug Alcohol Rev*. (2016) 35:359–66. doi: 10.1111/dar.12302

17. Miquel L, Rehm J, Shield KD, Vela E, Bustins M, Segura L, et al. Alcohol, tobacco and health care costs: a populationwide cohort study (n = 606 947 patients) of current drinkers based on medical and administrative health records from Catalonia. *Eur J Pub Health*. (2018) 28:674–80. doi: 10.1093/eurpub/ckx236

18. LaCalle E, Rabin E. Frequent users of emergency departments: the myths, the data, and the policy implications. *Ann Emerg Med*. (2010) 56:42–8. doi: 10.1016/j.annemergmed.2010.01.032

19. Giannouchos TV, Kum HC, Foster MJ, Ohsfeldt RL. Characteristics and predictors of adult frequent emergency department users in the United States: a systematic literature review. *J Eval Clin Pract*. (2019) 25:420–33. doi: 10.1111/jep.13137

20. Soril LJJ, Leggett LE, Lorenzetti DL, Noseworthy TW, Clement FM. Characteristics of frequent users of the emergency department in the general adult population: a systematic review of international healthcare systems. *Health Policy (New York)*. (2016) 120:452–61. doi: 10.1016/j.healthpol.2016.02.006

21. Van Tiel S, Rood PPM, Bertoli-Avella AM, Erasmus V, Haagsma J, Van Beeck E, et al. Systematic review of frequent users of emergency departments in non-US hospitals: state of the art. *Eur J Emerg Med*. (2015) 22:306–15. doi: 10.1097/MEJ.0000000000000242

22. Oliveras C, Bruguera P, Cordero Torres I, Millán Hernández A, Pons MT, Guzmán Cortez PR, et al. Another round: influence of alcohol-related conditions and other drug use-related disorders in emergency department frequent use – a single-site matched case-control study in Spain. *Eur Addict Res*. (2024) 30:275–287. doi: 10.1159/000538987

23. Van Der Zee J, Kroneman MW. Bismarck or Beveridge: a beauty contest between dinosaurs. *BMC Health Serv Res*. (2007) 7:1–11. doi: 10.1186/1472-6963-7-94

24. Vandenbroucke JP, Von Elm E, Altman DG, Gøtzsche PC, Mulrow CD, Pocock SJ, et al. Strengthening the reporting of observational studies in epidemiology (STROBE): explanation and elaboration. *PLoS Med*. (2007) 4:e297. doi: 10.1371/journal.pmed.0040297

25. Bruguera P, Barrio P, Oliveras C, Vázquez M, Soler V, Nuño L, et al. Detection and registration of alcohol use in the emergency department. *Rev Esp Salud Publica*. (2020) 94:E1–E8. doi: 10.4321/S1135-57272020000100021

26. World Health Organization. ICD-10: international statistical classification of diseases and related health problems. *tenth revision, 2nd* ed. Geneva (Switzerland): World Health Organization (2004).

27. American Psychiatric Association. Diagnostic and statistical manual of mental disorders. *5th* ed. Washington, D.C.: American Psychiatric Publishing (2013).

28. Kaji AH, Schriger D, Green S. Looking through the retrospectoscope: reducing bias in emergency medicine chart review studies. *Ann Emerg Med*. (2014) 64:292–8. doi: 10.1016/j.annemergmed.2014.03.025

29. Ondler C, Hegde GG, Carlson JN. Resource utilization and health care charges associated with the most frequent ED users. *Am J Emerg Med*. (2014) 32:1215–9. doi: 10.1016/j.ajem.2014.07.013

30. Verheij C, Rood PPM, Deelstra CK, Levendag MLL, Koch BCP, Polinder S, et al. Emergency department visits due to intoxications in a Dutch university hospital: occurrence, characteristics and health care costs. *PLoS One*. (2019) 14:e0226029. doi: 10.1371/journal.pone.0226029

31. Verelst S, Moonen PJ, Desruelles D, Gillet JB. Emergency department visits due to alcohol intoxication: characteristics of patients and impact on the emergency room. *Alcohol Alcohol*. (2012) 47:433–8. doi: 10.1093/alcalc/ags035

32. Ruger JP, Richter CJ, Spitznagel EL, Lewis LM. Analysis of costs, length of stay, and utilization of emergency department services by frequent users: implications for health policy. *Acad Emerg Med*. (2004) 11:1311–7. doi: 10.1197/j.aem.2004.07.008

33. Ruger JP, Richter CJ, Lewis LM. Clinical and economic factors associated with ambulance use to the emergency department. *Acad Emerg Med*. (2006) 13:879–85. doi: 10.1197/j.aem.2006.04.006

34. Meerding WJ, Bonneux L, Polder JJ, Koopmanschap MA, Van der Maas PJ. Demographic and epidemiological determinants of healthcare costs in Netherlands: cost of illness study. *Br Med J*. (1998) 317:111–5. doi: 10.1136/bmj.317.7151.111

35. Johnston MC, Crilly M, Black C, Prescott GJ, Mercer SW. Defining and measuring multimorbidity: a systematic review of systematic reviews. *Eur J Pub Health*. (2019) 29:182–9. doi: 10.1093/eurpub/cky098

36. Vu F, Daeppen JB, Hugli O, Iglesias K, Stucki S, Paroz S, et al. Screening of mental health and substance users in frequent users of a general Swiss emergency department. *BMC Emerg Med*. (2015) 15:27. doi: 10.1186/s12873-015-0053-2

frontiers | Frontiers in Public Health

TYPE Original Research
PUBLISHED 19 December 2024
DOI 10.3389/fpubh.2024.1455305

Check for updates

OPEN ACCESS

EDITED BY
Hai Fang,
Peking University, China

REVIEWED BY
Mohsen Khosravi,
Zahedan University of Medical Sciences, Iran
Shasha Yuan,
Chinese Academy of Medical Sciences and Peking Union Medical College, China

*CORRESPONDENCE
Shujie Guo
✉ 2591284370@qq.com

RECEIVED 26 June 2024
ACCEPTED 25 November 2024
PUBLISHED 19 December 2024

CITATION
Li C, Wang N, Zhang H, Yan Y, Chen H, Jiang R, Chang Y, Zhao P, Cheng Q, Song B and Guo S (2024) Rural patients' satisfaction with humanistic nursing care in Chinese Public Tertiary Hospitals: a national cross-sectional study.
Front. Public Health 12:1455305.
doi: 10.3389/fpubh.2024.1455305

Rural patients' satisfaction with humanistic nursing care in Chinese Public Tertiary Hospitals: a national cross-sectional study

Chuang Li[1,2], Ning Wang[3], Haixin Zhang[1,4], Yongguang Yan[1,5], Huiling Chen[6], Ruxin Jiang[1,7], Yulan Chang[8], Pingfan Zhao[1], Qiaomei Cheng[1], Bing Song[3] and Shujie Guo[1,2,9]*

[1]Henan Provincial People's Hospital, Zhengzhou University People's Hospital, Zhengzhou, Henan, China, [2]Outpatient Department, Henan Provincial People's Hospital, Zhengzhou, Henan, China, [3]Department of Orthopedic, Qilu Hospital of Shandong University Dezhou Hospital, Dezhou, Shandong, China, [4]Department of Nursing, Henan Provincial People's Hospital, Zhengzhou, Henan, China, [5]Research and Foreign Affairs Department, Henan Provincial People's Hospital, Zhengzhou, Henan, China, [6]Heart Center of Henan Provincial People's Hospital, Central China Fuwai Hospital, Central China Fuwai Hospital of Zhengzhou University, Zhengzhou, Henan, China, [7]Department of Anesthesiology and Perioperative Medicine, Henan Provincal People's Hospital, Zhengzhou, Henan, China, [8]Department of Nursing, Henan Vocational College of Nursing, Anyang, Henan, China, [9]South Henan Branch of Henan Provincial People's Hospital, Xinyang, Henan, China

Background: The provision of high-quality healthcare services and patient satisfaction are fundamental objectives in modern healthcare. Humanistic nursing care, which emphasizes empathy, respect for individuality, and cultural sensitivity, aims to build trust and improve the overall experience for patients. This approach is especially relevant for rural patients in China, who often face additional challenges in accessing care in large tertiary hospitals.

Methods: A multistage, stratified sampling method was employed to collect data from 8,263 patients aged 18 years or older in large public tertiary hospitals. Humanistic care satisfaction scores were measured using the Nurse Caring Instrument (NCI) questionnaire, a validated tool for assessing patient satisfaction with nursing care.

Results: Satisfaction with nursing humanistic care among rural Chinese patients attending large tertiary public hospitals was low with the overall mean satisfaction score 81.62 ± 16.85. Significant differences in satisfaction were found based on age, marital status, number of children, educational attainment, occupation, monthly household income, department visited, type of medical insurance, and first-time visitor. A multivariate analysis revealed positive correlations with satisfaction for factors such as having children, higher education, higher family monthly income, and first-time visitor, and negative correlations for factors such as older age, being widowed, department visited, and region.

Conclusion: Older adults, widowed individuals, and first-time patients expressed lower levels of satisfaction, highlighting the need for tailored interventions. The findings provide insights into the impact of humanistic nursing care for rural patients and emphasize the importance of culturally sensitive approaches to improve patient satisfaction in rural China. This study has several limitations. The cross-sectional design restricts the ability to establish causal relationships, and there is a potential for selection bias, as participants who completed the survey may have higher educational and economic levels, possibly leading to an overestimation of satisfaction. Lastly, as this study focused on rural patients in large public tertiary hospitals in China, the findings may not be generalizable to other settings or patient groups. Future studies should address these limitations for broader applicability and insight.

KEYWORDS

rural patients, humanistic nursing care, Chinese Public Tertiary Hospitals, patient satisfaction, cross-sectional study

1 Introduction

The provision of high-quality healthcare services and patient satisfaction are the fundamental objectives of modern healthcare. High-quality healthcare services encompass a multifaceted spectrum that not only includes essential biomedical interventions, such as pharmacotherapy, surgical procedures, and standard nursing care, but also the broader dimensions of humanistic nursing care. The concept of humanistic care was initially proposed in the 1970s by Madeleine Leininger, an American nursing scholar, and subsequently developed and expanded by Jean Watson, who established the theoretical underpinnings of nursing humanism (1–3). The essence of humanistic nursing care lies in meeting patients' needs and enabling them to feel both physical and psychological support through nursing competencies, attitudes, and behaviors. Its primary goal is to help patients achieve physiological, psychological, and sociocultural wellbeing. Humanistic care is not only a professional attitude and emotional labor but also a dynamic process that integrates nursing procedures with nurse-patient communication. As one of the fundamental needs of patients, humanistic care is not only a critical component of patient satisfaction but also a key indicator and intrinsic element of high-quality nursing services. With the continuous progress in social development, humanistic nursing care is practiced by more and more healthcare facilities around the world. Guided by the International Circulation Care Association, 42 Humanistic Care Guidelines for nurses were introduced in 2003. In China, expert Liu et al. incorporated Watson's 10 caring elements into research on humanistic nursing practice for care management. Using theoretical guidance, pilot caring wards, thematic research, international collaboration, and industry exchanges, they established an inpatient humanistic care model and improved evaluation indicators, providing strategic direction for nursing managers (4, 5). Humanistic nursing care emphasizes the establishment of profound empathetic connections between healthcare providers and patients with a focus on compassion, empathy, and culturally sensitive interactions (6, 7). Humanistic nursing is vital for patients; it is an important aspect of patient satisfaction and an essential component of quality nursing care (8, 9). The absence of humanistic nursing has a direct impact on patient recovery, reduces the quality of medical services and patient satisfaction, and can lead to nurse–patient conflict (10–12).

Guided by the International Circulation Care Association, 42 Humanistic Care Guidelines for nurses were introduced in 2003 (16). That year, Watson developed the ANCM model from a patient-centered approach to strengthen nurses' caring abilities through programs covering care assessment, planning, implementation, and continuous care (17). In China, expert Liu et al. (18–22) incorporated Watson's 10 caring elements into research on humanistic nursing practice for care management. Using theoretical guidance, pilot caring wards, thematic research, international collaboration, and industry exchanges, they established an inpatient humanistic care model and improved evaluation indicators, providing strategic direction for nursing managers.

While China has experienced rapid urbanization in recent years, a significant portion of its population remains predominantly rural, with the majority residing in rural areas. Despite this demographic landscape, the distribution of healthcare infrastructure and resources in China heavily favors urban centers, leaving rural areas inadequacy of healthcare resources. According to official statistics released by the National Health and Family Planning Commission of China in 2017, the total urban healthcare expenditure in China increased from 262.42 billion RMB in 2000 to 2,657.56 billion RMB in 2014, representing a more than tenfold increase. During the same period, the proportion of urban healthcare expenditure in the total national healthcare expenditure rose from 57% to 75%. In contrast, rural healthcare expenditure grew from 196.24 billion RMB in 2000 to 873.68 billion RMB in 2014, an approximately fourfold increase. However, the proportion of rural healthcare expenditure in the total national healthcare expenditure declined from 43% to 25% over the same period.

Consequently, most rural patients often choose to go to large tertiary hospitals in regional centers when they face more serious illnesses (13, 14). At present, rural patients in China constitute a significant proportion of the population seeking healthcare services in large tertiary hospitals, these patients often undertake arduous journeys to access specialized care, facing a myriad of challenges, including arduous journeys to access healthcare facilities, economic disparities, communication difficulties and cultural differences, and limited healthcare resources. This psychological dilemma of the helplessness is especially pronounced when traveling to a large medical institution in a regional city (15, 16). In this context, the provision of humanistic nursing care has become essential to enhancing rural patients' overall healthcare experience and satisfaction. It not only addresses patients' physical needs but also their emotional and psychological requirements, contributing to the provision of more comprehensive healthcare services.

This study assesses rural patients' satisfaction with humanistic nursing care in large public tertiary hospitals in China, and seeks to identify areas for improvement to ensure that rural patients receive healthcare that not only addresses their clinical needs but also their emotional and psychological requirements.

2 Methods

2.1 Study design

The study protocol was approved by the Ethics Committee of Tongji Medical College, Huazhong University of Science and Technolog (Approval No.: 2022S161). This national cross-sectional study used a multistage, stratified sampling method to obtain a representative sample of people aged 18 years or older to assess patient-reported satisfaction with humanistic nursing care among rural patients in large public tertiary hospitals in China from 1 July to 15 August 2022, based on the China Life Care Association. In the first stage, four regions—northeast, east, central, and west—were selected. Subsequently, specific provinces or municipalities within these regions were identified. A total of 30 provinces were chosen based on the regional distribution of hospital members affiliated with the China Life Care Association. The sample size for each province was determined proportionally to its population relative to the national population. In the second stage, the number of tertiary hospitals to be included from each province was calculated, taking into account the population distribution across cities within the province and the annual number of inpatients per hospital. This ensured a representative number of patients per hospital for the survey. In the third stage, hospital managers from the selected hospitals in the second stage served as the sampling units. Ultimately, a total of 83 hospitals were included in the study. Figure 1 presents a schematic diagram illustrating the process employed in this study.

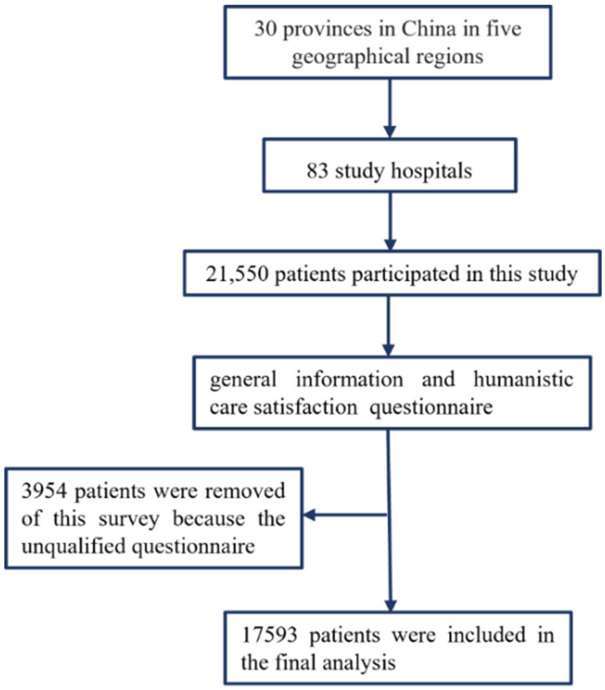


FIGURE 1
Hospital sites and respondent selection process.

2.2 Instruments and measures

The survey instruments were largely based on the Methodist Health Care System Nurse Caring Instrument (NCI) developed by the Nursing Care Quality Control Council of the Houston Health Care System in 2000 to assess inpatients' satisfaction with humanistic nursing (17). The survey comprised two sub-questionnaires, which were developed and approved by the research team based on a comprehensive literature review (18). The general information questionnaire included the patient's hospital, sex, age, marital status, number of children, education attainment, place of residence, monthly household income, whether it was the patient's first visit, time of visit, type of medical insurance, department visited, area of visit, and whether surgery was performed. The Humanistic Nursing Care Satisfaction Scale was assessed using the NCI, which was developed by the Nursing Care Quality Control Council of the Houston Health Care System as part of the Humanistic Care Satisfaction questionnaire (19–21). This questionnaire is the most frequently used instrument for assessing the quality of care and consists of 20 items covering 12 dimensions: care coordination, competence, teaching/learning, emotional support, respect for individuality, physical comfort, availability, helping/trusting relationships, patient/family involvement, physical environment, spiritual environment, and outcomes. The items reflect concepts from the caring literature and the caring theory of Watson and others, as well as items that are familiar areas of assessment on other instruments. Each item provides seven answers corresponding to a seven-point Likert scale. The items ("seldom or rarely," "often or frequently," "always or almost always," and "does not apply") were scored from one to seven, resulting in a total score of 140. A higher score indicates greater satisfaction with nurses' care.

After obtaining authorization from the original authors, we embarked on a comprehensive adaptation and reliability testing process. Our team meticulously employed a multifaceted scientific approach to develop, localize, and validate the questionnaire's reliability, feasibility, and acceptability. This robust process encompassed an extensive literature review, patient cognitive interviews, input from a diverse range of stakeholders (including healthcare regulators, hospital managers, doctors, nurses, and patients), psychometric analyses, pilot tests conducted across three provinces, small-scale multidisciplinary expert consultations, and field tests. To ensure the feasibility and acceptability of the tool, we analyzed missing item response percentages, reviewed interviewer-reported acceptability, and assessed the time and ease of administration. The internal consistency and reliability of each dimension were evaluated using Cronbach's α coefficients and inter-subscale correlations. The Chinese version of the NCI questionnaire demonstrated excellent reliability with an overall Cronbach's alpha of 0.982. The helping/trusting dimension obtained a Cronbach's α of 0.943, the respect for individuality dimension a Cronbach's α of 0.907, the patient/family involvement dimension a Cronbach's α of 0.937, the emotional support dimension a Cronbach's α of 0.895, and the care coordination dimension a Cronbach's α of 0.908. For the remaining dimensions, which consisted of single items, Cronbach's α coefficients could not be calculated. Overall, the questionnaire's strong reliability was well-supported within the context of our study, underscoring a coherent, logical, and methodically sound research design.

2.3 Sample size calculation

The survey's target population included inpatients admitted to large public tertiary hospitals. The inclusion criteria for participation were: (1) patients who were stably residing in rural areas of China, whether they paid rural health insurance or not; (2) patients who were older than 18 years; (3) patients who were hospitalized for >5 days; (4) patients who were conscious; and (5) patients who had voluntarily completed the questionnaire. The exclusion criteria were: (1) patients who were unable to use a smartphone or have intellectual or cognitive impairments to complete the cognitive assessments required for the trial; and (2) patients without smartphones or who were unable to answer the questionnaire using a smartphone.

Drawing on patient satisfaction rates reported for outpatient and inpatient settings in both China and internationally, we established the expected satisfaction rate at 70% (22–25). The primary formula used for determining the study's sample size was $n = u^2_{\alpha/2}\pi\ (1\text{-}\pi)/\delta^2$, where $u_{\alpha/2} = 1.96$, $\alpha = 0.05$, π represents anticipated patient satisfaction with humanistic nursing (70% in this study), and δ denotes the admissible error (10% for this study). Using this formula, the theoretical sample size was calculated as 90, with an additional 10% added to account for any potential loss during the study (26). After taking into account variations in the number of hospital inpatients and to make the data more representative, we decided to enroll a minimum of 200 patients from each tertiary hospital. The total number of patients interviewed for this study was 13,325. To control for selection bias, a final sample of 8,263 participants was included in the analysis after excluding incomplete or invalid questionnaires.

2.4 Data collection

The Human Care Professional Committee of the China Life Care Association initiated and coordinated the study to ensure high-quality data collection and analysis. The research was carried out utilizing the Questionnaire Star Platform. Following the acquisition of consent from hospital administrators, leaders from diverse hospitals nationwide, identified as research subjects, were briefed on the questionnaire's purpose and specific implementation details before the commencement of the nationwide survey. Trained researchers conducted a random-sampling survey of eligible rural inpatients at the hospital's discharge settlement office, after obtaining informed consent for their participation in the study and administering the questionnaire survey. All the survey questionnaires were completed and submitted anonymously. Rigorous quality control measures were instituted to uphold the scientific and authentic nature of data collection. The survey's data collectors received comprehensive training from various hospitals across the country before the nationwide survey. The training encompassed research objectives, significance, target population, and questionnaire completion methods to ensure the scientific and authentic nature of data collection. Throughout the questionnaire survey, strict adherence to the inclusion and exclusion criteria was maintained in the selection of research subjects. Patients were briefed on the purpose of the research, with an assurance of strict adherence to confidentiality and anonymity principles. Quality control measures involved scrutinizing the questionnaires' quality and excluding invalid questionnaires before data entry. Simultaneous input by two individuals during data entry was employed to ensure accuracy and precision.

2.5 Statistical analysis

The statistical analysis was conducted after excluding invalid questionnaires obtained from Questionnaire Star. The data were imported into SPSS (version 25.0) using an Excel spreadsheet. To ensure accuracy, a two-person crosscheck method was employed after eliminating invalid questionnaires. Continuous variable distributions were described using means and standard deviations, whereas categorical variable distributions were described using frequency counts. Univariate methods were initially used to analyze the relevant indicators in order to identify risk factors, which were subsequently incorporated into a multivariate logistic regression analysis.

3 Results

3.1 Participants' characteristics

A total of 13,225 patients were interviewed for this study, of which 8,263 patients had valid questionnaires; 4,962 patients' questionnaires were declared invalid and excluded, mostly due to incomplete responses. The 8,263 patients included in the study were distributed across 50 tertiary hospitals in 25 provincial administrative units across the country. The sample consisted of 4,328 (52.38%) male patients and 3,935 (47.62%) female patients, of which 5,679 (68.73%) were between 50 and 70 years old, 5,285 (63.96%) were married, and 7,510 (90.88%) had one or more children. Patients' literacy levels were generally concentrated at a high school level or below (7,049; 85.31%). Most were mainly engaged in agricultural production, employment, or contract work (5,329; 64.49%), the majority mainly resided in rural areas (5,568; 67.38%), and most had a monthly household income of <5,000 yuan (6,171; 74.68%). The purpose of their visit was mainly for internal medical or surgical treatment (6,916; 83.70%); 6,962 (83.82%) of the patients had rural co-operative medical insurance and 6,883 (83.30%) of them were visiting a large hospital for the first time. The patients' demographic characteristics are summarized in Table 1.

TABLE 1 Comparison of humanistic caring satisfaction scores of subjects with different demographic characteristics.

Project	Grouping	Numbers	Score ($x \pm s$)	Statistics	*P*-value
Overall	–	–	81.62± 16.85	–	–
Gender	Male	4,328	82.23 ± 13.29	16.28[a]	0.328
	Female	3,935	81.32 ± 15.68		
Age	18–30	453	93.23 ± 23.68	71.23[b]	0.022
	31–40	631	86.75± 13.85		
	41–50	526	85.91± 16.33		
	51–60	2,365	80.84± 16.27		
	61–70	3,214	80.32± 22.52		
	71–80	527	78.66 ± 19.36		
	≥81	547	76.32± 16.85		
Marital status	Married	5,285	86.25 ± 16.28	32.55[b]	0.039
	Unmarried	795	83.22 ± 17.87		
	Divorced/separated	525	79.62 ± 21.39		
	Widowed	1,658	76.21± 16.82		
Children	No child	653	77.21 ± 17.83	36.57[b]	0.036
	1 child	3,225	80.23 ± 10.29		
	≥2 children	4,385	84.03 ± 13.12		
Educational attainment	Primary school	1,536	75.58 ± 10.89	53.24[b]	0.026
	Junior high school	2,912	80.23 ± 12.39		
	High school/technical Secondary school	2,601	85.39 ± 12.28		
	College	862	90.82 ± 13.68		
	Bachelor degree or above	352	86.25 ± 15.62		
Occupation	Farmer	2,443	73.25 ± 12.35	57.98[b]	0.023
	Worker	825	86.95 ± 15.81		
	Military person	336	90.24 ± 22.69		
	Leader	0	–		
	Employed	1,361	81.07 ± 17.38		
	Self-employed	952	82.73 ± 18.08		
	Freelance	1,525	82.37 ± 15.99		
	Retired	0	–		
	Student	538	90.85 ± 17.97		
	Other	283	78.48 ± 15.36		
Place of residence	City	712	83.74 ± 18.92	19.68[b]	0.229
	Town	1,983	81.92 ± 15.36		
	Rural	5,568	77.28 ± 13.28		
Monthly household income (yuan)	<3,000	2,386	79.38 ± 13.33	68.85[b]	0.018
	3,000–<5,000	3,785	78.32 ± 16.86		
	5,000–<8,000	1,257	86.32 ± 16.87		
	8,000–<10,000	1,035	91.07 ± 19.69		
	>10,000	428	93.23 ± 15.54		
Department visited	Internal medicine department	3,089	81.32 ± 17.00	50.31[b]	0.031
	Surgical	3,827	81.12 ± 16.60		

(Continued)

TABLE 1 (Continued)

Project	Grouping	Numbers	Score ($x \pm s$)	Statistics	P-value
	Obstetrics and gynecology	763	80.58 ± 18.28		
	Pediatric	0	–		
	Intensive care medicine	51	73.41 ± 15.82		
	Other	533	80.37 ± 16.23		
Medical insurance type	Rural cooperative medical insurance	6,962	79.35 ± 16.99	45.96[b]	0.035
	Basic medical insurance scheme for urban employees	0	–		
	Basic medical insurance scheme for urban residents in urban areas	0	–		
	Commercial insurance	632	86.39 ± 18.32		
	Public expense	0	–		
	Own expense	359	75.35 ± 13.86		
	Other	310	80.87 ± 18.63		
Region	Northeast China	928	83.21 ± 16.49	10.17[b]	0.443
	North China	1,353	83.86 ± 18.32		
	East China	1,607	80.83 ± 15.62		
	Middle China	1,354	81.22 ± 19.32		
	West China	986	80.28 ± 15.36		
	Northwest China	823	79.29 ± 18.95		
	South China	1,212	79.33 ± 18.32		
First-time visitor	Yes	6,883	79.85 ± 18.36	66.35[a]	0.019
	No	1,380	85.33 ± 17.59		
Surgical patient	Yes	5,035	81.52 ± 18.36	7.22[a]	0.573
	No	3,228	83.05 ± 17.85		

[a]t-value.
[b]F-value.

