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Global population aging - health care, social and economic consequences, volume II

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Global population aging - health care, social and economic consequences, volume II

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Editorial: Global population aging – Health care, social and economic consequences, volume II

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Editorial on the Research Topic
Global population aging – Health care, social and economic consequences, volume II

While there had been some isolated periods of fertility decline in Europe in the last two centuries, the so-called third Demographic Transition phenomenon became broadly recognized mainly over the past three decades. It consists of falling female fertility, improved early childhood survival, extended longevity, and ultimately the rapid growth in the proportion of the older adults population in a society (1). Among the major underlying causes, the following are listed: growing living standards, improvements in medical services, public health, public education, the sexual revolution and consequent absorption of unpaid female labor into the labor markets. In the process, the families undergo significant changes in their social role; large or multi-generation families dissolve into nuclear families, keeping the reproduction, consumption, education, and health production functions but losing most of the functions for production and intergenerational resource transmission (2).

The transition to an aging society brings severe financial challenges to all institutions in any economy. Even most developed countries that had foreseen these problems coming for two decades are still struggling to find money to pay for the bulging retirement income and healthcare costs for the growing older adults population. Their transition has been made more difficult by the new revolutionary medical technologies, extremely costly, that are targeted to save the life of a relatively small number of patients. To what extent should public money be spent to save the life of the few, mostly the older adults?

Another unsolved health policy problem for high-income countries is long-term care for the older adults. With the longevity and differential gender mortalities, we observe a swelling population of the very old, overwhelmingly female and poor, living alone. Only two or three decades ago, they would have been taken care of by their children or their families, but with family ties weakening, the government is now asked to provide necessary social services for them. How should we finance these costs? How can we preserve incentives for family caregiving? (3).

These problems are no less serious, if not more, for most middle-income countries. Compared with the historical experiences of developed countries, their demographic transition is taking place much faster. While, at the moment, they may be enjoying huge "demographic dividends," they are bound to face much larger bills for retirement income, healthcare costs, and long-term care costs for their disproportionately large older adults populations (4).

There are significant gaps in the literature, particularly for less recognized middle-income regions, magnitudes of the demographic shocks involved, the size of the expected costs of aging and the distribution of these costs over generations. Although only some developed countries have succeeded in preparing for their demographic shocks, how are these countries preparing for the upcoming aging shocks? (5).

Today we have evidence that aging is occurring even among some of the poorest countries, bringing double burdens to their national health system. Still coping with the responsibility of infectious diseases, injuries, and high neonatal mortality, these communities face a high toll of chronic non-communicable diseases usually associated with old age in more developed countries (6).

The most comprehensive set of studies on basic medical insurance, private health insurance, healthcare, evaluation of financial sustainability of basic pension, evaluation of medication usage, aging, fertility and other topics are provided by authors from all around the globe.

With ∼8,500 employees, Semmelweis University is a leading institution in medicine and health sciences in Hungary and the Central European region. The Center of Preventive Services' mission is to provide comprehensive preventive services, such as health promotion programs, health status assessments, lifestyle counseling, and medical risk assessment. Monitoring and defining the effectiveness of a workplace health promotion/disease prevention program is a must, but evaluation methods developed for and applied in health promotion in various (primarily occupational) settings have frequently fallen short of the ideal.

Researchers from the Medical University of Sofia, Bulgaria, conducted an intriguing study regarding the identification of potentially inappropriate medication and potential prescribing omissions in older patients with cardiovascular diseases in Bulgaria. Krustev et al. carried out a questionnaire-based survey among 543 senior patients. This study's findings show a high percentage of potentially inappropriate medication among older patients with polypharmacy. With Bulgaria's aging population, the economic burden of polypharmacy, and the prevalence of cardiovascular diseases, it is critical to address potentially inappropriate medication use in cardiovascular patients.

Aging is a significant trend in the changing age structure of the world's population, and it is a major economic and social issue impeding the development of all nations. The data for this study, conducted by Zhang et al., came from the China Health and Retirement Longitudinal Survey (CHARLS) in 2013, 2015, and 2018. The findings show that health shocks hampered the improvement of the shared prosperity of the middle-aged and older adults in rural areas, with daily activities having the most significant negative impact. Yet, the government is expected to broaden the scope and proportion of essential medical insurance payments, gradually close the medical insurance gap between urban and rural residents, and achieve basic public service equalization.

Wang C. et al. conducted an exciting study on a similar topic, examining whether intergenerational support was associated with depressive symptoms differently among urban and rural Chinese older participants. A total of 3,498 participants were included from nine pairs of urban subdistricts and rural villages. The 10-item Center for Epidemiological Studies Depression Scale was used to assess depressive symptoms, and a self-designed questionnaire was used to evaluate intergenerational support mechanisms (financial, instrumental, and emotional). The findings support modernization theories that propose weakened economic functions but strengthened emotional ties in higher-developed societies.

A curious study by Zhu et al. focused on predicting models and associated factors on the fertility behaviors of the floating population in China. The data for this study came from the 2016 China Migrants Dynamic Survey, which used a stratified three-stage random sample proportional to the population and collected information *via* anonymous questionnaires. This study provided a total of 168,993 valid questionnaires. The factors influencing the reproductive behavior of the floating population were complex, including social health services, family income, and the burden of urban living. The high-accuracy prediction model of the population's childbearing behavior could assist relevant departments in better predicting and intervening in the development of the floating population and improving their fertility rate, ultimately alleviating population aging and promoting economic growth.

Chen et al. conducted a study of the private health insurance's (PHI's) complementary role in health using the three-wave balanced panel data of the China Health and Retirement Longitudinal Survey (CHARLS), which is conducive to providing evidence for PHI's policy expansion and encouraging the public to participate in PHI, which is insufficient in China in comparison to social health insurance (SHI). Participating in supplementary PHI can significantly improve the insured's health status and significantly impact patients with chronic diseases. PHI development should be encouraged further, while health disparities between income groups should be addressed.

Using the STOP-Bang questionnaire combined with the Epworth Sleepiness Scale (ESS) in screening for obstructive sleep apnea (OSA) in the population, Zheng et al. have done good work on screening patients for OSA. The combination of STOP-Bang ($\geq$3) and ESS significantly improved its specificity for predicting OSA. This screening method can help doctors conduct stratified management based on patients' OSA risk levels, identifying high-risk patients and ultimately reducing the harm caused by OSA.

Wang Y. et al. from the Liaoning University of China investigated how to alleviate the demographic structure dividend in the face of an aging population, increasing domestic demand and accelerating domestic movement. In this popular topic, there are numerous theoretical assumptions and potential solutions to this problem. To comprehensively stimulate consumption growth, it is necessary to accelerate urbanization development progress and rely on the Internet. According to the estimation results, the urbanization level, Internet usage rate, and developmental level of

the tertiary industry played a significant positive promotion role in the consumption structure upgrade.

A researcher from the Jiangxi University of Finance and Economics, China, provided exciting insight regarding population aging as a global issue. Chen examined the characteristics of the aging population of insureds participating in basic pension insurance before randomly simulating the basic pension insurance's long-term financial situation in this analysis. The study discovered that the aging of insureds has a "fierce coming and slow decline" and "long-term seriousness." He then examined the impact of the main parameter direction and degree on the fund's financial situation and the result of parameter value paths on the fund's final financial status to improve the fund's ability to strengthen its reserve. Among the many conclusions was the idea of going back to see if there was a way to enhance the basic pension insurance fund reserves.

In China, low fertility has become a major social issue. In this retrospective study conducted by Ning et al., data from the 2017 China General Social Survey have been collected. The results were exciting. Women's fertility intentions differ significantly $p < 0.01$ depending on their media use preferences, education level, and family income. New media use negatively influences women's fertility intentions, whereas traditional media use does not significantly influence women's fertility intentions. This paper argues that strengthening social trust and online agenda-setting is important for improving women's fertility intentions and that strategic information communication can change their perceptions of social trust. The government can utilize the new media agenda-setting to decrease work-family imbalance, thereby increasing fertility intentions. For women having lower identification with Chinese traditional gender roles, providing information that health losses of women with multiple roles can be reduced if the spouse shares the housework by engaging in frequent cleaning of the house (7) may be useful.

This Research Topic was created to address the challenges of global population aging, issues with basic and private health insurance, medication usage evaluation, and fertility issues, among other significant topics. The editors hope that these substantial and diverse subject contributions will expand existing knowledge and provide potential solutions to global problems. A diverse group of authors from academia, the pharmaceutical, medical device, and economics industries collaborated to present a comprehensive review of advanced understanding of various popular topics. This collection of articles is intended to pique the interest of other researchers and the general public.

Author contributions

MJ has prepared the draft manuscript while MJ, NK, and SO have revised it for important intellectual content. All authors contributed to the article and approved the submitted version.

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Conflict of interest

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REVIEW
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Semmelweis Caring University Model Program Based on the Development of a Center of Preventive Services: Health for All Employees at a University Occupational Setting

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The leadership of the Semmelweis University as a leading institution of higher education in Hungary and the Central Eastern European region within the area of medicine and health sciences has decided to reflect on the unfavorable public health situation in the country as well as the deteriorating health behavior and health status indicators in the Hungarian population by the development of an occupational setting-based personalized public health model program targeting its about 8500 employees. Based on its infrastructure and human resources the core element of the program is the establishment of the Center of Preventive Services (CPS) with units providing health risk assessment for each employee, and whenever necessary consultation with medical specialist in preventive medicine and public health, as well as counseling with dietician, physiotherapist and/or health psychologist. The service providers are the staff members of the relevant faculties in collaboration with partner primary and occupational care physicians. The units of the CPS can also serve as practical training sites for students at various levels of medical and health sciences training, and strongly contribute to the development and improvement of their skills to be able for working as a team in service provision. The employees are not only beneficiaries of health risk assessment and screening repeated

on a regular basis and adequate interventions at the right time, but they also serve as a sample for a longitudinal cohort study and further *ad hoc* surveys for defining and implementing interventions to support health protection, disease prevention and healthy aging among them.

Keywords: Semmelweis University, Caring University Model Program, employees, health risk assessment, occupational setting, multiprofessional public health team, counseling services, health promotion

INTRODUCTION

Health status of the Hungarian population is among the least favorable in the European Union. Life expectancy at birth exceeds 80 years in almost two-thirds of EU countries, but still remains at only around 76 years in Hungary, Serbia, Bulgaria, Latvia, and Romania (1). The life expectancy at birth in Hungary is as low as 76.5 years for 2019 in comparison with 81.3 years EU average (1, 2). The gap between the EU average and the Hungarian figures is 5.4 years for males (78.5 years vs. 73.1 years) and 4.3 years for females (84.0 years vs. 79.7 years). Regarding the causal structure of premature mortality the non-communicable diseases dominate; in 2016 the representation of malignant and cardiovascular diseases among the causes of early death was 34% and 33% for males, while 47% and 24% for females, respectively (3).

A number of risk factors, such as smoking (4), unhealthy nutrition (5) and physical inactivity (6) show very high prevalence in the Hungarian population, and consequently—as the OECD reported for 2016–Hungary has the highest obesity rate in Europe, and only the populations of the United States, Mexico and New-Zealand are more obese than Hungarians (7). The prevalence of metabolic syndrome (MetS), the most robust indicator of increased risk for cardiometabolic diseases was found as high as 39.8%, and that of insulin resistance characterized by HOMA-IR as 48.1% in the Hungarian population aged 20–64 years in a complex health (behavior and examination) survey in 2018 (8). It is important to mention that the trend of change in the prevalence of metabolic syndrome is very unfavorable: the prevalence of MetS increased significantly in the period between 2006 and 2018 (from 34.9% to 42.2%, $p = 0.035$) due to the increased prevalence of raised blood pressure (from 45.6% to 57.0%, $p = 0.002$) and raised fasting glucose concentration (13.2% vs. 24.8%, $p < 0.001$). It is even more unfavorable that the increase mainly affected the younger (20–34 years old) age group (12.1% in 2006 vs. 31.6% in 2018, $p = 0.001$). It is also worth mentioning that while the prevalence of MetS and its components has increased significantly, the prevalence of preventive medication is unchanged (antihypertensive and antidiabetic treatments) or even significantly decreased (lipid-lowering medication) indicating poor performance at the level of not only primary, but also secondary prevention (9).

The latest figures demonstrate the burden of malignant diseases is very severe in Hungary; mortality rate for both sexes from all cancers (averaged 149 deaths per 100,000) is the highest in Hungary among all countries worldwide, and it has first place in rankings of lung, colorectal and pancreas cancer deaths. The fact that although cancer morbidity is also very disadvantageous, the average incidence rate (338.2/100,000 population) is much lower than that is in some other countries with more favorable mortality figures (10), indicates that not only primary cancer prevention, but also cancer screening and/or treatment should be markedly improved.

Certainly, it cannot be assumed that the population of University employees is representative of the general Hungarian population, but it is reasonable to suppose that similar health and health behavior problems exist among them. The only one questionnaire-based *ad hoc* survey among employees of the Semmelweis University was carried out on a randomly selected sample ($n = 1{,}085$; average age 44.8 years; 27% males, 73% females) in 2019. Almost one third of the university employees (32%) perceived their health to be bad or very bad, and 44% of them mentioned to be affected by certain type(s) of chronic non-communicable diseases. The proportion of physically inactive people is estimated at 38% and only 17% of them engage in regular leisure time physical activity, while the prevalence of smoking is 16%. The average BMI value is 25.7 kg/m^2 (females: 24.7 kg/m^2; men 27.6 kg/m^2) (unpublished data from Magor Papp MD, the head of the Health Promotion Centre).

As the latest country report of the European Commission describes Hungary had the third highest preventable mortality rate and the fifth highest amenable mortality rate in the EU in 2016, which clearly indicates substantial room for improvement through more effective preventive interventions and adequate timely health care (11). In spite of severe challenges, public health is not on the health policy agenda in Hungary; previously the turbulent political debate on the reform of the health care system detracted almost all attention and resources (12).

Increasing prevalence of cardiometabolic risk factors (8, 9), and the fact that Hungary is among the three countries most affected by the COVID 19 pandemic regarding the death rate for one million population (13) substantiates the concern that the health status of Hungarians will further be deteriorated in the post-COVID period.

It cannot be emphasized enough how important and urgent it is to intensify public health interventions. Among them, health promoting activities at population level as well as at different settings to protect and promote health and strongly reduce preventable and amenable mortality caused by non-communicable diseases in Hungary. The focus should be on preventing and controlling metabolic disturbances mainly contributing to the development of CVDs, type 2 diabetes and malignant diseases (14, 15).

The basic document for health promotion, the Ottawa Charter (16) emphasizes that health promotion actions have "to be facilitated in schools, homes, work places and community settings" because "health is created and lived by people within the settings of their everyday life." A health promoting university (HPU) project was published by the WHO Regional Office for Europe in 1998 (17). In 2015 the Okanagan Charter (18) called on higher education institutions to incorporate health promotion values and principles into their mission and practice, however, information regarding how universities put these frameworks into actions is scarce. Recently a study by Suarez-Reyes et al. (19) analyzed how the HPU framework was implemented in 54 universities from 25 countries by using an online questionnaire. The action areas and items of work were defined and multi correspondence and cluster analysis was used to identify the types of universities based on the implementation of the HPU components. Their results demonstrated that universities implement the HPU framework for action very differently. In general, it can be stated that university/college health promotion programs predominantly target the university/college population (students and employees) as a whole with organized campaigns to promote healthy lifestyle among them (19). Authors who evaluated health promotion programs at college settings (20) clearly state that although the college setting offers some advantages for implementing health promotion programs, but they may also have unique challenges due to their large and diverse employee population. In addition, it is also concluded by them that "there is little research to show the effectiveness and unique challenges of college-based health promotion programs" (20).

CONTEXT

Semmelweis University's "Caring University" Initiative

The Semmelweis University is a leading institution in Hungary as well as in the Central European region within the area of medicine and health sciences. The University has six faculties (Medicine, Dentistry, Pharmaceutical Sciences, Health Sciences, Health and Public Administration, András Peto Faculty on Conductive Education), nearly 8,500 employees, and in addition to international teaching activities at undergraduate, graduate and postgraduate levels for around 11,000 students (one third of them from foreign countries), it is the largest provider of health care services in Hungary. The leadership of the Semmelweis University has realized the very severe and very complex public health challenges of Hungary and the advantages of workplace health promotion programs and decided to develop a new model program based on the HPU initiative, adapted to a health sciences university environment. The Semmelweis "Caring University" Model Program serves dual purpose. First, it is designed to improve the health of the university's staff and students using cutting-edge approaches of public health and preventive medicine. Second, it also serves as a pilot project for health promotion/disease prevention programs of medical and health colleges at occupational settings. In addition, its certain elements may serve as examples for the ongoing Hungarian primary health care reform.

The Semmelweis University's "Caring University" initiative to protect, promote health and prevent diseases among the employees of the University is based on a conceptually new approach. In addition to targeting the population of their employees as a whole, the concept of a more personalized prevention both at primary and secondary levels was introduced, which serves as basis to the development of its "Caring University" model program. This program targets all the employees with a sustainable and equitable, continuously operating preventive service provision. The participation in the Program is open for all University staff voluntarily, i.e., provided for everyone. The University leadership invites all its employees to take part in the Program by emphasizing the need of health promotion and disease prevention actions focusing on keeping people healthy. The staff members of the Departments of Public Health (as coordinator), Family Medicine, Behavioral Sciences, Physiotherapy, Dietetics and Nutritional Sciences, as well as that of the Health Promotion Center are actively involved in the recruitment of participants by winning the heads of all university departments to encourage the participation of their staff.

Setting and Community Targeted

Center of Preventive Services: Goals and Structure

Based on the infrastructure and academic human resources of the Semmelweis University a multifunctional service center (Center of Preventive Services–CPS) is created which adopts the concept and model of reorientation of primary care into public health services.