3.2 Humanistic nursing care satisfaction scores of patients with diverse characteristics

Table 1 summarizes the results of the comparative analysis of humanistic care satisfaction scores based on patients' characteristics. The Humanistic Care Satisfaction Scale's maximum score is 140, and the overall mean satisfaction score for humanistic care in this study was 81.62 ± 16.85, showing that satisfaction with nursing humanistic care among rural Chinese patients attending large tertiary public hospitals was generally at a low level. We found no statistical difference in satisfaction with humanistic care among patients by gender, place of residence, region, and whether or not they had surgery, while age, marital status, number of children, educational attainment, occupation, monthly household income, department visit, medical insurance type, and first-time visitor showed statistical differences (Table 1).

Specifically, the older the patient, the lower their satisfaction with humanistic care, and the lowest level of satisfaction with humanistic care was among patients over 80 years old (76.32 ± 16.85). Marital status also had a greater impact on patients' satisfaction, with the lowest level of satisfaction with humanistic care among widowed patients (76.21 ± 16.82 points). We also found a direct correlation between number of children and the patient's satisfaction with humanistic care. In terms of education attainment, rural patients with a primary school education had the lowest level of satisfaction with humanistic care (75.58 ± 10.89). In terms of occupation, farmer had the lowest level of satisfaction with humanistic care (73.25 ± 12.35). In terms of monthly household income, those with an income of <3,000 and 3,000–5,000 had the lowest satisfaction with humanistic care. First-time visitors also had lower levels of satisfaction with humanistic care (Table 1).

3.3 Factors associated with humanistic care satisfaction

The multiple linear regression analysis (Table 2) revealed significant associations between various factors and humanistic care satisfaction scores. The significant variables included in the

TABLE 2 Multiple linear regression analysis of the factors associated with humanistic care satisfaction scores.

Variable	β	SE	P	R^2	Adjusted R^2
Age	−0.232	0.051	0.036	0.592	0.376
Marital status	−0.135	0.029	0.039		
Number of children	0.363	0.076	0.028		
Educational attainment	0.285	0.062	0.033		
Occupation	0.265	0.032	0.568		
Monthly household income	0.391	0.061	0.027		
Department visited	0.383	0.114	0.353		
Medical insurance type	0.274	0.029	0.237		
First-time visitor	0.338	0.039	0.043		

model were selected based on their significance in the univariate analysis to ensure clarity and methodological transparency. Children number ($\beta = 0.363$, SE = 0.076), education attainment ($\beta = 0.285$, SE = 0.062), monthly household income ($\beta = 0.391$, SE = 0.061), and first time visited ($\beta = 0.338$, SE = 0.039) were found to have significant positive correlations with humanistic care satisfaction scores. In contrast, age ($\beta = -0.232$, SE = 0.051), marital status ($\beta = -0.135$, SE = 0.039) and department visited ($\beta = 0.383$, SE = 0.114) displayed significant negative correlations with humanistic care satisfaction scores. The R^2 value for this analysis was 0.592 and the adjusted R^2 value was 0.376.

4 Discussion

This national cross-sectional study's findings shed light on rural patients' satisfaction levels with humanistic nursing care at large public tertiary hospitals in China. The emphasis on humanistic care in healthcare settings has gained significance globally, and its impact on patient satisfaction is evident in various contexts. In rural healthcare settings in China, where challenges related to access, communication, and cultural differences are pronounced, understanding the nuances of humanistic nursing care is critical for improving healthcare outcomes (27–30). Our findings revealed that the overall satisfaction with humanistic nursing care among rural patients was moderately low, emphasizing a critical area for improvement within the healthcare system.

One significant finding was the influence of age on satisfaction levels. Older patients, particularly those over 80, reported the lowest satisfaction scores. This could be attributed to the increased vulnerability and higher expectations of this age group for empathetic and compassionate care. Additionally, older adult patients may face more chronic conditions and complex health issues, increasing their need for comprehensive care, which the current system might not fully meet. Older adult patients, particularly those of advanced age, often encounter significant challenges due to the prevalence of multiple chronic conditions, limited income, and lower educational attainment. These factors can lead to confusion and difficulty in navigating the healthcare system, especially in large tertiary hospitals. To address these issues, the government has implemented targeted measures for older adult patients in rural areas, including family doctor services, major illness insurance, medical assistance programs, and a long-term care insurance system. At the hospital level, efforts such as training ward and outpatient nurses in humanistic care and establishing humanistic care settings in patient wards have been undertaken (31–34). These initiatives aim to continuously improve patient satisfaction with humanistic care and ensure a more supportive healthcare experience. Marital status emerged as another crucial factor, with widowed patients reporting lower satisfaction levels. This demographic may experience heightened feelings of loneliness and lack of support, thus increasing their need for humanistic care. The loss of a spouse can result in a significant emotional support gap, leading to greater dependence on the healthcare system (35). Hospitals should consider implementing support systems and counseling services tailored to widowed patients to improve their overall healthcare experience.

Educational attainment and occupation were also significant determinants of satisfaction. Patients with lower educational levels and those engaged in farming reported lower satisfaction scores. These findings suggest that educational background and socioeconomic status may influence patients' perceptions and expectations of care. Patients with lower educational levels might lack understanding of medical information, affecting their perception of care quality. Farmers and low-income workers might feel overlooked and unfairly treated due to economic pressures and lack of social support. Efforts to enhance communication efforts to enhance communication and understanding between healthcare providers and patients with diverse educational and occupational backgrounds could lead to improved satisfaction. Over the years, national policies to support rural patients and low-income groups have become increasingly robust. Medical insurance reimbursement for rural patients has steadily expanded, and local governments often provide financial subsidies for low-income individuals, which reduces insurance premiums and alleviates the financial burden on rural patients (36–38). At the hospital level, several strategies have been implemented to improve satisfaction among rural patients. Humanistic care training is provided to healthcare staff to enhance communication skills and understanding of patients' psychological and emotional needs, fostering a more empathetic and personalized approach to patient care (39, 40). Guidance and navigation services are available to assist first-time visitors or patients unfamiliar with hospital procedures, helping rural patients locate relevant departments and understand the treatment process, thereby reducing anxiety and confusion. In collaboration with community health initiatives, some hospitals provide family doctor services for rural patients, ensuring continuity in health management and support before and after hospital visits. Additionally, specialized reception desks and consultation centers have been established to assist rural patients, answer questions, and offer personalized medical guidance. To address language and cultural barriers, patient services may incorporate local dialects or multiple languages, enabling rural patients from diverse backgrounds to understand medical information more effectively. Hospitals have also implemented humanistic care enhancements in hospital wards, creating a comfortable environment and providing psychological support and social work services to ensure that patients and their families feel supported during their stay. Financial counseling and assistance programs are available for economically disadvantaged rural patients, helping them navigate reimbursement procedures and access fee reduction policies to alleviate financial stress. Furthermore, health education initiatives, including lectures, brochures, and information dissemination, aim to inform rural patients about disease prevention and management, thereby improving their self-management capabilities. Collectively, these measures are designed to enhance the overall experience and satisfaction of rural patients during their medical treatment and care, contributing to a more inclusive and supportive healthcare environment.

Interestingly, first-time visitors to tertiary hospitals reported lower satisfaction levels compared to those with prior visits. This could be due to unfamiliarity with the hospital environment and processes, leading to increased anxiety and discomfort. First-time visitors may not be familiar with hospital procedures and facilities, which can add to their stress and anxiety. Hospitals should consider implementing orientation programs and support services for first-time visitors to help them navigate the healthcare system more comfortably. Income levels also played a significant role in determining satisfaction. Patients with lower monthly household incomes reported lower satisfaction scores, highlighting the impact of economic disparities on healthcare experiences. Low-income patients may face greater financial burdens and resource limitations, leading to lower expectations and satisfaction with healthcare services. Ensuring equitable access to high-quality humanistic care regardless of economic status is essential for improving overall patient satisfaction. The department visited by patients was another important factor influencing satisfaction. Departments that primarily deal with acute or severe medical conditions, such as intensive care units, reported lower satisfaction scores. This may be due to the high-stress environment and the critical nature of care provided in these settings. Patients in intensive care units often have severe conditions and higher demands for care quality, while healthcare providers in these environments might prioritize technical operations over emotional support. Enhancing humanistic care practices in such departments, including providing emotional support and clear communication, could improve patient satisfaction. Our study also found that the type of medical insurance held by patients influenced their satisfaction levels. Patients with rural cooperative medical insurance reported lower satisfaction compared to those with commercial insurance. This disparity may reflect differences in the perceived quality of care and financial burdens associated with different insurance types. The coverage and reimbursement rates of rural cooperative medical insurance may be lower than those of commercial insurance, resulting in greater financial pressure for patients. Addressing these disparities through policy changes and improving the coverage and benefits of rural cooperative medical insurance could enhance patient satisfaction.

4.1 Limitations

This study has several limitations that should be acknowledged. First, we did not conduct an in-depth analysis of each of the 12 dimensions of the NCI questionnaire, such as care coordination and emotional support. Due to the potential overlap between these dimensions, a detailed examination could introduce complexity and confusion. To maintain clarity and focus, we opted for an overall assessment of humanistic care. However, this approach may limit a deeper understanding of specific aspects of care. Future research could address this limitation by exploring each dimension individually, offering more granular insights into the components of humanistic nursing care.

Second, the cross-sectional design of this study precludes the establishment of causal relationships between patient characteristics and satisfaction with humanistic care. Longitudinal studies would be valuable in tracking changes over time, providing a more dynamic understanding of how various factors influence patient satisfaction. Third, there is a potential for selection bias, as participants who completed the survey and provided qualified data may have relatively higher educational and economic levels. This could result in an overestimation of rural residents' satisfaction with their medical visits. Future studies should aim to minimize this bias by employing more inclusive sampling strategies. Finally, this study focused exclusively on rural patients in large public tertiary hospitals in China. As a result, the findings may not be generalizable to other healthcare settings or patient populations. Future research should consider diverse healthcare environments and include a broader range of patient demographics to enhance the generalizability and applicability of the results.

5 Conclusions

This study presents a comprehensive evaluation of humanistic nursing care satisfaction among rural patients and elucidates the various factors that contribute to their perceptions of healthcare services. The outcomes of this cross-sectional investigation are poised to serve as a cornerstone for evidence-based recommendations, strategically designed to elevate the caliber of healthcare services tailored to the unique needs of rural patients in China. Older adults, widowed individuals, and first-time patients expressed lower levels of satisfaction, highlighting the need for tailored interventions. Factors such as education and family support play an important role in improving patient satisfaction with humanistic nursing. This national cross-sectional study significantly advances our understanding of the determinants influencing humanistic care satisfaction among rural patients within the context of China's public tertiary hospitals. The identified associations not only offer valuable insights but also lay the groundwork for targeted interventions and policy formulations and, ultimately, the overall quality of healthcare delivery.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Author contributions

CL: Data curation, Formal analysis, Investigation, Methodology, Writing – original draft. NW: Investigation, Methodology, Project administration, Software, Writing – review & editing. HZ: Formal analysis, Methodology, Project administration, Resources, Writing – review & editing. YY: Supervision, Validation, Visualization, Writing – review & editing. HC: Methodology, Project administration, Resources, Writing – review & editing. RJ: Investigation, Methodology, Software, Writing – review & editing. YC: Supervision, Validation, Visualization, Writing – review & editing. PZ: Software, Supervision, Validation, Visualization, Writing – review & editing. QC: Investigation, Project administration, Resources, Writing – review & editing. BS: Data curation, Investigation, Methodology, Project administration, Writing – review & editing. SG: Conceptualization, Funding acquisition, Supervision, Validation, Writing – review & editing.

Funding

The author(s) declare financial support was received for the research, authorship, and/or publication of this article. This study was supported by Henan Province Young and Middle-aged Health Science and Technology Innovation Leading Talent Training Program (LJRC2023020), Henan Provincial People's Hospital 23456 Nursing Talent Project.

Acknowledgments

Thanks to all the members of the Humanistic Nursing Professional Committee of China Life Care Association for their strong support of this study. Thanks to Dr. Marilyn A. Ray and Dr. Marian C. Turkel for our team version of caring for patients with sexual relationships scale (Relational Caring Questionnaire – Patient Form) in the Chinese context of localization and use of authorization. Thanks also to the patients who participated in the survey. We would also like to thank editage team for their grammatical polish work on this manuscript.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

References

1. Watson J, Smith MC. Caring science and the science of unitary human beings: a trans-theoretical discourse for nursing knowledge development. *J Adv Nurs.* (2002) 37:452–61. doi: 10.1046/j.1365-2648.2002.02112.x

2. Watson J. The theory of human caring: retrospective and prospective. *Nurs Sci Q.* (1997) 10:49–52. doi: 10.1177/089431849701000114

3. Watson MJ. New dimensions of human caring theory. *Nurs Sci Q.* (1988) 1:175–81. doi: 10.1177/089431848800100411

4. Wang Y, Zhang Y, Liu M, Zhou L, Zhang J, Tao H, et al. Research on the formation of humanistic care ability in nursing students: a structural equation approach. *Nurse Educ Today.* (2020) 86:104315. doi: 10.1016/j.nedt.2019.104315

5. Li M, Zhu W, Luo Q, Chen H, Duan Y, Xie H, et al. Psychological experience of humanistic care among medical staff in stroke wards: a qualitative research study conducted in China. *Front Psychiatry.* (2022) 13. doi: 10.3389/fpsyt.2022.791993

6. Minick P. The power of human caring: early recognition of patient problems. *Sch Inq Nurs Pract.* (1995) 9:303–17, 319–21. doi: 10.1891/0889-7182.9.4.303

7. Létourneau D, Goudreau J, Cara C. Humanistic caring, a nursing competency: modelling a metamorphosis from students to accomplished nurses. *Scand J Caring Sci.* (2021) 35:196–207. doi: 10.1111/scs.12834

8. Peršolja M. The quality of nursing care as perceived by nursing personnel: critical incident technique. *J Nurs Manag.* (2021) 29:432–41. doi: 10.1111/jonm.13180

9. Liu Y, Aungsuroch Y. Factors influencing nurse-assessed quality nursing care: a cross-sectional study in hospitals. *J Adv Nurs.* (2018) 74:935–45. doi: 10.1111/jan.13507

10. Zhang Y, Li Q, Liu H. From patient satisfaction to patient experience: a call to action for nursing in China. *J Nurs Manag.* (2020) 28:450–6. doi: 10.1111/jonm.12922

11. Mcnicholas A, Mccall A, Werner A, Wounderly R, Marinchak E, Jones P, et al. Improving patient experience through nursing satisfaction. *J Trauma Nurs.* (2017) 24:371–5. doi: 10.1097/JTN.0000000000000328

12. Wong CA, Cummings GG, Ducharme L. The relationship between nursing leadership and patient outcomes: a systematic review update. *J Nurs Manag.* (2013) 21:709–24. doi: 10.1111/jonm.12116

13. Li XM, Kou J, Yu Z, Xiao YY, Meng Q, He LP, et al. Health equity of rural residents in Southwest China. *Front Public Health.* (2021) 9:611583. doi: 10.3389/fpubh.2021.611583

14. Liu Y, Zhong L, Yuan S, van de Klundert J. Why patients prefer high-level healthcare facilities: a qualitative study using focus groups in rural and urban China. *BMJ Glob Health.* (2018) 3:e000854. doi: 10.1136/bmjgh-2018-000854

15. Han J, Wu MC, Yang T. Challenge of China's rural health. *BMJ.* (2016) 353:i2003. doi: 10.1136/bmj.i2003

16. Dummer TJ, Cook IG. Exploring China's rural health crisis: processes and policy implications. *Health Policy.* (2007) 83:1–16. doi: 10.1016/j.healthpol.2006.12.002

17. Watson J. Assessing and measuring caring in nursing and health science[M]. (2008).

18. Liu Y, Zhang F, Guan C, Song B, Zhang H, Fu M, et al. Patient satisfaction with humanistic nursing in Chinese secondary and tertiary public hospitals: a cross-sectional survey. *Front Public Health.* (2023) 11. doi: 10.3389/fpubh.2023.1163351

19. Turkel MC, Watson J, Giovannoni J. Caring science or science of caring. *Nurs Sci Q.* (2018) 31:66–71. doi: 10.1177/0894318417741116

20. Gunawan J, Aungsuroch Y, Watson J, Marzilli C. Nursing administration: watson's theory of human caring. *Nurs Sci Q.* (2022) 35:235–43. doi: 10.1177/08943184211070582

21. Watson J. Watson's view of nursing science quarterly's 35th anniversary. *Nurs Sci Q.* (2022) 35:67–9. doi: 10.1177/08943184211051366

22. Wei J, Shen L, Yang HB, Qin JB, Huang W, Zhang JJ, et al. Development and validation of a Chinese outpatient satisfaction questionnaire: evidence from 46 public general hospitals and 5151 outpatients. *Public Health.* (2015) 129:1523–9. doi: 10.1016/j.puhe.2015.03.004

23. Davidson KW, Shaffer J, Ye S, Falzon L, Emeruwa IO, Sundquist K, et al. Interventions to improve hospital patient satisfaction with healthcare providers and systems: a systematic review. *BMJ Qual Saf.* (2017) 26:596–606. doi: 10.1136/bmjqs-2015-004758

24. Kennedy GD, Tevis SE, Kent KC. Is there a relationship between patient satisfaction and favorable outcomes? *Ann Surg.* (2014) 260:592–600. doi: 10.1097/SLA.0000000000000932

25. Sheetz KH, Waits SA, Girotti ME, Campbell DA, Englesbe MJ. Patients' perspectives of care and surgical outcomes in Michigan. *Ann Surg.* (2014) 260:5–9. doi: 10.1097/SLA.0000000000000626

26. Li M, Zhang Q, Shi WJ, Li L, Li Y, Pang Y, et al. Epidemiological survey and analysis of asthma in children aged 0-14 years old in urban and rural areas of Chengdu region. *Transl Pediatr.* (2013) 2:160–6.

27. Feng QQ, Ao YB, Chen SZ, Martek I. Evaluation of the allocation efficiency of medical and health resources in China's rural three-tier healthcare system. *Public Health.* (2023) 218:39–44. doi: 10.1016/j.puhe.2023.02.009

28. Rao S, Xue H, Teuwen DE, Shi H, Yi H. Measurements of quality of village-level care and patients' healthcare-seeking behaviors in rural China. *BMC Public Health.* (2021) 21:1873. doi: 10.1186/s12889-021-11946-8

29. Luo D, Deng J, Becker ER. Urban-rural differences in healthcare utilization among beneficiaries in China's new cooperative medical scheme. *BMC Public Health.* (2021) 21:1519. doi: 10.1186/s12889-021-11573-3

30. Ma C, Song Z, Zong Q. Urban-rural inequality of opportunity in health care: evidence from China. *Int J Environ Res Public Health.* (2021) 18. doi: 10.3390/ijerph18157792

31. Yang M. Does the serious illness insurance in the new rural cooperative medical system reduce poverty? In: *2022 International Conference on Business and Policy Studies (CONF-BPS 2022), Vol 2.* (2022), p. 6. doi: 10.26914/c.cnkihy.2022.082186

32. Lili Z, Lijin P. Effect of major illness insurance on vulnerability to poverty: evidence from Chinaand#13. *Front Public Health.* (2021) 9:791817. doi: 10.3389/fpubh.2021.791817

33. Lai S, Huang Y, Zhang X, Wang Z, Feng J, Zhou Z, et al. Promoting equality in utilization of basic public health services in China: the role of the family doctor contract service. *J Med Econ.* (2024) 21:1444–55. doi: 10.1080/13696998.2024.2421115

34. Yang L, Guangfeng D, Linping X. Research on the design of serious illness insurance scheme in Shanghai based on micro-simulation. *BMC Health Serv Res.* (2022) 22:392. doi: 10.1186/s12913-022-07783-z

35. Peng J, Wu WH, Doolan G, Choudhury N, Mehta P, Khatun A, et al. Marital status and gender differences as key determinants of COVID-19 impact on wellbeing, job satisfaction and resilience in health care workers and staff working in academia in the UK during the first wave of the pandemic. *Front Public Health.* (2022) 10:928107. doi: 10.3389/fpubh.2022.928107

36. Mohr PE, Kintala K. The implementation of Medicare's outpatient prospective payment system and specific concerns for rural hospitals. *Policy Analysis Brief W Series.* (2003) 6:1–4.

37. Beibei Y, Weiyan J, Li H, Bingyu W, Dina B. The role of health system governance in strengthening the rural health insurance system in China. *Int J Equity Health.* (2017) 16:44. doi: 10.1186/s12939-017-0542-x

38. Sadiq AS, Ahmed S. Understanding of individual rationality and institutional constraints: the case of deficiency of doctors in rural Bangladesh. *J Glob Health Rep.* (2020). doi: 10.29392/001c.13385

39. Wang L, Huang R, Du Y, Huang J, Gao Y. Effectiveness of narrative nursing education on humanistic care quality of nursing interns. *Creat Educ.* (2024) 15:1328–36. doi: 10.4236/ce.2024.157080

40. Curcio F, Lommi M, Bermeo RNZ, Burgos AAE, Pucciarelli G, González CIA, et al. Identifying and exploring jean watson's theory of human caring in nursing approaches for patients with psychoactive substance dependence in medical and surgical acute wards. *Nurs Rep.* (2024) 14:2179–91. doi: 10.3390/nursrep14030162

frontiers | Frontiers in Public Health

TYPE Original Research
PUBLISHED 07 January 2025
DOI 10.3389/fpubh.2024.1423191

Check for updates

OPEN ACCESS

EDITED BY
Hai Fang,
Peking University, China

REVIEWED BY
Junxiang Chen,
Indiana University, United States
Semra Bulbuloglu,
Istanbul Aydın University, Türkiye

*CORRESPONDENCE
Zhaoting Zhang
✉ zhangzhaoting2024@163.com

RECEIVED 25 April 2024
ACCEPTED 18 December 2024
PUBLISHED 07 January 2025

CITATION
Zhang Z (2025) Analysis report on trends in public infectious disease control in China. *Front. Public Health* 12:1423191.
doi: 10.3389/fpubh.2024.1423191

Analysis report on trends in public infectious disease control in China

Zhaoting Zhang*

School of Public Policy and Management, China University of Mining and Technology, Xuzhou, China

Background: The prevention and control of public infectious diseases is a significant issue in the global health sector. Controlling infectious diseases is crucial for maintaining public health. As the most populous country in the world, China still faces a series of new challenges in the control of public infectious diseases. Therefore, it is of great significance to conduct an in-depth analysis of the trends in the control of public infectious diseases.

Methodology: This study selects the death rate, incidence rate, proportion of prevention and control funds input, and the proportion of professional technical personnel in China from 2018 to 2023 as research samples and conducts statistical analysis through multiple linear regression. Overall, factors such as the incidence rate, proportion of prevention and control funds input, and proportion of professional technical personnel can explain 98.7% of the trend changes in the infectious disease death rate.

Results: Through multiple regression analysis, the regression coefficient value of 0.001 for the incidence rate indicates a significant positive impact on the mortality rate, meaning that an increase in the incidence of infectious diseases leads to a rise in mortality. The regression coefficient value of −0.012 for the proportion of funding input suggests a significant negative impact on the mortality rate, implying that increased investment in prevention and control funds will correspondingly reduce the mortality rate of infectious diseases. On the other hand, merely increasing the number of professional and technical personnel is not sufficient to control the spread of infectious diseases; comprehensive use of various prevention and control measures is required for effective public infectious disease control.

Conclusion: Public infectious disease prevention and control is a complex process that requires the consideration of multiple factors, rather than merely changing a single factor, particularly in controlling incidence rates and reasonably allocating funds. By refining the analysis of infectious disease control strategies and integrating diverse preventive and intervention measures, it is possible to better control the spread and mortality of infectious diseases, thereby protecting public health and safety.

KEYWORDS

infectious disease, global health, incidence rate, prevention, death rate, mortality

1 Introduction

Public infectious disease prevention and control is a crucial issue in the global health sector, as controlling infectious diseases is paramount for maintaining public health (1). China, as one of the most populous countries in the world, directly relates its public health security and social stability to the control of public infectious diseases. With the acceleration of globalization and the increase in population mobility, the world faces various threats and challenges from infectious diseases such as influenza, tuberculosis, HIV/AIDS, avian influenza, etc. (2). In the past few decades, China has made significant progress in the field of public health by establishing sound monitoring systems, increasing investment in prevention, vaccination, improving health facilities, and enhancing international cooperation, successfully controlling the spread and outbreaks of various infectious diseases (3). However, with factors such as the spread of pathogens, urban–rural disparities, and environmental pollution, China still faces a series of new challenges, such as inadequate vaccination rates and increasing antibiotic resistance (4, 5). Therefore, conducting in-depth analysis of the trend of public infectious disease control is of great significance. Public infectious disease control trends refer to the development direction or trends presented in the control and management of infectious diseases in a specific region or country. The purpose of public infectious disease trend control is to reduce the incidence and mortality rates of infectious diseases. These trends involve various aspects, including the mortality rate, incidence rate, investment in prevention and control costs, transmission routes, and utilization of medical resources. Analysis of public infectious disease control trends can help governments, health institutions, and researchers better understand the dynamic changes of infectious diseases. This not only helps in comprehensively understanding the current public health challenges and issues but also aids in proposing control policy recommendations and prevention strategies concerning the development trends of infectious diseases (6). According to the medical community's definition of the nature of infectious diseases, infectious diseases are a class of diseases caused by various pathogens that can be transmitted between humans, animals, or between humans and animals (Figure 1) (7). According to the provisions of the Infectious Diseases Prevention and Control Law of the People's Republic of China, infectious diseases are classified into three categories (A, B, and C) based on the outbreak, prevalence, and degree of harm when they occur (8). Category A infectious diseases include plague and cholera; Category B infectious diseases include infectious atypical pneumonia, AIDS, viral hepatitis, poliomyelitis, human infection with highly pathogenic avian influenza, measles, epidemic hemorrhagic fever, rabies, epidemic encephalitis B, dengue fever, anthrax, bacterial and amoebic dysentery, tuberculosis, typhoid and paratyphoid fever, epidemic meningitis, pertussis, diphtheria, neonatal tetanus, scarlet fever, brucellosis, gonorrhea, syphilis, leptospirosis, schistosomiasis, and malaria; Category C infectious diseases include influenza, epidemic parotitis, rubella, acute hemorrhagic conjunctivitis, leprosy, epidemic and endemic typhoid and paratyphoid fever, black fever, hydatid disease, and filariasis, except for cholera, bacterial and amoebic dysentery, and typhoid and paratyphoid fever. Other infectious diseases outside the above catalog, according to their outbreak, prevalence, and degree of harm, need to be classified as category B or C infectious diseases, which are determined and announced by the health administrative department of the State Council of China (8).