The goal of the CPS is to provide integrated preventive services, including health promotion programs, health status assessment, lifestyle counseling and medical risk assessment. The blueprint of the CPS was originally developed and implemented in the framework of the Swiss Contribution Programme SH/8/1 titled "Public Health Focused Model Programme for Organizing Primary Care Services Backed by a Virtual Care Service Center" integrating the aforementioned services with traditional patients' care through general practitioners' (GPs') clusters (21, 22). The WHO Regional Director for Europe, Zsuzsanna Jakab praised the program in an Editorial of the European Journal of Public Health and expressed her hope that this work in Hungary would inspire many more such approaches elsewhere in the other 52 European Member States of WHO (23).

In the CPS model health professionals (medical specialists in preventive medicine and public health, non-medical public health professionals, physiotherapists, dieticians, health psychologists employed by the University as staff members of its Medical and Health Sciences faculties) competent to plan and implement various public health services collaborate with partner general practitioners and their practice nurses.

The CPS being developed at Semmelweis University extends the original blueprint and is composed of five main units which are in close collaboration with partner primary care practices and the occupation health care service of the University (**Figure 1**).

The costs of the operation of the Program are being covered from the University's central budget, while certain surveys built

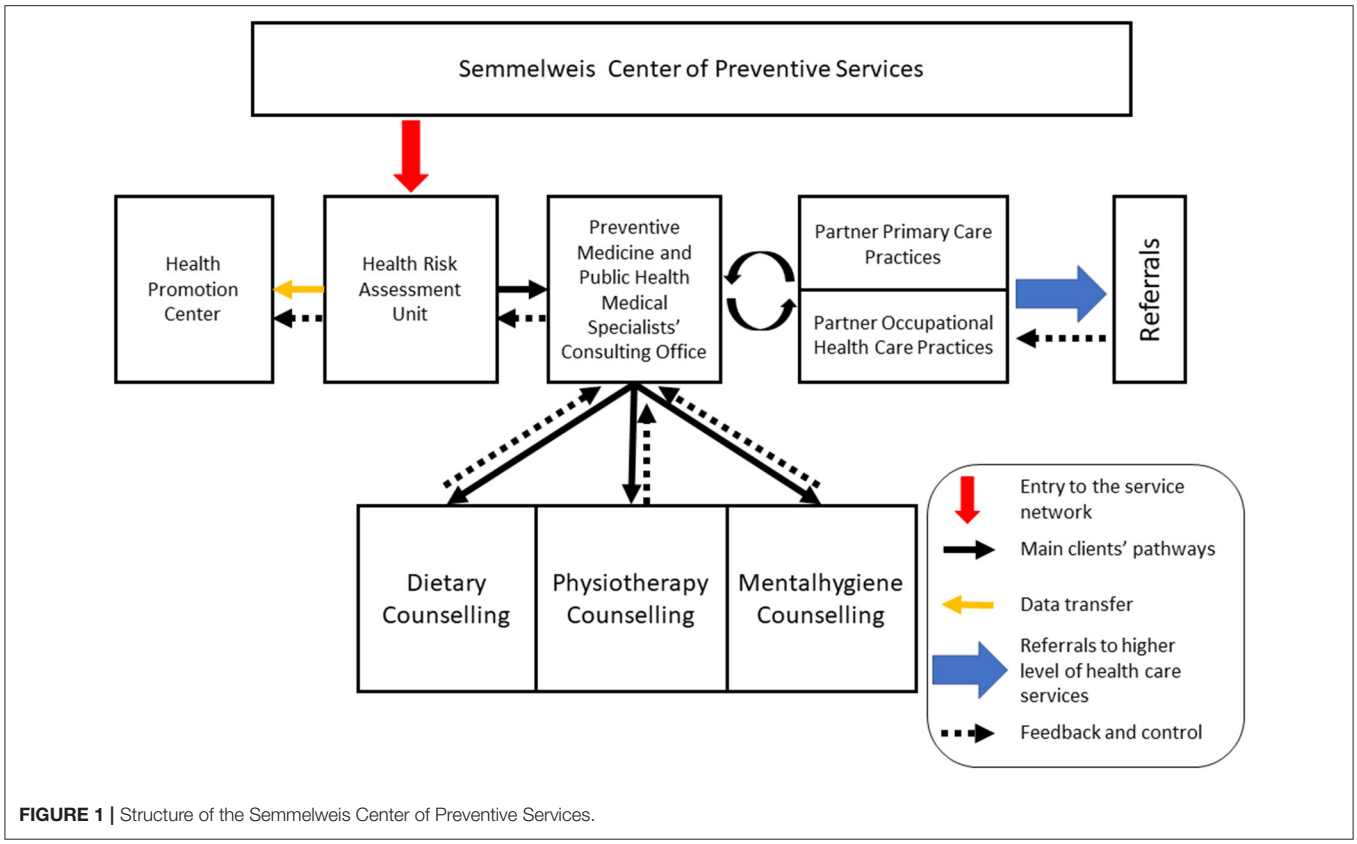

FIGURE 1 | Structure of the Semmelweis Center of Preventive Services.

on it are financed from grants of the Ministry of Innovation and Technology. Medical services provided in the Program are covered by the National Health Insurance Fund with which the University as a health service provider has a contract. In addition the CPS acts also as a didactical infrastructure and the costs of operation are being covered partly from the resources for teaching.

KEY PROGRAMMATIC ELEMENTS

The following services are to be provided by the units of CPS:

Health Risk Assessment

This unit serves as the entry point into the network. Preliminary risk assessment will be carried out by using a questionnaire based on the European Health Interview Survey (EHIS) wave 2 which consists of four modules on (a) health status, (b) health care use, (c) health determinants, and (d) socio-economic variables. In these modules, the following topics are covered: (a) self-perceived health, chronic diseases known by the respondents, limitation in activities, and mental health, (b) use of different types of health care services, including hospitalizations, consultations, preventive (among them screening) services, and medications, and unmet needs for health care, and (c) smoking and alcohol consumption, physical activity, and dietary habits and additional background variables on demographics and socio-economic status such as sex, age, living conditions, education, income, and employment (24). In addition anthropometric (weight, height and waist circumference) and blood pressure (BP) measurements will be obtained for each participant by using the European Health Examination Survey protocol (25). After overnight fasting blood samples will be taken for measurement of key laboratory parameters, including total cholesterol, HDL-C, LDL-C, triglyceride, and glucose. Laboratory tests will be carried out in the Central Laboratory of the University. In addition to the calculation of the body mass index (BMI) the body composition will be determined. Individuals with health risks identified will be sent to the medical consulting office.

Consultation With Medical Specialists in Preventive Medicine and Public Health–Medical Health Risk Assessment

After careful review of the health risk assessment record further risk assessment examinations (especially for clarifying CVD, diabetes and cancer risks) will be carried out and if it seems to be of additional diagnostic benefit after overnight fasting blood samples will be taken for laboratory tests to measure creatinine, uric acid, C-reactive protein, apolipoprotein A1, apolipoprotein B100 concentrations, alanine aminotransferase, aspartate aminotransferase, gamma-glutamyl-transferase, alkaline phosphatase activities, folic acid, Hemoglobin A1c, and insulin concentrations. Laboratory tests will be carried out in the Central Laboratory of the University.

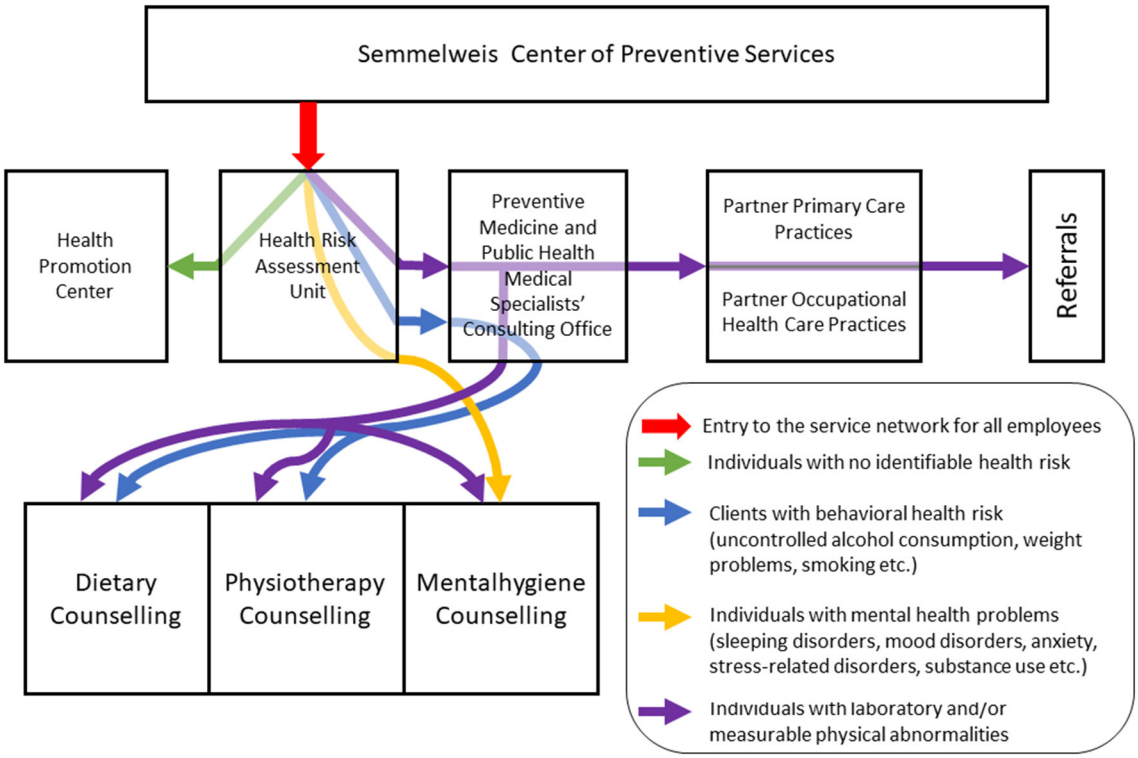

FIGURE 2 | The employees' pathways in the Semmelweis Center of Preventive Services' network.

Dietary, Physiotherapy, and Mental Hygiene Counseling

If the medical risk assessment confirms that the health behavior and consequently the health status of the employee can be improved by life-style counseling he/she will be sent to the specific counseling unit(s) with detailed description of the problems identified. This service is available to clients by direct referral from medical specialists in preventive medicine and public health. In *dietary counseling* interventions are provided for overweight and obese persons, for persons at risk for cardiometabolic diseases and/or cancer, and special counseling for prediabetic/diabetic patients, as well as for persons with disturbances in lipid metabolism will also be given. *Physiotherapy counseling* will be provided for employees with locomotor problems among them for individuals with chronic low back pain, as well as for overweight or obese individuals. Special programs for clients with cardiorespiratory problems should also be considered. *Mental health promotion counseling* would be recommended for employees with signs of sleeping disorders, mood disorders, anxiety and stress-related disorders and substance abuse. Counseling can identify the need for further examinations by psychiatrist for schizophrenia, bipolar disorder or personality disorder. This service can be proposed for clients also for loss and bereavement management. Mental health promotion counseling also provides group-based services for stress-management and burnout prevention.

Combination of life-style counseling services (for example in case of body weight control programs), as well as group therapy (especially if it has advantages in comparison with individual therapy) for clients with the same problems will be considered and indicated by the medical specialist as a consequence of medical health risk assessment. The counseling methods will be tailored to the specific level of health literacy of the client.

Health Promotion Center

The Health Promotion Center was founded in 2019, as part of the first phase of the implementation of the Caring University initiative. It operates as a central unit responsible for organizing coordinated and comprehensive health promoting programs in collaboration with the Department of Public Health mainly at community level for employees and students. Examples of the workplace health program components and strategies already implemented or being implemented include health education classes and university-wide health promotion programs open to students and staff, including fitness and recreation programs, programs that promote behavior change through gamification, programs that enhance resilience, interventions to prevent and reduce the negative effects of stress, as well as programs to reduce alcohol and other drug-related risk and harm on campus. A key mission is to highlight the role that healthy nutrition and physical activity play in supporting academic success and personal health. There are related programs in place to promote a healthy work environment through actions such as making

healthy foods available and accessible through campus cafeterias. Within this framework the university also provides access to both university-owned and local fitness facilities and implement policies that promote healthy behaviors (e.g., limiting tobacco use on campus).

Partner primary care services and the occupational health care practice of the University will be involved in case of clients suspected to be diseased and/or need to be referred to higher levels of healthcare.

Regarding the employees' pathway the health status assessment unit represents the entry point into the CPS network (**Figure 1**). Individuals with no identifiable health risks will be instructed to participate in programs organized by the Health Promotion Center. Those with behavioral risks and/or laboratory or measurable physical abnormalities will be referred to the Preventive Medicine and Public Health Medical Specialists' Office. Based on the results of this medical risk assessment and further exploration of the risk status of the employees, they will either be sent to the relevant life-style counseling unit(s) of the CPS. Individuals with mental health problems will be oriented first to the mental hygiene unit where further specific examinations (for example specific tests to define depression or other mental disorders or sleep-wake problems) can be carried out. Those with suspected diseases will be oriented to the partner primary care practices for further diagnostic tests and examinations, defining medication or referrals to higher level of health care services (typically to the relevant specialists, but also to hospital care) as if it is necessary (**Figure 2**). In-person and virtual communications between CPS's units will be available at a regular basis.

The CPS operates in concerted actions of the relevant departments of university faculties (**Table 1**). The units of the CPS serve as practical training sites for medical students, residents in a clinical residency program in Public Health and Preventive Medicine, as well as for students in BSc in Public Health, BSc and MSc in Physiotherapy, and BSc and MSc in Nursing courses, as well for PhD students working on relevant topics.

TABLE 1 | Faculties and departments of the Semmelweis University participating in the Caring University Model Program.

	Participating Departments
Faculty of Medicine*	**Department of Public Health (coordinator of CPS)**
	Department of Family Medicine
	Institute of Behavioral Sciences
Faculty of Health Sciences*	**Department of Dietetics and Nutritional Sciences**
	Department of Physiotherapy
	Department of Addictology
	Department of Nursing
	Department of Social Sciences
	Department of Public Health Sciences
Faculty of Health and Public Administration	Health Services Management Training Center
	Institute of Digital Health Sciences
	Institute of Mental Health
Faculty of Dentistry*	
Faculty of Pharmacology*	
Health Promotion Center	

The academic staffs of the departments indicated in bold are the main actors in the CPS. Faculties whose students participate in the teaching activities of the Caring University Model Program, including the health risk assessment, are labeled with "".*

DISCUSSION

It has been well-established that health and well-being of the population, especially of working people, are crucial prerequisites for productivity and are of utmost importance for overall socioeconomic and sustainable development (26). Health promotion and disease prevention programs at occupational settings have a direct effect on the health of employees and by this way strongly contribute to the prosperity of institutions serving as their workplace (27, 28). Morbidity and mortality caused by non-communicable diseases are traditionally very unfavorable in Hungary which can be largely attributed to non-existent national public health program and primary care provision with no financial incentives to deliver preventive services (29). At an occupational setting an assessment to define employees' health and health risks followed by reflective interventions and/or adequate treatment (in collaboration with partner primary care providers) as well as monitoring the effects of these interventions is a good framework not only for improvement of health status of employees, but it has the potential to impact areas such as productivity and recruitment/retention ability of the employing institutions, reduction of absenteeism and reduction of health care costs at social level, as well.

The Semmelweis University as the leading training institution in the field of medical and health sciences of Hungary decided to create a public health model program for its employees at occupational settings. The core component of the program is a Preventive Service Center (CPS) including units with well-defined functions and services.

The Semmelweis Caring University Model Program and the operation of the CPS provide several benefits. First, they act as convincing evidence that the University recognizes the value of its employees and considers their health and well-being as a key issue. Second, they demonstrate that the University understood the link between the control of risks, the health and well-being of employees and the success of the organization itself. Third, they increase the reputation and attractiveness of the University, further strengthens the prestige of the "Semmelweis University" brand name. Fourth, they serve as models for other universities/colleges at national and international level. Recommendations can be specifically formulated for them, involving their staff in medical and health sciences trainings and provision of public health and health care services. Fifth, the units of the CPS serve as a training ground for teaching interdisciplinary team skills for students of the Faculties of Medicine, Pharmaceutical Sciences, Dentistry and

Health Sciences. Sixth, the CPS also serves as a pilot project for the ongoing Hungarian primary health care reform.

In addition, the Semmelweis Caring University Model Program and the CPS will also benefit the research mission of Semmelweis University. The population of employees will be used as a cohort of a longitudinal epidemiological study, similar to the Whitehall Study II population (30, 31). The infrastructure of the Semmelweis Caring University Model Program and the CPS will serve as the basis to the development of the Semmelweis Study aiming to better understand the protective factors and barriers of healthy aging in Hungary. In this unique cohort study public health initiatives promoting healthy aging can be evaluated, facilitating the translation and dissemination of geroscience discoveries into sustainable, evidence-based public health programs and system-level strategies (32). The cohort can also be used as sampling frame to *ad hoc* surveys.

Monitoring and to define effectiveness of a workplace health promotion/disease prevention program is an essential requirement, although evaluation methods derived for and applied within the field of health promotion at different (especially occupational) settings have often fallen short of the ideal. In the most recent systematic review and meta-analysis carried out by Peñalvo et al. (33) could extract sufficient information to calculate pooled estimates for 20 different outcomes, of which 13 were found positively affected by workplace health promotion/disease prevention programmes, and could demonstrate beneficial effects on dietary factors, body anthropometrics, and cardiometabolic risk. These outcome indicators will be evaluated regularly every 5 years. Concerning the fact that in the Semmelweis Caring University Model Program the key programmatic elements are taken over from the "Public Health Focused Model Programme for Organizing Primary Care Services Backed by a Virtual Care Service Center" (21, 22), both process and outcome indicators on preventive service delivery are available to monitor the implementation and effectiveness of the Model Program proposed (29, 34). Process indicators (as attendance of the participants, program delivery in comparison to that which was intended, as well as an assessment of whether health-related interventions were implemented at the worksite, etc) will also be followed on a regular basis. A formative evaluation to see whether these indicators are in line with the assumptions will be carried out yearly.

AUTHOR CONTRIBUTIONS

ZU: conceptualization and writing–original draft. RÁ: conceptualization, writing–original draft, and visualization. AS: conceptualization, project administration, and writing–review and editing. GD, MM, GP, LK, and MK: writing–review and editing. PV: writing–review and editing and project administration. PT: conceptualization and writing–review and editing. BM: conceptualization, writing–review and editing, supervision, and funding acquisition. All authors contributed to the article and approved the submitted version.

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How Media Use Influences the Fertility Intentions Among Chinese Women of Reproductive Age: A Perspective of Social Trust

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Background: The low fertility level has become a serious social problem in China. Previous research has argued the significant influence of media use and social trust on fertility intentions, but the interaction between the two variables and how they influence fertility intentions remain further investigation. This study explored the influence mechanism of media use on Chinese women's fertility intentions from the perspective of social trust.

Methods: This study collected data from the 2017 China General Social Survey, investigated the relationships between variables through bivariate correlation coefficients, and explored the differences in fertility intentions among women of reproductive age (20–49). Also, this paper examined the influence of media use and social trust by regression analysis and tested the mediating role of social trust between media use and fertility intentions with Bootstrap sampling.

Results: Women with different media use preferences, education levels, and family incomes have significant differences ($p < 0.01$) in fertility intentions. New media use negatively influences women's fertility intentions, while traditional media use has no significant influence on women's fertility intentions. Social trust significantly influenced women's fertility intentions and partially mediated the impact of new media use on fertility intentions.

Conclusion: Online communication influences fertility intentions among Chinese women of reproductive age. It tends to influence their social trust by amplifying negative social news, affecting their fertility intentions further. This paper suggests the importance of strengthening social trust and online agenda-setting to improve women's fertility intentions that strategic information communication can change their perceptions of social trust.

Keywords: media use, fertility intentions, social trust, Chinese reproductive-aged women, social media

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INTRODUCTION

Fertility is the driving force behind human development, and low fertility has become an important global issue, impacting the global society, economy, finance, and national security (1). The fertility rates in China have declined dramatically over the past few decades, and the annual total fertility rate only reached 1.65% from 2006 to 2019 (2). The low level of fertility caused a decreasing birth rate year by year. Mainland China's birth rate dropped to a record low of 7.52‰ in 2021 (3), which poses a huge challenge to China's demographic structure and social development (4). With the development of the social economy, the low fertility rate is no longer primarily driven by fertility policies but rather reflects the low fertility intentions in the current socio-economic context (5). In 2001, Bongaarts (6) proposed a model to explain the relationship between fertility intentions and fertility levels. Many studies have shown the correlation between fertility intentions and fertility rates from multiple perspectives (7–10). Among the factors influencing fertility rates, scholars identified low fertility intentions as an important cause of low fertility rates (11). They believed that fertility intentions could predict fertility rates, and the result is more accurate in the short term (12).

Studies have examined that media information is an important factor influencing fertility intentions. In addition to providing fertility-related health knowledge and policy propaganda to the public (13, 14), the media information can influence fertility intentions through moderating or mediating variables such as social role perceptions and gender attitudes (15, 16). In the mediated society constructed by traditional and new media, people gain diverse types of information, and new media platforms provide space for people to read, discuss and express (17). Topics like fertility policies, marriage and fertility values, which were rarely mentioned in the traditional media era, can be discussed on social media.

Social trust refers to an individual's belief about the general trustworthiness of others, and it is a part of an individual's worldview (18). Social trust plays a mediating role and thus influences people's certain behaviors in the complex-mediated environment (19). Studies have also examined that social trust is a significant factor in improving fertility intentions (20), thus influencing people's fertility behaviors. The influence mechanism needs further explanation in the mediated environment. In detail, whether media use can affect fertility intentions through social trust. If so, what role social trust plays in the mechanism.

Within the traditional Chinese culture, women were disadvantaged in their fertility choices, and childbirth is always necessary for common myths (21). Due to the patriarchal ideology, some women would not stop childbirth until they have a boy under the family and social pressures (22). Studies described women's fertility intentions under traditional Chinese fertility culture as 'passive following', which is full of compromise (23). As society has progressed, women have access to higher education and earn higher social status. Chinese women have also gained more social roles and gradually broken free from the shackles that bind them to fertility (24). With the change in women's roles and attitudes in modern fertility discourse, women's fertility intentions deserve further attention.

On this basis, this study collected data from the 2017 Chinese General Social Survey (CGSS 2017), targeting women aged 20 to 49, to explore the influence of media use on fertility intentions among Chinese women and the role of social trust in the relationship between the two variables. Compared to previous research, the main contributions of this study are: (1) Scholars have explored the factors influencing women's fertility intentions from a socio-economic perspective. This study examined the influence of media on women's fertility intentions from the perspective of the mediated society. (2) Few studies based on the media perspective focused on Internet use, neglecting that the media environment is constructed with traditional and new media. The 'media use' in this study contains traditional media use, enhancing the understanding of the influence of diverse media types on women's fertility intentions. (3) Liu's research (16) selected gender attitudes as a mediating variable to investigate the influence of Internet use frequency on women's fertility intentions. Different from their views, this study considered social trust as an important factor in forming and influencing women's fertility intentions and expanded the knowledge of the social trust mechanism in media research.

LITERATURE REVIEW

Fertility Intentions of Women and the Influencing Factors

As a part of fertility decisions, fertility intention is a key indicator of measuring fertility (25). Fertility intentions can be defined from fertility desires, attitudes, and behaviors (26). Regarding fertility desires, fertility intentions include the desired number of children, the desired gender of children, and the interpregnancy interval (27, 28). Biologically, women are the ultimate bearers of childbirth. Women's fertility intentions decline more than men's intentions to have children as they get aging (29), which further directly affects fertility behaviors and thus fertility rates. Furthermore, scholars argued that female empowerment is an important reason causing the decline in female fertility intentions (30). Individualism, feminism, gender equality, and changes in marriage and family values also contributed to low fertility rates (31). Thus, women's fertility intentions become essential in a low-fertility environment. Regarding the CGSS data, this paper conceptualized fertility intentions as the desired number of children among reproductive-aged women.

The factors influencing women's fertility intentions are mainly related to the macro socio-economic and micro individual characteristics (28). In China, the role of individual fertility intentions in determining their fertility behaviors has become increasingly prominent with the gradual relaxation of fertility policies (32, 33). Many studies have examined the social status of women (34), gender role attitudes (16), education levels (35), family income (36), housing situation (37), cultural beliefs (38), and social security system (39) have significant influences on fertility intentions of women.

Abbreviations: CGSS: Chinese General Social Survey.

Combined with the relevant variables from the previous studies and the CGSS, this study determined education levels, family income, housing situation, and social status as control variables.

Media Use and the Fertility Intentions of Women

In addition to traditional social, family, and individual factors, media as an important part of the social system has driven researchers' attention to exploring its impact on women's fertility. In terms of traditional media use, an Indian study showed that the official monopoly media, DoorDarshan India, significantly reduced women's fertility intentions through strong discussion about family planning and contraceptive use (14). In Indonesia, the expansion of private broadcast television and the growth of its subscribers have caused a low fertility rate as private television reinforced the promotion of modern contraceptives (40). Another study argued that media more likely influence fertility intentions of women with long-term media exposure. These women are more inclined to use contraception to reduce fertility possibilities and control the family size (41). Information and communication technology has rapidly developed since the 1990s, and new media based on the internet has been a vital factor in social change and an important trans-formative force in reconfiguring individual behaviors. Researchers began to focus on the impact of new media on women's fertility intentions. A study on Chinese women's fertility intentions indicated that attention to news on new media negatively correlated with women's fertility intentions (16). Cheng (13) found that social networks play an important role in spreading knowledge about contraception, reducing women's fertility intentions. Adair et al. (42) shared a finding based on content analysis of tweets that most people had a negative attitude to parenting, and single people who released the relevant content also had low fertility intentions.

In this regard, we proposed the following hypotheses:

H1: Media use negatively correlates with fertility intentions among Chinese women.

H1-1: Chinese women of reproductive age have lower fertility intentions when having more frequent traditional use.

H1-2: Chinese women of reproductive age have lower fertility intentions when having more frequent new media use.

Social Trust, Media Use, and the Fertility Intention of Women

Studies on the impact of media use on women's fertility intentions found that media act in conjunction with other variables to influence fertility intentions. An experimental study from the United States indicated that media increased the willingness of non-student, unmarried, childless women to have children by reinforcing the portrayal of women's social roles (43). Liu et al. (16) believed that Chinese women have lower identification with Chinese traditional gender roles as the increase of their internet use, which further reduces their fertility intentions. Billari et al. (44) revealed a finding from German panel data that the internet can effectively mitigate work-family conflict by increasing the likelihood of remote working, which positively influences women's fertility intentions. Another research argued that social support from Facebook could reduce the abortion rate and thus increase fertility rates (45). The above studies have proven that media use can change the social roles of women and the perceptions of traditional gender roles and provide social support for women, further influencing the fertility intentions of women. The studies from different perspectives all emphasized the correlation between social factors and women's fertility intentions and the influence of media use on social factors.

Empirical research found that trust affects attitudes (46, 47) and causes individual and social behavior outcomes (48). Some scholars used social trust as a variable to explore its influence on fertility intentions and illustrated that trust is more important for fertility in countries with high trust and women with high education levels (49). A high-trust society is helpful for work-family balance, mainly achieved by the stability of key institutions and generous welfare support, thereby increasing fertility intentions (50). A study used panel data from 24 OECD countries during 1980–2004 and found that enhanced social trust can increase fertility rates (20). Thus, in a mediated society, whether media communication can influence social trust and further affect people's attitudes and intentions toward fertility desires a further exploration.

Early research on mass media and social trust suggested that mass media use has a certain impact on social trust. For example, a study with 1996 United States elections data indicated that the use of newspapers and television affects social trust (51). Another penal data research illustrated that mass media use affects social trust next year (52). With the advent of social media based on internet technology, scholars have found that social media influences social trust, but their findings are different. Some of them believed that social media use has more controllability of information that people can weed out mistrustful relations early and reduce the uncertainty (53). Also, local social media use can enhance interpersonal trust (54). A random sampling survey on US residents showed that people cultivate and build trusted relations through online interactions (55). Another survey on university students in Texas, USA, revealed a positive correlation between the intensity of Facebook use and social trust among university students (56). In contrast, Putnam (48) argued that the role of the internet in building trust is time-consuming, thus preventing face-to-face communication and limiting interaction with familiar people. Rheingold (57) also supported that fake identity online may lure vulnerable individuals into harmful relationships. In addition, researchers argued that the use of different media or different media use behaviors also has distinctions. Reading newspapers and watching entertainment content from television can enhance social trust while watching television news will weaken social trust (51). The internet positively impacts social trust when people use it for information exchange. Still, the internet negatively correlates with social trust when using it for social entertainment (58).

Existing research has proved the influence of media use and social trust on fertility intentions and the

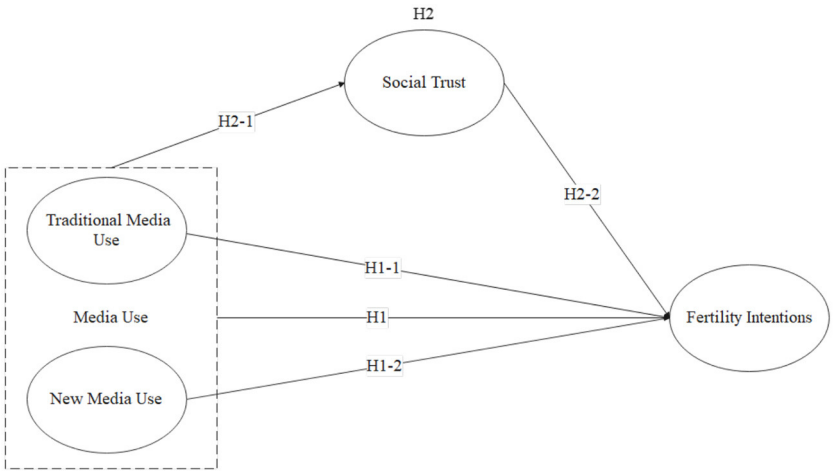

FIGURE 1 | Hypothesized model.

impact of media use on social trust. However, the exact influence mechanisms are undetermined. Whether social trust plays a role in media use influencing fertility intentions needs further exploration. This study proposed the following hypotheses (see **Figure 1** for full hypothesized model):

H2: Social trust mediates the relationship between media use and fertility intentions among women of reproductive age.

H2-1: Media use among women of reproductive age positively correlates with social trust.

H2-2: Social trust among women of reproductive age positively correlates with fertility intentions.

METHODS

Study Design

This study explored the influence of media use and social trust on women's fertility intentions. First, we conducted descriptive statistics of media use, social trust, and fertility intentions of reproductive-aged women. Then, we used ANOVA to test whether there was a difference in fertility intentions of reproductive-aged women under different demographic variables. Furthermore, we utilized bivariate correlation coefficient and linear regression analysis to test the influencing relationships between the variables. Finally, we explored the influence of social trust on fertility intentions through a mediating effect model.

Data Sources

CGSS is one of the authoritative academic survey projects in China and is widely used in Chinese social studies (59). National Survey Research Center at Renmin University of China (NSRC) is responsible for conducting the project, selecting samples through stratified random sampling and stratified-stage sampling. Participants in the projects are residents from 31 provinces, autonomous regions, and municipalities directly under the Central Government, excluding the Hong Kong Special Administrative Region, the Macau Special Administrative Region, and Taiwan. The latest CGSS data is updated to 2017 and includes a valid nationally representative sample of 14,670. Although the family planning regulations of China explain that the reproductive age of women is 15–49 (60), considering the legal age of marriage for women in China is 20 years old, this study selected data related to women aged 20–49. After deleting data with missing values and outliers, we obtained a valid sample of 2,649. **Table 1** shows the sociodemographic information of selected samples.

TABLE 1 | Sociodemographic information of the samples.

Variable	*n* (%) or Mean ± SD
Age (year)	36.493 ± 8.657
Education level	
Uneducated	152 (5.74)
Primary school	466 (17.59)
Middle school	743 (28.05)
High school/technical secondary school	467 (17.63)
Junior college	326 (12.31)
Bachelor's degree	429 (16.19)
Master's degree and above	66 (2.49)
Housing situation	
Owner-occupied	801 (30.2)
Non-owner-occupied	1,848 (69.8)
Fertility intentions	1.851 ± 0.732
Family income	97,500.178 ± 146,573.099
Social trust	3.328 ± 1.043
Social status	4.311 ± 1.623
Traditional media use	2.148 ± 0.632
New media use	2.897 ± 1.104

Variables Selection

Dependent Variable

Fertility Intentions

For fertility intentions studies, the American scholar George Gallup (61) introduced the concept of ideal family size for the first time. He used the question "what do you think is the ideal number of children for the average American family?" for the measurement, which has been widely used to measure people's intentions to have children since then (61). The question contained in CGSS2017, "how many children would you like to have if there were no policy restrictions" is consistent with the previous survey question measuring fertility intentions. Furthermore, scholars also used the same question to investigate fertility intentions (16). Thus, this study selected the data of this survey question to examine fertility intentions. Zero means that the respondent has no intentions to have children, and the higher value represents higher fertility intentions. Also, we standardized the data on fertility intentions of a 5-point Likert scale to maintain statistical consistency.

Independent Variable

Media Use

Media use is defined as "the extent to which an audience is exposed to a particular message or media content" (62). This study divided media use into traditional media use (newspapers, magazines, radio, television) and new media use (Internet and customized mobile news). CGSS asked the participants to answer their media use in the past year, measuring a Likert scale from 1 (never) to 5 (always). Besides, this study added the variable of media preference to compare the differences between traditional and new media use. We coded the situation that new media use is more than traditional media use as 1, representing the new media preference; new media use is less than traditional media use as 2, representing the traditional media preference; new media use equals traditional media use as 3, representing no media preference.

Social Trust

Social trust refers to shared expectations of each other, usually expressed as beliefs; that is, people behave wisely and mutually beneficial, when necessary, in their interactions with others. The shared expectations generate strong and stable relationships between people (63). This study chose the question, "Generally, do you agree that most people in the society can be trusted?" (64), as the indicator of social trust, responses ranging from 1 (strongly disagree) to 5 (strongly agree) with a five-point Likert scale.

Control Variables

The literature shows that education levels, family incomes, housing situation, and social status can influence women's fertility intentions, so this study viewed them as control variables. Specifically, the education level was selected from the question "What is your highest education?"; family income was assessed from annual household income, and the selected question is "What was your annual household income in 2016?"; housing situation was derived from the item "Do you own (including jointly with others) any property currently?"; social status refers to the question "In general, which social level are you at?", ranging from 1 (the lowest level) to 10 (the highest level). This study coded the relevant variables to ensure statistical consistency: education levels (without education = 0 to postgraduate and above = 6), housing situation (owner-occupied = 1, non-owner-occupied = 0), family income was measured into different household income levels based on the average annual household income (low family income = 1, high family income = 2); social status was divided into three groups (values 1–3 were defined as low social status = 1, values 4–7 were middle social status = 2, and values 8–10 were high social status = 3).

TABLE 2 | Descriptive analysis.

Variables	Mean	Standard deviation
Traditional media use	2.148	0.632
New media use	2.897	1.104
Social trust	3.328	1.043
Fertility intentions	1.851	0.732

RESULTS

Descriptive Statistical Analysis

Table 2 provides a statistical description of media use, social trust, and fertility intentions of reproductive-aged women. In terms of media use, the frequency of new media use (M = 2.897) is higher than traditional media use (M = 2.148). Besides, social trust is relatively high (M = 3.328). The overall fertility intentions of reproductive-aged women are low (M = 1.851).