This article collected and analyzed the number of cases and deaths of category A, B, and C infectious diseases in China since 2018, as well as the government's financial expenditure on the control of major public infectious diseases and the number of professional and technical personnel for prevention and control of infectious diseases. It analyzed the trend of public infectious diseases and their control and conducted multivariate linear regression analysis on relevant factors. The purpose of this article is to emphasize the critical role of public infectious disease prevention and control in maintaining public health and social stability through a study of the correlation trends in

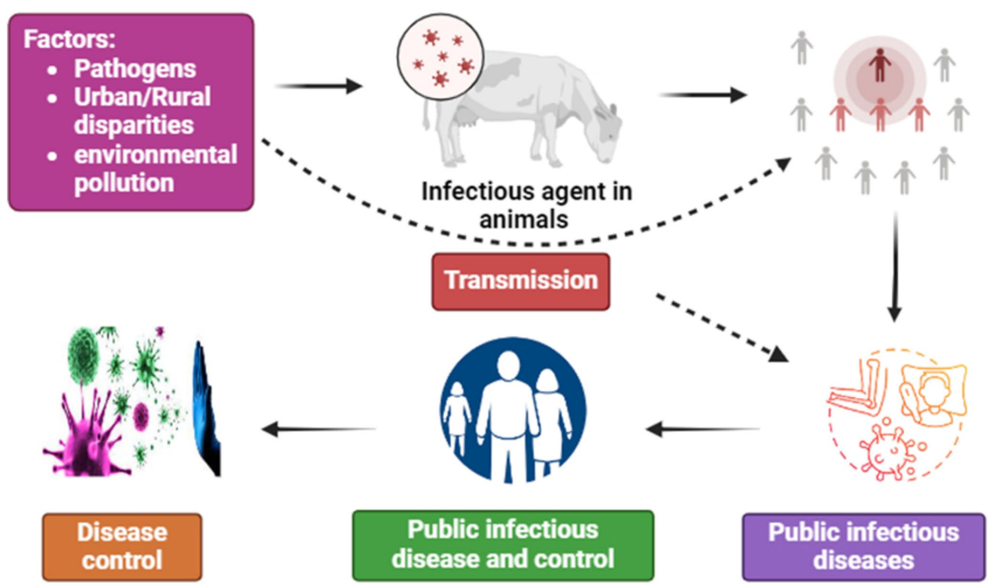


FIGURE 1
Prevalence of public infectious disease and control.

public infectious disease control. It aims to provide governments, health institutions, and researchers with deeper insights to formulate more targeted control policies and methods, thereby helping to enhance China's public health response capabilities to better address the threats posed by infectious diseases and ensure the health and stability of the public. This is also the contribution of this article.

2 Literature review

The analysis of trends in public infectious disease control is an important research field involving multiple disciplines such as public health, epidemiology, and medicine (9). The theoretical foundation of research on trends in public infectious disease control involves various disciplines and theoretical frameworks, mainly including epidemiological theory, behavioral science theory, and health services management theory (10). Epidemiological theory views public infectious diseases and other epidemiological phenomena as the study of disease spread and impact within populations. Through epidemiological investigations and analysis, it can reveal the patterns, transmission routes, and high-risk populations of public infectious disease outbreaks, providing a scientific basis for the development of effective strategies to control disease transmission (11). Behavioral science theory focuses on individual and collective behavior patterns, preferences, and decisions. This theoretical perspective is crucial for understanding people's behavioral responses and health decisions in the context of infectious disease transmission control. Behavioral science theory can be used to analyze the public's cognition, attitudes, and behaviors regarding infectious disease trends, guiding the design of effective health education and control strategies (12). Health services management theory involves aspects such as the organization, management, policy formulation, and resource allocation of health systems. It is essential for planning, implementing, and evaluating the control of public infectious disease trends. Health services management theory can be utilized to assess the responsiveness of infectious disease control systems, the effectiveness of trend control policies, and the fairness of medical resource allocation (13). It can be observed that the theoretical foundation of research on trends in public infectious disease control encompasses multiple theoretical perspectives. It requires the comprehensive application of epidemiology, behavioral science, health services management, sociology, and information technology to comprehensively and systematically understand and address the challenges faced in controlling trends in public infectious diseases.

Both internationally and domestically in China, many scholars have conducted research and analysis on the trends in public infectious disease control. The research encompasses various aspects, typically covering the processes, challenges, strategies, and trends in infectious disease trend control over the past, present, and future. These studies include: "Infectious disease in an era of global change" by Rachel E. Bake et al. This paper analyzes the epidemiological trends of major infectious diseases globally, including HIV/AIDS, tuberculosis, malaria, and influenza. It summarizes the transmission patterns, influencing factors, and effectiveness of control strategies for these diseases, providing reference for the formulation of global infectious disease control policies (14). "Mathematical modeling of infectious disease dynamics" by Constantinos I. Siettos and Lucia Russo. This paper introduces the application of mathematical modeling and simulation in infectious disease control. By constructing mathematical models of disease transmission and utilizing computer simulation techniques, researchers can evaluate the effects of different intervention measures, optimize prevention and control strategies, and predict the development trends of epidemics, thus providing scientific basis for decision-making in disease control (15). "Global trends in emerging infectious diseases" by Kate E. Jones et al. This paper focuses on analyzing the global trends and challenges of emerging infectious diseases, including the impact of pathogen variation, population mobility, and globalization on disease transmission. It emphasizes the need for closer global cooperation to address the challenges posed by emerging infectious diseases (16). "Emphasis of infection prevention and control: A review" by Harsh Thakur and Rahul Rao. This paper reviews the trends and prospects of infectious disease prevention and control measures, including innovations in funding, vaccine development, drug treatment, and rapid testing technology. It suggests that with continuous technological advancements, infectious disease prevention and control will become more intelligent and precise, offering new possibilities for achieving comprehensive disease control (17). In China, the article "China's 70-year Effectiveness in the Prevention and Control of Infectious Diseases" by Yang Weizhong analyzes the prevention and control processes of infectious diseases such as smallpox, plague, cholera, dysentery, typhoid fever, measles, diphtheria, pertussis, meningococcal meningitis, mumps, schistosomiasis, and hemorrhagic fever over the past 70 years. It significantly reduced the incidence and mortality of infectious diseases, providing confidence and insights for future disease prevention and control efforts (18). Additionally, Zhou Yuhui's article "Research on the Current Situation of Infectious Diseases and the Construction of Prevention and Control System in China" comprehensively reviews the epidemic situation of infectious diseases in China and systematically analyzes the prevention and control system from aspects such as legal and regulatory framework, joint prevention and control mechanism, prevention and control institutions, monitoring and early warning system, vaccine research and development, and fundraising mechanism. The article proposes recommendations for the development of a modernized infectious disease prevention and control system from the perspectives of comprehensive prevention and control strategies, monitoring and early warning capabilities, increased funding, enhanced technological innovation support, and strengthened international communication and cooperation (19). Although these literature pieces analyze the development and measures of infectious disease prevention and control from various perspectives, they lack more detailed data analysis on the correlation between the incidence, mortality, and control measures of infectious diseases in specific regions and countries. This paper aims to study the changing trends in the incidence and mortality of infectious diseases in China in recent years and analyze the linear relationship between infectious disease mortality rate and control measures using multivariate linear regression methods. The goal is to explore the trends in infectious disease control and provide insights and measures for future epidemic trend control, which is the purpose of this study.

3 Data and methodology

3.1 Data

The People's Republic of China established the Ministry of Health in 1952 and set up institutions for the prevention and control of infectious diseases and epidemiological research, strengthening the monitoring and control of infectious diseases. In 1955, China successfully controlled a large-scale outbreak of plague (20). Meanwhile, China gradually established a surveillance and reporting system for infectious diseases, forming a four-level disease monitoring network at the national, provincial, municipal, and county levels. Disease monitoring and reporting have become important means of prevention and control, helping to detect outbreaks promptly (21). From the late 20th century to the early 21st century, China faced a series of severe infectious disease outbreaks, such as Severe Acute Respiratory Syndrome (SARS) and avian influenza. These outbreaks posed new challenges to China's infectious disease prevention and control efforts and prompted the government to take more proactive measures to strengthen the prevention and control system for infectious diseases and enhance its capacity to respond to public health emergencies (22). This study selected the trend changes in the mortality rate and incidence proportion of infectious diseases in China from 2018 to 2023 as the research sample. Due to the wide scope of the outbreak of novel coronavirus infections, government special funding and separate plans were implemented for prevention and control, so they were not included in the analysis scope of this study.

In 2018, there were 3.063 million reported cases and 23,174 reported deaths from Class A and B infectious diseases nationwide in China. The top five reported diseases by incidence were viral hepatitis, pulmonary tuberculosis, syphilis, gonorrhea, and bacterial and amoebic dysentery, accounting for 92.2% of the total reported cases of Class A and B infectious diseases. The top five reported diseases by mortality were AIDS, pulmonary tuberculosis, viral hepatitis, rabies, and Japanese encephalitis, representing 99.3% of the total reported deaths from Class A and B infectious diseases. In 2018, the mainland population of China was 1,395.38 million (excluding Hong Kong, Macao, and Taiwan). Calculated per 100,000 people, the incidence rate of Class A and B infectious diseases nationwide was 219.51/100,000, and the mortality rate was 1.66/100,000 (23). In 2019, there were 3.072 million reported cases and 24,981 reported deaths from Class A and B infectious diseases nationwide in China. The top five reported diseases by incidence were viral hepatitis, pulmonary tuberculosis, syphilis, gonorrhea, and scarlet fever, accounting for 91.1% of the total reported cases of Class A and B infectious diseases. The top five reported diseases by mortality were AIDS, pulmonary tuberculosis, viral hepatitis, rabies, and epidemic hemorrhagic fever, representing 99.6% of the total reported deaths from Class A and B infectious diseases. In 2019, the mainland population of China was 1,400.05 million (excluding Hong Kong, Macao, and Taiwan). Calculated per 100,000 people, the incidence rate of Class A and B infectious diseases nationwide was 219.44/100,000, and the mortality rate was 1.78/100,000 (24). In 2020, there were 2.58 million reported cases and 21,655 reported deaths from Class A and B infectious diseases nationwide in China. The top five reported diseases by incidence were viral hepatitis, pulmonary tuberculosis, syphilis, gonorrhea, and AIDS, accounting for 94.39% of the total reported cases of Class A and B infectious diseases. The top five reported diseases by mortality were AIDS, pulmonary tuberculosis, viral hepatitis, rabies, and syphilis, representing 99.5% of the total reported deaths from Class A and B infectious diseases. In 2020, the mainland population of China was 1,411.77 million (excluding Hong Kong, Macao, and Taiwan). Calculated per 100,000 people, the incidence rate of Class A and B infectious diseases nationwide was 183.19/100,000, and the mortality rate was 1.53/100,000 (25). In 2021, there were 2.712 million reported cases and 22,177 reported deaths from Class A and B infectious diseases nationwide in China. The top five reported diseases by incidence were viral hepatitis, pulmonary tuberculosis, syphilis, gonorrhea, and brucellosis, accounting for 93.3% of the total reported cases of Class A and B infectious diseases. The top five reported diseases by mortality were AIDS, pulmonary tuberculosis, viral hepatitis, rabies, and epidemic hemorrhagic fever, representing 99.7% of the total reported deaths from Class A and B infectious diseases. In 2021, the mainland population of China was 1,412.60 million (excluding Hong Kong, Macao, and Taiwan). Calculated per 100,000 people, the incidence rate of Class A and B infectious diseases nationwide was 191.98/100,000, and the mortality rate was 1.57/100,000 (26). In 2022, there were 2.431 million reported cases and 21,834 reported deaths from Class A and B infectious diseases nationwide in China (excluding novel coronavirus infections). The top five reported diseases by incidence were viral hepatitis, pulmonary tuberculosis, syphilis, gonorrhea, and brucellosis, accounting for 93.4% of the total reported cases of Class A and B infectious diseases. The top five reported diseases by mortality were AIDS, pulmonary tuberculosis, viral hepatitis, rabies, and epidemic hemorrhagic fever, representing 99.8% of the total reported deaths from Class A and B infectious diseases. In 2022, the mainland population of China was 1,411.75 million (excluding Hong Kong, Macao, and Taiwan). Calculated per 100,000 people, the incidence rate of Class A and B infectious diseases nationwide was 172.22/100,000, and the mortality rate was 1.55/100,000 (27). In 2023, there were 3.5078 million reported cases and 25,525 reported deaths from Class A and B infectious diseases nationwide in China (excluding novel coronavirus infections). The top five reported diseases by incidence were viral hepatitis, pulmonary tuberculosis, syphilis, gonorrhea, and brucellosis, accounting for 92.5% of the total reported cases of Class A and B infectious diseases. The top five reported diseases by mortality were AIDS, pulmonary tuberculosis, viral hepatitis, rabies, and syphilis, representing 99.8% of the total reported deaths from Class A and B infectious diseases. In 2023, the mainland population of China was 1,409.67 million (excluding Hong Kong, Macao, and Taiwan). Calculated per 100,000 people, the incidence rate of Class A and B infectious diseases nationwide was 248.83/100,000, and the mortality rate was 1.81/100,000 (28).

specific data can be found in Table 1.

Overall, from 2018 to 2023, the reported incidence and mortality of Class A and B infectious diseases nationwide showed a downward trend (Table 1). However, in 2023, due to the emergence of monkeypox as a Class B contagious disease, there was an upward trend in the reported incidence of Class B infectious diseases.

In 2018, there were a total of 4.708 million reported cases and 203 deaths from Class C infectious diseases nationwide in China. The top five reported diseases by incidence were hand, foot, and mouth disease; other infectious diarrheal diseases; influenza; epidemic parotitis; and acute hemorrhagic conjunctivitis, accounting for 99.8% of the total reported cases of Class C infectious diseases. The diseases with the highest number of reported deaths were influenza, hand, foot, and mouth disease, and other infectious diarrheal diseases, representing 100% of the total reported deaths from Class C infectious diseases. In 2018, the mainland population of China was 1,395.38 million (excluding Hong Kong, Macao, and

TABLE 1 Statistics of the incidence and mortality of class A and B public infectious diseases in China from 2018 to 2023.

Project/year	Number of cases in million	Number of deaths	Population in million	Incidence rate/100,000	Death rate/100,000
2018	3.063	23,174	1395.38	219.51	1.66
2019	3.072	24,981	1400.05	219.44	1.78
2020	2.58	21,655	1411.77	183.19	1.53
2021	2.712	22,177	1412.60	191.98	1.57
2022	2.431	21,834	1411.75	172.22	1.55
2023	3.5078	25,525	1409.67	248.83	1.81

Data source: Chinese Health Commission and Chinese National Administration of Disease Control and Prevention website (23–28).

Taiwan). Calculated per 100,000 people, the incidence rate of Class C infectious diseases nationwide was 337.38/100,000, and the mortality rate was 0.0146/100,000 (23). In 2019, there were a total of 7.172 million reported cases and 304 deaths from Class C infectious diseases nationwide in China. The top five reported diseases by incidence were influenza, hand, foot, and mouth disease; other infectious diarrheal diseases; epidemic parotitis; and acute hemorrhagic conjunctivitis, accounting for 99.5% of the total reported cases of Class C infectious diseases. The diseases with the highest number of reported deaths were influenza, hand, foot, and mouth disease, and other infectious diarrheal diseases, representing 99.3% of the total reported deaths from Class C infectious diseases. In 2019, the mainland population of China was 1,400.05 million (excluding Hong Kong, Macao, and Taiwan). Calculated per 100,000 people, the incidence rate of Class C infectious diseases nationwide was 512.28/100,000, and the mortality rate was 0.021/100,000 (24). In 2020, there were a total of 3.13 million reported cases and 85 deaths from Class C infectious diseases nationwide in China. The top five reported diseases by incidence were influenza; other infectious diarrheal diseases; hand, foot, and mouth disease; epidemic parotitis; and acute hemorrhagic conjunctivitis, accounting for 94.7% of the total reported cases of Class C infectious diseases. The diseases with the highest number of reported deaths were influenza, other infectious diarrheal diseases, and hand, foot, and mouth disease, representing 96.5% of the total reported deaths from Class C infectious diseases. In 2020, the mainland population of China was 1,411.77 million (excluding Hong Kong, Macao, and Taiwan). Calculated per 100,000 people, the incidence rate of Class C infectious diseases nationwide was 221.95/100,000, and the mortality rate was 0.0061/100,000 (25). In 2021, there were a total of 3.506 million reported cases and 19 deaths from Class C infectious diseases nationwide in China. The top five reported diseases by incidence were hand, foot, and mouth disease; other infectious diarrheal diseases; influenza; epidemic parotitis; and acute hemorrhagic conjunctivitis, accounting for 99.9% of the total reported cases of Class C infectious diseases. The diseases with the highest number of reported deaths were hand, foot, and mouth disease; other infectious diarrheal diseases; and influenza, representing 94.7% of the total reported deaths from Class C infectious diseases. In 2021, the mainland population of China was 1,412.60 million (excluding Hong Kong, Macao, and Taiwan). Calculated per 100,000 people, the incidence rate of Class C infectious diseases nationwide was 248.22/100,000, and the mortality rate was 0.0013/100,000 (26). In 2022, there were a total of 4.210 million reported cases and 27 deaths from Class C infectious diseases nationwide in China. The top five reported diseases by incidence were influenza; other infectious diarrheal diseases; hand, foot, and mouth disease; epidemic parotitis; and acute hemorrhagic conjunctivitis, accounting for 99.9% of the total reported cases of Class C infectious diseases. The diseases with the highest number of reported deaths were influenza, other infectious diarrheal diseases, and hand, foot, and mouth disease, representing 92.6% of the total reported deaths from Class C infectious diseases. In 2022, the mainland population of China was 1,411.75 million (excluding Hong Kong, Macao, and Taiwan). Calculated per 100,000 people, the incidence rate of Class C infectious diseases nationwide was 298.23/100,000, and the mortality rate was 0.0019/100,000 (27). In 2023, there were a total of 15.6618 million reported cases and 86 deaths from Class C infectious diseases nationwide in China. The top five reported diseases by incidence were influenza; other infectious diarrheal diseases; hand, foot, and mouth disease; epidemic parotitis; and acute hemorrhagic conjunctivitis, accounting for 96.6% of the total reported cases of Class C infectious diseases. The diseases with the highest number of reported deaths were influenza and dengue fever, representing 98.8% of the total reported deaths from Class C infectious diseases. In 2023, the mainland population of China was 1,409.67 million (excluding Hong Kong, Macao, and Taiwan). Calculated per 100,000 people, the incidence rate of Class C infectious diseases nationwide was 1,111.03/100,000, and the mortality rate was 0.006/100,000 (28). Overall, from 2019 to 2022, the reported incidence and mortality of Class C infectious diseases nationwide showed a downward trend. However, in 2023, due to mutations in the coronavirus and other factors such as climate, there was a significant increase in influenza (29).

Specific data can be found in Tables 2, 3.

Here's the summary of the reported incidence and mortality rates of Class A, B, and C infectious diseases per 100,000 people: In 2018, the nationwide reported incidence rate of Class A, B, and C infectious diseases combined was 556.89/100,000, and the combined mortality rate was 1.67/100,000; In 2019, the nationwide reported incidence rate of Class A, B, and C infectious diseases combined was 731.72/100,000, and the combined mortality rate was 1.81/100,000; In 2020, the nationwide reported incidence rate of Class A, B, and C infectious diseases combined was 405.14/100,000, and the combined mortality rate was 1.54/100,000; in 2021, the nationwide reported incidence rate of Class A, B, and C infectious diseases combined was 440.2/100,000, and the combined mortality rate was 1.57/100,000; in 2022, the nationwide reported incidence rate of Class A, B, and C infectious diseases combined was 470.45/100,000, and the combined mortality rate was 1.55/100,000. In 2023, the nationwide reported incidence rate

TABLE 2 Statistics of the incidence and mortality of class C public infectious diseases in China from 2018 to 2023.

Project\year	Number of cases in million	Number of deaths	Population in million	Incidence rate/100,000	Death rate/100,000
2018	4.708	203	1395.38	337.38	0.0146
2019	7.172	304	1400.05	512.28	0.021
2020	3.13	85	1411.77	221.95	0.0061
2021	3.506	19	1412.6	248.22	0.0013
2022	4.21	27	1411.75	298.23	0.0019
2023	15.6618	86	1409.67	1111.03	0.006

Data source: Chinese Health Commission and Chinese National Administration of Disease Control and Prevention website (23–28).

TABLE 3 Number of reported incidences and deaths of class C infectious diseases nationwide from 2018 to 2023.

Disease name	Number of cases						Death toll					
	2018	2019	2020	2021	2022	2023	2018	2019	2020	2021	2022	2023
Influenza	765,186	3,538,213	1,145,278	668,246	2,442,797	12,515,250	153	269	70	4	13	81
Mumps	259,071	299,961	129,120	119,955	104,016	89,642			1			
Rubella	3,930	32,539	2,201	840	784	2,118					1	
Acute hemorrhagic conjunctivitis	38,250	41,439	28,471	28,350	26,097	197,041						
Leprosy	225	233	200	180	143	372						
Typhus	971	1,173	1,069	1,310	1,291	1,665						
Kala azar	160	151	202	230	226	544			1		1	4
Hydatid disease	4,327	4,003	3,327	2,799	2,341	3,724		2	1	1		
Filariasis				1		42,950						
Other infectious diarrhea diseases	1,282,270	1,335,627	1,062,277	1,329,790	959,636	1,128,115	15	13	9	6	6	
Hand foot and mouth disease	2,353,310	1,918,830	761,355	1,354,548	672,911	1,680,376	35	20	3	8	6	1
Total	4,707,700	7,172,169	3,133,500	3,506,249	4,210,242	15,661,797	203	304	85	19	27	86

Unit: individual. Data source: Chinese Health Commission and Chinese National Administration of Disease Control and Prevention website (23–28).

of Class A, B, and C infectious diseases combined was 1359.86/100,000, and the combined mortality rate was 1.82/100,000. Specific data can be found in Table 4.

Public infectious disease prevention and control involves various measures to prevent the spread and outbreak of infectious diseases in populations, thereby reducing mortality rates and ensuring public health security. Common measures for public infectious disease prevention and control include government investment in prevention and control funding, monitoring and early warning by professional technical personnel, vaccination, health education and public awareness campaigns, medical interventions, and more. Although vaccines and vaccination are among the most cost-effective public health interventions (30). However, due to the variety of vaccine types and the multitude of vaccination providers, the total volume and coverage rate of vaccine administration for infectious diseases cannot be accurately measured. Promotion, public awareness, and medical interventions are subject to the scope and technical proficiency, making quantitative comparisons challenging. Government investment in prevention and control funding and the number of technical personnel in specialized infectious disease prevention and control institutions can be quantified. Therefore, this study selects

TABLE 4 Statistics of total cases and deaths of class A, B and C public infectious diseases from 2018 to 2023.

Years\ Project	2018	2019	2020	2021	2022	2023
Incidence rate/100,000	556.89	731.72	405.14	440.2	470.45	1359.86
Death rate/100,000	1.67	1.81	1.54	1.57	1.55	1.82

Data source: Chinese Health Commission and Chinese National Administration of Disease Control and Prevention website (23–28).

government investment in prevention and control funding and the number of technical personnel in specialized prevention and control institutions as the analytical sample for infectious disease control measures. On the one hand, these two measures are directly related to the trends in infectious disease prevention and control. On the other hand, the data for these two measures can be analyzed quantitatively.

From 2018 to 2023, the Chinese government consistently provided special subsidies for major infectious disease prevention and control funding. The subsidy funds were mainly used for expanding efforts in the prevention and treatment of infectious diseases and other relevant major public health services, and were incorporated into the government's annual budget expenditures. In 2018, the investment in prevention and control funding amounted to 16981.77 billion RMB, for every 100,000 people, the funding allocation is 1,217,000 RMB (31). In 2019, the investment in prevention and control funding reached 16525.61 billion RMB, for every 100,000 people, the funding allocation is 1,180,400 RMB (32). In 2020, the investment in prevention and control funding was 17525.61 billion RMB, for every 100,000 people, the funding allocation is 1,241,400 RMB (33). In 2021, the investment in prevention and control funding totaled 19212.08 billion RMB, for every 100,000 people, the funding allocation is 1,360,100 RMB (34). In 2022, the investment in prevention and control funding rose to 20379.58 billion RMB, for every 100,000 people, the funding allocation is 1,443,600 RMB (35). In 2023, the investment in prevention and control funding increased to 23820.01 billion RMB, for every 100,000 people, the funding allocation is 1,689,800 RMB (36). It can be observed that the amount and proportion of investment in prevention and control funding have shown an increasing trend annually from 2018 to 2023. Specific data can be found in Table 5.

The Chinese government has specifically established around 3,400 professional disease prevention and control centers nationwide, separate from hospitals. The mission of these centers is to create a healthy environment and safeguard public health through the prevention and control of infectious diseases and other illnesses. Their responsibilities include formulating regulations, policies, standards, and prevention and control plans related to infectious diseases and public health; developing national implementation plans for the prevention and control of major infectious diseases and other illnesses; monitoring the development and distribution patterns of infectious diseases and proposing prevention and control strategies; participating in and guiding local responses to major epidemics and public health emergencies; and establishing emergency response systems for major public health issues such as major infectious diseases and disaster prevention and disease control.

The number of professional technical personnel in disease prevention and control institutions is closely related to the prevention and control of infectious diseases. In 2018, there were 140,000 professional technical personnel, accounting for 10.03 per 100,000 people (23). In 2019, there were 140,000 professional technical personnel, accounting for 9.99 per 100,000 people (24). In 2020, there were 145,000 professional technical personnel, accounting for 10.27 per 100,000 people (25). In 2021, there were 158,000 professional technical personnel, accounting for 11.19 per 100,000 people (26). In 2022, there were 169,000 professional technical personnel, accounting for 11.97 per 100,000 people (27). In 2023, there were 166,000 professional technical personnel, accounting for 11.76 per 100,000 people (28). As disease prevention and control institutions are not treatment facilities but rather research and management entities, the number of professional technical personnel does not need to be particularly large. It can be observed that the total number and proportion of professional technical personnel have shown an increasing trend annually from 2018 to 2023. For specific data, please refer to Table 6.

3.2 Methodology

The content of this study focuses on the trend analysis of public infectious disease prevention and control. The research objective aims to control the spread and prevalence of infectious diseases within populations through relevant measures. There are two key indicators for infectious disease control: mortality rate control and incidence rate control (37). Among them, controlling the mortality rate of infectious disease infections is a crucial indicator.

Below, we employ multiple linear regression to analyze several factors related to infectious diseases: mortality rate, incidence rate, proportion of expenditure, and proportion of professional technical personnel. Specifically, we take the mortality rate of infectious diseases as the dependent variable (Y) and the incidence rate, proportion of expenditure, and proportion of professional technical personnel as independent variables (X) for multiple regression analysis. We select data from 2018 to 2023 for infectious disease mortality rate, incidence rate, proportion of expenditure, and proportion of professional technical personnel as the sample, with $N = 6$. All these samples are valid, with no invalid samples present. See Table 4 for specific data (see Table 7)

This study conducts computations and analyses using SPSS (Statistical Package for the Social Sciences) software. The data from 2018 to 2023 for infectious disease mortality rate, incidence rate, proportion of expenditure, and proportion of professional technical personnel, as presented in the tables above, are analyzed using SPSS. Regression analysis begins with assessing the model fit, primarily through analyzing the R-square value to evaluate how well the model fits the data. Additionally, analysis of the Variance Inflation Factor (VIF) is conducted to determine if there are multicollinearity issues in the model. Subsequently, the regression model equation is

TABLE 5 Investment of prevention and control funds from 2018 to 2023.

Year\project	2018	2019	2020	2021	2022	2023	Remark
Prevention and control funds	16981.77	16525.61	17525.61	19212.1	20379.58	23820.01	RMB million
Proportion of prevention and control funds	121.7	118.04	124.14	136.01	144.36	168.98	10000RMB/100,000 people

Data sources: China Ministry of Finance and China National Center for Disease Control and Prevention websites (31–36).

TABLE 6 Statistics of public infectious disease prevention and control technicians from 2018 to 2023.

Year\project	2018	2019	2020	2021	2022	2023	Remark
Number of technicians	14	14	14.5	15.8	16.9	16.6	Ten thousand
Proportion of technical personnel	10.03	9.99	10.27	11.19	11.97	11.76	/100,000 people

Data source: The data description of prevention and control technicians mentioned above (23–28).

TABLE 7 Statistical table of the mortality rate, incidence rate, funding investment ratio, and professional and technical personnel ratio of infectious diseases per 100,000 people from 2019 to 2023.

Year\project	2018	2019	2020	2021	2022	2023
Mortality rate	1.67	1.81	1.54	1.57	1.55	1.82
Incidence	556.89	731.72	405.14	440.2	470.45	1359.86
Proportion of funding investment	121.7	118.04	124.14	136.01	144.36	168.98
Proportion of number of professional and technical personnel	10.03	9.99	10.27	11.19	11.97	11.76

Data source: summary of mortality, morbidity and other data indicators above.

TABLE 8 Linear regression analysis results (N = 6).

Project	Unstandardized coefficient		Standardized coefficient	T	P	Collinearity diagnosis	
	B	Standard error	beta			VIF	Tolerance
Constant	1.576	0.182	-	8.654	0.013*	-	-
Incidence	0.001	0	1.831	8.533	0.013*	7.185	0.139
Funding investment ratio	−0.012	0.003	−1.767	−4.347	0.049*	25.772	0.039
Proportion of number of professional and technical personnel	0.117	0.044	0.805	2.68	0.116	14.077	0.071
R^2	0.987						
Adjustmentr^2	0.968						
F	F(3,2)=51.363, p = 0.019						
D-W value	3.026						

Parameter settings, dependent variable Y is: mortality rate, $p < 0.05$ $p < 0.01$.

derived. Next, the significance of the independent variables (X) is analyzed. If they exhibit significance (p-value less than 0.05 or 0.01), it indicates an influential relationship between X and the dependent variable (Y). The direction of this influence is also analyzed. Finally, a summary of the analysis is provided. The results of the regression analysis conducted through the SPSS system are presented in Table 8.

After analysis, it is evident from the table that conducting a linear regression analysis with the incidence rate, proportion of expenditure, and proportion of professional technical personnel as independent variables (X), and mortality rate as the dependent variable (Y), yields the following model equation: Mortality Rate = 1.576 (constant) + 0.001 (regression coefficient B) * Incidence Rate (X1)–0.012 (regression coefficient B) * Proportion of Expenditure (X2) + 0.117 (regression coefficient B) * Proportion of Professional Technical Personnel (X3). The R-square value of the model is 0.987, indicating that 98.7% of the variance in mortality rate can be explained by the incidence rate, proportion of expenditure, and proportion of professional technical personnel. The model passed the F-test (F = 51.363, $p = 0.019 < 0.05$), indicating that at least one of the variables (incidence rate, proportion of expenditure, and proportion of professional technical personnel) has a significant impact on mortality rate. Additionally, multicollinearity was detected, as indicated by VIF values exceeding 10. Further analysis of the specific data reveals that the regression coefficient for the incidence rate is 0.001 (T = 8.533, $p = 0.013 < 0.05$), indicating a significant positive relationship between the incidence rate and mortality rate. The regression coefficient for the proportion of expenditure is −0.012 (T = −4.347, $p = 0.049 < 0.05$), indicating a significant negative relationship between the proportion of expenditure and mortality rate. However, the regression coefficient for the proportion of professional technical personnel is 0.117 (T = 2.680, $p = 0.116 > 0.05$), indicating that it does not significantly affect mortality rate. In summary, the analysis indicates that the incidence rate has a significant positive effect on mortality rate, while the proportion of expenditure has a significant negative effect on mortality rate. However, the proportion of professional technical personnel does not affect mortality rate.

TABLE 9 ANOVA table (intermediate process).

Project	Sum of square	DF	Mean square	F	p value
Return	0.082	3	0.027	51.363	0.019
Residual	0.001	2	0.001		
Total	0.083	5			

The analysis results indicate that the model passes the F-test (F = 51.363, $P = 0.019 < 0.05$), which means that the model construction is meaningful.

Regarding the issue of using the F-test to determine the significance of a regression model, if the model passes the F-test ($p < 0.05$), it indicates that the model is meaningful, and at least one X variable influences Y. If the model fails the F-test ($p > 0.05$), it suggests that the model construction is not meaningful, and none of the X variables affect Y. According to the SPSS analysis results, specific data are shown in Table 9.

4 Results

With the continuous improvement of China's healthcare system and the strengthening of public health measures, the incidence rates of many infectious diseases have shown a declining trend. For example, the incidence rates of infectious hepatitis, tuberculosis, and AIDS have all decreased in recent years (38). However, overall, due to the impact of diseases such as seasonal flu, the mortality and incidence rates of infectious diseases have shown a fluctuating trend, with an increase in mortality rates and a significant increase in incidence rates in 2023.

To study the trends in public infectious disease prevention and control, this study selected several parameters including the mortality rate, incidence rate, proportion of expenditure, and proportion of professional technical personnel, analyzing methods to control the spread of infectious diseases. Through multiple regression analysis, the regression coefficient value of the incidence rate is 0.001 (T = 8.533, $p = 0.013 < 0.05$), indicating a significant positive impact of the incidence rate on the mortality rate. This suggests that an increase in the incidence rate of infectious diseases corresponds to an upward trend in mortality rates. The regression coefficient value of the expenditure ratio is −0.012 (T = −4.347, $p = 0.049 < 0.05$), meaning that the expenditure ratio has a significant negative impact on the mortality rate. An increase in expenditure on prevention and control leads to a decrease in the mortality rate of infectious diseases. The regression coefficient value of the proportion of professional technical personnel is 0.117 (T = 2.680, $p = 0.116 > 0.05$), indicating that the proportion of professional technical personnel does not have a significant impact on the mortality rate. This means that an increase in the number of professional technical personnel in infectious disease prevention and control institutions does not significantly control the decline in mortality rates, requiring the comprehensive use of other prevention and control measures. This study demonstrates that although there are many measures for infectious disease prevention and control, whether they can directly control the mortality rate of infectious diseases requires detailed analysis. Infectious disease prevention and control is the result of the application of comprehensive measures. The analysis of the model's R-squared value of 0.987 indicates that the incidence rate, expenditure ratio, and proportion of professional technical personnel can explain 98.7% of the trend changes in mortality rates.

5 Discussion

In the 1950s, China had high incidence, prevalence, and mortality rates for infectious diseases. Severe infectious diseases such as plague, cholera, and smallpox frequently broke out. In some years, there were as many as 40,000 cases of smallpox, 9.5 million cases of measles, and a total of 12 million cases of schistosomiasis. Infectious diseases ranked first among all causes of death. In the early 1990s, cholera had serious outbreaks in some local areas. During the 1980s and early 1990s, epidemic hemorrhagic fever and rabies were rampant, and reported cases of hepatitis B continued to rise. From the end of 1988 to the beginning of 1989, a large-scale hepatitis A outbreak occurred in the Shanghai area, infecting over 300,000 people in just over a month (18). From 2018 to 2023, the Chinese government provided special subsidies for the prevention and control of major infectious diseases, incorporating this into the government's annual budget expenditure projects. In 2018, the investment in infectious disease prevention and control reached 16,981.77 billion RMB, and by 2023, it had increased to 23,820.01 billion RMB, showing a trend of annual growth in the investment amount. Meanwhile, the government has strengthened the monitoring and early warning systems for public infectious diseases and implemented various measures such as vaccination, health education, public awareness campaigns, and medical interventions to control the spread of public infectious diseases. In recent years, the incidence of Class A, B, and C infectious diseases has been controlled at an average of 400–500 cases per 100,000 people, and the mortality rate has been greatly reduced.

China's control of the incidence of public infectious diseases is similar to that of other developing countries. In some developing countries, the lack of medical resources and inadequate public health systems means that infectious disease outbreaks often lead to the overloading of healthcare systems, resulting in high mortality rates. For example, in Sub-Saharan African countries, the rise in the incidence of infectious diseases like AIDS and tuberculosis has led to a significant increase in mortality. Although China's medical conditions have improved, rising incidence rates still have a major impact on mortality rates. In contrast, developed countries demonstrate stronger control over infectious diseases. Europe and North America, through comprehensive vaccination programs, disease monitoring, and early intervention mechanisms, are able to prevent increases in incidence from translating into high mortality rates. The proportion of funding investment has a significant negative impact on mortality, indicating that increased funding helps reduce mortality rates, a pattern observed globally. Developed countries have higher public health prevention expenditure ratios, such as the United States and Germany, where the proportion of public health prevention funding is relatively high, effectively controlling mortality from infectious diseases. The U.S. Centers for Disease Control and Prevention (CDC) invests substantial funds annually in the prevention and control of infectious diseases to ensure a rapid response to outbreaks. The U.S. per capita public health expenditure on preventive care varies from year to year, but estimates show that around $250 to $350 per person is spent annually on preventive healthcare services, including funding for vaccination, health checkups, and health education programs. This amount is significantly higher than in many developing countries (39).

China is a populous country, and population density is particularly high in the central and eastern regions, making the control of infectious disease outbreaks and transmission critically important. Although health and epidemic prevention departments at all levels in China have made significant efforts, controlling the incidence and mortality rates of public infectious diseases still faces many challenges. From 2018 to 2023, the mortality rates per 100,000 population for Class A, B, and C infectious diseases were 1.67, 1.81, 1.54, 1.57, 1.55, and 1.82, respectively, while the incidence rates per 100,000 population were 556.89, 731.72, 405.14, 440.2, 470.9, and 1359.86, respectively. Looking at the data, the mortality rate increased from 1.67 in 2018 to 1.81 in 2019, then decreased to around 1.5 from 2020 to 2023, before rising again to 1.82 in 2023. Similarly, the trend of incidence and mortality rates is similar, with the incidence rate increasing to 1359.86 in 2023. The increase in mortality and incidence rates in 2023 was primarily due to the widespread outbreak of influenza, mainly attributed to the mutation of the coronavirus and severe winter weather conditions (29). From this trend, it is evident that the control of infectious diseases is complex, with fluctuations occurring between different years. The fluctuation in infectious disease trends does not follow a single directional trend, indicating that the difficulty of infectious disease prevention and control is significant, and cannot be achieved by a single control measure alone.

This study selected several parameters, including the mortality rate, incidence rate, proportion of funding allocation, and proportion of professional technical personnel, for regression analysis. Although the incidence rate and mortality rate of infectious diseases are directly related, the mortality rate is also influenced by the medical institution's treatment capacity. The regression coefficient of the incidence rate is 0.001, indicating a direct positive relationship with the mortality rate. However, the level of mortality rate is also affected by the capacity of medical institutions to provide treatment. The selection of the proportion of funding allocation and the proportion of professional technical personnel for analysis does not imply that only these two factors can control the fluctuation of infectious disease mortality and incidence. In reality, there are many factors involved in infectious disease control, including investment in prevention and control, increasing and involving professional technical personnel, establishing sound monitoring and warning systems, vaccination, personal protective measures, medical and health measures, health education and public awareness, international cooperation and information sharing, emergency plans, and crisis management measures, among others. Many of these measures cannot be quantified, and some lack available data indicators. Therefore, the study chose parameters such as the incidence rate, proportion of funding allocation, and proportion of professional technical personnel to participate in the analysis. The aim was to provide an analytical method and model for understanding the relationship between the development trend of public infectious diseases and control measures. It is hoped that such methods and models can be used to analyze the effectiveness of infectious disease control measures and further provide relevant measures to control the spread of infectious diseases.

6 Conclusion

Through the data analysis conducted above, it is evident that the incidence rate and mortality rate of public infectious diseases fluctuate between different years, indicating that the trend of public infectious diseases is not consistently decreasing or increasing in the same direction. This fluctuation is attributed to various factors causing the onset of public infectious diseases, including social and natural environments, pathogen infections, and individual poor hygiene habits and lifestyles, among others. Many of these disease-causing factors are not easily controllable. Although substantial preventive and control measures have been implemented by society and government agencies, the prevention and control of public infectious diseases constitute a long-term and continuous process. On the other hand, there are numerous prevention and control measures for public infectious diseases. However, factors such as the number of professional technical personnel may not significantly contribute to controlling the spread of infectious diseases. Therefore, controlling the transmission trend of public infectious diseases requires the comprehensive utilization of various prevention and control measures to achieve effective prevention and control.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

ZZ: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Validation, Visualization, Writing – original draft, Writing – review & editing, Project administration, Software, Supervision.

Funding

The author(s) declare that no financial support was received for the research, authorship, and/or publication of this article.

Conflict of interest

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2024.1423191/full#supplementary-material

References

1. Hein W. Control of communicable diseases as a global public good. *Med One*. (2020) 5:e200002. doi: 10.20900/mo20200002

2. Bloom DE, Cadarette D. Infectious disease threats in the twenty-first century: strengthening the global response. *Front Immunol*. (2019) 10:3–12. doi: 10.3389/fimmu.2019.00549

3. Yan JJ. Coordination and modularization: the experience of the joint prevention and control mechanism to COVID emergencies in China. *Front Public Health*. (2024) 12:4–13. doi: 10.3389/fpubh.2024.1244769

4. Stolfi P, Vergni D, Castiglione F. An agent-based multi-level model to study the spread of gonorrhea in different and interacting risk groups. *Front Appl Math Stat*. (2023) 9:2–6. doi: 10.3389/fams.2023.1241538

5. Salam MA, Al-Amin MY, Salam MT, Pawar JS, Akhter N, Rabaan AA, et al. Antimicrobial resistance: a growing serious threat for global public health. *Healthcare*. (2023) 11:1946. doi: 10.3390/healthcare11131946

6. Shausan A, Nazarathy Y, Dyda A. Emerging data inputs for infectious diseases surveillance and decision making. *Front Digit Health*. (2023) 5:2–5. doi: 10.3389/fdgth.2023.1131731

7. Chen JM, Ji YF, Duan ZJ, Wei B. Editorial: zoonotic emerging viral infectious diseases. *Front Vet Sci*. (2023) 10:1–3. doi: 10.3389/fvets.2023.1194324

8. Ministry of Ecology and Environment of China. Law of the People's Republic of China on the prevention and control of infectious diseases. (2005). Available at: https://www.mee.gov.cn/ywgz/gtfwyhxpgl/wxfw/200504/t20050418_65993.shtml (Accessed April 12, 2024).

9. Manaf NH, Cheah YK, Yunus NM. Editorial: public health matters: pandemic, policies, Processes. *Front Public Health*. (2022) 10:1–2. doi: 10.3389/fpubh.2022.922652

10. Green LW, Ottoson JM, Garcia C, Hiatt RA. Diffusion theory and knowledge dissemination, utilization, and integration in public health. *Annu Rev Public Health*. (2009) 30:151–74. doi: 10.1146/annurev.publhealth.031308.100049

11. Pearce N, Merletti F. Complexity, simplicity, and epidemiology. *Int J Epidemiol*. (2006) 35:515–9. doi: 10.1093/ije/dyi322

12. Glanz K, Bishop DB. The role of behavioral science theory in development and implementation of public health interventions. *Annu Rev Public Health*. (2010) 31:399–418. doi: 10.1146/annurev.publhealth.012809.103604

13. Liang ZM, Howard SL, Leggat S, Bartram T. Development and validation of health service management competencies. *J Health Organ Manag*. (2018) 32:157–75. doi: 10.1108/JHOM-06-2017-0120

14. Baker RE, Mahmud AS, Miller IF, Rajeev M, Basambainarivo F, Rice BL, et al. Infectious disease in an era of global change. *Nat Rev Microbiol*. (2022) 20:193–205. doi: 10.1038/s41579-021-00639-z

15. Siettos CI, Russo L. Mathematical modeling of infectious disease. *Dynamics*. (2013) 4:295–306. doi: 10.4161/viru.24041

16. Jones K, Patel N, Levy M, Gard AS, Balk D, Gittleman JL, et al. Global trends in emerging infectious diseases. *Nature*. (2008) 451:990–3. doi: 10.1038/nature06536

17. Thakur H, Rao R. Emphasis on infection prevention and control: a review. *J Popul Ther Clin Pharmacol*. (2024) 31:2238–49. doi: 10.53555/jptcp.v31i2.4604

18. Yang WZ. The prevention and control of infectious diseases in China has achieved results over the past 70 years. *Chin J Epidemiol*. (2019) 40:1493–8. doi: 10.3760/cma.j.issn.0254-6450.2019.12.001

19. Zhou YH. A study on the epidemic status and prevention and control system of infectious diseases in China. *Chin J Health Policy*. (2023) 16:74–8. doi: 10.3969/j.issn.1674-2982.2023.04.011

20. Yu DZ. Current status and development of plague surveillance in China. *Dis Surveill*. (2007) 7:433–5. Available at: https://www.cqvip.com/qk/98376a/200707/25119334.html

21. Wang K, Mao AY, Meng YL, Yang YJ, Dong P, Qiu WQ. Development history, current situation, problems and strategies of public health system construction in China. *Chin J Public Health*. (2019) 35:801–5. Available at: http://html.rhhz.net/ZGGGWS/html/20190703.htm

22. Li C, Ren RQ, Zhou L. A review on the preparedness plans on influenza pandemics, by WHO and China: the current status and development. *Chin J Epidemiol*. (2018) 39:1032–5. Available at: http://html.rhhz.net/ZGGGWS/html/20190703.htm

23. Department of Planning, development and Informatization, China National Health Commission. Statistical bulletin on the development of my country's health careers in 2018. (2019). Available at: http://www.nhc.gov.cn/guihuaxxs/s10748/201905/9b8d52727cf346049de8acce25ffcbd0.shtml (Accessed April 16, 2024).

24. Department of Planning, development and Informatization, China National Health Commission. Statistical bulletin on the development of my country's health careers in 2019. (2020). Available at: http://www.nhc.gov.cn/guihuaxxs/s10748/202006/ebfe31f24cc145b198dd730603ec4442.shtml (Accessed April 16, 2024).

25. Department of Planning, Development and Informatization, China National Health Commission. Statistical bulletin on the development of my country's health careers in 2020. (2021). Available at: http://www.nhc.gov.cn/guihuaxxs/s10743/202107/af8a9c98453c4d9593e07895ae0493c8.shtml (Accessed April 16, 2024).

26. Department of Planning, Development and Informatization, China National Health Commission. Statistical bulletin on the development of my country's health careers in 2021. (2022). Available at: http://www.nhc.gov.cn/cmssearch/xxgk/getManuscriptXxgk.htm?id=51b55216c2154332a660157abf28b09d (Accessed April 16, 2024).

27. Department of Planning, development and Informatization, China National Health Commission. Statistical bulletin on the development of my country's health careers in 2022. (2023).Available at: http://www.nhc.gov.cn/guihuaxxs/s3585u/202309/6707c48f2a2b420fbfb739c393fcca92.shtml (Accessed April 16, 2024).

28. National Administration of Disease Control and Prevention of China. Overview of the national epidemic situation of notifiable infectious diseases in December 2023. (2024) Available at: https://www.ndcpa.gov.cn/jbkzzx/c100016/common/content/content_1746766719346462720.html (Accessed April 16, 2024).

29. Pan QC, Tang ZH, Yu YS, Zang GQ, Chen XH. Co-circulation and co-infection of COVID-19 and influenza in China: challenges and implications. *Front Public Health*. (2023) 11:2–5. doi: 10.3389/fpubh.2023.1295877

30. Kim CL, Agampodi S, Marks F, Kim JH, Excler JL. Mitigating the effects of climate change on human health with vaccines and vaccinations. *Front Public Health*. (2023) 11:2–10. doi: 10.3389/fpubh.2023.1252910

31. Ministry of Finance of China. Notice of the Ministry of Finance and the health commission on issuing the budget for public health service subsidy funds (major public health services) in 2018. (2018). Available at: http://sbs.mof.gov.cn/zxzyzf/ggwsfwbzzj/201811/t20181123_3074724.htm (Accessed April 16, 2024).

32. Ministry of Finance of China. Notice from the Ministry of Finance and the National Health Commission on the release of the budget for the prevention and control of major infectious diseases in 2019. (2019). Available at: http://sbs.mof.gov.cn/zxzyzf/ggwsfwbzzj/201907/t20190705_3292352.htm (Accessed April 16, 2024).

33. Ministry of Finance of China. Notice from the Ministry of Finance and the National Health Commission on the release of the budget for the prevention and control of major infectious diseases in 2020. (2020). Available at: http://sbs.mof.gov.cn/zxzyzf/ggwsfwbzzj/202007/t20200721_3554001.htm (Accessed April 16, 2024).

34. Ministry of Finance of China. Notice from the Ministry of Finance and the National Health Commission on the release of the budget for the prevention and control of major infectious diseases in 2021. (2021). Available at: http://sbs.mof.gov.cn/zxzyzf/ggwsfwbzzj/202108/t20210816_3745364.htm (Accessed April 16, 2024).

35. Ministry of Finance of China. The Ministry of Finance, the National Health Commission, and the National Administration of disease control and prevention issued a notice on the budget for the prevention and control of major infectious diseases in 2022. (2022). Available at: http://sbs.mof.gov.cn/zxzyzf/ggwsfwbzzj/202301/t20230119_3863750.htm (Accessed April 16, 2024).

36. Ministry of Finance of China. The Ministry of Finance, the National Health Commission, and the National Administration of disease control and prevention issued a notice on the budget for the prevention and control of major infectious diseases in 2023. (2023). Available at: http://sbs.mof.gov.cn/zxzyzf/ggwsfwbzzj/202307/t20230721_3897809.htm (Accessed April 16, 2024).

37. Fu MH, Tao FF, Chen J. Research progress on early warning indicators of infectious diseases. *Shanghai Prev Med*. (2024) 36:90–7. doi: 10.19428/j.cnki.sjpm.2024.23226

38. Xu XF. Prevention and control of chronic viral hepatitis B and related diseases. The world's latest medical information abstract (electronic version) (2015)75: 181–182. Available at: https://scholar.google.com.hk/scholar?cluster=943402547447911396&hl=zh-CN&as_sdt=2005&sciodt=0,5

39. Sandhu S, Sharma A, Cholera R, Bettger JP. Integrated health and social Care in the United States: a decade of policy Progress. *Int J Integr Care*. (2021) 21:9–15. doi: 10.5334/ijic.5687

frontiers | Frontiers in Public Health

TYPE Original Research
PUBLISHED 07 January 2025
DOI 10.3389/fpubh.2024.1359902

Check for updates

OPEN ACCESS

EDITED BY
Hai Fang,
Peking University, China

REVIEWED BY
Eduardo Jose Fernandez-Rodriguez,
University of Salamanca, Spain
Saurabh Raj,
Babasaheb Bhimrao Ambedkar Bihar
University, India

*CORRESPONDENCE
Yin Tang
✉ tykaratora@gs.econ.keio.ac.jp

RECEIVED 22 December 2023
ACCEPTED 17 December 2024
PUBLISHED 07 January 2025

CITATION
Tang Y (2025) Regional disparities and dynamic evolution of suicide prevention and intervention efficiency in Japan.
Front. Public Health 12:1359902.
doi: 10.3389/fpubh.2024.1359902

Regional disparities and dynamic evolution of suicide prevention and intervention efficiency in Japan

Yin Tang*

Graduate School of Economics, Keio University, Tokyo, Japan

Introduction: This study investigates the cost-effectiveness of suicide prevention and intervention (SPI) efforts by prefectural governments in Japan. It represents the first application of a public sector efficiency evaluation model to assess government SPI initiatives. The research aims to identify spatial disparities and dynamic evaluation in SPI efficiency, providing actionable insights for policymakers.

Methods: We employed a three-stage Modified Slacks-Based Measure of Super Efficiency to evaluate the SPI implementation efficiency of prefectural governments. This approach accounted for exogenous environmental and stochastic factors to isolate actual managerial efficiency. Additionally, the Luenberger productivity index was utilized to analyze the changes in SPI efficiency over time, focusing on the contributions of technological advancements and efficiency improvements.

Results: The analysis revealed significant spatial disparities in SPI efficiency across prefectural governments. However, a substantial portion of these differences was attributable to exogenous environmental and stochastic factors, indicating relatively limited variations in actual managerial efficiency. The Luenberger productivity index indicated an overall upward trend in SPI productivity, driven primarily by technical change. Conversely, the analysis highlighted a decline in efficiency changes, predominantly due to reduced scale efficiency.

Discussion: The findings underscore the importance of considering external environmental and stochastic factors when evaluating SPI efficiency. While technical advancements have positively influenced SPI productivity, policymakers should address the deteriorating trend in scale efficiency changes to ensure sustainable improvements in efficiency. Strategies that balance technical change and efficiency enhancements are essential for optimizing local SPI efforts.

KEYWORDS

suicide prevention, suicide intervention, Efficiency, three-stage data envelopment analysis, Luenberger productivity index

1 Introduction

Although suicide prevention is a complex challenge, it is preventable through the formulation of effective public policies and the implementation of targeted interventions (1). In 2019, the Seventy-second World Health Assembly passed the World Health Organization's (WHO) first Mental Health Action Plan. Suicide prevention is a critical component of this plan, with the goal of reducing suicide rates by one-third by 2030 (2). The plan's development was inspired, in part, by Japan's success in suicide prevention efforts. Since the early 1990s, Japan's suicide rate has increased, reaching its peak in 1998, and has since remained around 30,000 individuals annually (3). To alleviate the ongoing rise in the suicide rate, the Japanese government has implemented a series of suicide prevention and intervention (SPI) measures, including encouraging local governments and municipalities to play an active role in SPI while providing financial support for related activities.

Many scholars attribute the sustained decrease in suicide rates, particularly among males, after 2009 to the allocation of funds from the Regional Comprehensive Suicide Prevention Emergency Strengthening Fund, or Regional Fund (RF) (4–6). Between 2009 and 2014, local prefectural governments received 18.35 billion Japanese yen from the RF to support SPI activities among local public organizations[1] (7). This allocation effectively granted prefectural governments discretion in fund utilization. Specifically, based on SPI implementation plans and declared amounts submitted by municipal governments under their jurisdiction, prefectural governments formulated SPI implementation plans and applied for funds from the RF. As per the RF management guidelines, prefectural governments were responsible for fund allocation and oversight of fund utilization by subordinate public entities (8).

However, the severe financial burden and imperfect policy effectiveness have raised doubts regarding the cost-effectiveness of RF. They advocate for government efforts to improve regional SPI plans for greater cost-effectiveness (9) and propose the need for more detailed observations to establish an evidence-based and cost-effective fiscal budget structure for SPI (6). Therefore, assessing the policy effectiveness and cost-effectiveness of local governments in SPI would aid Japan's central government in overseeing local government policy execution efficiency and providing references for future policy formulation.

As such, this study aims to analyze the cost-effectiveness of RF in local Japanese governments to understand the dynamic evolution of local SPI efficiency. The primary contributions are as follows: Firstly, surpassing existing research that overly emphasizes government outcomes in SPI while overlooking cost-effectiveness, this study utilizes input–output efficiency measurement models to assess the efficiency of SPI by local governments. It takes into account environmental and luck factors' influence on the efficiency of local government policy implementation, filtering out relatively objective SPI efficiency using the three-stage Super Efficiency (SE) and Modified Slacks-Based Measure (MSBM) model framework (In the following text, it is abbreviated as SE-MSBM). The analysis demonstrates significant differences in SPI efficiency among local governments, where these disparities are partially attributed to environmental and luck factors, and the efficiency differences resulting from differences in local government management are exaggerated. Secondly, this paper dynamically decomposes the factors contributing to the evolution of SPI efficiency from the perspectives of productivity changes, which can be decomposed into efficiency changes and technological changes. Over time, the study confirms an overall improvement in SPI productivity, but with a declining marginal improvement, resulting from joint progress in efficiency and technological changes. Moreover, there is a tendency for productivity improvement to excessively rely on technological progress while relatively neglecting efficiency improvement, particularly in pure efficiency. As a policy recommendation, based on the research findings, we advocate for recognizing the positive role of external environmental improvements in the cost-effectiveness of SPI. Furthermore, local governments should reduce reliance on technological progress and strive to promote SPI productivity through efficiency improvement, especially in pure efficiency.