Table 3 compares the differences in fertility intentions of reproductive-aged women from the perspectives of media use preference, education levels, annual family income, social status, and social trust. The variance results show that women with different media use preferences, education levels, and family incomes have significant differences ($p < 0.01$) in fertility intentions. However, there are no significant differences in fertility intentions between reproductive-aged women with different housing situations, social status, and social trust.

Preliminary Analyses

Table 4 shows the correlations coefficients of the variables in this study, and social status ($p < 0.05$) and social trust ($p < 0.05$) are positively correlated with fertility intentions. Combined with the ANOVA results, women with higher social trust have the most significant fertility intentions (M = 1.87 ± 0.72). Education levels ($p < 0.01$), family income ($p < 0.01$), new media use ($p < 0.01$) are negatively correlated with fertility intentions. The results show that groups with high education level (M = 1.75 ± 0.74), high annual family income (M = 1.77 ± 0.74), and new media preference (M = 1.82 ± 0.75) have lower fertility intentions.

This study conducted a hierarchical multiple regression analysis to investigate further the factors influencing women's fertility intentions. First, we used education levels, housing situation, social status, and annual family income as control

TABLE 3 | Differences in fertility intentions of reproductive-aged women from the different variables.

Variables	Groups	Fertility intentions (M±SD)	F	*p*
Education levels	Low (n = 1,828)	1.90 ± 0.72	23.968	0.000**
	High (n = 821)	1.75 ± 0.74		
Family income	Low (n = 1,761)	1.89 ± 0.72	17.401	0.000**
	High (n = 888)	1.77 ± 0.74		
Media use preference	New media (n = 1,895)	1.82 ± 0.75	8.591	0.000**
	Traditional media (n = 571)	1.96 ± 0.69		
Housing situation	No preference (n = 183)	1.83 ± 0.59	1.639	0.201
	Non-owner-occupied (n = 1,848)	1.84 ± 0.70		
	Owner-occupied (n = 801)	1.88 ± 0.80		
Social status	Low (n = 767)	1.80 ± 0.71	2.679	0.069
	Middle (n = 1,823)	1.87 ± 0.73		
	High (n = 59)	1.93 ± 0.85		
Social trust	Low (n = 724)	1.82 ± 0.77	1.803	0.165
	Middle (n = 365)	1.81 ± 0.72		
	High (n = 1,560)	1.87 ± 0.72		

*$p < 0.01$.

TABLE 4 | Bivariate correlation between the variables.

	1	2	3	4	5	6	7	8
1. Fertility intentions	1							
2. Education levels	−0.140**	1						
3. Family income	−0.088**	0.526**	1					
4.Social status	0.046*	0.275**	0.353**	1				
5. Housing situation (owner-occupied)	0.025	−0.02	0.087**	0.066**	1			
6. Traditional media use	−0.03	0.341**	0.262**	0.198**	0.054**	1		
7. New media use	−0.107**	0.522**	0.408**	0.205**	−0.038*	0.350**	1	
8. Social trust	0.040*	0.075**	0.035	0.076**	0.01	0.044*	0.008	1

*$p < 0.05$. **$p < 0.01$.

variables for regression analysis with fertility intentions, forming Model 1. Then, we added media (traditional and new media) use and social trust based on the control variables to regress with fertility intentions, forming Model 2. As shown in **Table 5**, Model 1 indicates that education levels and annual family income negatively influence fertility intentions of reproductive-aged women, and social status positively influences fertility intentions. Model 2, with adding key variables, presents that under the control variables of education levels and social status, preference for new media use negatively affects fertility intentions of reproductive-aged women (B = −0.033, $p < 0.05$), and social trust positively affect fertility intentions (B = 0.030, $p < 0.05$). Regarding the correlation between traditional media use and fertility intentions is not significant, Hypothesis 1 is partially supported. In detail, H1-1 is not supported, and H1-2 is supported. Besides, H2-2 is also supported.

Testing for Mediation Effect

This study used social trust as the mediating variable to further investigate the influence of media use and social trust on women's fertility intentions, exploring the possible influencing mechanism. This study employed the hierarchical regression analysis to test the mediating effect. First, we took education levels, housing situation, social status, and annual family income as the control variables and added media use (traditional and new media) on this basis to regress with fertility intentions, forming Model 3. Then, we added media (traditional and new media) use based on the four control variables to regress with social trust, forming Model 4. Model 2 (seen as **Table 5**), Model 3, and Model 4 (seen as **Table 6**) showed that new media is positively correlated with social media ($p < 0.01$), while traditional media use is not significantly correlated with social trust. Thus, H2-1 is partially supported.

For the issue of small values in the Model 1-4, R^2 is a descriptive variable in most situations but not a test variable (65). Besides, the significant p-value and cons value still can fit better explanatory variable relationships even with a relatively low R^2 value (66). R^2 is a less fundamental statistic than regression slope, and it may change in response to variance changes in the independent

TABLE 5 | Results of hierarchical multiple regression analysis ($n = 2,649$).

	Model 1					Model 2				
	B	SE	t	p	β	B	SE	t	p	β
Constants	2.028**	0.080	25.26	0.000	-	1.930**	0.097	19.91	0.000	-
Education levels	−0.066**	0.011	−6.19	0.000	−0.14	−0.061**	0.012	−5.17	0.000	−0.13
Housing situation (owner-occupied)	0.033	0.031	1.063	0.288	0.021	0.027	0.031	0.864	0.388	0.017
Social status	0.046**	0.009	4.921	0.000	0.102	0.044**	0.009	4.739	0.000	0.098
Annual family income	−0.009*	0.004	−2.20	0.028	−0.05	−0.010	0.004	−1.82	0.069	−0.04
Traditional media use						0.025	0.024	1.026	0.305	0.022
New media use						−0.033*	0.015	−2.11	0.035	−0.05
Social trust						0.030*	0.014	2.221	0.026	0.043
R^2	0.029					0.033				
Adjusted R^2	0.028					0.031				
F value	$F(4.2644) = 20.057, p = 0.000$					$F(7.2641) = 12.952, p = 0.000$				
ΔR^2	0.029					0.004				
ΔF value	$F(4.2644) = 20.057, p = 0.000$					$F(3.2641) = 3.406, p = 0.017$				

Dependent variable: fertility intentions.
*$p < 0.05$ ** $p < 0.01$.*

TABLE 6 | Results of mediating effect analysis ($n = 2,649$).

	Model 1					Model 2				
	B	SE	t	p	β	B	SE	t	p	β
Constant	2.024**	0.087	23.213	0	-	3.145**	0.126	25.055	0	-
Education levels	−0.059**	0.012	−5.029	0	−0.125	0.057**	0.017	3.351	0.001	0.084
Housing situation	0.027	0.031	0.876	0.381	0.017	0.013	0.044	0.299	0.765	0.006
Social status	0.046**	0.009	4.876	0	0.101	0.041**	0.013	3.062	0.002	0.064
Annual family income	−0.008	0.004	−1.848	0.065	−0.044	−0.005	0.006	−0.76	0.447	−0.018
Traditional media use	0.026	0.024	1.076	0.282	0.023	0.041	0.035	1.161	0.246	0.025
New media use	−0.034*	0.015	−2.204	0.028	−0.052	−0.047*	0.022	−2.112	0.035	−0.05
Dependent variable	Fertility intentions					Social trust				
R^2	0.031					0.011				
Adjusted R^2	0.029					0.009				
F	$F(6.2642) = 14.267, p = 0.000$					$F(6.2642) = 5.015, p = 0.000$				

*$p < 0.05$ **$p < 0.01$.*

variables despite the absence of structural differences across the population (67).

This study utilized the product of the coefficients method to examine the results of mediating effects. The product of the coefficients method has been widely used for its statistical efficacy over the causal step method (68). The product of the coefficients method contains two types. One is the Sobel test based on a normal sampling distribution with mediating effects. The other is asymmetric confidence interval based on a non-normal sampling distribution with mediating effects, including Bootstrap and product distribution. A simulation study by Mackinnon et al. (69) found that Bootstrap had the highest statistical efficacy in mediating effects analysis. Thus, this study used Bootstrap sampling for testing significance. In this study, a denotes the regression coefficient of media use to social trust; b represents the regression coefficient of social trust to fertility intentions; c represents the regression coefficient of media use to fertility intentions (without mediator), which is the total effect; and c' represents the regression coefficient of media use to fertility intentions (with a mediator), which is the direct effect. According to the procedure, the bootstrap sampling test for mediating effect was strictly processed. If a and b are significant, and c' is significant, and a*b is synonymous with c,' it is partially mediated. Suppose at least one of a and b is not significant, and the 95% confidence interval (BootCI) for a*b includes 0. In that case, the mediating effect is insignificant (70).

Table 7 tells that a, b and c' are significant in Model 4, and a*b is synonymous with c', suggesting a mediating effect. Social media plays a mediating role in the relationship between new media use and fertility intentions. We combined the above findings and concluded that new media use negatively influences fertility intentions of reproductive-aged women and further influences

TABLE 7 | Results of mediating effects.

Item		Model 3	Model 4
c	Total effect	0.026	−0.034*
a		0.041	−0.047*
b		0.030*	0.030*
a*b	Mediating effect value	0.001	−0.001
a*b	(Boot SE)	0	0
a*b	(z value)	80.413	−63.99
a*b	(*p*-value)	0	0
a*b	(95% BootCI)	−0.001 ∼ 0.003	−0.004 ∼ 0.001
c'	Direct mediating effect	0.025	−0.033*
Test result		Not significant	Partially mediated
Effect account		0	4.14%

*$p < 0.05$.
Model 3: traditional media use-social trust-fertility intentions.
Model 4: new media use-social trust-fertility intentions.

fertility intentions through the mediating effect of social trust. Thus, H2 is partially supported. The final model is depicted in **Figure 2**.

DISCUSSION

Issue of Low Fertility in Mainland China: Increase Women's Fertility Intentions

As mentioned above, the fertility rate in mainland China has dropped to a record low in 2021. Prolonged low fertility rates will cause rapid decline and high aging of the population, and a range of adverse socio-economic consequences, putting China at significant risk of fertility crisis (4). Demographers consider fertility intentions an important predictor of fertility rates (71), a determining factor of fertility behaviors, and a key factor influencing fertility rates (72). In terms of the correlation between fertility intentions and fertility behaviors, the prevailing view is that the actual fertility behaviors of people are lower than their reported fertility intentions in a low-fertility society at the end of the demographic transition (73). Wu and Li (4) summarized the results of the surveys on fertility intentions in China in recent years and found that the average ideal number of children for the reproductive-aged Chinese people was significantly lower than the replacement level. Besides, their average intended number of children and the desired number of children were lower than the ideal number. The emergence of be-low-replacement fertility intentions marks a new stage in which low-fertility countries are stepping (74). The findings from this study also suggested low fertility intentions among Chinese women of reproductive age, which explained the low fertility rates in mainland China.

The Chinese government has noticed the issue of low fertility rates. It has begun to relax its long-standing one-child policy, such as the selective two-child policy in 2013 and the universal two-child policy in 2015. The effect of these policies on increasing the births number was relatively weak (75). In June 2020, the Chinese government announced implementing the three-child policy after releasing the seventh national census results. Some local governments complemented support such as fertility subsidies, housing security, and childcare support (76). However, the birth rates in China still declined after implementing the new policy. Although the short duration of the policy can explain the decline, the low birth rates in 2021 also suggested re-examining the relationship between fertility intentions and fertility behaviors. The governments need to simultaneously increase fertility intentions and behaviors of the reproductive-aged population when im-proving the fertility policies and enhancing relevant support (77). Factors influencing fertility intentions involved individual characteristics and structural factors such as economic, social, cultural, and institutional factors, requiring adjusting of structural factors to construct a fertility-friendly society (4).

Influence Mechanisms of Media Use on Women's Fertility Intentions

This study found that the influence of different media use on fertility intentions of reproductive-aged women was inconsistent. Groups with new media preference have significantly lower fertility intentions than groups with traditional media preference, and the increased new media use reduced fertility intentions of reproductive-aged women.

On the one hand, China's media system contributed to the above situation. Traditional media, such as radio, television, newspapers, and magazines, release reports under the premise of the party-controlled media and the state-owned system and take responsibility for propagating the policies and guidelines of the party and the nation (78). Thus, fertility issues in traditional media mainly focus on introducing and interpreting national fertility policies. On the other hand, traditional media communications are mostly one-way communication with weak interactions between media and audiences and between the audiences themselves.

In contrast, information dissemination on the internet is open and anonymous, allowing people to express their opinions of events and issues freely. With the interactions and discussions, people easily explore a certain issue deeply. In the context of traditional Chinese culture, the fertility issue has often been discussed within interpersonal communication, especially the transmission of fertility conceptions from parents to offspring. Research confirmed that traditional concepts about fertility, such as "a man should have a wife, and a woman should have a husband," "carrying forward the family with a son," and "raising children for the old," are still transmitted intergenerationally in rural areas of China (79). People obtain fertility information from diverse recourses in the digital age and form more rational and pluralistic fertility conceptions through direct opinion expressions and interactions.

Furthermore, compared to traditional media, which promote fertility policies actively, online platforms disseminate fertility information and concepts via more diverse formats. First, new media platforms allow more information, including news reports, individual narratives, and expressions about fertility and parenting. Individual expressions on fertility issues can be positive or negative, while traditional media news is always

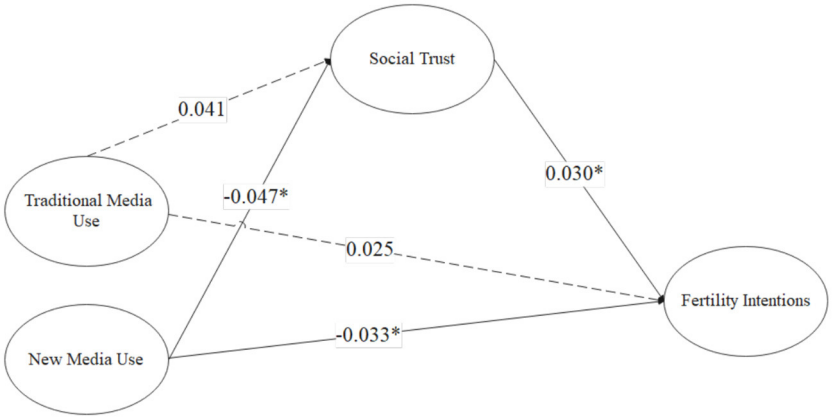

FIGURE 2 | Final model.

positive. Studies showed that individual narratives are more persuasive to audiences than factual reports (80, 81). From the content of Chinese social media, many women expressed the pain of childbirth and parenting on social media, which is more likely to influence women's fertility intentions than positive fertility policy propaganda. Also, the online dissemination of controversial policies and negative marriage and fertility news easily triggered and fermented negative emotions on social media, which further influences the fertility intentions of reproductive-aged women. For example, the Supreme People's Court of Shandong Province posted a WeChat article titled "Divorce cannot be sought solely on the grounds of cheating" on January 3, 2022, which quickly fermented on Sina Weibo and then generated strong negative emotions. Many female netizens expressed as "stay safe without marriage and childbirth" and "stay away from men or be unfortunate," reflecting women's general distrust of men and marriage. A big data analysis of public opinion on the three-child policy on Sina Weibo indicated that Weibo users were generally negative and neutral to the policy and supporting measures. The negative emotions mainly reflected the worries about implementing the supporting policies, the high cost of raising children, and the fragmentation of retirement, fertility, and education policies (82). The negative public opinion and emotions indicated the public distrust in current fertility policies and the social support system, thus expressing negative fertility intentions.

How to Increase Fertility Intentions Through Improving Social Trust

This study suggested that social trust positively influences fertility intentions and mediating between media use and fertility intentions among reproductive-aged women. Many studies have confirmed the positive role of social trust in fertility intentions. The influence mechanism is that groups with high social trust are more willing to rely on social services and security institutions to support fertility, parenting, and education, helping women maintain the relationship between work and fertility (52). Improvement of the social systems of fertility, childcare, and education needs the support of trusted policies and supporting measures. In terms of enhancing social trust, scholars proposed to increase both interpersonal and institutional trust (83). Interpersonal trust needs moral and educational influences and the reduction of social polarization and income disparity (84). Besides, reducing social conflicts and ensuring public safety from the public policies are also necessary for enhancing interpersonal trust (85). To increase institutional trust, public policies should be responsible for the fair and effective implementation of the legal system, enhancement of social justice, insurance of employment, and economic development and equity in income and economic opportunities (83).

How to increase women's fertility intentions through social trust improvement is also a matter for media. The literature revealed that media has a certain impact on social trust (13, 14, 25, 42, 43). This study showed that new media use among Chinese reproductive-aged women positively correlated with social trust. Therefore, in the mediated society, there is a particular need to consider how social trust can be enhanced via new media platforms and further moderate women's fertility intentions. This study found that new media use negatively influenced the fertility intentions of reproductive-age women. Scholars argued that new media greatly increases women's perceptions of the potential fertility risks, such as family finances, children's education, marital status, childbirth risks, postpartum depression, postpartum recovery and life quality, which reduces women's fertility intentions (86). Women's perceived risks of fertility also reflected the distrust in fertility policies and social support systems. On this occasion, the government has to monitor online public opinion and sentiment and timely respond to women's concerns about fertility issues. Furthermore, the government can utilize the new media agenda-setting to guide people to face fertility rationally. For example, the government can provide a detailed introduction and interpretation of the fertility policies and social support system and conduct scientific communication on fertility. Some countries have already implemented their online fertility health promotion programs. The Australian government has funded interactive

websites and social media accounts, gaining over 5 million annual visits to the websites and 96,000 users' engagement on social media (87). European countries have also set up websites on fertility topics, promoting public discourse around fertility issues and education and aiming to increase scientific awareness of fertility among their public (88).

CONCLUSION

This study used CGSS data to examine that new media use negatively influences fertility intentions of reproductive-aged women, and social trust plays a mediating role between media use and fertility intentions. Besides, we further explored the mechanisms of how media use and social trust influence fertility intentions. This study provides a new perspective when researching fertility intentions and suggests strategies for the Chinese government to improve fertility intentions. The governments can utilize agenda-setting and change media reporting strategies.