The rest of this paper is structured as follows: Section two reviews the literature related to SPI and the efficiency measurement of public sector. Section three outlines the model-building process. Section four introduces the data sources and the analytical results of the model. Section five discusses the model analysis results from section four and provides relevant policy recommendations. The final section draws conclusions based on the entire discourse presented in the paper.

2 Literature review

The decline in Japan's suicide rates post-2009 owes significantly to proactive interventions at national, local government, and community levels. At the national level, policies such as the 2006 Basic Act for Suicide Prevention, the 2007 General Principles of Suicide Prevention Policy, and a series of fiscal support policies (including RF) have been proven effective in some studies (4, 5, 10). However, some studies suggest its actual policy impact has been notably limited (11). Regarding central fiscal support and SPI, research falls into two categories. One focuses on government investment in public health and welfare, along with redistribution policies and their correlation with suicide behavior (12, 13). For instance, Shiroyama, Fukuyama (13) demonstrated a correlation between reduced suicide death rates and expenditure in "public health," "police," "ambulance/firefighting," "welfare," and "education" sectors in Japan from 2009 to 2018. The second category emphasizes the significance of central fiscal support for local SPI efforts (5, 6, 10, 14). Nakanishi, Yamauchi (10) highlighted that national fund facilitated the establishment of community SPI systems, streamlining the implementation of local SPI projects.

The WHO noted that besides evidence on the effect or impact of suicide prevention strategies, health planners and policymakers also need to understand the expected costs and cost-effectiveness to ensure that these strategies are economically viable. However, there is still a global shortage of robust economic research on the cost-effectiveness of suicide prevention (1). In the case of Japan, the focus on the cost-effectiveness of local government suicide intervention policies (SPI) stems partly from strained fiscal conditions (5, 6) and partly from the unstable and variable effectiveness of SPI measures. Yonemoto, Kawashima (14) found that although almost all local governments offered gatekeeper training programs, there was a lack of assessment of policy outcomes. Kato and Okada (5), analyzing prefectural data, noted variations in the policy impact of RF on male and female suicide rates. Yet, scarce objective studies have quantitatively evaluated the cost-effectiveness of national or local government executions of SPI policies in Japan.

The WHO categorizes the risk factors influencing suicide rates into several levels: health system, society, community, relationships, and individual, and provides corresponding intervention measures (although these are not exhaustive) (1). Similarly, Stack (15) categorizes influences on suicide into political, social, cultural, and economic dimensions. From a political perspective, increased social welfare and public assistance often correlate with reduced suicide rates (15, 16). Socially, marital and parental social institutions remain protective factors against suicide, albeit with gender disparities in their protective effects (17, 18). Additionally, most articles support the view that social isolation causally relates to suicide, while social support serves a protective function against suicide (19). Some studies indicate a correlation between alcohol consumption issues and suicide rates (15, 20, 21). Culturally, religious beliefs often negatively

1 The RF was allocated 10 billion yen in the supplementary budget for the 2009 fiscal year, 3.7 billion yen in the third supplementary budget for the 2021 fiscal year, 30.2 billion yen in the first supplementary budget for the 2022 fiscal year, and 16.3 billion yen in the first supplementary budget for the 2023 fiscal year.

correlate with suicide rates, but mediating factors require further exploration (15). Moreover, Japan's traditional notion of honorable suicide and modern conservative attitudes toward suicide are considered reasons for high suicide rates (22). Lastly, economically, a sluggish economic environment correlates with high suicide rates. Specifically, high unemployment rates and low job availability elevate suicide rates, especially among middle-aged men (22, 23). However, some research contests the direct causality between unemployment rates and suicide rates, at least concerning Japan (24). Additionally, macroeconomic indicators like regional GDP and CPI are believed to influence suicide rates (25, 26). Therefore, to derive relatively objective management efficiency in evaluating local government efficiency, environmental factors influencing the implementation of local government policies need consideration.

Assessing public sector policy efficiency has been a widely debated topic in academia. However, scarcely any studies have delved into efficiency assessments of SPI policies. With respect to the possible reasons, on one hand, efficiency analyses in healthcare sectors primarily focus on healthcare facility (hospitals, primary healthcare facilities) efficiency, with few studies exploring system-level (national or sub-national) efficiency (27). On the other hand, some studies suggest inconsistencies in the effectiveness of SPI policies across countries, with limited evidence supporting their impact on reducing suicide rates (11, 28, 29). Nevertheless, in Japan, there's a prevalent belief in academia that the implementation of RF is causally linked to the decline in suicide rates, particularly among males (5, 6, 10).

3 Materials and methods

This study can be divided into two parts. The first part involves estimating the SPI efficiency of each prefecture using a three-stage SE-MSBM model. The second part calculates the Luenberger total factor productivity (LTFP) index based on the estimated SPI efficiency to reflect the dynamic evolution of this efficiency.

3.1 Three-stage SE-MSBM model

The Slacks-Based Measure is a type of Data Envelopment Analysis (DEA), which is a is a non-parametric method used to evaluate the efficiency of decision-making units (DMUs) by constructing a piecewise linear frontier against which all observations are compared. It uses slack variables to evaluate the efficiency of DMUs. This method was proposed by Tone (30), who also introduced a way to assess the SE of these units. However, traditional Slacks-Based Measure struggles with translation invariance. This can cause distortions when assessing DMUs with negative inputs or outputs. To resolve this, Sharp, Meng (31) developed the MSBM. This method is tailored for systems that naturally include negative values.

The three-stage SE-MSBM model builds on the existing three-stage DEA framework. It replaces the traditional DEA model with the SE-MSBM. This model, proposed by Fried and Lovell, improves on earlier DEA versions. The three-stage DEA method proposed by Fried and Lovell (32). It overcomes the limitations of the one-stage DEA method, which cannot measure factors affecting efficiency, and the two-stage DEA method, which assumes a given form of influencing factor functions and cannot eliminate environmental impact factors. The main goal of this model is to filter out environmental effects and statistical noise from managerial inefficiency. This makes the efficiency assessments of DMUs more precise.

For a detailed methodological explanation, refer to Figure 1. It provides a comprehensive framework for the three-stage SE-MSBM model.

3.1.1 Stage 1: initial MSBM evaluation of DMUs performance

The standard form of efficiency score evaluated by MSBM is given as follows:

$$\min\rho=\frac{1-\frac{1}{m}\sum_{i=1}^{m}\frac{s_i^-}{R_{i0}^-}}{1+\frac{1}{q}\sum_{r=1}^{q}\frac{s_r^+}{R_{r0}^+}}$$
$$\begin{aligned}\text{s.t.}\ &\sum_{j=1,\neq 0}^{n}x_{ij}\lambda_j+s_i^-=x_{i0}\\ &\sum_{j=1,\neq 0}^{n}y_{rj}\lambda_j-s_r^+=y_{r0}\\ &\sum_{j=1,\neq 0}^{n}\lambda_j=1\\ &R_{i0}^-=x_{i0}-\min(x_i)\\ &R_{r0}^+=\max(y_r)-y_{r0}\\ &\lambda_j,s_i^-,s_r^+\geq 0\end{aligned}\quad(1)$$

Here,

- j indicates the j^{th} DMU in n DMUs.
- x_i and y_r represent the i^{th} input variable in m input variables and the r^{th} output variable in q variables, respectively.
- R_{i0} and R_{r0} represent the range of possible improvement for the corresponding inputs and outputs. λ denotes the weight vector. Additionally, if $R_{i0}^-=0$, the respective $\frac{s_i^-}{R_{i0}^-}$ term is removed from the objective function, and if $R_{r0}^+=0$, the corresponding $\frac{s_i^+}{R_{r0}^+}$ term is removed from the objective function.

For the DMU(x_0,y_0) that is efficient under the SBM, we define its super-efficiency as the optimal objective function value ρ^* given by:

$$\rho^*=\min\rho=\frac{\frac{1}{m}\sum_{i=1}^{m}\frac{\bar{x}_i}{R_{i0}^-}}{\frac{1}{q}\sum_{r=1}^{q}\frac{\bar{y}_r}{R_{r0}^+}}$$
$$\begin{aligned}\text{s.t.}\ &\bar{x}\geq\sum_{j=1,\neq 0}^{n}\lambda_j x_j\\ &\bar{y}\geq\sum_{j=1,\neq 0}^{n}\lambda_j y_j\\ &\sum_{j=1,\neq 0}^{n}\lambda_j=1\\ &R_{i0}^-=x_{i0}-\min(x_i)\\ &R_{r0}^+=\max(y_r)-y_{r0}\\ &\bar{x}\geq x_0,\bar{y}\leq y_0\text{ and }\lambda\geq 0.\end{aligned}\quad(2)$$

In this stage, we conducted a simple SE-MSBM under the assumption of variable returns to scale (VRS) and obtained the

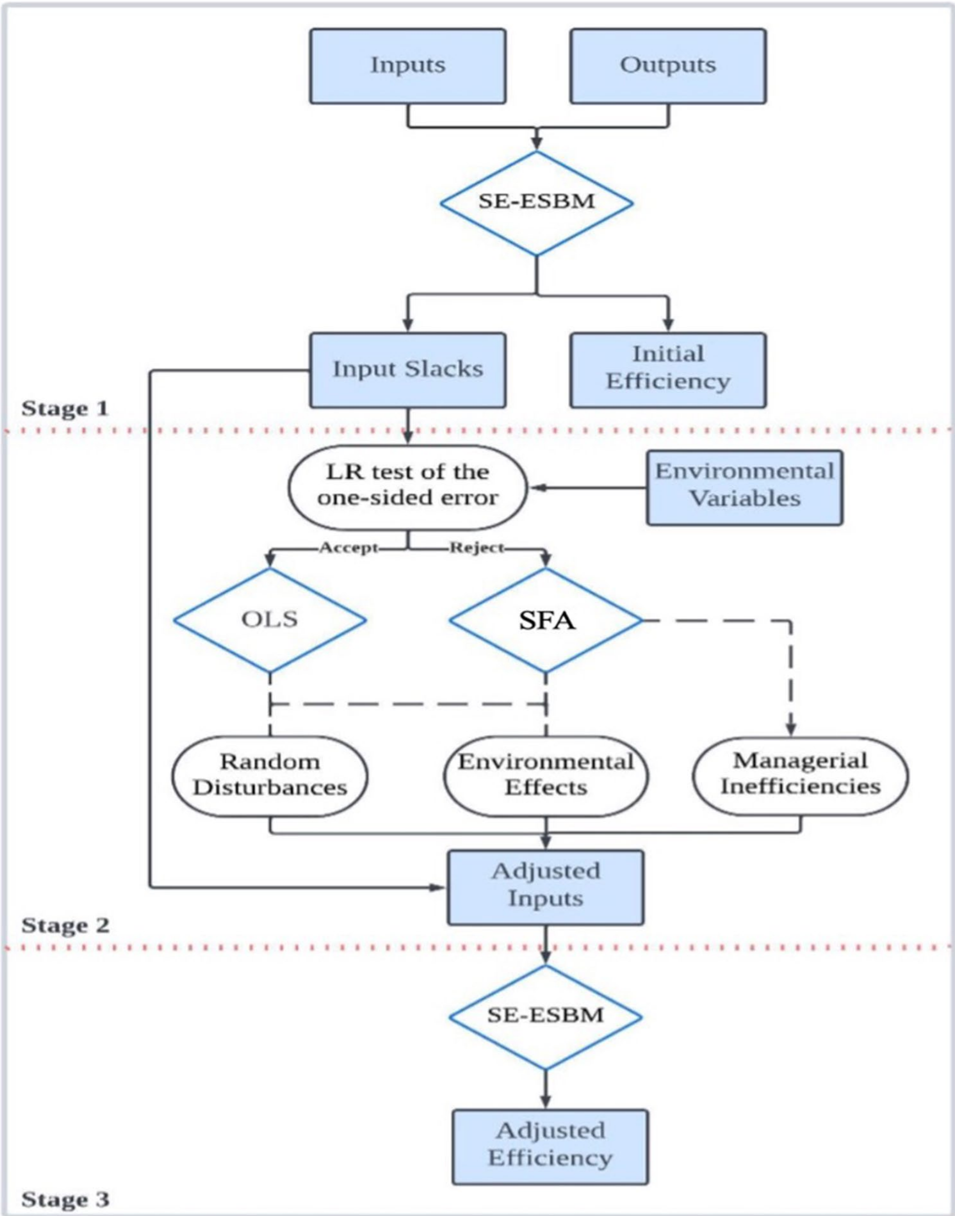


FIGURE 1
Methodological framework of the three-stage SE-MSBM model.

efficiency values of each DMU without excluding environmental factors and the slack variables of each input variable. The former will be used for subsequent comparative analysis, while the latter will be included as dependent variables in the second stage.

3.1.2 Stage 2: filtering out the influence of environmental effects

Based on the MSBM model from the first stage and input–output variable data, we can determine the slack values of each input and output, which represent the difference between the actual values and the optimal values. The slack value is influenced by environmental effects, statistical noise, and managerial inefficiency (32).

What we aim to do in the stage 2 is filter out the environmental effects and statistical noise, which are unrelated to managerial efficiency, from slacks. Subsequently, based on this, we adjust the original input and output indicators so that all DMUs face the same external environment and luck factors. According to Fried, Lovell (32), it is acceptable to adjust either inputs or outputs, or to simultaneously adjust both inputs and outputs. In this study, we follow the approach adopted by most scholars, adjusting only the input indicators (33–35).

To do this, we construct a Stochastic Frontier Analysis (SFA) model, as presented in Equation 3:

$$s_{ijt}^{-} = f\left(Z_{ijt};\beta_{it}\right) + v_{ijt} + u_{ijt},$$
$$i = 1,2\ldots,m; r = 1,2\ldots,q; j = 1,2\ldots,n; t = 2010,2011\ldots2014 \quad (3)$$

where:

- s_{ijt}^{-} is the slack value of the i^{th} input of the j^{th} DMU at time t.
- $Z_{ijt} = \left[Z_{1jt}, Z_{2jt} \ldots, Z_{mjt}\right]$ represents the set of environmental variables.
- β_{it} denotes the coefficients of environmental variables to be estimated in the secondary regression equation.
- $f^{i}\left(Z_{ijt};\beta_{it}\right)$ are deterministic feasible slack frontiers, which capture the impact of the environmental variables on the input slack value s_{ijt}^{-}.
- $v_{ijt} + u_{ijt}$ represents the error structure, where v_{kit} denotes random disturbances and $v \sim N\left(0,\sigma_v^2\right)$. It is assumed that the managerial inefficiency term u_{ijt} follows a half-normal distribution $u \sim N\left(\mu,\sigma_u^2\right)$.

Before estimation, we need to specify the form of the error structure. According to Fried, Lovell (32), if the LR test of the one-sided error results fail to reject the hypothesis $\sigma_u^2 = 0$, it indicates that the managerial inefficiency in that input does not affect the variation in the deterministic feasible slack frontiers, and the error term comprises only random disturbances. In such a scenario, this study will utilize Ordinary Least Squares (OLS) to estimate the influence of environmental factors and use their estimated coefficients to adjust the input indicators.

Moreover, assuming a parameter $\gamma = \frac{\sigma_u^2}{\sigma_u^2 + \sigma_v^2}$, which indicates the contribution of the managerial inefficiency in the variation of error. Additionally, considering whether the unit possesses time variability determines the use of either a time-invariant model or a time-varying decay model. In the time-invariant model, the v_{ijt} and u_{ijt} are independent of each other. The time-varying decay model features $u_{it} = u_i e^{-\eta(t-T_i)}$, where T_i is the last period for input i and η is the decay coefficient. Utilizing panel SFA estimation involves initially employing the time-varying decay model to estimate the equation and then conducting a test on the estimated decay parameter η. If rejecting the null hypothesis $\eta = 0$, a time-varying decay model should be used; otherwise, a time-invariant model is employed for estimation.

The estimation method for the random disturbance term is based on Jondrow, Lovell (36)'s approach, as presented in Equation 4:

$$E\left(u_{ijt} \mid v_{ijt} + u_{ijt}\right) = \frac{\sigma\lambda}{1+\lambda^2}\left[\frac{\varphi\left(\frac{\varepsilon_{it}\lambda}{\sigma}\right)}{\phi\left(\frac{\varepsilon_{it}\lambda}{\sigma}\right)} + \frac{\varepsilon_{it}\lambda}{\sigma}\right]. \quad (4)$$

Where $\lambda = \frac{\sigma_u}{\sigma_v}, \varepsilon_{it} = v_{ijt} + u_{ijt}$. φ and ϕ respectively represent the probability density function and cumulative distribution function of the standard normal distribution.

Next, we use the estimation results of the SFA model to adjust the external environment of all DMUs to the same extent, by adjusting the input indicators through the Equation 5, aiming to eliminate the influence of heterogeneity. This adjustment ensures that the subsequent efficiency calculations are based on a homogeneous environment.

$$X_{ijt}^{*} = X_{ijt} + \left\{\max\left[f\left(Z_{ijt};\hat{\beta}_{it}\right)\right] - f\left(Z_{ijt};\hat{\beta}_{it}\right)\right\} + \left[\max\left(v_{ijt}\right) - v_{ijt}\right],$$
$$i = 1,2\ldots,m; j = 1,2\ldots,n; t = 2010,2011\ldots2014. \quad (5)$$

Where X_{ijt}^{*} represents the adjusted i^{th} input indicator of the j^{th} DMU at time t. After adjusting for environmental factors and random error terms, all DMUs will face the same external environment and luck factors.

3.1.3 Stage 3: running MSBM again after adjusting input variables

Using the adjusted input variables X_{ijt}^{*} obtained from the second stage to replace the original input data X_{ijt}, calculate the new efficiency values based on the SE-MSBM model performed in Stage 1. As the influence of environmental and random error factors has been eliminated, the efficiency scores obtained in the third stage more accurately reflect the managerial efficiency of each DMU.

3.2 SBM based adjacent Luenberger productivity index

At present, the Malmquist-Luenberger method stands as the most commonly used approach for measuring production indices, yet it harbors certain unavoidable limitations. On one hand, within the Malmquist-Luenberger productivity index measurement method, there's a need to select a measurement angle either under conditions of cost minimization or profit maximization (37). On the other hand, the multiplicative form of index construction renders it incapable of calculating the Malmquist-Luenberger index when negative efficiencies exist. Luenberger proposed an alternative, addressing these issues with the LTFP index. On one hand, it allows for profit maximization usage and reduces measurement inputs without selecting a measurement perspective, thereby enhancing output (37, 38). On the other hand, even in the presence of negative efficiencies, the additive structure of LTFP index make it possible to reflect real efficiency improvements. Hence, this study opts for the LTFP index to gauge improvements in efficiency over a time series.

During period t, assuming $D_0^t\left(x_0^t,y_0^t\right)$ represents the optimal solution for Problem 1; if $D_0^t\left(x_0^t,y_0^t\right)$ is deemed efficient, then $D_0^t\left(x_0^t,y_0^t\right)$ is the optimal solution for Problem 2. If $DMU\left(x_0^{t+1},y_0^{t+1}\right)$ is observable, similarly, assuming $D_0^{t+1}\left(x_0^{t+1},y_0^{t+1}\right)$ is the optimal solution for period $t+1$. Moreover, if we simply transfer inputs and outputs from period t to period $t+1$, the optimal solution under the reference set of DMUs in period $t+1$ can be denoted by the reciprocal efficiency $D_0^{t+1}\left(x_0^t,y_0^t\right)$. Similarly, $D_0^t\left(x_0^{t+1},y_0^{t+1}\right)$ represents the optimal solution of transferring inputs and outputs from period $t+1$ to period t within the reference set of DMUs in period t. The optimal problem of $D_0^t\left(x_0^{t+1},y_0^{t+1}\right)$ is given as Equation 6:

$$\min D_0^t\left(x_0^{t+1},y_0^{t+1}\right) = \frac{1 - \frac{1}{m}\sum_{i=1}^{m}\frac{s_i^-}{R_{i0t}^-}}{1 + \frac{1}{q}\sum_{r=1}^{q}\frac{s_r^+}{R_{r0t}^+}}$$

$$\text{s.t.} \sum_{j=1,\neq 0}^{n} x_{ijt}\lambda_j + s_i^- = x_{i0,t+1}$$

$$\sum_{j=1,\neq 0}^{n} y_{rjt}\lambda_j - s_r^+ = y_{r0,t+1}$$

$$\sum_{j=1,\neq 0}^{n} \lambda_j = 1$$
$$R_{i0t}^{-} = x_{i0,t+1} - \min(x_{it})$$
$$R_{r0t}^{+} = \max(y_{rt}) - y_{r0,t+1} \tag{6}$$
$$\lambda_j, s_i^-, s_r^+ \geq 0$$

For the efficient $DMU(x_0, y_0)$ under the SBM, its super-efficiency as the optimal objective function value given by Equation 7:

$$D_0^t\left(x_0^{t+1}, y_0^{t+1}\right)^* = \min D_0^t\left(x_0^{t+1}, y_0^{t+1}\right) = \frac{\frac{1}{m}\sum_{i=1}^{m} \frac{\bar{x}_i}{R_{i0t}^{-}}}{\frac{1}{q}\sum_{r=1}^{q} \frac{\bar{y}_r}{R_{r0t}^{+}}}$$
$$\text{s.t.} \bar{x} \geq \sum_{j=1,\neq 0}^{n} \lambda_j x_j$$
$$\bar{y} \geq \sum_{j=1,\neq 0}^{n} \lambda_j y_j$$
$$\sum_{j=1,\neq 0}^{n} \lambda_j = 1$$
$$R_{i0}^{-} = x_{i0} - \min(x_i)$$
$$R_{r0}^{+} = \max(y_r) - y_{r0} \tag{7}$$
$$\bar{x} \geq x_0, \bar{y} \leq y_0 \text{ and } \lambda \geq 0.$$

The aforementioned $D_0^t\left(x_0^t, y_0^t\right)$, $D_0^{t+1}\left(x_0^{t+1}, y_0^{t+1}\right)$, $D_0^t\left(x_0^{t+1}, y_0^{t+1}\right)$, and $D_0^{t+1}\left(x_0^t, y_0^t\right)$ represent the optimal solutions under the VRS assumption, i.e., subject to the constraint $\sum_{j=1,\neq 0}^{n} \lambda_j = 1$. By removing this constraint, we obtain the optimal solutions under the assumption of constant returns to scale (CRS). For clarity, subscripts v and c are used to, respectively, indicate the optimal solutions under VRS and CRS assumptions. Additionally, it's important to note that under the CRS assumption, in the MSBM model, the maximum potential improvement R_{i0} of the evaluated DMU_0 might exceed s_i, implying $s_i > R_{i0}$, which could lead to a negative value for the objective function (31). This is one of the reasons why we opt for the LTFP index to specify productivity changes.

Therefore, the LTFP index, which reflects the dynamic change of productivity in two adjacent periods can be expressed as Equation 8:

$$LTFP_{t-1}^{t} = \frac{1}{2}\left[D_c^t\left(x^t, y^t\right) - D_c^t\left(x^{t-1}, y^{t-1}\right)\right]$$
$$+\frac{1}{2}\left[D_c^{t-1}\left(x^t, y^t\right) - D_c^{t-1}\left(x^{t-1}, y^{t-1}\right)\right]. \tag{8}$$

The LTFP index consists of two main components: efficiency change (LEC) (Equation 9) and technical change (LTC) (Equation 10). Additionally, LEC and LTC can be decomposed into pure efficiency changes (LPEC) (Equation 11) and scale efficiency changes (LSEC) (Equation 12), as well as pure productivity technology changes (LPTP) (Equation 13) and technology scale changes (LTPSC) (Equation 14). Their formulas are as follows (37, 39):

$$LEC_{t-1}^{t} = D_c^t\left(x^t, y^t\right) - D_c^{t-1}\left(x^{t-1}, y^{t-1}\right) \tag{9}$$

$$LTC_{t-1}^{t} = \frac{1}{2}\left[D_c^{t-1}\left(x^t, y^t\right) - D_c^t\left(x^t, y^t\right)\right]$$
$$+\frac{1}{2}\left[D_c^{t-1}\left(x^{t-1}, y^{t-1}\right) - D_c^t\left(x^{t-1}, y^{t-1}\right)\right] \tag{10}$$

$$LPEC_{t-1}^{t} = D_v^t\left(x^t, y^t\right) - D_v^{t-1}\left(x^{t-1}, y^{t-1}\right) \tag{11}$$

$$LSEC_{t-1}^{t} = \left[D_c^t\left(x^t, y^t\right) - D_v^t\left(x^t, y^t\right)\right]$$
$$-\left[D_c^{t-1}\left(x^{t-1}, y^{t-1}\right) - D_v^{t-1}\left(x^{t-1}, y^{t-1}\right)\right] \tag{12}$$

$$LPTP_{t-1}^{t} = \frac{1}{2}\left[D_v^{t-1}\left(x^t, y^t\right) - D_v^t\left(x^t, y^t\right)\right]$$
$$+\frac{1}{2}\left[D_v^{t-1}\left(x^{t-1}, y^{t-1}\right) - D_v^t\left(x^{t-1}, y^{t-1}\right)\right] \tag{13}$$

$$LTPSC_{t-1}^{t} = \frac{1}{2}\{[D_c^{t-1}(x^t, y^t) - D_v^{t-1}(x^t, y^t)] - [D_c^t(x^t, y^t)$$
$$-D_v^t(x^t, y^t)]\}$$
$$+\frac{1}{2}\{[D_c^{t-1}(x^{t-1}, y^{t-1}) - D_v^{t-1}(x^{t-1}, y^{t-1})]$$
$$-[D_c^t(x^{t-1}, y^{t-1}) - D_v^t(x^{t-1}, y^{t-1})]\}. \tag{14}$$

These indices satisfy the following relationship presented in Equation 15:

$$LTFP_{t-1}^{t} = LEC_{t-1}^{t} + LTC_{t-1}^{t} = LPEC_{t-1}^{t}$$
$$+LSEC_{t-1}^{t} + LPTP_{t-1}^{t} + LTPSC_{t-1}^{t}. \tag{15}$$

According to the definitions of the LTFP index and its decomposition, LEC reflects the change in relative efficiency of the DMU across different periods, known as the "catch-up effect." On the other hand, LTC represents the movement of the efficiency frontier between periods t and t-1, denoting the "frontier shift effect." Additionally, both LEC and LTC can be decomposed into two components: changes in pure efficiency and changes in scale efficiency.

The computation of the LTFP index requires estimation under CRS and VRS assumptions, where four are derived based on CRS and the remaining four are computed assuming VRS. In this context, LPEC, LPTP, LSEC, and LTPSC being greater than 0 (or less than 0) signify specific changes: pure technical productivity increases (or decreases), technological advancement (or regression), scale efficiency improvement (or decline), and deviation of technology from the optimal scale state of the DMU from period t to $t+1$.

4 Results

4.1 Variable and data selection

The study utilized data from various prefectures in Japan for a period spanning 2010 to 2014, encompassing a total of 5 years. Despite RF being established in 2009, the initial financial declaration data from each prefecture was incomplete at its inception. Therefore, we excluded the data for the year 2009. Additionally, due to the non-directional nature of the MSBM model, which does not support the efficiency calculation for DMUs with all inputs or outputs equal to zero, we omitted DMUs that had no reported RF declarations, resulting in the removal of a collective total of five observations.

4.1.1 Stage 1 and stage 3: input and output indicators

The per capita amounts allocated to the five programs funded by the RF[2]: Development Program of Leaders and Listeners (DPLL), Personal Consultation Support Program (PCSP), Telephone Consultation Support Program (TCSP), Enlightenment Program (EP), Intervention Model Program (IMP) are included as input indicators in the SE-MSBM model. According to Cantor and Poh (40), the evaluation framework for the efficiency of primary healthcare institutions in the DEA model requires the inclusion of primary inputs related to labor, capital-related inputs, and inputs related to consumable resources. As per the lines for the Management and Operation of the Regional Suicide Prevention Emergency Strengthening Fund, necessary expenses, wages, compensation, social insurance premiums, travel expenses, necessary expenses, service charges, usage fees, rental fees, equipment purchase costs, commission fees, subsidies, etc., can all be withdrawn from the RF. Therefore, utilizing RF as input indicators is justified (8). Additionally, the data for RF is sourced from publicly available data provided by the Japanese Ministry of Health, Labour, and Welfare.

Regarding the output indicators, I have selected the decrease in suicide rates for both men (DSRM) and women (DSRW) compared to 2008 as two separate output variables. The suicide rate is defined as the proportion of deaths by suicide to the total population of the DMUs for the current period, which is sourced from publicly available data provided by the Japan National Police Agency (41). This data is compiled based on the location where the individuals who died by suicide were discovered, rather than their registered residential address. Therefore, the decline in the suicide rate for males and females, as output variables, can be defined as Equations 16, 17, respectively:

$$\mathrm{DSRM}_{jt} = \frac{\text{Number of male suicides}_{j2008}}{\text{male population}_{j2008}} - \frac{\text{Number of male suicides}_{jt}}{\text{male population}_{jt}} \tag{16}$$

$$\mathrm{DSRW}_{jt} = \frac{\text{Number of female suicides}_{j2008}}{\text{female population}_{j2008}} - \frac{\text{Number of female suicides}_{jt}}{\text{female population}_{jt}}. \tag{17}$$

The reasons for designing output indicators in this manner is as follows:

Firstly, why differentiate between genders? According to the nationwide suicide rate statistics in Japan depicted in Figure 2, over the 6 years (2009–2014) within which the RF fund was available nationwide, there was a significant overall decrease in the national suicide rate. However, the contribution to the decline in the male suicide rate was notably greater than that in the female suicide rate (7). If a DMU's inputs from RF led to a decrease in male suicide rates but an increase in female suicide rates, using the total population's suicide rate as an output variable could potentially result in a calculated output of zero, which would evidently be unfair. Therefore, separating the output variables by gender would better aid in evaluating the actual efficiency of the DMU.

Secondly, why use the difference from the 2008 suicide rates as inputs rather than including the suicide rate of each year as undesirable outputs in the model? As per the Guidelines for the Management and Operation of the Regional Suicide Prevention Emergency Strengthening Fund, any SPI program funded or subsidized by the national treasury implemented by each DMU before the establishment of RF, as well as personnel expenses of permanent staff in relevant administrative agencies, are not covered within the scope of RF funding. Consequently, it is assumed that before 2009, some DMUs had already been implementing SPI projects, which continued post-RF establishment. Therefore, the variations in suicide rates from 2009 onwards can be regarded as the policy effects resulting from RF input.

The detailed information regarding input and output indicators is provided in Table 1.

4.1.2 Stage 2: environmental variable

In the second phase of analysis, we designate an environmental variable matrix that includes stillbirth rates, alcohol consumption volume, year-on-year changes in the CPI (excluding owner-occupied rent), job availability ratio, unemployment rate, Prefectural Income per Capita[3] (unit: thousand yen), divorce rate, and marriage rate. These variables are considered factors capable of inducing input slacks, besides random disturbances and managerial inefficiencies. Their descriptive statistics are given in Table 2. Additionally, the data on alcohol consumption is sourced from the National Tax Agency of Japan and the Okinawa Regional Taxation Office, while the remaining data is obtained from publicly available information provided by the Ministry of Health, Labour, and Welfare.

2 The RF data utilized in this study is the sum of the portion directly requested by prefectural governments from the central government and the portion representing funding usage plans submitted by municipalities within the jurisdiction of the prefectures.

3 Based on 2011 standard.

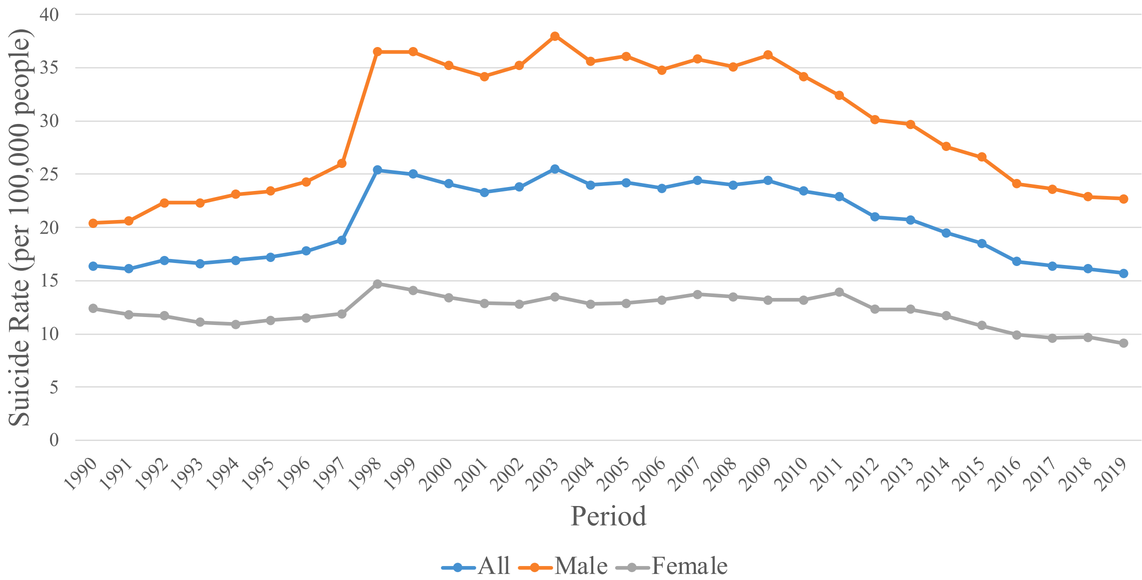


FIGURE 2
Trends in suicide rates in Japan (by gender).

4.2 Measurement and correction of efficiency values

4.2.1 Stage 1: initial efficiency scores based on original inputs

This stage employed the SE-MSBM model in the MaxDEA software to evaluate the SPI efficiency across various prefectures in Japan from 2010 to 2014. The efficiency values calculated are presented in Table 3. DMUs with efficiency values less than 1 are considered inefficient in management; those with efficiency values equal to 1 are regarded as efficient and highlighted in yellow in the table; DMUs with efficiency values greater than 1 are considered supper-efficient and marked in red. The last row and column in Table 3 represent the average efficiency values across all DMUs for each year and the average efficiency values for each DMU across all periods, respectively. The evaluation was performed using original inputs and outputs, thus encompassing not only managerial efficiency but also the impact of environmental factors and random noise.

Overall, the average efficiency across observed DMUs exhibits a U-shaped trend, which starts at 0.922 in 2010, declines rapidly to a minimum of 0.561 by 2011, then steadily rises, reaching a supper-efficient 1.017 by 2014. Moreover, the proportion of DMUs categorized as efficient or supper-efficient compared to all observed DMUs for each period also follows a U-shaped pattern, with percentages of 63.83, 34.09, 24.44, 48.94, and 48.94% for 2010 through 2014, respectively. This indicates an initial decrease followed by an increase in the overall average efficiency of DMUs. On the other hand, the standard deviation of DMU efficiency shows fluctuating trends across periods, reaching a peak of 2.129 in 2012, signifying significant regional disparities in SPI efficiency among prefectures.

A cross-sectional comparison of DMU efficiency over the five-year span reveals that only the average efficiency values of Hokkaido, Aomori, Tokyo, Wakayama, Tottori, Hiroshima, Kagoshima, and Okinawa achieved efficient or supper-efficient levels. Among these, only Wakayama and Tottori consistently achieved efficient or supper-efficient levels throughout the 5 years. This reflects that, even without considering non-managerial factors, hardly any prefecture has an environment or luck factor that readily leads to consistently high-efficiency values.

4.2.2 Stage 2: SFA and OLS

In this stage, the SFA or OLS models are employed to separate the environmental effects and random noise affecting DMU efficiency. Initially, a one-sided error LR test is conducted to test the null hypothesis $H_0 : \sigma_u^2 = 0$. Rejecting this hypothesis indicates that the managerial inefficiency in the input leads to deterministic feasible slack frontiers variations, requiring the use of the SFA model to estimate environmental effects. Failing to reject the null hypothesis suggests that the managerial inefficiency in the input does not affect stochastic frontier variations, indicating that the error term is solely composed of random disturbances, allowing direct estimation using the OLS model. The SFA and OLS models are run using Frontier 2.0 and Stata software, respectively.

According to the results of the LR one-sided error test in Table 4, it's evident that, at a 95% significance level, we cannot reject the hypothesis of $\sigma_u^2 = 0$ for TCSP, EP, and IMP. Therefore, direct estimation using the OLS model is employed. However, for the slack variables of DPLL and PCSP, at a 95% significance level, the hypothesis of $\sigma_u^2 = 0$ is rejected, hence employing the SFA model for estimation. Moreover, the γ values indicate that managerial inefficiency in these two inputs contributes 43.2 and 56.9% to the error variance, respectively. Additionally, for these two input slacks, we cannot reject the hypothesis of $\eta = 0$, thus the time invariant SFA model is employed to estimate environmental effects and random influences.

As environmental variables affect input slacks inversely to their impact on efficiency values, assessing the influence of environmental variables on efficiency can be done through the sign of regression coefficients. (1) The estimated coefficient for marriage rate is positive, indicating that higher marriage rates tend to lead to slacks in PCSP. Similarly, the positive coefficient for divorce rate suggests that higher divorce rates are associated with slacks in PCSP and IMP. The

TABLE 1 Descriptive statistics of input and output indicators.

Indicators	*N*	Mean	SD	Max	Min
Input					
PCSP	230	4197.617	4169.657	26502.622	0
TCSP	230	3156.205	2975.839	19492.743	0
DPLL	230	4653.228	3460.617	21484.079	0
EP	230	13855.281	9854.502	56547.962	0
IMP	230	7535.673	7265.083	44015.145	0
Output					
DSRM	230	6.774	5.365	24.607	−6.61
DSRW	230	1.454	2.615	11.331	−4.532

TABLE 2 Descriptive statistics of environmental variables.

	N	Mean	SD	Max	Min
Marriage rate	230	4.921	0.551	7.1	3.7
Divorce rate	230	1.795	0.224	2.59	1.33
Unemployment rate	230	3.999	0.888	7.5	2.3
Job availability ratio	230	0.801	0.255	1.57	0.29
Year-on-year changes in the CPI	230	0.512	1.479	4	−1.7
Alcohol consumption volume	230	79.591	10.764	127	60.2
Stillbirth rate	230	23.983	3.102	32.2	17.3
Prefectural Income per Capita	230	2694.174	489.635	5,411	1972

connection between high divorce rates, high marriage rates, and low efficiency values implies a causal relationship between residents' marital life entanglements, and the decrease in SPI efficiency. (2) The job availability ratio to some extent reflects the social economic conditions; higher job availability rates correspond to lower slacks in DPLL and PCSP, which favor the improvement of SPI efficiency. (3) CPI positively impacts slacks in EP, suggesting that DMUs with higher CPI exhibit lower SPI efficiency. This reflects a negative correlation between rising living costs and the improvement in SPI efficiency. (4) Alcohol consumption shows a negative correlation with relaxation in PCSP, indicating that DMUs with higher alcohol consumption demonstrate higher SPI efficiency. (5) Stillbirth rates show a negative causal relationship with slacks in IMP, implying that DMUs with higher natural death rates are more likely to enhance SPI efficiency.

4.2.3 Stage 3: final efficiency scores based on adjusted inputs

In the third stage, adjustments were made to the original input indicators based on the regression results from the second stage. Subsequently, the SE-MSBM model was run again using the adjusted input indicators. Table 5 presents the efficiency values of each DMU in the third stage. DMUs with efficiency values greater than 1 are marked in red, while those with efficiency values equal to 1 are marked in yellow.

The adjustments to the original input indicators in the second stage subjected all DMUs to the worst external environmental and luck-related factors, consequently leading to a decrease in efficiency values for most DMUs. Specifically, after removing the influences of external environment and luck-related factors, the number of DMUs with 5-year average efficiency values greater than or equal to 1 decreased from 8 in the first stage to 4, including Hokkaido, Aomori, Wakayama, and Tottori. Furthermore, compared to the first stage, 61.7% of DMUs experienced a decline in their average efficiency values over the 5-year period. However, despite the removal of external environmental and luck-related factors, Wakayama and Tottori continued to maintain efficient or super-efficient level over the 5-year period.

In contrast to the U-shaped average efficiency trend across all observed DMUs in the first stage, the average efficiency of DMUs displayed a fluctuating downward trend after the removal of external environmental and luck-related factors. Starting from its peak of 0.715 in 2010, the average efficiency demonstrated a steady decline, reaching 0.593 by 2014, with a minor uptick in 2013. This indicates that, at least during the ascending phase (2011 to 2014) of the U-shaped average efficiency trend observed in the first stage, favorable external environmental and luck-related factors masked the fact of low managerial efficiency among DMUs, resulting in a rebound trend in average efficiency. Additionally, compared to the first stage, the standard deviation of efficiency values for DMUs across periods tended to stabilize, indicating that external environmental and luck-related factors increased regional disparities in the efficiency of SPI among DMUs.

TABLE 3 The initial efficiency score in the Stage 1.

DMUs	2010	2011	2012	2013	2014	Mean
Hokkaido	1.004	0.441	-	1.62	2.366	1.358
Aomori	1.147	1.288	-	1.436	1	1.218
Iwate	0.412	1.225	0.287	0.256	0.145	0.465
Miyagi	1.158	1.913	0.018	0.532	0.406	0.805
Akita	0.223	-	3.012	0.38	0.308	0.981
Yamagata	0.518	0.141	0.044	0.448	0.384	0.307
Fukushima	1.014	1	0.11	0.398	0.381	0.581
Ibaraki	1.008	0.078	0.026	0.592	0.538	0.448
Tochigi	0.678	0.046	0.258	1.171	1.008	0.632
Gunma	1	-	0.022	0.579	0.595	0.549
Saitama	1.018	0.138	0.025	1.018	1.194	0.679
Chiba	1.144	0.069	0.04	1.08	1.091	0.685
Tokyo	1	0.125	0.023	1.163	2.699	1.002
Kanagawa	1.288	0.199	0.069	1.594	1.362	0.903
Niigata	0.38	0.1	0.077	1.081	0.439	0.415
Toyama	1.196	0.098	0.21	0.41	1.077	0.598
Ishikawa	1.206	0.26	0.212	0.458	1.231	0.674
Fukui	0.408	1.206	0.045	0.604	0.599	0.572
Yamanashi	0.495	1	1	1	1.358	0.971
Nagano	0.615	0.172	1	0.552	0.354	0.539
Gifu	1.118	0.052	0.028	1.157	1.292	0.73
Shizuoka	0.603	0.023	1	0.397	1.011	0.607
Aichi	1.081	0.042	0.078	1.682	1.902	0.957
Mie	1.237	0.295	0.017	0.417	0.532	0.5
Shiga	0.463	0.042	1	0.41	0.492	0.481
Kyoto	1.169	0.115	0.037	0.273	0.358	0.391
Osaka	1.105	1.016	0.293	1.007	1	0.884
Hyogo	1.015	0.157	0.019	0.406	0.416	0.403
Nara	0.349	1.013	0.011	0.421	0.328	0.424
Wakayama	1	4.244	1.175	1	1	1.684
Tottori	1.71	1	1.689	4.298	7.458	3.231
Shimane	1.52	1.08	1.165	0.37	0.592	0.946
Okayama	1	0.067	0.044	1.685	0.519	0.663
Hiroshima	1.883	0.234	0.061	1.279	2.414	1.174
Yamaguchi	1.017	0.199	0.215	1.106	1	0.707
Tokushima	0.556	1.683	0.091	0.219	0.146	0.539
Kagawa	0.217	0.018	0.032	0.307	0.415	0.198
Ehime	1.955	0.181	0.085	1.219	1.162	0.92
Kochi	1.051	-	0.284	1	1	0.834
Fukuoka	1.261	0.015	0.038	1.044	0.759	0.623
Saga	0.221	0.063	0.013	0.31	0.33	0.187
Nagasaki	1.265	1.094	1.542	0.625	0.47	0.999
Kumamoto	0.281	0.076	0.058	1.151	1.743	0.662
Oita	0.219	1	0.028	1	1	0.649
Miyazaki	1.407	1.083	0.106	0.53	0.401	0.705
Kagoshima	1.475	0.239	1.043	1.053	1.275	1.017
Okinawa	0.222	0.148	14.067	0.549	0.251	3.047
Mean	0.922	0.561	0.682	0.878	1.017	0.816
S.D.	0.454	0.772	2.129	0.663	1.130	0.574

"-" indicates that the observed values of the DMU for that period are excluded because all of its input indicators are zero, which does not meet the eligibility criteria for the SE-MSBM model.

TABLE 4 The results of SFA and OLS in Stage 2.

	SFA		OLS		
	Slack variable of DPLL	Slack variable of PCSP	Slack variable of TCSP	Slack variable of EP	Slack variable of IMP
Marriage rate	566.348 (1.243)	1133.739*** (10.028)	−549.625 (−0.796)	−388.885 (−0.200)	−100.818 (−0.068)
Divorce rate	−188.854 (−0.901)	5501.821*** (84.097)	1,778.137 (1.188)	5,869.685 (1.390)	6,886.430** (2.128)
Unemployment rate	320.415 (0.816)	−255.686 (−0.769)	−726.406* (−1.856)	267.710 (0.242)	299.417 (0.354)
Job availability ratio	−4324.645*** (−21.275)	−3805.223*** (−107.497)	−1,743.026 (−1.340)	−3,725.113 (−1.015)	−440.437 (−0.157)
Year-on-year changes in the CPI	433.096* (2.232)	96.232 (0.478)	−122.107 (−0.754)	938.764** (2.055)	463.961 (1.325)
Alcohol consumption volume	−7.699 (−0.302)	−85.726** (−2.783)	−13.965 (−0.699)	27.424 (0.487)	36.417 (0.843)
Stillbirth rate	−48.600 (−0.628)	−63.606 (−0.668)	18.746 (0.233)	−20.678 (−0.091)	−347.203** (−1.997)
Prefectural Income per Capita	0.789 (1.190)	0.705 (1.371)	0.710 (1.168)	2.286 (1.333)	−0.608 (−0.462)
Constant	−4359.331*** (−43.258)	−8,322.469 (−1.370)	1,318.705 (0.470)	−18,840.891** (−2.378)	−10715.563*** (−3725.296)
σ^2	1.283E+07***	1.971E+07***	8.269E+06***	6.066E+07***	3.752E+07***
LR test of the one-sided error	16.561**	30.082***	6.951	2.631	4.970
γ	0.432***	0.569***	-	-	-
η	−0.091	−0.068	-	-	-

t-statistics in parentheses ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

4.3 Dynamic evolution of suicide prevention efficiency

For the specific causes of SPI efficiency's variation, a further dynamic decomposition is necessary. Utilizing the MaxDEA software, this study employs the adjacent LTFP analysis to examine the relative shifts between prefectures and the production frontier, wherein LTFP, LPEC, LSEC, LPTP, and LTPSC, respectively, denote total factor productivity, pure efficiency changes, scale efficiency changes, pure productivity technology changes, and technology scale changes. It's important to note that in contrast to interpreting results from SE-MSBM, if LTFP and its decomposition are greater than 0, it signifies an improvement in productivity, efficiency, or technology compared to the base period; conversely, if it's less than 0, it indicates a decline.

Table 6 displays the average LTFP and its decomposition for all observed DMUs from 2010 to 2014. From Table 6, we observe that the national LTFP is positive from 2010 to 2013, indicating an overall increase in SPI productivity. However, the reasons for this productivity increase differ. The rise in LTFP from 2010 to 2011 is attributed to the enhancement of LSEC, leading to an improvement in LEC. Conversely, the regression in LTPSC diminished the magnitude of the productivity increase during that period. Improvements in productivity from 2011 to 2012 and 2012 to 2013 are credited to LTC. The former is due to improvements in LPTP, while the latter stems from the enhancement of LTPSC. Lastly, from 2013 to 2014, both LPTP and LTPSC exhibit notable improvements. However, the decline in LPEC and LSEC is greater, resulting in a slight regression in productivity.

Overall, over the five-year period from 2010 to 2014, the average SPI productivity across Japan increased by 28.3%. Among this, 13.9% is attributed to the progress of LEC, while 12.3% is credited to LTC's advancements. Notably, the majority of LEC's progress comes from the enhancement of LSEC, while the advancements of LTC overall benefits from the progress of LPTP. Furthermore, in terms of developmental trends, LEC has exhibited a gradual decline since 2011, with the rate of decrease intensifying each year. This decline primarily stems from the overall regression of LSEC, which has shown a progressively increasing downward trend, while the contribution from changes in LPEC remains relatively limited. Conversely, although LTC displayed a significant decline from 2010 to 2011, it has since stabilized and shown a consistent upward trend, with the rate of increase intensifying each year. Both LPTP and LTPSC have made significant contributions to the changes observed in LTC from 2011 onward.

4.4 Robustness test

The concern regarding the robustness of this study originates from the insignificance of the OLS regression in the second stage SE-MSBM. Despite Fried, Lovell (32)'s indication that under the circumstances where the LR one-sided error test fails to reject the null hypothesis $H_0 : \sigma_u^2 = 0$, the stochastic frontier specification is

TABLE 5 The adjusted efficiency score in the Stage 3.

DMUs	2010	2011	2012	2013	2014	Mean
Hokkaido	0.666	1.004	-	1.299	1.233	1.05
Aomori	1.106	1.174	-	2.064	1	1.336
Iwate	0.271	1.114	0.285	0.208	0.11	0.398
Miyagi	0.414	1.087	0.445	0.439	0.281	0.533
Akita	0.181	-	1.156	0.253	0.221	0.453
Yamagata	0.359	0.405	0.35	0.324	0.271	0.342
Fukushima	0.588	1.156	0.425	0.291	0.258	0.544
Ibaraki	0.658	0.392	0.461	0.507	0.431	0.49
Tochigi	0.499	0.436	0.576	0.673	0.461	0.529
Gunma	0.385	-	0.38	0.467	0.388	0.405
Saitama	0.537	0.461	0.521	1	1.061	0.716
Chiba	1.063	0.436	0.5	0.797	0.686	0.697
Tokyo	1	0.464	0.521	1.047	1.251	0.857
Kanagawa	1.488	0.504	0.617	1.005	1.342	0.991
Niigata	0.239	0.492	0.449	0.522	0.228	0.386
Toyama	1.139	0.381	0.486	0.367	0.417	0.558
Ishikawa	0.321	0.503	0.541	0.436	0.453	0.451
Fukui	0.344	1.042	0.364	0.439	0.364	0.511
Yamanashi	0.347	1	1	1	1.582	0.986
Nagano	0.426	0.453	1.075	0.415	0.241	0.522
Gifu	0.623	0.401	0.374	0.514	0.734	0.529
Shizuoka	0.376	0.376	1.025	0.367	0.671	0.563
Aichi	0.411	0.346	0.488	1.214	1.24	0.74
Mie	1.571	0.533	0.416	0.417	0.362	0.66
Shiga	0.207	0.345	1.022	0.4	0.334	0.461
Kyoto	0.497	0.446	0.422	0.311	0.342	0.404
Osaka	1.01	1.005	0.719	1	1	0.947
Hyogo	0.496	0.58	0.512	0.409	0.271	0.454
Nara	0.25	0.645	0.342	0.345	0.243	0.365
Wakayama	1	4.388	1.194	1	1	1.716
Tottori	1	1	1.231	4.434	2.097	1.952
Shimane	1.346	1.025	1.004	0.244	0.287	0.781
Okayama	1.386	0.496	0.534	0.593	0.383	0.678
Hiroshima	1.684	0.468	0.538	1.051	0.62	0.872
Yamaguchi	1	0.399	0.485	1	1	0.777
Tokushima	0.493	1.494	0.495	0.17	0.114	0.553
Kagawa	0.239	0.308	0.408	0.283	0.236	0.295
Ehime	2.05	0.469	0.478	1.038	0.489	0.905
Kochi	0.353	-	0.558	0.384	0.286	0.396
Fukuoka	1.533	0.446	0.575	0.655	0.51	0.744
Saga	0.181	0.32	0.322	0.295	0.248	0.273
Nagasaki	0.626	1.016	1.131	0.504	0.312	0.718
Kumamoto	0.224	0.405	0.463	0.575	1.036	0.54
Oita	0.22	0.56	0.487	0.529	0.3	0.419
Miyazaki	1.465	0.506	0.482	0.421	0.271	0.629
Kagoshima	1.165	0.545	0.658	0.65	1.027	0.809
Okinawa	0.182	0.34	1.183	0.336	0.179	0.444
Mean	0.715	0.713	0.616	0.696	0.593	0.666
S.D.	0.491	0.644	0.278	0.668	0.444	0.335

"-" indicates that the observed values of the DMU for that period are excluded because all of its input indicators are zero, which does not meet the eligibility criteria for the SE-MSBM model.

TABLE 6 Luenberger total factor productivity and its composition.

Period	LTFP						
		LEC			LTC		
			LPEC	LSEC		LPTP	LTPSC
2010–2011	0.903	2.084	−0.03	2.114	−1.18	0.204	−1.384
2011–2012	0.131	−0.042	−0.085	0.043	0.146	0.233	−0.087
2012–2013	0.170	−0.534	0.036	−0.570	0.704	−0.21	0.914
2013–2014	−0.052	−0.874	−0.103	−0.771	0.798	0.383	0.415
Mean	0.283	0.139	−0.046	0.185	0.123	0.149	−0.026

rejected, hence obviating the need for the SFA model. However, the OLS regression in Table 4 demonstrates less significant estimation effects for environmental factor coefficients. As a robustness check, this study revisits the estimation of environmental factors' contribution on the slacks in TCSP, EP, and IMP in the second stage, using the SFA model to estimate the coefficients instead of the OLS, and subsequently adjusts the input indicators with the estimated coefficients from SFA. As shown in Table 7, compared to OLS, the results from SFA exhibit greater significance, indicating an enhanced explanatory power of environmental variables on the slacks of TCSP, EP, and IMP after accounting for managerial inefficiency's impact.

Following adjustments to the related input variables based on estimated coefficients, the third stage of the SE-MSBM model is rerun. The efficiency values estimated are then utilized for a subsequent adjacent LTFP analysis, as presented in Table 8. Contrasting the results obtained from Table 6, the most notable change observed after considering managerial inefficiency in certain inputs is the shift of the 2013–2014 LTFP from negative to positive. This reversal is attributed to the absolute difference between positive LTC and negative LEC. Furthermore, for other periods and the overall productivity coefficients, the results of the robustness test exhibit minimal discrepancies from the primary analysis, signifying the robustness of the original analytical outcomes.