However, this study has certain limitations and desires further qualitative research on this topic. On the one hand, this study used secondary data, and the research data is somewhat limited by the original survey questions. For example, the items of media use in the survey are limited. Our future research will further explore the relations between media use, social trust and women's fertility rates with a self-designed questionnaire. Also, future research will take the new fertility policies in China into account, such as the three-child policy. On the other hand, this study focused on women's fertility intentions, and the future study will expand the research attention to a more general dimension, which concludes the intentions of the male and the female.

DATA AVAILABILITY STATEMENT

Publicly available datasets were analyzed in this study. This data can be found at: http://cgss.ruc.edu.cn.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by the Institutional Board at Nanjing Normal University. Written informed consent for this study was not required in accordance with local legislation and national guidelines. Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements.

AUTHOR CONTRIBUTIONS

CN and HG designed the study and revised the manuscript. YY and HP analyzed the data. NY and JW were involved in manuscript writing. All authors have read and approved the manuscript.

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The Aging Trend of Insureds and Stochastic Evaluation of Financial Sustainability of Basic Pension in China

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The document, *National Medium and Long Term Plan for Actively Responding to the Aging of Population* points out that in order to actively respond to the aging population in China, it is necessary to steadily increase the endowment wealth reserves. To achieve this goal, it is urgent to stochastically assess the future financial situation of the basic pension insurance in China, grasp its various possible conditions, trends, and corresponding confidence intervals, so that the government can take targeted measures to gradually consolidate the wealth reserves for this basic insurance first, and then steadily increase the social wealth reserves for the elderly. Thus, this paper first analyzes the characteristics of the aging population of insureds participating in basic pension insurance, and then randomly simulates the long-term financial situation of the basic pension insurance. The study found that the aging of the insureds has the characteristics of "fierce coming and slow decline" and "long-term seriousness." Among the six indicators of the financial situation of basic pension insurance, Indicator 1 (the current year's expenditures as a proportion of current year's contributions), Indicator 2 (current year's balance of contributions and expenditures), Indicator 3 (current year's payment gap as a proportion of current year's contributions), Indicator 4 (accumulated balance), Indicator 5 (fund ratio), and Indicator 6 (accumulated payment gap as a proportion of current year's contributions) are respectively in the range of [0.73%, 1.80%], [−12.05, −0.12] trillion yuan, [0.29%, 3.89%], [−133.39, −5.62] trillion yuan, [2032, 2043] years and [6.72%, 215.63%] with a probability of 95%. We analyzed the influence direction and degree of main parameters on the financial situation of the fund and analyzed the impact of parameter value paths on the final financial status of the fund to improve the ability to strengthen fund reserve. The backtracking found that if the value path of the average salary growth rate shows a trend of rising first and then falling, then the final financial situation at the end of the period will be "worse." If it shows a trend of falling first and then rising, the final financial situation will be "better."

Keywords: aging population, basic pension, financial situation, evaluation, stochastic simulation

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INTRODUCTION

The response to population aging has become a global issue, which not only affects the health and care of the elderly population (1, 2) but also brings challenges to the elderly's retirement life, such as insufficient pension and short supply of the elderly service industry. As for China, the Central Committee of the Communist Party and the State Council initiated the document of *National Medium and Long Term Plan for Actively Responding to the Aging of Population* (the "Plan" for short) in November 2019, which indicates that coping with population, aging has become a national strategy in China. The "Plan" points out that it is necessary to steadily increase the endowment wealth reserves in order to consolidate the social wealth reserves in response to population aging. Basic pension insurance, as a system that covers the whole people and ensures the basic life of retirees, and the tamping degree of its wealth reserves are the premises to realize the steady increase of endowment wealth reserves. Thus, it is urgent to use stochastic technology to evaluate the future financial situation of the basic pension insurance system and master its various possible future financial conditions and their corresponding confidence intervals, which are conducive to the comprehensive regulation and control of the government. First, we gradually consolidated the fund reserves of basic pension insurance, and then achieved the goal of a steady increase in endowment wealth reserves.

From a long-term perspective (the next 72 years), under the complex and changeable economic environment, we analyzed the following factors: What kind of change process will the fund reserves of basic pension insurance undergo? What is the corresponding confidence interval? What will the fund reserve be at the end of the prediction period? Is it seriously insufficient or abundant?

In view of the complex and volatile economic environment, stochastic technology needs to be introduced into the financial evaluation of basic pension insurance. Using stochastic technology to describe the uncertainty of the future value of parameters, which is in line with the complex and changeable environment to the greatest extent. In this way, various possibilities for the long-term fund reserves of the basic pension insurance can be depicted. At present, most studies on the evaluation of the financial situation of China's basic pension insurance use actuarial methods, but they rarely consider the random fluctuation of parameters. These studies can be divided into three categories. The first category is to measure the size of implicit debt (3–5). The second category is to explore the contribution and expenditure gap or financial burden of pension insurance (6–8). The third category is to evaluate the long-term financial status and sustainability of pension insurance (9–14). The actuarial methods used in these studies are worth learning from, but they cannot answer the above-mentioned problems since stochastic technology is not introduced.

There are still few studies on the application of stochastic techniques in China's basic pension insurance. The Lee–Carter model was originally used to predict trends in population mortality dynamics (15). Subsequently, Lee and his collaborators continued to explore and stochastically simulated future population changes in the United States, replacing the "high," "medium," and "low" scenarios of traditional population forecasting (16). The "OASDI" report of the United States first used stochastic technology to evaluate the long-term financial situation of public pension insurance in 2003. Today's "OASDI" report mainly uses the randomization technology of standardized time series (17). Learning from these experiences, stochastic technology is gradually applied to the research of basic pension insurance in China. Dong et al. (18) calculated the implicit debt of basic pension insurance considering that both interest rate and mortality are random variables. Wang and Mi (19) considered the random fluctuation of bookkeeping interest rate and salary growth rate in each year, and randomly simulated the individual total substitution rate and net substitution rate of the pension insurance. Sun (20) assumed that retirement age, interest rate, and mortality were random variables, which deduced actuarial functions, such as life annuity and retirement annuity, and numerically simulated the influence of relevant factors on actuarial functions. Zheng and Liao (21) assumed that the payment status and retirement time were random variables that established the contribution and expenditure prediction model for the basic pension insurance. The accuracy of the model was verified by the data of Beijing in 2014, but the parameter setting process was complex, which limited the popularization and application of their model. The randomization methods of relevant parameters in these studies are worth learning from, but they do not directly focus on the long-term financial status or fund reserves of basic pension insurance, and thus do not directly answer the above questions.

Although Tian and Zhao (22) considered the random fluctuations of the fertility rate, mortality, and average salary growth rate and predicted the finance of basic pension in the next 75 years, the model construction did not consider the provisions of the decision of *the State Council Decision on Improving the Public Pension System for Enterprise Employees* (State Council Document 38 of 2005), and the model is relatively rough. Chen and Yang (23) assumed that the bookkeeping interest rate and return on investment (ROI) were random variables that simulated the finances of individual accounts in the next 50 years, and found that individual accounts have better self-balancing. However, these studies only focus on the long-term finance of a certain part of the basic pension insurance for urban employees, and do not examine the long-term fund reserves of the basic pension insurance as a whole (that is, including the basic pension, transition pension, and individual account pension at the same time), so they cannot comprehensively answer the above questions. What is more, the existing studies consider at most three random parameters, and lack comprehensive randomization of suitable parameters, so it is impossible to accurately answer the above questions.

In recent years, the Chinese government has successively issued the *Implementation Plan for Transferring Part of State-owned Capital to Enrich Social Security Funds* and established a central adjustment system for basic pension funds for enterprise employees. The transfer of state-owned capital does not affect the current balance of revenue and expenditure of the basic pension funds but can enrich the accumulated balance. Although the

central adjustment system can effectively delay the year when the current payment gap appears in some provinces (24) and play the role of "robbing the rich and helping the poor," its impact on the total amount of basic pension funds in the whole country is neutral (25). Different from the first two, the *Comprehensive Scheme on Reducing Social Insurance Contribution Rates* in 2019 lowered the contribution rate paid by work units for employees and adjusted the calculation caliber of the average salary of urban employees, which will inevitably affect the contributions and pension expenditures of basic pension insurance. Thus, in the context of the implementation of this comprehensive plan, and assuming that the basic pension insurance is in a more severe environment (i.e., without considering the transfer of state-owned capital and possible future delaying retirement policies to isolate their beneficial effects), we take the basic pension insurance for enterprise employees as an example. According to the *State Council Decision on Establishing Unified Public Pension System for Enterprise Employees* (State Council Document 26 of 1997) and the State Council Document 38 of 2005, the contributions and expenditures of the actuarial prediction model of basic pension insurance in the forecast period is established. Considering the random factors suitable for parameters to simulate the uncertain future environment as much as possible, we obtained various possibilities of long-term fund reserves of basic pension insurance funds by random simulation.

There are five differences between this study and the existing literature. First, this study positively and accurately responds to the possible change trend of long-term fund reserves of China's basic pension insurance and the possible situation of fund reserves at the end of the forecast period. Second, the study conducts a more comprehensive randomization of the appropriate parameters in the contributions and expenditures prediction model of the basic pension insurance, specifically considering nine random variables, more than three random variables from the existing literature. Third, when doing sensitivity analysis, the traditional single change value is replaced by continuously changing the parameter value, so that the sensitivity analysis result is more robust and reliable. Fourth, based on the benchmark case, the influence of the fluctuation of each main parameter on the long-term fund reserve status is simulated one by one and sorted. Fifth, the concept of backtracking is introduced to analyze whether the random value path of the main parameters has certain characteristics when the final fund reserve is "worse" or "better."

ACTUARIAL PREDICTION MODEL CONSTRUCTION AND PARAMETER RANDOM SETTING METHOD

The fund reserve status of the basic pension insurance is measured by six indicators: Indicator 1 (the current year's expenditures as a proportion of current year's contributions), Indicator 2 (current year's balance of contributions and expenditures), Indicator 3 (current year's payment gap as a proportion of current year's contributions), Indicator 4 (accumulated balance), INDICATOR 5 (fund ratio), and Indicator 6 (accumulated payment gap as a proportion of current year's contributions). Indicator 1 refers to the proportion of pension expenditures in the current year to the pension insurance contribution revenues in the current year, which measures the trend of changes in the fund reserves. Indicator 2 is the flow indicator of the fund reserves, specifically referring to the difference between the pension insurance contribution revenues and the pension expenditures in the current year. Indicator 3 measures the severity of the payment gap in the current year, which refers to the proportion of the scale of the pension payment gap in the pension insurance contribution revenues in the current year.

Indicator 4 is the stock indicator, which refers to the accumulated balance of the fund at the end of the current year. Its calculation formula is as follows: if the accumulated balance of the previous year is negative, the accumulated balance is equal to the accumulated balance of the previous year plus the balance of contributions and expenditures of the current year directly. If the accumulated balance of the previous year is positive, the accumulated balance is equal to the accumulated balance of the previous year $\times$ (1 + ROI) + balance of contributions and expenditures of the current year. Indicator 5 measures the actual payment ability of the fund reserves and refers to how long the accumulated funds at the end of the previous year can be used to pay the pension of the current year. Indicator 6 refers to the proportion of the accumulated balance deficit formed in the past in the current year's pension insurance contribution revenues, which means how many times the current year's pension insurance contribution revenues are required to fill the gap in the fund reserves.

According to the State Council Document 26 of 1997, the insureds of basic pension insurance can be subdivided into "old people," "middle people," and "new people". The "old people" refer to the insureds who have retired before he implementation of the document; "middle people" refer to the insureds who joined before the implementation of the document and retired after the implementation; "new people" refer to the employees who participate in the basic pension insurance after the implementation of the document. According to the provisions of the State Council Document 26 of 1997 and the State Council Document 38 of 2005, the balance of contributions and expenditures of basic pension insurance in year t is equal to the sum of the balance of contributions and expenditures of the social pooling accounts and the individual accounts in year t. The contributions and expenditures balance of the social pooling accounts and individual accounts in year t are equal to the difference between the pension insurance contribution revenues and pension expenditures of their corresponding accounts. The pension expenditures in social pooling accounts are equal to the basic pension of the "old people" plus the basic pension, the transition pension, and individual accounts pension exceeding the stipulated payment months of the retired "middle people" plus the basic pension and individual accounts pension exceeding the stipulated payment months of the retired "new people." The expenditures in individual accounts are equal to the individual accounts pension within the stipulated payment months of retired "middle people" and "new people"

plus the return amounts of individual accounts balance when the insureds die.

Model Symbol Settings

Let the age of persons to become firm employees and participate in the pension be e, the retirement age of insureds be r, and the ultimate age of insureds be ω. The contribution rate of basic pension insurance paid by enterprises for employees (i.e., enterprise contribution rate) is b_t, and the contribution rate paid by employees for themselves (i.e., individual contribution rate) is c_t. $L_{t,x}$ refers to the number of insureds aged x in year t. $\bar{S}_t$ is the weighted average salary of urban employees in year t. $S_{t,x}$ is the salary of employees aged x in year t, and s is the growth rate of seniority salary. $B_{t,x}$, $T_{t,x}$, and $I_{t,x}$ are the basic pension, transition pension, and individual accounts pension, respectively, received by retirees aged x in t. The i_t, j_t, g_t, and ρ_t are the ROIs, bookkeeping interest rate, average salary growth rate, and pension growth rate in year t, respectively. The transitional coefficient to pay transitional benefits is ε. The z is the implementation year of the State Council Document 26 of 1997, that is, $z = 1997$. It is assumed that pension contributions and pension expenditures occur at the beginning of each year.

Contribution Revenues of Basic Pension Insurance Fund

The contribution revenues from social pooling accounts and individual accounts are equal to the pension insurance premiums paid by the employers for the insured employees and paid by the insured employees for themselves, respectively. Since some salary items are included in the statistical salary and not included in the contributory salary, the contributory salary is lower than the statistical salary. The contributory salary is the product of the insured employee's salary in the previous year and the ratio, d_t of the contribution salary to the statistical salary. The contribution revenues from social pooling accounts and individual accounts are as follows:

$$b_t \sum_{x=e}^{r-1} L_{t,x} \cdot d_t S_{t-1,x-1} \tag{1}$$

$$c_t \sum_{x=e}^{r-1} L_{t,x} \cdot d_t S_{t-1,x-1} \tag{2}$$

The $S_{t,x}$ can be calculated by the following formula. The t_o is the starting year of the measurement. From $S_{t,x} = (1+s)\, S_{t,x-1} = \cdots = (1+s)^{x-e} S_{t,e}$, we know $\bar{S}_t = \sum_{x=e}^{r-1} L_{t,x} S_{t,x} / \sum_{x=e}^{r-1} L_{t,x} = S_{t,e} \cdot \sum_{x=e}^{r-1} L_{t,x} \cdot (1+s)^{x-e} / \sum_{x=e}^{r-1} L_{t,x}$, then $S_{t,e} = \bar{S}_t \cdot \sum_{x=e}^{r-1} L_{t,x} / \sum_{x=e}^{r-1} L_{t,x} \cdot (1+s)^{x-e}$ can be deduced. When $t > t_o$, $\bar{S}_t = \prod_{k=t_{o+1}}^{t} (1+g_k) \cdot \bar{S}_{t_o}$; When $t < t_o$, we can check the data published in the relevant statistical yearbook to get it. Thus, the $S_{t,x}$ of employees of each age in year t can be obtained, and then the contribution revenues from social pooling accounts and individual accounts can be calculated.

Benefit Expenditures of Basic Pension Insurance Fund

Pension Expenditures of the "Old People"

The age range of "old people" is $[r+t-z, \omega]$. According to the original regulations, the government only pays the basic pension for the "old people." The pension of the "old people" aged x in t is about the salary $S_{t-(x-r)-1,\, r-1}$ of the previous year when they retire, multiplied by the pension replacement rate, $\hat{R}_{t-(x-r)}$ in the year of retirement. The pension of "old people" is paid by the social pooling accounts, and its expenditures are as follows:

$$PC_t^O = \sum_{x=r+t-z}^{\omega} L_{t,x} \cdot \hat{R}_{t-(x-r)} S_{t-(x-r)-1,\, r-1} \cdot \prod_{h=t-(x-r)}^{t} (1+\rho_h)/(1+\rho_t) \tag{3}$$

Pension Expenditures of the "Middle People"

The age range of retired "middle people" is initially $[r, r+t-z-1]$ years old. When retired "new people" appear, that is, $t \geq z+2+l_m$, it becomes $[r+t-z-1-l_m, r+t-z-1]$ years old, where $l_m = r-e-1$, so the age range can be abbreviated as $[\max(r, r+t-z-1-l_m), r+t-z-1]$ years old. The pension expenditures of the retired "middle people" include the expenditures of basic pension, transition pension, and individual accounts pension:

$$PC_t^M = \sum_{x=\max(r,\, r+t-z-1-l_m)}^{r+t-z-1} L_{t,x} \cdot \left(B_{t,x} + T_{t,x} + I_{t,x}\right) \tag{4}$$

The general formulas of $B_{t,x}$, $T_{t,x}$ and $I_{t,x}$ are shown below, respectively.

$$B_{t,x} = \frac{\bar{S}_{t-(x-r)-1}}{2} \left[1 + \frac{1}{\min[t-(x-r)-z, r-e]} \sum_{k=1}^{\min[t-(x-r)-z,\, r-e]} \frac{d_{t-(x-r)-k} S_{t-(x-r)-k-1, r-k-1}}{\bar{S}_{t-(x-r)-k-1}} \right] \times \min\left[t-(x-r)-z, r-e\right] \% \times \frac{\prod_{h=t-(x-r)}^{t} (1+\rho_h)}{1+\rho_t} \tag{5}$$

$$T_{t,x} = \frac{\bar{S}_{t-(x-r)-1}}{t-(x-r)-z} \left(\sum_{k=1}^{t-(x-r)-z} \frac{d_{t-(x-r)-k} S_{t-(x-r)-k-1, r-k-1}}{\bar{S}_{t-(x-r)-k-1}} \right) \cdot [r-e-(t-(x-r)-z)] \cdot \varepsilon \cdot \frac{\prod_{h=t-(x-r)}^{t} (1+\rho_h)}{1+\rho_t} \tag{6}$$

$$I_{t,x} = I_{t-(x-r),r} = \frac{12}{m_r} \times \sum_{k=\max(z,\ t-(x-r)-1-l_m)}^{t-(x-r)-1} \left[c_k d_k S_{k-1,x+(k-1)-t} \cdot \prod_{h=k}^{t-(x-r)-1} (1+j_h) \right] \quad (7)$$

Where the stipulated payment months for individual accounts pension is m_r. The individual accounts pay of the individual accounts pension within the stipulated payment months of retired "middle people" is calculated using the formula PC_t^M. The social pooling accounts pay basic pension, the transition pension, and individual accounts pension exceeding the stipulated payment months of the retired "middle people" are calculated using the formula PC_t^M.