5 Discussion

In the three-stage SE-MSBM model, the results from the first stage reflect the SPI efficiency of each prefecture under their respective environmental and stochastic influences. The outcomes from the third stage represent the relative actual managerial efficiency of each prefecture after removing the effects of environmental and stochastic factors. Comparing the results from the third stage with those from the first stage, it's observed that the differences in suicide prevention efficiency among prefectures are more pronounced in the first stage. This suggests that the uneven distribution of external environmental and stochastic factors amplifies regional disparities in SPI efficiency among prefectures. From another perspective, the differences in suicide prevention efficiency observed in reality, attributable solely to managerial efficiency across prefectures, only constitute a portion of the overall observed differences. Neglecting the influence of exogenous factors might potentially exaggerate spatial discrepancies in SPI efficiency.

The analysis concerning the impact of environmental factors on input slack in the second stage has revealed some intriguing findings. (1) Both marriage rates and divorce rates are positively correlated with input slack (negatively associated with efficiency values). Assuming that the societal institution of marriage has a protective effect on suicide prevention (17, 18), higher marriage rates and lower divorce rates should result in decreased suicide rates, thereby enhancing SPI efficiency. However, the negative correlation between marriage rates and efficiency values suggests that married life could potentially serve as a trigger for higher suicide rates. According to publicly available data from the Japan National Police Agency (41), family issues remained the second leading cause of female suicide after health issues during this period, and approximately 10% of male suicides were attributable to family issues. Thus, entering into marriage may offer some protection against suicide on one hand, while on the other hand, it may introduce additional stressors, thereby increasing suicide risk. Moreover, the impact of marriage rates on input slack via the PCSP underscores the significant role of "seeking help" in reducing the suicide rate among individuals facing marital and family problems. Inefficient management and utilization of funds in this sector might lead to an increase in suicides related to marital issues, consequently affecting the overall SPI efficiency of the DMUs. (2) The negative correlation between the job availability ratio and input slack implies that a robust economic environment is more conducive to improving SPI efficiency. Economic and livelihood issues were the second leading cause of male suicides in Japan between 2009 and 2014 (41). Additionally, the surge in Japan's suicide rate in 1998 is believed to be causally linked to economic downturns (20, 42). Therefore, in terms of enhancing SPI efficiency, prefectures facing poorer economic conditions encounter stronger resistance. (3) The negative correlation between CPI and efficiency suggests that increased pressure from higher prices may elevate the risk of suicide, consequently impeding improvements in the effectiveness of SPI. (4) Elevated alcohol consumption tends to decrease the slacks of PCSP, subsequently enhancing efficiency. Despite the common belief that high alcohol consumption increases the risk of suicide (15, 21, 43), considering the impact of alcohol consumption on PCSP slacks and its potential for alleviating tension and anxiety (44), it is speculated that individuals may be more inclined to engage in conversations ('talk it out') post-alcohol consumption, thus paradoxically reducing the risk of suicide to some extent. However, conflicting evidence in prior studies necessitates further

TABLE 7 The results of SFA for robustness test.

	Slack variable of TCSP	Slack variable of EP	Slack variable of IMP
Marriage rate	−540.976*** (−43.829)	−382.821*** (−25.485)	−60.352 (−0.620)
Divorce rate	1777.163*** (166.431)	5872.930*** (722.722)	6889.457*** (1003.856)
Unemployment rate	−683.387*** (−9.422)	284.469*** (7.021)	407.418 (1.529)
Job availability ratio	−1756.093*** (−76.788)	−3728.465*** (−476.787)	−456.843*** (−11.125)
Year-on-year changes in the CPI	−207.760 (−1.555)	921.354*** (22.935)	408.200** (2.930)
Alcohol consumption volume	−17.924 (−0.919)	−1.732 (−0.031)	11.519 (0.266)
Stillbirth rate	29.615 (0.565)	37.096 (0.258)	−324.267** (−2.708)
Prefectural Income per Capita	0.734* (2.164)	2.629** (2.767)	−0.255 (−0.383)
Constant	1,318.705 (0.470)	−21401.608*** (−5296.289)	−10715.563*** (−3725.296)
σ^2	8.269E+06***	6.066E+07***	3.752E+07***
LR test of the one-sided error	6.951	2.631	4.970
γ	-	-	-
η	−0.114	−0.048	−0.028

t-statistics in parentheses ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

TABLE 8 Luenberger total factor productivity and its composition for robustness test.

Period	LTFP	LEC			LTC		
			LPEC	LSEC		LPTP	LTPSC
2010–2011	0.933	2.111	−0.034	2.145	−1.178	0.219	−1.397
2011–2012	0.132	−0.043	−0.085	0.042	0.148	0.245	−0.097
2012–2013	0.153	−0.565	0.054	−0.619	0.719	−0.224	0.943
2013–2014	0.157	−0.248	−0.112	−0.136	0.363	0.381	−0.018
Mean	0.342	0.303	−0.045	0.348	0.015	0.152	−0.137

examination of the mediating effects between alcohol consumption and the effectiveness of SPI. (5) There exists a positive correlation between the stillbirth rate and efficiency. Previous studies commonly assert that the stillbirth rate increases the risk of female suicide, which contradicts the findings here. One plausible explanation for this outcome could be, according to the Guidelines for the Management and Operation of the Regional Suicide Prevention Emergency Strengthening Fund (8), the IMP project serves as a safety net, wherein funds that cannot be allocated to other projects are designated to IMP. Therefore, the causal relationship between the stillbirth rate and the IMP slacks likely attributes to the funding division method of RF.

The analysis of the LTFP index indicates an overall upward trend in SPI productivity across Japan, despite a slight setback observed in 2013–2014. Additionally, there is a declining trend in the marginal improvement of productivity. Although the contributions of LEC and LTC to productivity improvement seem similar based on the outcomes, the developmental trends since 2011 reveal a gradual deterioration in LEC, contrasted with a gradual improvement in LTC. Moreover, the absolute values of the marginal change rates for both indicators have been steadily increasing. This indicates that post-2011, the overall improvement in SPI productivity of DMUs relied predominantly on technological enhancements, and technological advancements masked the deterioration in efficiency. Focusing on the causes of efficiency decline, it becomes evident that due to limited fluctuations in LPEC, the deteriorating trend in LSEC should primarily shoulder the responsibility.

We consider that the 2011 Great East Japan Earthquake has certain connections with the SPI efficiency across Japan. Occurring on March 11, 2011, this natural disaster is considered to have affected residents' psychological and mental health, increasing the risk of suicide (11, 45, 46). According to nationwide studies, female suicide rates surged rapidly in the months following the earthquake, whereas male suicide rates, especially among middle-aged and older men, notably decreased in the months following the earthquake, although the declining trend weakened over time (45, 47). The contrasting trends in male and female suicide rates posed challenges for prefectural SPI efforts. Furthermore, in the 2 years following the earthquake, the proportion of female suicides attributed to "health issues" gradually increased (48). According to the findings of Kato and Okada (5), female suicide rates were inversely proportional to the amount of DPLL at the municipal level in the RF. Therefore, the post-2011 improvement in the management and utilization efficiency of DPLL might have contributed more to the efficiency enhancement. Lastly, the Great East Japan Earthquake might be an important exogenous environmental factor influencing SPI efficiency across prefectures. However, due to the inability to accurately delineate the effects of the natural disaster and its spillover effects on residents' suicide risk, this study could not precisely control for its impact on DMU efficiency, suggesting room for improvement in future research.

6 Conclusion

Existing studies on the decline in suicide rates in Japan from 2009 to 2014 have predominantly focused solely on the changes in suicide rates, overlooking the fiscal costs incurred by the government in controlling these rates. In the context of severe financial constraints, this outcome-oriented research approach has led to a lack of understanding regarding the cost-effectiveness of policies, consequently detaching the assessment of policy effectiveness from practical implications. Thus, this study concentrates on the cost-effectiveness of SPI by prefectural governments in Japan from 2009 to 2014, marking the first application of the DEA analysis framework to evaluate the government's efficiency in SPI.

Specifically, we employed the SE-MSBM model, using the declared amounts of RF as inputs and the reduction in male and female suicide rates as outputs to assess the efficiency of SPI across Japanese prefectures. Furthermore, to eliminate the influence of exogenous environmental factors and luck on efficiency, we utilized a three-stage analysis framework to derive a relatively objective managerial efficiency of SPI in these prefectures. Subsequently, to elucidate the dynamic changes in efficiency and their causes, we employed the LTFP index and its decomposition to analyze the productivity changes in SPI efficiency.

The analysis results indicate the following: Firstly, in the three-stage SE-MSBM analysis, the spatial differences in SPI efficiency reflected in the results of the third stage are relatively minor compared to those in the first stage. This suggests that efficiency values directly based on inputs and outputs are easily influenced by exogenous environmental and luck factors. However, after filtering out these exogenous factors, the differences in efficiency values resulting from the managerial efficiency disparities among prefectures are relatively limited. Secondly, the analysis in the second stage of the impact of environmental and luck factors on efficiency values reveals that high divorce rates, high marriage rates, high year-on-year changes in the CPI, low job availability ratio, and low alcohol consumption are likely to hinder the improvement of SPI efficiency. Finally, in the analysis of the LTFP index, we found that although the overall average productivity of SPI in prefectures maintains an upward trend, the marginal improvement demonstrates a diminishing trend. Additionally, productivity improvement comprises positive technical changes and negative efficiency changes, with the negative efficiency changes primarily attributable to the continuous deterioration of scale efficiency.

The results of this study provide some insights for policymakers: Firstly, in the process of enhancing the efficiency of SPI, efforts should not only focus on improving management efficiency but also consider improving the external environment. Secondly, an excessive reliance on technical advancements is observed in the improvement of SPI productivity, insufficiently supported by productivity enhancements arising from efficiency improvements. This highlights the need for further optimization of policy execution efficiency in each prefecture, ensuring that resources are used efficiently. Lastly, optimizing scale efficiency to promote positive efficiency changes, thereby enhancing SPI productivity, appears to be the most evident approach.

We must acknowledge several limitations in this study. Firstly, in the selection of environmental variables, our approach was to include external factors influencing input–output and factors affecting input–output conversion rates in the environmental variable matrix. However, the declaration rules of RF generally did not have specific limitations based on the external environment of each prefecture. Moreover, the input–output conversion rates mainly reflect the fund management and utilization efficiency of DMUs, which is precisely the efficiency that the three-stage SE-MSBM model aims to measure. Therefore, most variables eventually considered as environmental factors tend to exert exogenous influences on output variables, namely male and female suicide rates. The limitation of this variable selection approach lies in the possibility that if other exogenous environmental variables exist, the second stage's filtering effect on environmental and stochastic factors might be inadequate. Secondly, considering that RF does not subsidize SPI policies that had received other subsidies before 2009, we assumed that relevant policies implemented before 2009 continued unchanged during the study period. If this assumption does not hold, the reduction in suicide rates following RF implementation might contain confounding factors. Further examinations and analyses would rely on more precise data support.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

YT: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing.

Funding

The author(s) declare that no financial support was received for the research, authorship, and/or publication of this article.

Acknowledgments

Thanks to Terai and Doi for their valuable comments on this paper.

Conflict of interest

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Generative AI statement

The author(s) declare that Generative AI was used in the creation of this manuscript. ChatGPT 4.0 was used to edit and polish the language of this paper.

Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2024.1359902/full#supplementary-material

References

1. World Health Organization (2014). Preventing suicide: a global imperative.

2. World Health Organization (2021). Comprehensive mental health action plan 2013–2030.

3. Cabinet Office, Government of Japan (2014). White paper on suicide prevention in Japan: 2014 edition (Heisei 26). Tokyo, Japan.

4. Takeshima T, Yamauchi T, Inagaki M, Kodaka M, Matsumoto T, Kawano K, et al. Suicide prevention strategies in Japan: a 15-year review (1998-2013). *J Public Health Policy*. (2015) 36:52–66. doi: 10.1057/jphp.2014.42

5. Kato R, Okada M. Can financial support reduce suicide mortality rates? *Int J Environ Res Public Health*. (2019) 16:4797. doi: 10.3390/ijerph16234797

6. Okada M, Hasegawa T, Kato R, Shiroyama T. Analysing regional unemployment rates, GDP per capita and financial support for regional suicide prevention programme on suicide mortality in Japan using governmental statistical data. *BMJ Open*. (2020) 10:e037537. doi: 10.1136/bmjopen-2020-037537

7. Ministry of Health, Labour and Welfare (2012). Evaluation report on the regional comprehensive suicide prevention emergency strengthening fund.

8. Ministry of Health, Labour and Welfare (2009). Guidelines for the management and operation of the regional suicide prevention emergency strengthening fund.

9. Nakano T, Hasegawa T, Okada M. Analysing the impacts of financial support for regional suicide prevention Programmes on suicide mortality caused by major suicide motives in Japan using statistical government data. *Int J Environ Res Public Health*. (2021) 18:3414. doi: 10.3390/ijerph18073414

10. Nakanishi M, Yamauchi T, Takeshima T. National strategy for suicide prevention in Japan: impact of a national fund on progress of developing systems for suicide prevention and implementing initiatives among local authorities. *Psychiatry Clin Neurosci*. (2015) 69:55–64. doi: 10.1111/pcn.12222

11. Nakanishi M, Endo K, Ando S, Nishida A. The impact of suicide prevention act (2006) on suicides in Japan. *Crisis*. (2020) 41:24–31. doi: 10.1027/0227-5910/a000599

12. Inoue K, Nishimura Y, Okazazi Y, Fukunaga T. Discussion based on analysis of the suicide rate and the average disposable income per household in Japan. *West Indian Med J*. (2014) 63:340–3. doi: 10.7727/wimj.2012.298

13. Shiroyama T, Fukuyama K, Okada M. Effects of financial expenditure of prefectures/municipalities on regional suicide mortality in Japan. *Int J Environ Res Public Health*. (2021) 18:8639. doi: 10.3390/ijerph18168639

14. Yonemoto N, Kawashima Y, Endo K, Yamada M. Implementation of gatekeeper training programs for suicide prevention in Japan: a systematic review. *Int J Ment Heal Syst*. (2019) 13:2. doi: 10.1186/s13033-018-0258-3

15. Stack S. Contributing factors to suicide: political, social, cultural and economic. *Prev Med*. (2021) 152:106498. doi: 10.1016/j.ypmed.2021.106498

16. Flavin P, Radcliff B. Public policies and suicide rates in the American states. *Soc Indic Res*. (2008) 90:195–209. doi: 10.1007/s11205-008-9252-5

17. Fujimoto M, Yokoyama K. Family ties: exploring suicide using prefecture-level panel data. *Oikonomika*. (2016) 52:1–15.

18. Fukuchi N, Kakizaki M, Sugawara Y, Tanji F, Watanabe I, Fukao A, et al. Association of marital status with the incidence of suicide: a population-based cohort study in Japan (Miyagi cohort study). *J Affect Disord*. (2013) 150:879–85. doi: 10.1016/j.jad.2013.05.006

19. Motillon-Toudic C, Walter M, Séguin M, Carrier JD, Berrouiguet S, Lemey C. Social isolation and suicide risk: literature review and perspectives. *Eur Psychiatry*. (2022) 65:e65. doi: 10.1192/j.eurpsy.2022.2320

20. Nakanishi M, Endo K. National Suicide Prevention, local mental health resources, and suicide rates in Japan. *Crisis*. (2017) 38:384–92. doi: 10.1027/0227-5910/a000469

21. Brady J. The association between alcohol misuse and suicidal behaviour. *Alcohol Alcohol*. (2006) 41:473–8. doi: 10.1093/alcalc/agl060

22. Russell R, Metraux D, Tohen M. Cultural influences on suicide in Japan. *Psychiatry Clin Neurosci*. (2017) 71:2–5. doi: 10.1111/pcn.12428

23. Kuroki M. Suicide and unemployment in Japan: evidence from municipal level suicide rates and age-specific suicide rates. *J Socio-Econ*. (2010) 39:683–91. doi: 10.1016/j.socec.2010.06.009

24. Huang C-J, Ho Y-H. Does high unemployment rate cause high suicide rate? Evidence from Japan and South Korea. *J Rev Glob Econ*. (2016) 5:165–70. doi: 10.6000/1929-7092.2016.05.14

25. Erdem C, Dinç M. The socioeconomic determinants of suicide: a panel data analysis. *Yildiz Soc Sci Rev*. (2022) 8:1–12. doi: 10.51803/yssr.1146860

26. Yosano A. Proposal of a novel strategy for identifying independent variables for causal analysis of suicide rates: pilot study applying self-organizing maps. *Trust Soc*. (2023) 3:1–28.

27. Mbau R, Musiega A, Nyawira L, Tsofa B, Mulwa A, Molyneux S, et al. Analysing the efficiency of health systems: a systematic review of the literature. *Appl Health Econ Health Policy*. (2023) 21:205–24. doi: 10.1007/s40258-022-00785-2

28. Dunlap LJ, Orme S, Zarkin GA, Arias SA, Miller IW, Camargo CA Jr, et al. Screening and intervention for suicide prevention: a cost-effectiveness analysis of the ED-SAFE interventions. *Psychiatr Serv*. (2019) 70:1082–7. doi: 10.1176/appi.ps.201800445

29. Linskens EJ, Venables NC, Gustavson AM, Sayer NA, Murdoch M, MacDonald R, et al. Population- and community-based interventions to prevent suicide. *Crisis*. (2023) 44:330–40. doi: 10.1027/0227-5910/a000873

30. Tone K. A slacks-based measure of super-efficiency in data envelopment analysis. *Eur J Oper Res*. (2002) 143:32–41. doi: 10.1016/S0377-2217(01)00324-1

31. Sharp JA, Meng W, Liu W. A modified slacks-based measure model for data envelopment analysis with 'natural' negative outputs and inputs. *J Oper Res Soc*. (2017) 58:1672–7. doi: 10.1057/palgrave.jors.2602318

32. Fried HO, Lovell CAK, Schmidt SS, Yaisawarng S. Accounting for environmental effects and statistical noise in data envelopment analysis. *J Prod Anal*. (2002) 17:157–74. doi: 10.1023/A:1013548723393

33. Guan HJ, Wang Y, Dong LY, Zhao AW. Efficiency decomposition analysis of the marine ship industry chain based on three-stage super-efficiency SBM model-evidence from Chinese A-share-listed companies. *Sustain For*. (2022) 14:2155. doi: 10.3390/su141912155

34. Chen YD, Li CH, Li XX, Zhang XL, Tan Q. Efficiency of water pollution control based on a three-stage SBM-DEA model. *Water*. (2022) 14:1453. doi: 10.3390/w14091453

35. Chen Y, Ma L, Zhu Z. The environmental-adjusted energy efficiency of China's construction industry: a three-stage undesirable SBM-DEA model. *Environ Sci Pollut Res Int*. (2021) 28:58442–55. doi: 10.1007/s11356-021-14728-2

36. Jondrow J, Lovell CAK, Materov IS, Schmidt P. On the estimation of technical inefficiency in the stochastic frontier production function model. *J Econ*. (1982) 19:233–8. doi: 10.1016/0304-4076(82)90004-5

37. Fang Z, Jiang L, Fang Z. Does economic policy intervention inhibit the efficiency of China's green energy economy? *Sustain For*. (2021) 13:3412. doi: 10.3390/su132313412

38. Chambers RG, Fāure R, Grosskopf S. Productivity growth in Apec countries. *Pac Econ Rev*. (2007) 1:181–90. doi: 10.1111/j.1468-0106.1996.tb00184.x

39. Grosskopf S. Some remarks on productivity and its decompositions. *J Prod Anal*. (2003) 20:459–74. doi: 10.1023/A:1027364119672

40. Cantor VJM, Poh KL. Integrated analysis of healthcare efficiency: a systematic review. *J Med Syst*. (2017) 42:8. doi: 10.1007/s10916-017-0848-7

41. Suicide Statistics. Fundamental data on suicide in the region [internet]. Japan National Police Agency. (2014). Available at: https://www.mhlw.go.jp/stf/seisakunitsuite/bunya/0000140901.html (Accessed January 12, 2023).

42. Okamura K, Ikeshita K, Kimoto S, Makinodan M, Kishimoto T. Suicide prevention in Japan: government and community measures, and high-risk interventions. *Asia Pac Psychiatry*. (2021) 13:e12471. doi: 10.1111/appy.12471

43. Sher L. Alcohol consumption and suicide. *QJM*. (2006) 99:57–61. doi: 10.1093/qjmed/hci146

44. Abrams KB, Mei L, Chen CS, Koele E, Kwan J, Montes Z, et al. The paradoxical association between tension-reduction alcohol outcome expectancies and tension following alcohol consumption. *Am J Drug Alcohol Abuse*. (2022) 48:206–16. doi: 10.1080/00952990.2021.1992772

45. Orui M. Suicide and suicide prevention activities following the great East Japan earthquake 2011: a literature review. *Int J Environ Res Public Health*. (2022) 19:906. doi: 10.3390/ijerph191710906

46. Suzuki Y, Kim Y. The great East Japan earthquake in 2011; toward sustainable mental health care system. *Epidemiol Psychiatr Sci*. (2012) 21:7–11. doi: 10.1017/S2045796011000795

47. Osaki Y, Otsuki H, Imamoto A, Kinjo A, Fujii M, Kuwabara Y, et al. Suicide rates during social crises: changes in the suicide rate in Japan after the great East Japan earthquake and during the COVID-19 pandemic. *J Psychiatr Res*. (2021) 140:39–44. doi: 10.1016/j.jpsychires.2021.05.035

48. Inoue K, Fujita Y, Miyaoka T, Ezoe S, Horiguchi J. Importance of measures to prevent suicides related to the great East Japan earthquake among women. *Psychiatry Clin Neurosci*. (2015) 69:596. doi: 10.1111/pcn.12288

Frontiers in Public Health

TYPE Original Research
PUBLISHED 14 January 2025
DOI 10.3389/fpubh.2024.1415908

Check for updates

OPEN ACCESS

EDITED BY
Hai Fang,
Peking University, China

REVIEWED BY
Sudhanshu Kumar Bharti,
Patna University, India
Kaijian Hou,
Shantou University, China

*CORRESPONDENCE
Unchalee Permsuwan
✉ unchalee.permsuwan@cmu.ac.th

RECEIVED 11 April 2024
ACCEPTED 18 December 2024
PUBLISHED 14 January 2025

CITATION
Permsuwan U and Deerochanawong C (2025) Budget impact analysis of insulin glargine vs. isophane protamine insulin treatment for patients with type-2 diabetes and severe hypoglycemia in Thailand.
Front. Public Health 12:1415908.
doi: 10.3389/fpubh.2024.1415908

Budget impact analysis of insulin glargine vs. isophane protamine insulin treatment for patients with type-2 diabetes and severe hypoglycemia in Thailand

Unchalee Permsuwan[1,2]* and Chaicharn Deerochanawong[3]

[1]Department of Pharmaceutical Care, Faculty of Pharmacy, Chiang Mai University, Chiang Mai, Thailand, [2]Center for Medical and Health Technology Assessment (CM-HTA), Department of Pharmaceutical Care, Faculty of Pharmacy, Chiang Mai University, Chiang Mai, Thailand, [3]Rajavithi Hospital, College of Medicine, Ministry of Public Health, Rangsit University, Bangkok, Thailand

Objective: This study aimed to assess the financial impact of different adoption rates of insulin glargine (IGlar) treatment compared to isophane protamine (neutral protamine hagedorn [NPH]) insulin treatment for patients with type-2 diabetes (T2D) and severe hypoglycemia in Thailand from the payer's perspective.

Methods: The budget impact analysis (BIA) model over a period of 5 years was used to estimate the net budget impact (NBI) of IGlar treatment by comparing the total budget expenditures under two scenarios: scenario 1 involved only NPH insulin and scenario 2 included the introduction of IGlar. The total budget included either the cost of insulin or a combination of the costs of insulin and the expense related to severe hypoglycemia. Scenario 2 started at 20% uptake of IGlar and a yearly increase of 20%. NBI was calculated as the difference between the total budgets of scenarios 1 and 2. NBI and one-way sensitivity analyses were conducted for evaluation.

Results: Considering only the cost of insulin, the use of IGlar for patients with T2D and severe hypoglycemia resulted in a yearly average NBI of 174.9 million Thai baht (THB) (5.1 million USD). However, when the cost related to severe hypoglycemia was included, the total budget incurred from scenario 2 was less than that of scenario 1, leading to a negative NBI or cost savings.

Conclusion: The NBI of IGlar adoption would be substantial when considering only the cost of insulin; however, the significant benefit of IGlar in terms of a lower rate of severe hypoglycemia compared with NPH insulin would clearly offset the additional cost of IGlar.

KEYWORDS
budget impact analysis, insulin glargine, NPH insulin, diabetes, Thailand

1 Introduction

Type-2 diabetes (T2D) is a rapidly rising public health issue globally. In 2021, T2D affected approximately 536.6 million people worldwide and is estimated to increase to approximately 783.2 million by 2045 (1). In Thailand, 6.1 million adults are affected by diabetes (1); according to the Fifth National Health Examination Survey, nearly 8.9 and 10.8% of Thai men and women, respectively, were affected by T2D, among which less than one-half (45.9 and 36.4%, respectively) received T2D treatment (2). Hypoglycemia is a risk for people with T2D being treated with insulin, with reported rates of severe hypoglycemia approximately 2.5 events per person per year (3). Severe hypoglycemic events may generate expensive hospitalization. Minor hypoglycemic events do not require hospitalization, but the occurrence of minor events in high frequency might result in substantial costs and lost productivity (4). Costs of severe hypoglycemia for outpatient visits and inpatient admissions in Thailand were approximately 3,102 THB (103 USD) and 74,532 THB (2,475 USD), respectively (5). Therefore, issues such as glycemic control, adverse events, convenience, and costs should be considered before selecting an appropriate insulin type for individuals with T2D.

In Thailand, insulin glargine (IGlar) is currently listed in the National List of Essential Medicine (NLEM) Category D, referring to medicines used only for particular indications and diseases. IGlar can be prescribed only for type-1 diabetes (T1D) under the conditions that patients have severe hypoglycemia or nocturnal hypoglycemia after using multiple daily human insulin injections (6). Human insulin is the primary type listed in the NLEM for T2D. The study of 36,793 patients with T2D from 1,018 healthcare facilities across Thailand reported that 22.80% were insulin users (7). Since IGlar is more expensive than human insulin, budget impact analysis (BIA) is required to provide economic evidence for the overall financial budget to decide on whether to extend IGlar use for T2D patients. Therefore, this study was conducted regarding the NLEM in Thailand to assess the financial impact of different adoption rates of IGlar treatment instead of conventional insulin treatment for patients with T2D and severe hypoglycemia.

2 Materials and methods

The analytical framework for BIA analysis of IGlar uptake for patients with T2D and severe hypoglycemia is shown in Figure 1. In this study, conventional insulin is referred to as isophane protamine (NPH) insulin. BIA required epidemiologic data that included prevalence, incidence, mortality rate, and cost. All inputs were based on the published studies and the data from Thailand.

2.1 Study inputs

2.1.1 Estimation of insulin glargine candidates

We began to estimate insulin users based on the market sale of NPH insulin in Thailand. The yearly average NPH insulin use from 2017 to 2021 was 844,472,700 units. Based on the expert's opinion, daily insulin dosage was 25 units/patient, resulting in insulin use of 9,125 units/patient/year. Therefore, currently, the total number of NPH insulin users sums up to 92,545 patients (844,472,700/9,125) in Thailand.