Pension Expenditures of the "New People"

The age range of retired "new people" is [r, r+t–z–l–l_m-1] years old, that is [r, t–z+e–1] years old. The "new people" continue to replace "old people" and "middle people" as the years go by. When $t \geq z$–e+ω +1, all the retired people are "new people", and the "old people" and retired "middle people" are disappeared successively. The pension expenditures, PC_t^N of the retired "new people" include basic pension and individual accounts pension.

$$PC_t^N = \sum_{x=r}^{t-z+e-1} L_{t,x} \cdot (B_{t,x} + I_{t,x}) \quad (8)$$

Where $B_{t,x}$ and $I_{t,x}$ are consistent with the corresponding expressions of formula (5) and formula (7), respectively. The social pooling accounts pay basic pension and individual accounts pension exceeding the stipulated payment months of the retired "new people" are calculated using the formula PC_t^N. The individual accounts pay of the individual accounts pension within the stipulated payment months of the retired "new people" are calculated using the formula, PC_t^N.

Pension Expenditures of Individual Accounts Balance Refund

The individual accounts balance refund I_t^D include the pension expenditures of the insured in-service workers (i.e., in-service "middle people" and "new people") when they die, and retirees (i.e., retired "middle people" and "new people") when they die within the stipulated payment months.

$$I_t^D = \sum_{x=e}^{r\text{-}1} \sum_{k=0}^{\min(t-z,x-e)} \left[c_{t-k} d_{t-k} S_{t-k-1,x-k-1} \cdot \frac{\prod_{n=0}^{k} (1+j_{t-n})}{(1+j_t)} \right] \cdot D_{t,x} + \sum_{x=r}^{\min(r+t-z-1,\ r+[m_r/12]-1)} \left(\frac{m_r}{12} - x + r - 1 \right) \cdot I_{t,x} \cdot D_{t,x} \quad (9)$$

Where $D_{t,x}$ is the number of insureds who died at the age of x in year t.

Random Setting Method of Main Parameters

The purpose of parameter randomization is to obtain the values of parameters and their corresponding random fluctuations in each year ($t > t_0$) of the forecast period through standardized time series techniques or other applicable randomization methods based on historical data. The "OASDI" report of the United States uses standardized time series technology (ARIMA) to randomize parameters, such as fertility rate, real salary growth rate, and the number of legal immigrants and immigrants. Wang and Mi (19) used lognormal distribution to fit random distributions of average salary growth rate and bookkeeping interest rate. Xie and Wu (26) and Zhao et al. (27) proved that the Vasicek model can better fit the volatility behavior of China's interest rate market. Then Chen and Yang (23) used Vasicek model to fit the ROI of pension funds, so different parameters have different randomization methods.

Drawing from the experience of previous studies (17, 19, 23), and according to the actual situation of China's basic pension insurance, the values of parameters, such as the growth rate of seniority salary and the transition coefficient are relatively fixed, which are not suitable for randomization. Thus, the following nine parameters are selected as the main parameters and randomized, which are mortality, urbanization rate, unemployment rate, average salary growth rate, ROI, bookkeeping interest rate, pension growth rate, enterprise contribution rate, and individual contribution rate. The suitable randomization methods for each parameter are different. Mortality was randomized using the Lee–Carter model (15, 16). The urbanization rate, unemployment rate, average salary growth rate, and pension growth rate were randomized using standardized time series techniques (17). The ROI was randomized using the Vasicek model (23, 27). The bookkeeping interest rate is assumed to be lognormally distributed (19). The enterprise contribution rate and individual contribution rate of basic pension insurance are assumed to be normally distributed.

BASIC ASSUMPTIONS AND DYNAMIC ESTIMATION OF PARAMETERS

Basic Assumptions

According to *China population and Employment Statistical Yearbook 2020*, the age composition of urban employees in the first group (16–19 years old) accounts for only 0.8%, and that in the second group (20–24 years old) accounts for 6.8%. With the improvement of the education level of employees, the age e of employees who get the first job can be set as the starting age of the second group, which is 20 years old. The current legal retirement age, r of male workers, female workers, and female cadres are 60, 50, and 55, respectively. According to the provisions of the State Council Document 38 of 2005, the corresponding individual accounts pension payment months, mr are 139, 195, and 170 months, respectively. The maximum statistical age of the national population by age and gender in the *China Population and Employment Statistical Yearbook* over the years is 100 years old, so the ultimate age ω of the insureds is set to 100 years old.

The growth rate of seniority salary s is set to be 1.363% (8). The pension transition coefficient ε is generally controlled between 1 and 1.4% (28), and we take the middle value of 1.2%. The annual report on *China's social insurance development 2015* announced

that the official pension replacement rate for enterprise retirees is about 67.50%. According to the *China Human Resources and Social Security Yearbook 2018*, the average retirement benefits of employees in 2017 and the average salary of on-the-job employees in the previous year were 29,880 yuan and 72,703 yuan, respectively. We divided the average retirement benefits by the current official pension replacement rate of 67.5%, and then divided it by the average salary of on-the-job employees, the proportion d_t of contribution salary in statistical salary is 60.89%, which is assumed to remain unchanged during the forecast period. Since the earliest year of the data on the average retirement benefits of employees in *China Human Resources and Social Security Yearbook 2018* is 1998, the data of that year are used to estimate the replacement rate,$\hat{R}$of "old people" pension. From the yearbook,the average retirement benefits of retirees in 1998 and the average salary of on-the-job workers in the previous year were found to be 5,304 yuan and 7,405 yuan, respectively. By dividing the average retirement benefits by the average salary of on-the-job employees in the previous year, $\hat{R}$ is calculated as 71.63%, and it is assumed that the pension replacement rate of "old people" is the same.

Parameter Dynamic Estimation

Estimated Number of Insureds

The number of in-service insureds aged x in t years is equal to the product of the corresponding age population, $P_{t,x}$ in the national population distribution by age and sex in that year and the labor participation rate, urbanization rate, pension insurance coverage rate, and the proportion of the number of on-the-job enterprises' employees in the number of on-the-job employees in cities and towns of China. In the same way, the number of retired insureds aged x in year t can be obtained. Then, we can estimate the number of insured persons as $L_{t,x}$ in each year. The mortality $q_{t,x}$ (the mortality of x-year-olds in year t) is multiplied by $L_{t,x}$ to obtain the number of insureds $D_{t,x}$ who died by age and sex in each year.

Estimates of the national population distribution by age and sex *($P_{t,x}$)*. According to the data of the United Nations Population Division in 2019, China's net migrant population in 2018 was −1,742,000, accounting for only 0.125% of the total population, with little impact. Thus, the international migration will not be considered for the time being. The cohort element method is used to build a population forecasting model. Without considering the immigration and emigration, the general form of this model is as follows:

$$\begin{cases} P_{t,0} = \frac{SRB_t}{1+SRB_t} \cdot \sum_{x=15}^{49} P_{t,x}^F \cdot FR_{t,x} + \left(1 - \frac{SRB_t}{1+SRB_t}\right) \cdot \sum_{x=15}^{49} P_{t,x}^F \\ \qquad\qquad \cdot FR_{t,x}, \quad x = 0 \\ P_{t,x} = P_{t-1,x-1} \cdot \left(1 - q_{t,x}\right), \qquad x > 0 \end{cases} \tag{10}$$

Where $P_{t,x}^F$ is the number of women of childbearing age at the age of x in year t, The $FR_{t,x}$ is the fertility rate of women of childbearing age at the age of x in year t, and SRB_t is the sex ratio of newborns in year t.

From the *China Population and Employment Statistical Yearbook 2020*, we know about the national population distribution by age and gender in 2019. The population distribution by age is divided by the corresponding sampling ratio, and the result is used as the initial population distribution. The $FR_{t,x}$ of each year in the forecast period is calculated from $TFR_t \cdot \overline{h}_{t,x}$, where TFR_t is the total fertility rate in year t, and $h_{t,x}$ is the standardized fertility coefficient. The total fertility rate, TFR_t for each year of the forecast period refers to the results of the intermediate scenario forecast by the United Nations Population Division in 2019.

The average fertility rate, $FR_{t,x}$ of urban women of childbearing age by age from 2000 to 2019 is obtained from the *China Population and Employment Statistical Yearbook*. The total fertility rate of the corresponding year is obtained by the formula, $TFR_t = \sum_{x=15}^{49} FR_{t,x}$, and then the standardized fertility coefficient of these 20 years are obtained by the formula, $h_{t,x} = FR_{t,x}/TFR_t$, taking their mean value as the standardized fertility coefficient, $\overline{h}_{t,x}$ of each year in the prediction period. The sex ratio, SRB_t of newborns in each year of the prediction period also refers to the intermediate program results predicted by the United Nations Population Division in 2019.

Estimation of dynamic mortality $q_{t,x}$. The general form of the Lee—Carter model is $\ln(m_{x,t}) = \alpha_x + \beta_x k_t + \varepsilon_{x,t}$, where $m_{x,t}$ represents the central mortality of the x-year-old at t, α_x refers to the average mortality of the x-year-old, β_x refers to the sensitivity of age x to changes in mortality, k_t refers to the degree of change in mortality over time, $\varepsilon_{x,t}$ is the error term, and it obeys $N(0, {\sigma_\varepsilon}^2)$ distribution. The weighted least squares method (29) was used to fit the parameters, α_x and β_x, and the double stochastic process (30) was used to fit and predict the parameter, k_t. The sample data of national age-specific sex mortality from 1994 to 2019 used to fit the above parameters are derived from the data of *China population and Employment Statistical Yearbook* and the fifth and sixth national censuses over the years. For the absence of the mortality of the elderly in the statistical yearbook, the Coale–Kisker method was used to estimate (31).

Dynamic estimates of the unemployment rate, u_t and the urbanization rate, ub_t in each year of the forecast period. The historical data on the unemployment rate from 1978 to 2019 are obtained from the *China Statistical Yearbook of Population and Employment 2020*, and the historical data on the urbanization rate from 1980 to 2019 are obtained from the *China Statistical Yearbook 2020*. The ARIMA model is used to fit the historical data of the unemployment rate, u_t and the urbanization rate, ub_t respectively, and the obtained model estimation formulas are:

$$\triangle u_t = 0.5851 \triangle u_{t-1} + \varepsilon_t, \varepsilon_t \sim N(0, 0.2616^2) \tag{11}$$

$$\triangle ub_t = 1.0476 + 0.7042 \triangle ub_{t-1} + \varepsilon_t, \varepsilon_t \sim N(0, 0.2815^2) \tag{12}$$

Since the lower limit of the unemployment rate is 0, the fluctuating unemployment rate obtained by formula (11) is ≥ 0. After obtaining the fluctuation of the unemployment rate in each year of the forecast period, since the labor participation rate = 1 − unemployment rate, the fluctuation of the labor participation rate are also obtained. Wang and Ge (32) believed that the upper limit of China's urbanization rate is 80%, so the upper limit is taken when the fluctuation range of urbanization rate obtained

from formula (12) exceeds 0.8. The 5,000 times Monte Carlo simulation distribution of unemployment rate and urbanization rate in each year of the prediction period are shown in **Figure 1**.

Estimation of other parameters. Referring to previous practical experience, the pension insurance coverage rate will increase by one percentage point year by year from 85% in 2015 to 95% in 2025 and will remain unchanged in subsequent years; the number of female workers is four times that of female cadres. From the *China Human Resources and Social Security Yearbook* 2020, we come to know that the number of insured employees in enterprises over the years accounted for the proportion of insured employees in urban areas across the country, and the average value of 93.70% is taken as the value of this ratio in each year of the forecast period. In the same way, the average ratio of the number of the retired insureds in the enterprise to that of the national urban retired insureds is 94.40%, which is the value of each year in the forecast period.

Estimation of Average Salary Growth Rate and Pension Growth Rate

According to the *China Human Resources and Social Security Yearbook 2020*, we come to know about the average salary of on-the-job employees of enterprises from 1997 to 2019, and then we get the historical data of the average salary growth rate, g_t from 1998 to 2019. Fitting them with ARIMA model, the obtained estimation formula is as follows:

$$\triangle g_t = -0.0010 - 0.3095\ \triangle g_{t-1} + \varepsilon_t, \varepsilon_t \sim N(0, 0.0258^2) \quad (13)$$

Due to the rigidity of salary, that is, the decline of salary is sticky, the lower limit of the fluctuation of the average salary growth rate obtained from formula (13) is not < 0. In addition, the report of the 19th CPC National Congress in 2017 pointed out that China's economy has turned to a high-quality development stage, and the economic growth has been gradually slowing down. Since the average salary growth rate is closely related to the economic growth rate, it is assumed that the average salary growth rate in the forecast period is not $>$ the average salary growth rate of 9.20% in 2017. Thus, the average salary growth rate in the forecast period fluctuates between 0% and 9.20%.

According to *China Demographic and Employment Statistical Yearbook 2020*, the average salary and number of urban nonprivate sector employees and the average salary and number of urban private sector employees at the end of 2019 can be obtained, respectively. It can be estimated that the weighted average salary $\bar{S}_t$ of urban unit employees in the 2019 is 63,182 yuan, which will increase by g_t in years after 2019. The $\bar{S}_t$ in the years before 2019 is the average salary of the on-the-job employees of the enterprise in the corresponding year published in the statistical yearbook, so $\bar{S}_t$ can be obtained. The pension growth rate, ρ_t is generally 60–80% of the average salary growth rate, and 80% is taken here (25), so the fluctuation distribution of the pension growth rate can also be obtained.

Estimation of ROI

The Vasicek model is used for fitting, and a relatively active and representative 30-day "interbank pledged repo weighted interest rate" is used as a sample of ROI i_t (23). The data are obtained from the observed values of trading days from January 4, 2015 to September 30, 2021. The estimated Vasicek model formula is:

$$i_t = 0.0015002 + 0.95275 i_{t-1} + 0.0020282 dW_t \quad (14)$$

Where W_t is the standard Brownian motion, and dW_t (i.e., W_t–W_{t-1}) obeys the standard normal distribution. In September 2021, the National Council of Social Security Funds issued the 2020 annual report on the entrusted operation of the basic pension insurance fund, pointing out that the average annual ROI of the fund since the entrusted investment is 6.89%, which is the initial ROI. Then the ROI of each year in the prediction period can be obtained from formula (14).

Estimation of Bookkeeping Interest Rate

It is assumed that the fluctuation of bookkeeping interest rate follows a lognormal distribution (19). Since China's General Office of the Ministry of Human Resources and Social Security and the General Office of the Ministry of Finance began to publish the bookkeeping interest rate of individual accounts of basic pension insurance for urban employees in 2016, the one-year deposit interest rate of the bank over the years in the website of the people's Bank of China can be used as the bookkeeping interest rate for the year 2015 and previous years with reference to practical experience. The maximum likelihood method is used for fitting, and the estimated lognormal distribution result is ln (–3.173, 0.364).

Estimation of Contribution Rates

The enterprise contribution rate, b_t of the basic pension insurance is reduced from 20% stipulated in the State Council Document 38 of 2005 to 16% of the *Comprehensive Plan for Reducing Social Insurance Rates* (the document 13 of 2019 issued by the General Office of the State Council). The pace of adjusting enterprise contribution rate in various provinces to achieve this goal may be different, so the enterprise contribution rate, b_t will fluctuate between 20 and 16%. In order to further reduce the payment burden of enterprises, the enterprise contribution rate, b_t may even drop to 12% in the future. Considering the current situation of the enterprise contribution rate b_t, the probability of its fluctuation value of 16% should be the maximum, so it can be assumed that it obeys a normal distribution with a mean value of 16% and a fluctuation probability of 95% in the range of 12–20%. The meaning of this distribution is that the enterprise contribution rate fluctuates by 4 percentage points around 16% with a 95% probability. Looking at the standard normal distribution function table, it can be calculated that its standard deviation is (20–16%)/1.96, which is equal to 0.0204, so $b_t$obeys the normal distribution of N (0.16, 0.0004).