In contrast to economic evaluation using close cohorts, BIA applies open cohorts, which means that the individuals can be included or excluded along a time horizon by incorporating

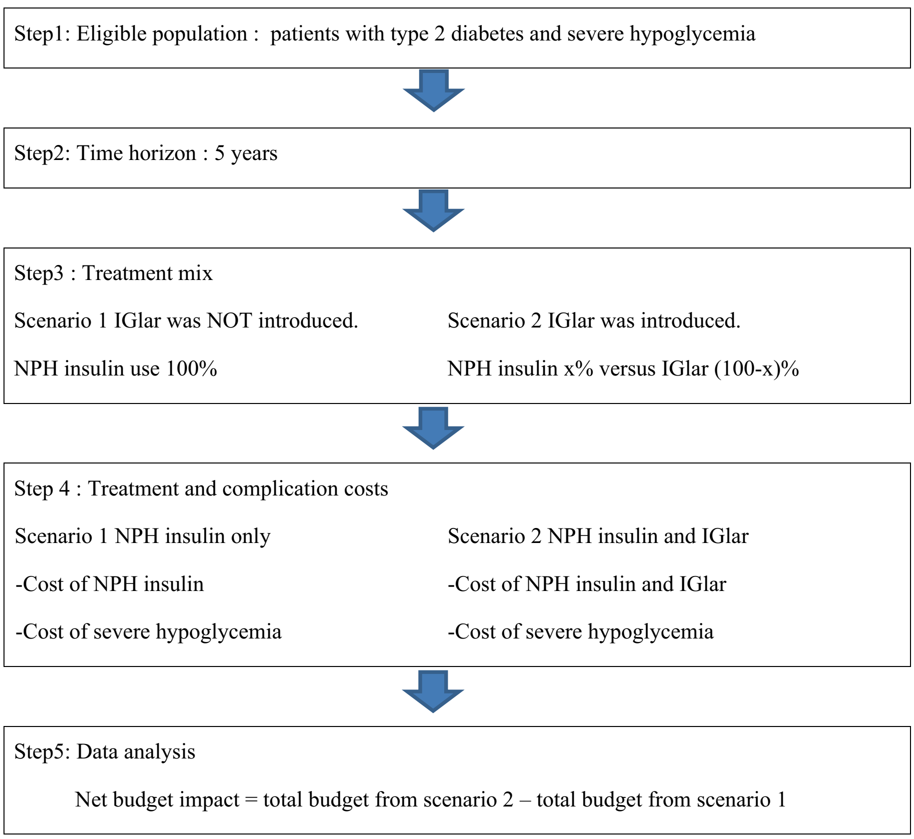


FIGURE 1
Framework of budget impact analysis. IGlar, insulin glargine; NPH, isophane protamine insulin.

disease incidence and mortality rate in the analysis. Based on the findings of the national cross-sectional study of 36,793 patients with T2D from 1,018 healthcare facilities across Thailand (7), 41.22% undertook at least two oral antidiabetic drugs; 25.52% could not control HbA1c to target 3 times consecutively; and 22.80% received insulin treatment. The estimated incidence of insulin users was 2.4% (22.80% × 41.22% × 25.52%). Therefore, the number of yearly new insulin users was determined by multiplying the number of patients with T2D and the estimated incidence, summing up to 72,487 patients.

2.1.2 Mortality rate of patients with T2D

Risk of death from T2D was reported by the Department of Disease Control, Ministry of Public Health (8) and the mortality rate of the general Thai population was obtained from the Public Health Statistics, Ministry of Public Health (9). Compared with non-insulin users, insulin users indicated a hazard ratio (95% confidence interval [CI]) for the mortality rate of patients with severe hypoglycemia of 3.6 (3.1–4.3) (10). We derived the mortality rate of patients with T2D and severe hypoglycemia by multiplying the hazard ratio and mortality rate of the Thai population at the age of 60 years. This rate was eventually converted to risk. The risk of death from having T2D and the risk of death from having severe hypoglycemia were incorporated in the BIA model to estimate the eligible population.

2.1.3 Prevalence of severe hypoglycemia

The yearly prevalence of severe hypoglycemia was 15% for patients with T2D and insulin treatment (11). Compared with NPH insulin, the risk of severe hypoglycemia for patients with IGlar was reduced by 46% ($p = 0.0442$) (12).

2.1.4 Costs

The cost of IGlar was determined using a pharmaceutical company. IGlar 100 IU/mL of 3 mL cost 0.83 THB per unit while IGlar 100 IU/mL of 10 mL and 300 IU/mL of 1.5 mL cost 1.28 THB per unit. The 0.83 THB per unit was employed in the base-case analysis, and the higher cost was used in sensitivity analysis. The cost of NPH insulin was obtained from the Drug and Medical Supply Information Center, Thailand Ministry of Public Health (13). The costs of NPH insulin 100 IU/mL of 3 mL and 10 mL were 0.26 THB per unit and 0.13 THB per unit, respectively. The 5-year market share of both dosage forms was 46% vs. 54%. Therefore, the average cost of NPH insulin was equal to 0.19 THB per unit (0.26 × 0.46 + 0.13 × 0.54). The total yearly cost of insulin was estimated from the daily-dose multiplied by 365 days. Based on the expert's opinion, the daily insulin dose in Thailand was found to be 25 units/day/patient.

The cost per event of severe hypoglycemia was obtained from the previous cost-effectiveness of IGlar in Thailand (14). The total cost of severe hypoglycemia was estimated from the cost per event of severe hypoglycemia and the prevalence of severe hypoglycemia. All costs were adjusted to 2022 values using the medical care component of the Thai consumer price index (15). The costs were converted at a rate of 34.54 THB/USD as on December 30, 2022 (16).

2.2 Study perspective

This study considered the payer's perspective; therefore, only the direct medical costs—the costs of NPH insulin and IGlar and the cost associated with severe hypoglycemia—were included. For base-case analysis, the cost of severe hypoglycemia was excluded.

2.3 Data analyses

2.3.1 Base-case analysis

The BIA was performed over a period of 5 years based on the Thailand Health Technology Assessment guidelines (17). The details of BIA inputs were shown in Table 1. The total budget was calculated from the following two scenarios: Scenario 1 was that all patients with T2D and severe hypoglycemia received NPH insulin and scenario 2 was the replacement of NPH insulin by IGlar at the rate of 20% in year 1. The uptake rate of IGlar increased by 20% each year until achieving 100% in year 5. The total budget considered only the cost of insulin and the combination of costs of insulin and severe hypoglycemia. The net budget impact (NBI) was the difference in the total budget between scenarios 1 and 2. The results were reported as the yearly cost of NBI and the average cost of NBI.

TABLE 1 Budget impact model inputs.

Variable	Value	Reference
Number of type-2 diabetes cases	3,022,674	Public Health Statistics (9)
Mortality rate of type-2 diabetes	2.5%	Department of Disease Control (8)
Mortality rate of Thai population at the age of 60 years	1.2%	Public Health Statistics (9)
Hazard ratio of mortality rate from severe hypoglycemia (insulin users vs. non-insulin users)	3.6	Akirov A, et al. (10)
Prevalence of severe hypoglycemia	15%	Zammitt NN, et al. (11)
Risk reduction of severe hypoglycemia by insulin glargine compared with NPH insulin	46%	Rosenstock J, et al. (12)
Cost of insulin glargine (THB per unit)	0.83	Industry
Cost of NPH insulin (THB per unit)	0.19	Drug and Medical Supply Information Center (13)
Cost of severe hypoglycemia THB (USD)	29,119 (843.06)	Permsuwan U, et al. (14)

NPH, isophane protamine insulin; THB, Thai baht; USD, US dollar.

2.3.2 Sensitivity analysis

Deterministic sensitivity analysis was carried out to assess the impact of parameter uncertainty. The key parameters, such as the uptake rate of IGlar and the cost of IGlar, varied. The 100% uptake rate of IGlar was applied from the first year. The cost of IGlar increased from 0.83 THB per unit to 1.28 THB per unit with varying IGlar uptake starting at 20 or 100%.

3 Results

3.1 Base-case results

When IGlar replaced NPH insulin, the total budget would increase depending on the uptake rate of IGlar. In this study, the starting uptake rate of IGlar was 20% and increased by 20% each year. The NBI was approximately 29.1 to 361.1 million THB (0.8–10.5 million USD) from years 1–5, with a yearly average cost of 174.9 million THB (5.1 million USD) when only the cost of insulin was considered. The total budget incurred by the use of NPH insulin only (scenario 1) was higher than that of the uptake of IGlar (scenario 2). This resulted in a negative NBI of 37.3–463.1 million THB or 1.0 to 13.4 million USD with a yearly average cost of 224.3 million THB (6.5 million USD). The results are shown in Table 2.

3.2 Sensitivity analysis results

With an increase in the uptake rate of IGlar to 100% from the first year, the cost of NBI was approximately 4.2–10.5 million USD—that is, with a yearly average cost of 7.4 million USD. When the cost of severe hypoglycemia was included, the NBI would become negative, indicating less total budget of IGlar adoption (scenario 2) compared with no IGlar adoption (scenario 1). The yearly average cost saving was 9.5 million USD or 327.7 million THB. All results are shown in Figure 2.

Although the cost of IGlar increased from 0.83 THB per unit to 1.28 THB per unit, negative NBI was still observed with the inclusion of the cost of severe hypoglycemia. The cost saving was found for the starting IGlar uptake of 20%. However, discarding the cost of severe hypoglycemia, NBI would be substantial depending on the uptake rate of IGlar. The yearly average cost saving of NBI was 8.6 million USD for starting 20% IGlar uptake and 12.6 million USD for 100% IGlar uptake. All results are shown in Figure 3.

4 Discussion

The BIA study represents an important tool to support informed decision-making to estimate the financial impact for a specified population of implementing a new health intervention or technology (17). The findings of this study showed that replacing NPH insulin with IGlar would increase the NBI due to a higher unit cost of IGlar compared to that of NPH insulin. The extent of the NBI depends on the rate of IGlar uptake. Specifically, the yearly average cost of NBI was equal to 174.9 million THB (5.1 million USD) when starting with a 20% uptake of IGlar, while it increased to 255.5 million THB (7.4 million USD) with 100% uptake.

However, when we factored in the costs associated with severe hypoglycemia, the narrative shifted dramatically. The introduction of IGlar leads to significant cost savings, with the NBI transitioning to a negative value, indicating that the expenses related to treating severe hypoglycemia effectively offset the higher costs of IGlar. Specifically, the analysis shows a yearly average cost saving of approximately 224.3 million THB (6.5 million USD) when the costs of severe hypoglycemia treatment are included. This underscores the critical importance of considering broader health outcomes in BIA analysis.

TABLE 2 Net budget impact from insulin costs with and without the cost of severe hypoglycemia.

Year	Total budget from cost of insulin THB (USD)		NBI THB (USD)	Total budget from costs of insulin and severe hypoglycemia THB (USD)		NBI THB (USD)
	Scenario 1	Scenario 2		Scenario 1	Scenario 2	
	NPH only	NPH + IGlar		NPH only	NPH + IGlar	
1	42,201,022 (1,221,801)	71,258,041 (2,063,059)	29,057,019 (841,257)	763,041,784 (22,091,540)	725,781,452 (21,012,781)	−37,260,331 (−1,078,759)
2	58,923,562 (1,705,951)	140,065,818 (4,055,177)	81,142,256 (2,349,226)	1,065,404,053 (30,845,514)	961,353,899 (27,833,060)	−104,050,154 (−3,012,454)
3	74,927,544 (2,169,298)	229,698,989 (6,650,231)	154,771,445 (4,480,934)	1,354,773,972 (39,223,334)	1,156,307,803 (33,477,354)	−198,466,169 (−5,745,981)
4	90,243,842 (2,612,734)	338,789,199 (9,808,604)	248,545,357 (7,195,870)	1,631,709,816 (47,241,164)	1,312,995,695 (38,013,772)	−318,714,121 (−9,227,392)
5	104,902,007 (3,037,117)	466,047,242 (13,492,972)	361,145,235 (10,455,855)	1,896,745,869 (54,914,472)	1,433,642,927 (41,506,744)	−463,102,941 (−13,407,728)
Average	74,239,595 (2,149,380)	249,171,858 (7,214,009)	174,932,262 (5,064,628)	1,342,335,099 (38,863,205)	1,118,016,355 (32,368,742)	−224,318,743 (−6,494,463)

IGlar, insulin glargine; NBI, net budget impact; NPH, isophane protamine insulin; THB, Thai baht; USD, US dollar.
[1]Net budget impact = Total budget (scenario 2) – Total budget (scenario 1).

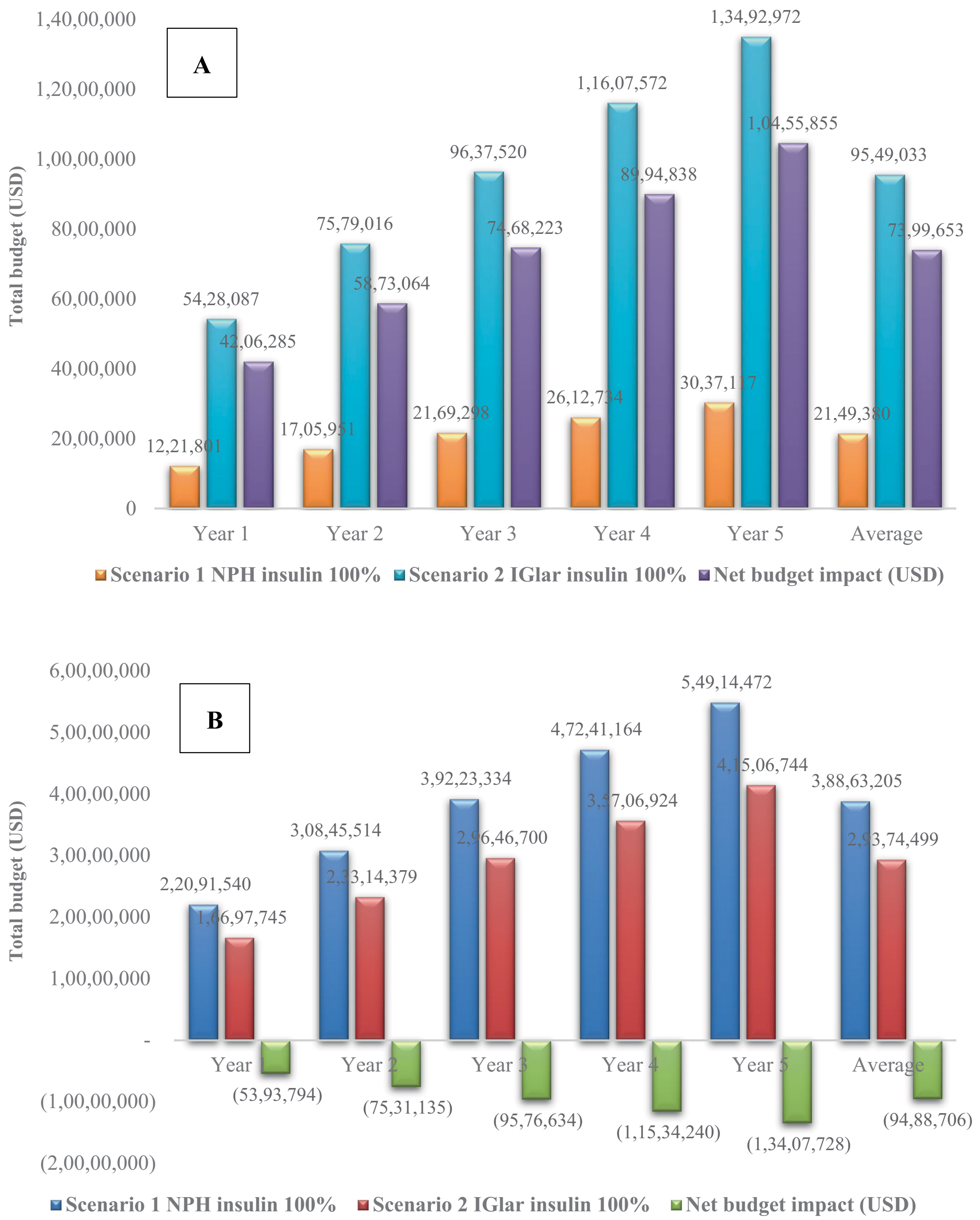
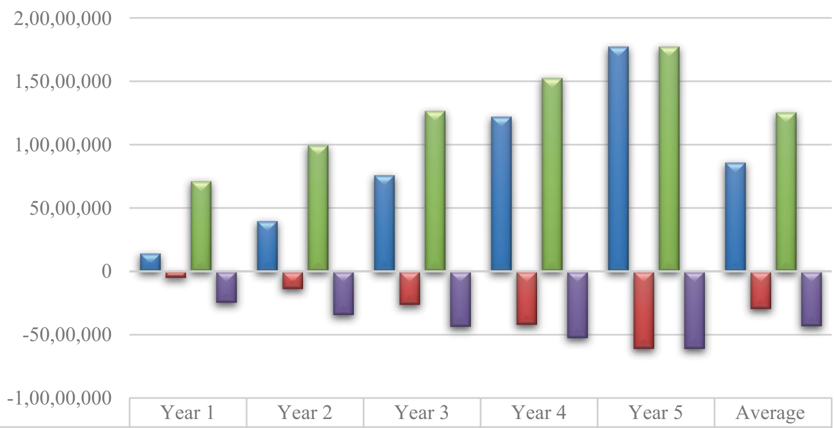


FIGURE 2
Sensitivity analysis with 100% uptake of insulin glargine considering **(A)** only the cost of insulin and **(B)** both costs of insulin and severe hypoglycemia. IGlar, insulin glargine; NPH, isophane protamine insulin; USD, US dollar.

In addition, the unit cost of IGlar was a significant factor influencing the analysis. The cost of NBI increased substantially due to the high acquisition cost of IGlar. The yearly cost of NBI increased by approximately 122.4 million THB (3.5 million USD) when the cost of IGlar increased from 0.83 THB per unit to 1.28 THB per unit. Clinical evidence demonstrates that IGlar effectively reduces overall symptomatic and nocturnal hypoglycemia (12). Consequently, the cost of severe hypoglycemia was incorporated into the BIA analysis, resulting in a negative NBI. Reducing the occurrence of severe hypoglycemic events was crucial in offsetting the additional cost associated with IGlar treatment—this benefit persisted even when the unit cost increased to 1.28 THB per unit.

The findings of our study align with other studies that have evaluated the economic impact of IGlar in various healthcare settings. For instance, a survey conducted in the US found that the transition to IGlar was associated with lower overall healthcare costs due to fewer hypoglycemic events and related complications.

This study revealed several strengths; the study was conducted at the request of the Health Economic Working Group (HEWG),



	Year 1	Year 2	Year 3	Year 4	Year 5	Average
NBI (IGlar uptake 20%, no SH cost)	14,29,845	39,92,868	76,16,031	1,22,30,480	1,77,71,322	86,08,109
NBI (IGlar uptake 20%,with SH cost)	-4,90,171	-13,68,812	-26,10,884	-41,92,782	-60,92,262	-29,50,982
NBI (IGlar uptake 100%, no SH cost)	71,49,224	99,82,169	1,26,93,384	1,52,88,100	1,77,71,322	1,25,76,840
NBI (IGlar uptake 100%, with SH cost)	(24,50,856)	(34,22,030)	(43,51,473)	(52,40,978)	(60,92,262)	(43,11,520)

FIGURE 3
Net budget impact for the cost of glargine 1.28 THB per unit. IGlar, insulin glargine; NPH, isophane protamine insulin; SH, severe hypoglycemia; USD, US dollar.

working under the subcommittee for the development of the NLEM in Thailand and was conducted after the cost-effectiveness study of IGlar in Thailand (14). Accordingly, some inputs were obtained from the related cost-effectiveness study. This would help the findings of this BIA study to be relevant to the previous cost-effectiveness study and could inform decision-makers when developing reimbursement policies within the resource constraints of the healthcare system. In addition, this BIA study is the first in Thailand to evaluate the financial impact of changing the adoption rate of IGlar use among patients with T2D with severe hypoglycemia. The meeting with an endocrinologist and health economist to validate the BIA model and inputs was established. The suggestions received were considered for the study's quality improvement. Although no randomized controlled trial has compared IGlar with NPH insulin in Thailand, the risk reduction of severe hypoglycemia by IGlar compared with NPH insulin was based on the results of a meta-analysis of randomized controlled trials, which is classified as the highest level of evidence.

Despite the strengths of this study, including the robust data inputs derived from previous cost-effectiveness analysis, there are several limitations that warrant consideration. First, the assumption that different formulations of IGlar have equivalent clinical efficacy and safety may oversimplify the analysis. The patient-level meta-analysis showed that IGlar 300 IU/mL provided comparable glycemic control to IGlar 100 IU/mL with less severe hypoglycemia at any time of day and less nocturnal hypoglycemia (18). Future studies could benefit from examining the specific impacts of IGlar 300 IU/mL in reducing severe hypoglycemia compared with IGlar 100 IU/mL, potentially enhancing the economic argument for adopting the higher concentration formulation. Second, except for the cost of severe hypoglycemia, this BIA model did not capture the effect of severe hypoglycemia concerning other aspects such as other hypoglycemia-related complications. Third, this study did not include indirect costs and patients' health-related quality of life owing to the perspective of the study. Finally, in the absence of actual data on the adoption rate of IGlar, we assumed an initial adoption rate of 20% based on expert opinion.

5 Conclusion

The yearly NBI of IGlar adoption in the treatment of patients with T2D and severe hypoglycemia from NPH insulin was 174.9 million THB (5.1 million USD). A lower rate of severe hypoglycemia with IGlar than those treated with NPH insulin generates cost savings, resulting in significantly reduced additional costs of IGlar. Therefore, the yearly NBI became negative.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors upon reasonable request, without undue reservation.

Author contributions

UP: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. CD: Conceptualization, Methodology, Supervision, Validation, Visualization, Writing – review & editing.

Funding

The author(s) declare that no financial support was received for the research, authorship, and/or publication of this article.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

Author disclaimer

This paper represents the views of the authors. This study was conducted at the request of the HEWG. This manuscript is one part of the project "Budget impact analysis of insulin glargine sterile solution for patients with type 2 diabetes having severe hypoglycemia from conventional insulin treatment" which was used to support the policy-making process under the Subcommittee for the Development of the NLEM in Thailand through the HEWG but the HEWG is not responsible for the study findings or their dissemination.

References

1. Sun H, Saeedi P, Karuranga S, Pinkepank M, Ogurtsova K, Duncan BB, et al. IDF diabetes atlas: global, regional and country-level diabetes prevalence estimates for 2021 and projections for 2045. *Diabetes Res Clin Pract*. (2022) 183:109119. doi: 10.1016/j.diabres.2021.109119

2. Aekplakorn W, Chariyalertsak S, Kessomboon P, Assanangkornchai S, Taneepanichskul S, Putwatana P. Prevalence of diabetes and relationship with socioeconomic status in the Thai population: National Health Examination Survey, 2004–2014. *J Diabetes Res*. (2018) 2018:1654530–8. doi: 10.1155/2018/1654530

3. Khunti K, Alsifri S, Aronson R, Cigrovski Berković M, Enters-Weijnen C, Forsén T, et al. Rates and predictors of hypoglycaemia in 27 585 people from 24 countries with insulin-treated type 1 and type 2 diabetes: the global HAT study. *Diabetes Obes Metab*. (2016) 18:907–15. doi: 10.1111/dom.12689

4. Deerochanawong C, Ferrario A. Diabetes management in Thailand: a literature review of the burden, costs, and outcomes. *Glob Health*. (2013) 9:11. doi: 10.1186/1744-8603-9-11

5. Phrommintikul A, Dilokthornsakul P, Permsuwan U. Economic burdens for treatment of patients with type 2 diabetes in North Thailand: a hospital-based observational study. *Front Endocrinol*. (2022) 13:4545. doi: 10.3389/fendo.2022.824545

6. Thai National Drug Development Committee. (2023). The national list of essential medicine. Available at: http://drug.fda.moph.go.th:81/nlem.in.th/ (Accessed February 20, 2023).

7. Rangsin R, Tatsanavivat PMedResNet. Data collection and analysis for care among patients diagnosed with type 2 diabetes and hypertension visiting hospitals in care of Ministry of Public Health and Hospital in Bangkok in Thailand. Thailand: National Health Security Office (2018).

8. Division of Non-Communicable Diseases, Department of Disease Control, Ministry of Public Health. (2020). Mortality rate of five non-communicable diseases year 2016. Available at: (http://www.thaincd.com/2016/mission/documents.php?tid=32&gid=1-020)

9. Strategy and Planning Division. Ministry of Public Health: World health statistics 2020. Geneva: World Health Organization (2022).

10. Akirov A, Grossman A, Shochat T, Shimon I. Mortality among hospitalized patients with hypoglycemia: insulin related and noninsulin related. *J Clin Endocrinol Metab*. (2017) 102:416–24. doi: 10.1210/jc.2016-2653

11. Zammitt NN, Frier BM. Hypoglycemia in type 2 diabetes: pathophysiology, frequency, and effects of different treatment modalities. *Diabetes Care*. (2005) 28:2948–61. doi: 10.2337/diacare.28.12.2948

12. Rosenstock J, Dailey G, Massi-Benedetti M, Fritsche A, Lin Z, Salzman A. Reduced hypoglycemia risk with insulin glargine: a meta-analysis comparing insulin glargine with human NPH insulin in type 2 diabetes. *Diabetes Care*. (2005) 28:950–5. doi: 10.2337/diacare.28.4.950

13. Drug and Medical Supply Information Center. (2022). News and activities medical information center. Available at: http://dmsic.moph.go.th (Accessed March 1, 2022).

14. Permsuwan U, Chaiyakunapruk N, Dilokthornsakul P, Thavorn K, Saokaew S. Long-term cost-effectiveness of insulin glargine versus neutral protamine Hagedorn insulin for type 2 diabetes in Thailand. *Appl Health Econ Health Policy*. (2016) 14:281–92. doi: 10.1007/s40258-016-0228-3

15. Bureau of Trade and Economics Indices, Ministry of Commerce. (2022). CPI. Available at: http://www.price.moc.go.th/default5.aspx (Accessed February 8, 2022).

16. Bank of Thailand. (2022). Foreign exchange rates. Available at: https://www.bot.or.th/App/BTWS_STAT/statistics/ReportPage.aspx?reportID=123&language=th (Accessed September 14, 2022).

17. Leelahavarong P. Budget impact analysis In: U Chaikledkaew and Y Teerawattananon, editors. Guidelines for health technology assessment in Thailand. Nonthaburi: Ministry of Publich Health (2013). 120–35.

18. Ritzel R, Roussel R, Bolli GB, Vinet L, Brulle-Wohlhueter C, Glezer S, et al. Patient-level meta-analysis of the EDITION 1, 2 and 3 studies: glycaemic control and hypoglycaemia with new insulin glargine 300 U/ml versus glargine 100 U/ml in people with type 2 diabetes. *Diabetes Obes Metab*. (2015) 17:859–67. doi: 10.1111/dom.12485

Frontiers in Public Health

Explores and addresses today's fast-moving healthcare challenges

One of the most cited journals in its field, which promotes discussion around inter-sectoral public health challenges spanning health promotion to climate change, transportation, environmental change and even species diversity.

Discover the latest Research Topics

See more →

Frontiers

Avenue du Tribunal-Fédéral 34
1005 Lausanne, Switzerland
frontiersin.org

Contact us

+41 (0)21 510 17 00
frontiersin.org/about/contact