Similarly, according to the State Council Document 26 of 1997 and the State Council Document 38 of 2005, the individual contribution rate, c_t of basic pension insurance has changed from the previous 11 to 8%. When the individual contribution rate is allowed to fluctuate, it can be assumed that this rate follows the normal distribution with a mean of 8%, and the probability of fluctuating around 3 percentage points of 8% is 95%. It can be

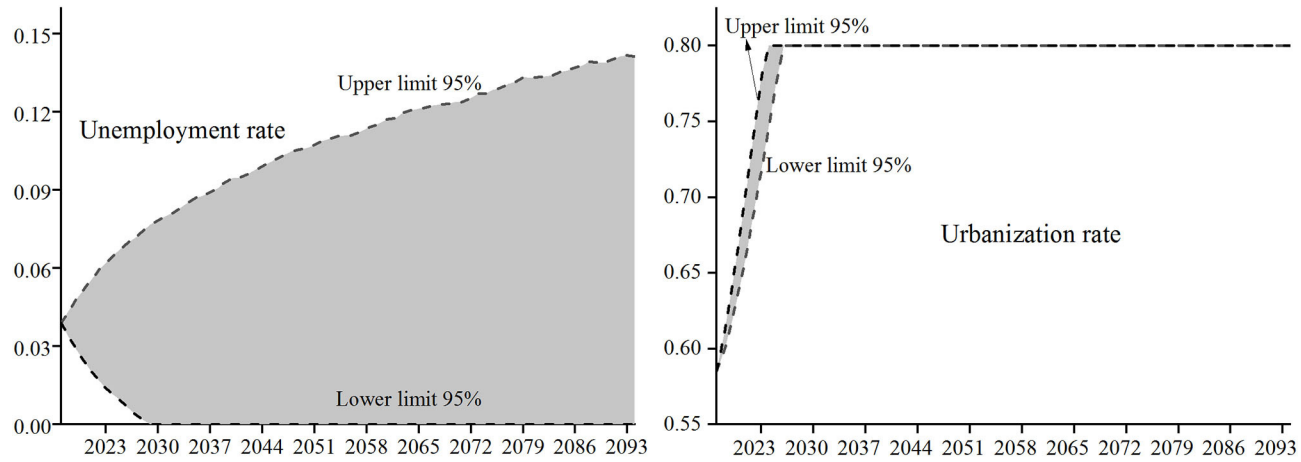

FIGURE 1 | Simulated distribution of unemployment rate and urbanization rate.

seen that the standard deviation of this distribution is 0.0153, so the c_t follows the normal distribution of $N(0.08, 0.0002)$.

AGING CHARACTERISTICS OF INSUREDS AND FINANCIAL STATUS OF BASIC PENSION FUND

Aging Characteristics of Insureds

The insured elderly population refers to the insureds, aged 60 and above. The trend of changes in the number of elderly insureds is used as an indicator to measure the aging characteristics of the insureds. The proportion of population aging generally refers to the proportion of people aged 60 and above in the total number of people. Similarly, the proportion of the number of the elderly insureds in the total number of insureds is taken as another important indicator to measure the aging characteristics of insureds. According to the above estimation of the number of insureds and the parameter setting method, the number of elderly insureds in each year of the prediction period and its proportion in the total number of insureds can be obtained. The variation trend (dotted line in the figure) and its 95% confidence interval (between the two solid lines in the figure) obtained from 5,000 Monte Carlo simulations of the two indicators are shown in **Figure 2**.

In the early forecast period, the number of elderly insureds (male and female) has been rising rapidly. The number of women will reach the peak of aging around 2,053, while the number of men will be about 4 years later than that of women. In the following years, the number of elderly insureds will slowly decline, and the decline in the number of women is slightly > that of men. It may be that the family planning policy implemented in China in the early stage and the rising cost of living year by year have led to the continuous decline of the fertility rate, resulting in the gradual reduction of the population participating in work and insurance, which further led to the slow downward trend of the elderly insureds retired around 2,050. The number of elderly insureds show the characteristics of a rapid increase at first and then a slow decline, indicating that the aging of the insureds has the characteristics of "fierce coming and slow decline."

From the perspective of the proportion of the number of elderly insureds among the total number of insureds, in the early stage of the forecast and the proportions of men and women are rising rapidly with a diagonal slope of about 45 degrees. Until 2057, the proportion of different genders shows different trends. This proportion of women fluctuated smoothly, to about 0.42 in 2094; while this proportion of men was still rising, slowing down, and falling back halfway, to about 0.41 by 2094. Although the aging of the insureds has the characteristics of "fierce coming and slow decline," the decline stage has not significantly reduced the value of this proportion, so the aging of the insureds also has the characteristics of "long-term seriousness," Then, based on these two characteristics of the elderly insureds, what kind of change trend will the long-term fund reserves of basic pension insurance show?

Fund Reserves Under the Scenario of Fixed Parameter Values

The research scenario without considering the random fluctuation of parameters is called the fixed parameter value scenario. Taking the mean value of the random distribution of the above nine main parameters, the fixed values of these parameters in each year of the prediction period can be obtained. For example, in formula (11), the formula is $\Delta\ u_t = 0.5851\ \Delta\ u_{t-1}$ after taking its mean value. Combined with the values of other non-random parameters, the fund reserve status under the fixed scenario can be obtained. According to *China's Labor Statistics Yearbook 2021*, the initial cumulative amount of basic pension insurance fund for enterprise employees in 2020 is 4,440.17 billion yuan. In the absence of continuous financial subsidies, the calculation results of the six indicators (Indicator 1: the current year's expenditures as a proportion of current year's contributions, Indicator 2: current year's balance of contributions and expenditures, Indicator 3: current year's payment gap as a proportion of current year's contributions, Indicator 4: accumulated balance, Indicator 5: fund ratio, and

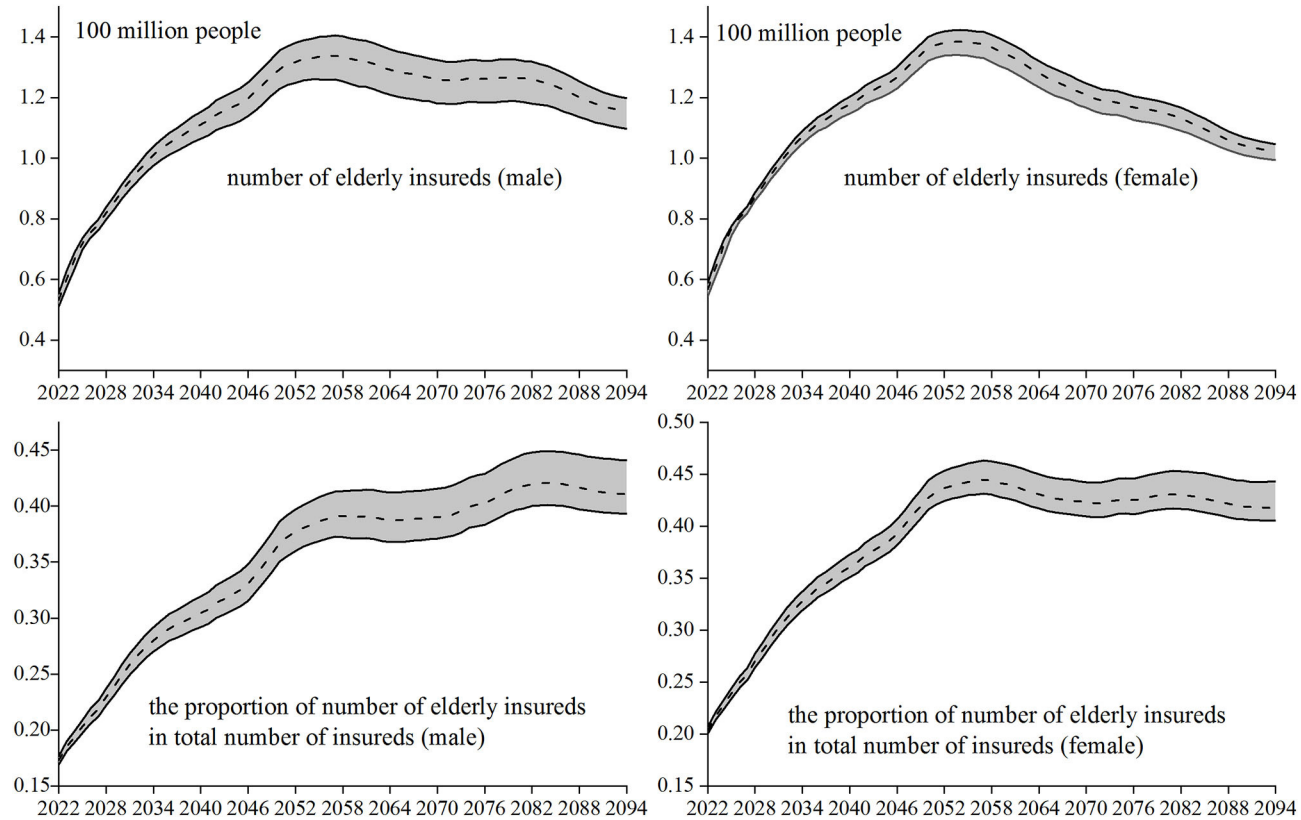

FIGURE 2 | Aging characteristics of insureds.

Indicator 6: accumulated payment gap as a proportion of current year's contributions) to measure the status of long-term fund reserves are shown in **Table 1**.

Indicator 1 (the proportion of current year's expenditures to current year's contributions) continued to rise during the forecast period, resulting in the continuous decline of Indicator 2 (current year's balance of contributions and expenditures) and Indicator 4 (accumulated balance). The fund reserves of basic pension insurance will face the dilemma of "income does not cover expenditure" in 2027, that is, there will be a payment gap in the current year. After that year, Indicator 3 (the proportion of current year's payment gap to current year's contributions) will increase year by year, and it will rise to 0.85 in 2094. The accumulated balance or fund ratio (Indicator 5) indicates that its wealth reserves will be exhausted in 2037, and Indicator 6 (the proportion of accumulated payment gap to current year's contributions) in subsequent years rises rapidly, reaching as high as 17.69 in 2094. It can be seen that the fund reserves of basic pension insurance will be seriously insufficient in the long run, and the conclusions are similar to previous studies (14, 22, 33).

Fund Reserves Under Random Scenario of Parameter Values

The random fluctuations of nine main parameters, such as mortality, urbanization rate, unemployment rate, average salary growth rate, etc. are considered to simulate the various possibilities of long-term fund reserves of basic pension insurance under complex and changeable environment to the greatest extent. They are recorded as the random scenario of the parameter value. Based on MATLAB software and Monte Carlo technology, 5,000 random simulation results of the long-term fund reserve status of the basic pension insurance are obtained. The change trend and 95% confidence interval of the six indicators during the prediction period are shown in **Figure 3**.

The change trend (dotted line in the figure) of the six indicators measuring the long-term fund reserves under the scenario of random-parameter value is basically consistent with the change trend of each indicator under the scenario of fixed-parameter value, but the random scenario of the parameter value can provide very rich information on the change trend of fund reserves. For example, the average annual growth rate to measure the trend of Indicator 1 (the current year's expenditures as a proportion of current year's contributions) is 1.12%, the average annual growth rate of the lower bound of the 95% confidence interval (solid line at the bottom of the figure) is 0.73%, and the average annual growth rate of the upper limit is 1.80%, so its average annual growth rate of Indicator 1 will be in the interval [0.73%, 1.80%] with a probability of 95%.

Let the average annual change = (the value at the end of the forecast period – the value at the start of the forecast period) /

TABLE 1 | Fund reserve status under fixed parameter value scenario.

Year	Indicator 1	Indicator 2 (trillion yuan)	Indicator 3	Indicator 4 (trillion yuan)	Indicator 5	Indicator 6
2022	0.86	0.73	—	9.19	1.75	—
2023	0.90	0.58	—	10.07	1.65	—
2024	0.93	0.44	—	10.83	1.55	—
2025	0.96	0.28	—	11.46	1.49	—
2026	0.99	0.10	—	11.93	1.43	—
2027	1.00	−0.04	0.01	12.27	1.34	—
2028	1.03	−0.27	0.03	12.39	1.23	—
2029	1.06	−0.56	0.06	12.23	1.11	—
2034	1.17	−2.19	0.17	6.26	0.38	—
2037	1.21	−3.41	0.21	−2.25	0.00	0.14
2039	1.25	−4.53	0.25	−10.71	0.00	0.60
2044	1.33	−8.03	0.33	−43.68	0.00	1.82
2049	1.46	−14.28	0.46	−100.64	0.00	3.24
2054	1.54	−21.42	0.54	−194.72	0.00	4.87
2059	1.55	−28.32	0.55	−323.20	0.00	6.27
2064	1.54	−35.85	0.54	−486.34	0.00	7.38
2069	1.58	−47.66	0.58	−698.13	0.00	8.54
2074	1.67	−65.57	0.67	−986.02	0.00	10.02
2079	1.75	−87.16	0.75	−1375.59	0.00	11.85
2084	1.80	−108.84	0.80	−1878.29	0.00	13.86
2089	1.81	−127.51	0.81	−2478.29	0.00	15.74
2094	1.85	−152.70	0.85	−3187.41	0.00	17.69

the number of years in the forecast period. Let the annual average change rate = (the value at the end of the forecast period – the value of the year in which the payment gap occurs at the earliest) / the number of years between the end of the forecast period and the earliest year.

Then the average annual change in Indicator 2 (current year's balance of contributions and expenditures) is −1.41 trillion yuan, in the lower limit of the confidence interval is −12.05 trillion yuan, and in the upper limit of the confidence interval is −0.12 trillion yuan, so the average annual change of Indicator 2 is in the range [−12.05, −0.12] trillion yuan with a 95% probability. The annual average change rate in Indicator 3 (current year's payment gap as a proportion of current year's contributions) is 1.27%, in the lower limit of the confidence interval is 0.29%, and in the upper limit of the confidence interval is 3.89%, so the annual average change rate of Indicator 3 is in the range [0.29%, 3.89%] with a 95% probability.

Similarly, the average annual change in Indicator 4 (accumulated balance) is −31.70 trillion yuan, in the lower limit of the confidence interval is −133.39 trillion yuan, and in the upper limit of the confidence interval is −5.62 trillion yuan, so the average annual change of Indicator 4 is in the interval [−133.39, −5.62] trillion yuan with a 95% probability. Indicator 5 (fund ratio) indicates that the fund reserves will be exhausted in [2037, 2032] under pessimistic conditions (i.e., lower limit) and 2043 under optimistic conditions (i.e., upper limit). Thus, the fund reserves will be exhausted in [2032, 2043] with a 95% probability. The annual average change rate in Indicator 6 (accumulated payment gap as a proportion of current year's contributions) is 31.34%, and in the lower limit of the confidence and in the upper limit of the confidence interval, it is 6.72 and 215.63%, respectively, so the annual average change rate of Indicator 6 is in the interval [6.72%, 215.63%] with a probability of 95%. It can be seen that the fund reserve results obtained by stochastic simulation considering parameter uncertainty can cover various possibilities, including the results under the scenario of fixed-parameter value. While improving the forecast accuracy, more information on the changing trend in the fund reserves of basic pension insurance is provided.

The accumulated balance at the end of the forecast period measures the final state of the fund reserve of the basic pension insurance. Various possible states of the final fund reserve can be known from the accumulated balance in 2094 in the above 5,000 Monte–Carlo simulation results, and the results are shown in **Figure 4**.

From **Figure 4**, it is clear that in the relatively harsh environment without considering the transfer of state-owned capital, possible delaying retirement and financial subsidies in the future (i.e., isolating their beneficial effects) and the final fund reserve of basic pension insurance will be seriously insufficient in the prediction period.

FURTHER ANALYSIS OF INCREASING FUND RESERVES

Using stochastic technology to simulate various possibilities of the long-term fund reserves of basic pension insurance, it is

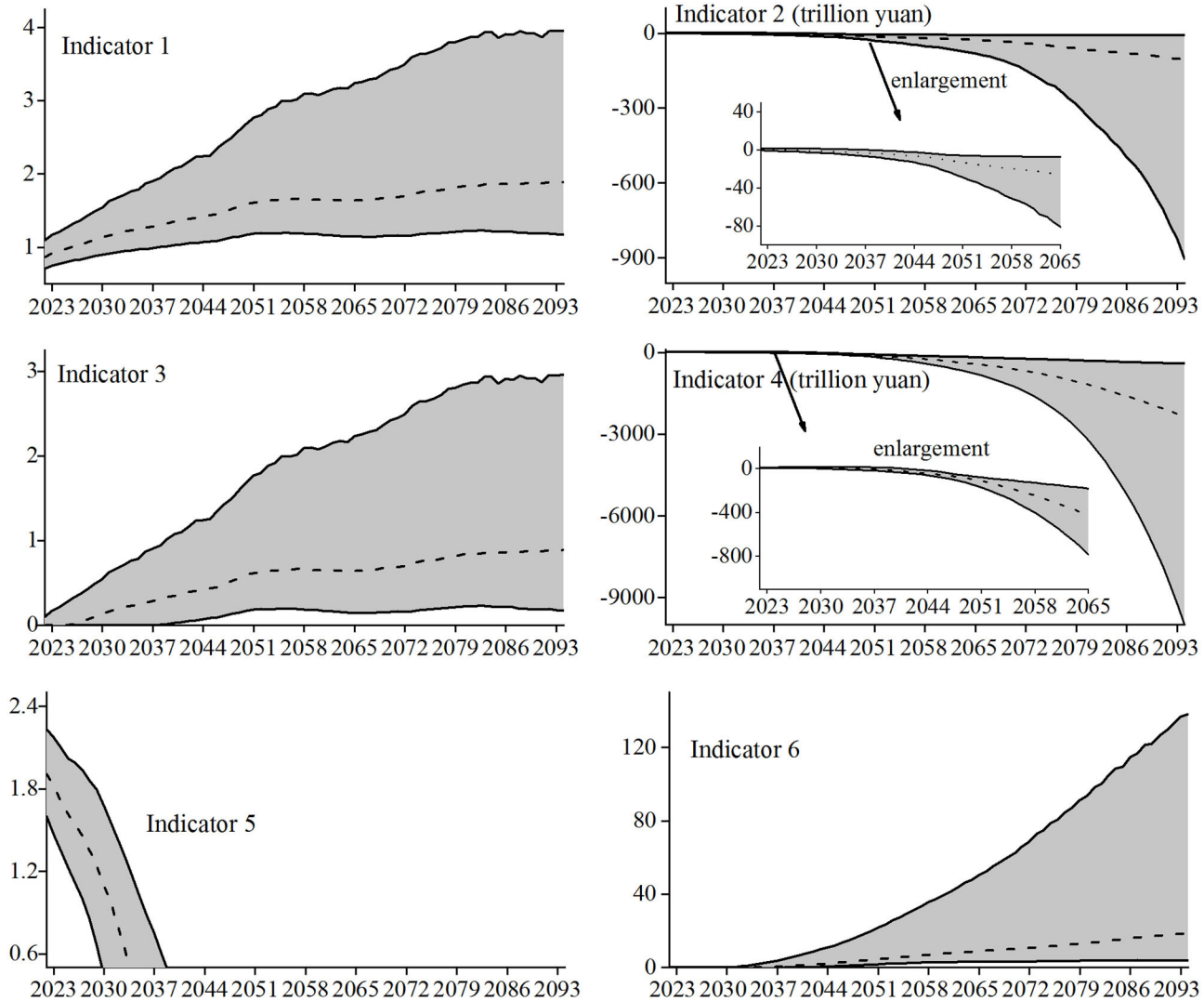

FIGURE 3 | Change trend and confidence interval of long-term fund reserves.

found that the fund reserves will decline rapidly and will be exhausted in [2032, 2043] with a 95% probability, and the final fund reserve at the end of the forecast period will be seriously insufficient, indicating that the long-term fund reserves of basic pension insurance are extremely worrying. Thus, it is necessary to deeply grasp the relationship between these main parameters and the fund reserve status, so that the government can take measures to increase the fund reserves of the basic pension insurance.

Impact Direction of Main Parameters on Fund Reserves

The calculation results of long-term fund reserves under the scenario of fixed parameter values are regarded as the benchmark case. Based on this situation, the sensitivity analysis of nine main parameters can be carried out to obtain the impact direction of these parameters on fund reserves. The sensitivity analysis of most existing literature is usually to change the value of a parameter once and analyze its influence compared with the benchmark case. However, a single change in parameter value can have different effects on fund reserves, which may destabilize the sensitivity analysis results. In order to avoid this kind of instability as much as possible, the influence of the continuous change of the parameter value is investigated here, and we obtained the relatively stable influence of the parameter.

The nine main parameters, such as mortality, unemployment rate, urbanization rate, etc., are continuously changed as follows:

the new values of the parameter = the value of the parameter under the benchmark case $\times$ $(1+\tau\%)$

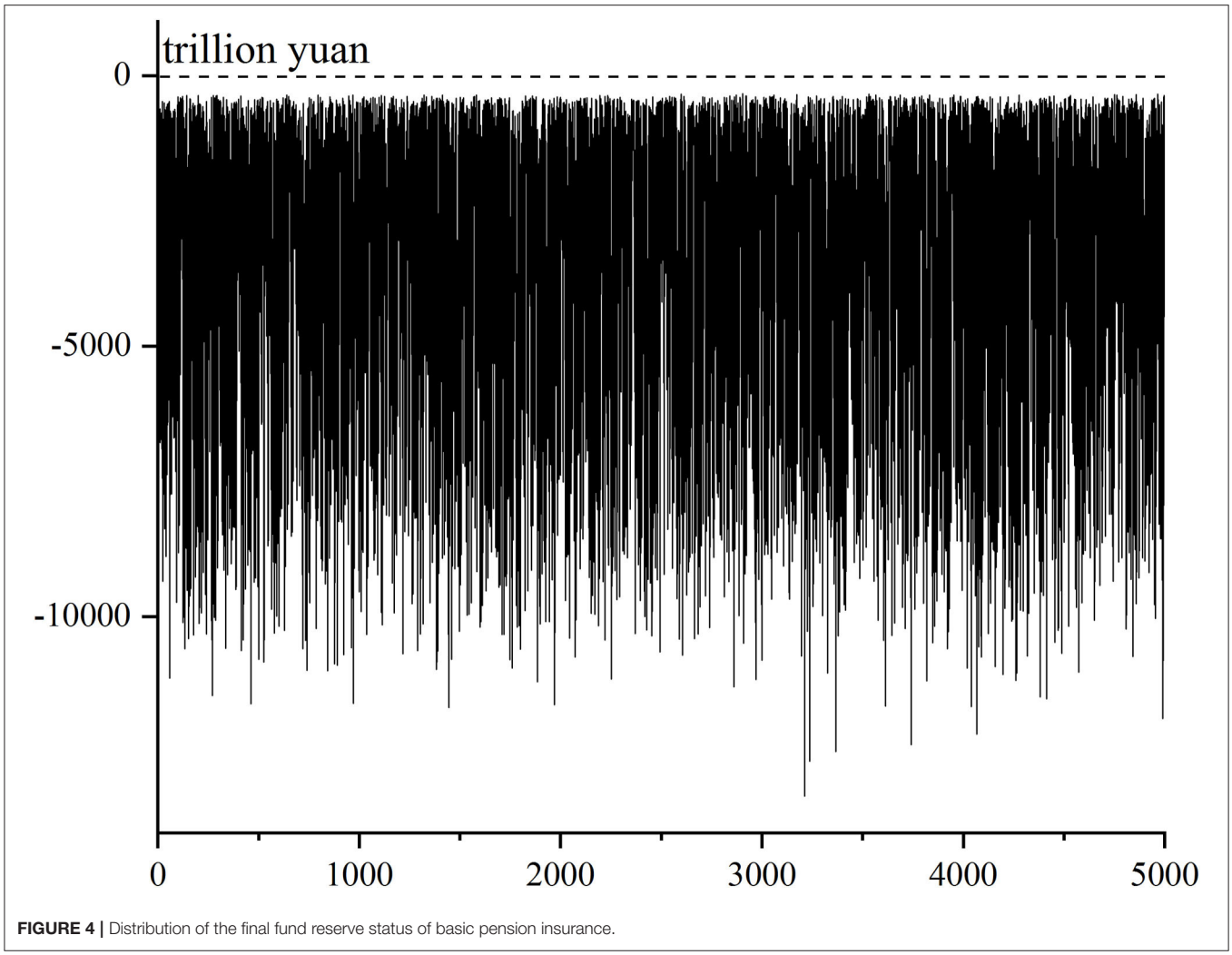

FIGURE 4 | Distribution of the final fund reserve status of basic pension insurance.

Where τ is $[-25, -1]$ and $[1, 25]$, which means that the parameter values gradually change from a uniform decrease of 25% to a uniform increase of 25%, that is, there are 50 sets of observations for each parameter. Using the change of Indicator 4 (accumulated balance) to examine the impact of parameter changes on the fund reserves, the elasticity of the accumulated balance to each main parameter is shown in **Figure 5**.

The influence directions of the nine main parameters can be divided into three categories. The first category includes the parameters that make the accumulated balance change in the same direction, such as mortality, urbanization rate, ROI, enterprise contribution rate, and individual contribution rate. The second category includes the parameters that reverse the change of accumulated balance, such as unemployment rate, pension growth rate, and bookkeeping interest rate. The third category includes the parameter that makes the accumulated balance change in the same direction first and then in the opposite direction, such as the average salary growth rate.

The Influence Degree of Each Main Parameter on the Fund Reserves

The environment of basic pension insurance is complex and changeable, and the value of main parameters will be volatile. Based on the benchmark case, the influence degree of the random fluctuation of each main parameter on the fund reserves of the basic pension insurance is examined one by one. First, the the upper and lower limits of the 95% confidence interval of the fluctuation range of the accumulated balance in each year of the forecast period caused by the parameter fluctuation are obtained, then the upper limit is subtracted from the lower limit, and the mean value of the difference between these two limits is taken as the index A to measure the influence degree of the parameter on the fund reserve status.

For example, to calculate the influence degree of random fluctuations in mortality on fund reserves, first, the values of the remaining parameters are fixed, and only the mortality values that fluctuate, and 5,000 simulation operations of the fund reserve status are carried out. Second, the 5,000 simulation results of the accumulated balance from small to large are ranked, and

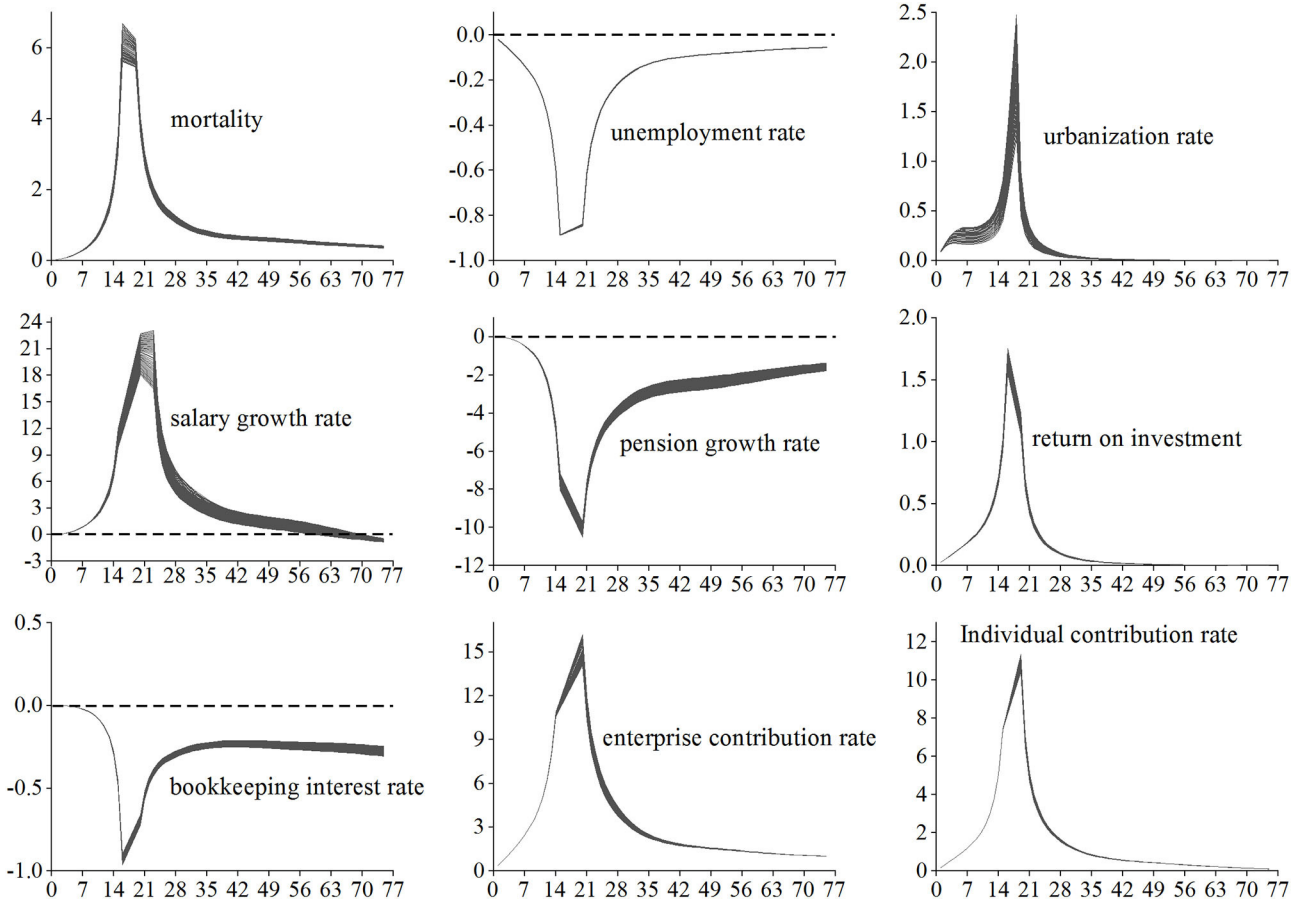

FIGURE 5 | Elasticity of accumulated balance to each main parameter.

the upper and lower limits of the 95% confidence interval of the accumulated balance in each year of the prediction period are obtained. Third, according to the meaning of index *A*, the influence degree of random fluctuation of mortality on fund reserves is calculated. Similar to the above calculation process, the influence degree of the fluctuation of each parameter on the fund reserve status is obtained. The influence degree of these main parameters is in the descending order: average salary growth rate, pension growth rate, unemployment rate, enterprise contribution rate, bookkeeping interest rate, mortality, individual contribution rate, ROI, and urbanization rate.

Feature Search of Parameter Value Paths Under "Better" Fund Reserve Status

The final fund reserve of the basic pension insurance in the forecast period in **Figure 4** are sorted from small to large, and the results are shown in **Figure 6**, which can be divided into two different statuses. One is the fund reserve status above the 90% quantile (about 500 simulation results), with the minimum value of −524.63 trillion yuan, which is much larger than −3,187.41 trillion yuan in the benchmark case. Thus, these final fund reserves that are better than the benchmark case can be called "better" fund reserve status, which means that under the complex and changeable environment, these final fund reserves of basic pension insurance are lucky to occupy a more favorable position than the benchmark case. Similarly, the other is the fund reserve status below the 10% quantile, with the maximum value of −8,437.70 trillion yuan, which is far $<$ −3,187.41 trillion yuan in the benchmark case, which is called the "worse" fund reserve status.

Then how does the basic pension insurance fortunately make its final fund reserve in a "better" position? That is, in a complex and changeable environment, how should the main parameters be valued so that the final fund reserve of the basic pension insurance is in a favorable position, and is there any obvious characteristic in the value path?

The concept of backtracking is introduced here. For any calculation result in random simulation, the value taking process of random parameters in each year of the prediction period can be traced back or recorded to form the parameter-value taking path corresponding to the result. We make a backtracking analysis on why the basic pension insurance is in the "better" fund reserve status and the "worse" fund reserve status, respectively

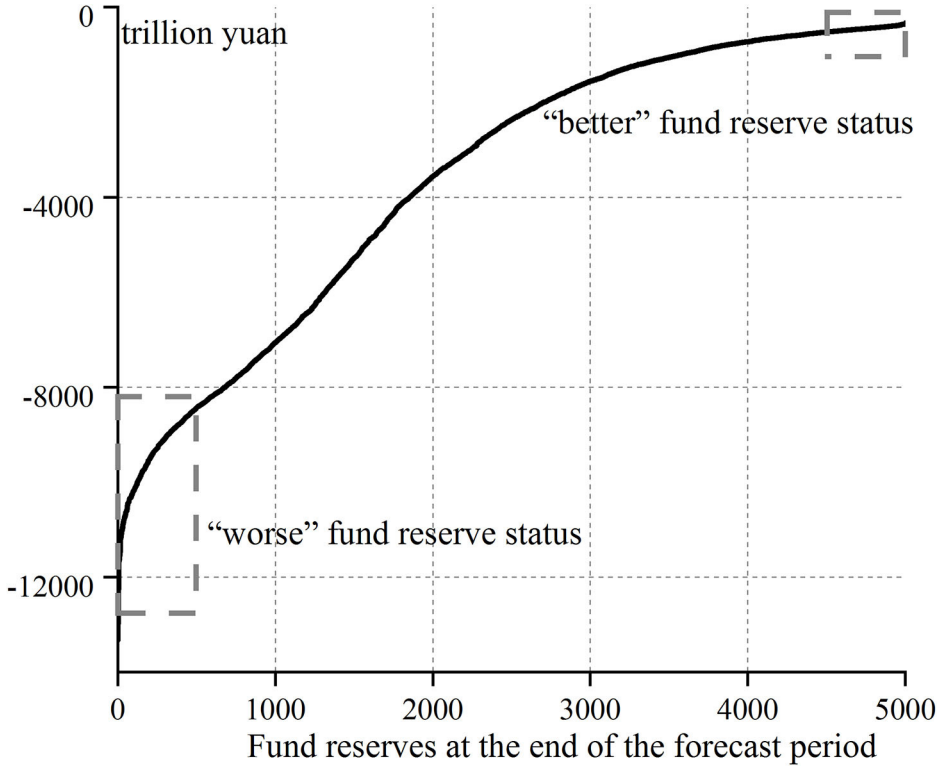

FIGURE 6 | Schematic diagram of the meaning of "better"and "worse" fund reserve status.

and compared to find whether there are some characteristics in the parameter-value path.

The fluctuation of mortality, urbanization rate, and unemployment rate can be comprehensively reflected in the fluctuation of number of insureds. For the 500 simulation results in which the final fund reserve is "better" and the 500 simulation results in which it is "worse" in **Figure 6**, the number of insureds, average salary growth rate, ROI, bookkeeping interest rate, enterprise contribution rate, and individual contribution rate are tracked back respectively. The value paths of the number of insureds and the average salary growth rate are shown in **Figure 7**. The **Figures 7A,C** are the parameter value paths when the final fund reserve status is in the "worse" position, and the **Figures 7B,D** are the parameter value paths in the "better" position.

There is no significant difference between the two value paths of the number of insureds, indicating that the random value paths of the number of insureds are almost the same if the final fund reserve status is in the "better" and "worse" position, and there is no value feature that causes the significant difference in the final reserve status. The two value paths of ROI, bookkeeping interest rate, enterprise contribution rate, and individual contribution rate are also similar. These are consistent with the number of insureds, and there is no significant difference. The average salary growth rate is different, and the two value paths are significantly different. As shown in **Figure 7**, if the value path of the average salary growth rate follows a trend of rising first and then falling, the final reserve status will be "worse"; on the contrary, if it follows a trend of first falling and then rising, the final reserve status will be "better".

CONCLUSIONS AND IMPLICATIONS

To actively promote the consolidation progress of fund reserves of basic pension insurance and to contribute to the steady increase of social endowment wealth reserves, it is urgent to give priority to the stochastic evaluation of its future fund reserves. This study first analyzes the aging characteristics of the insureds of basic pension insurance and establishes the actuarial prediction model of contributions and expenditures for basic pension insurance based on the State Council Document 26 of 1997 and the State Council Document 38 of 2005 and considering the latest provisions of the *Comprehensive Scheme on Reducing Social Insurance Contribution Rates*. Then the nine main parameters are randomized, and various possibilities of the long-term fund reserve status of basic pension insurance are randomly simulated.

The study found that the aging of the insureds have two characteristics of "fierce coming and slow decline" and "long-term seriousness." Among the six indicators to measure the fund reserve status of basic pension insurance, Indicator 1 (the current year's expenditures as a proportion of current year's contributions), Indicator 2 (current year's balance of

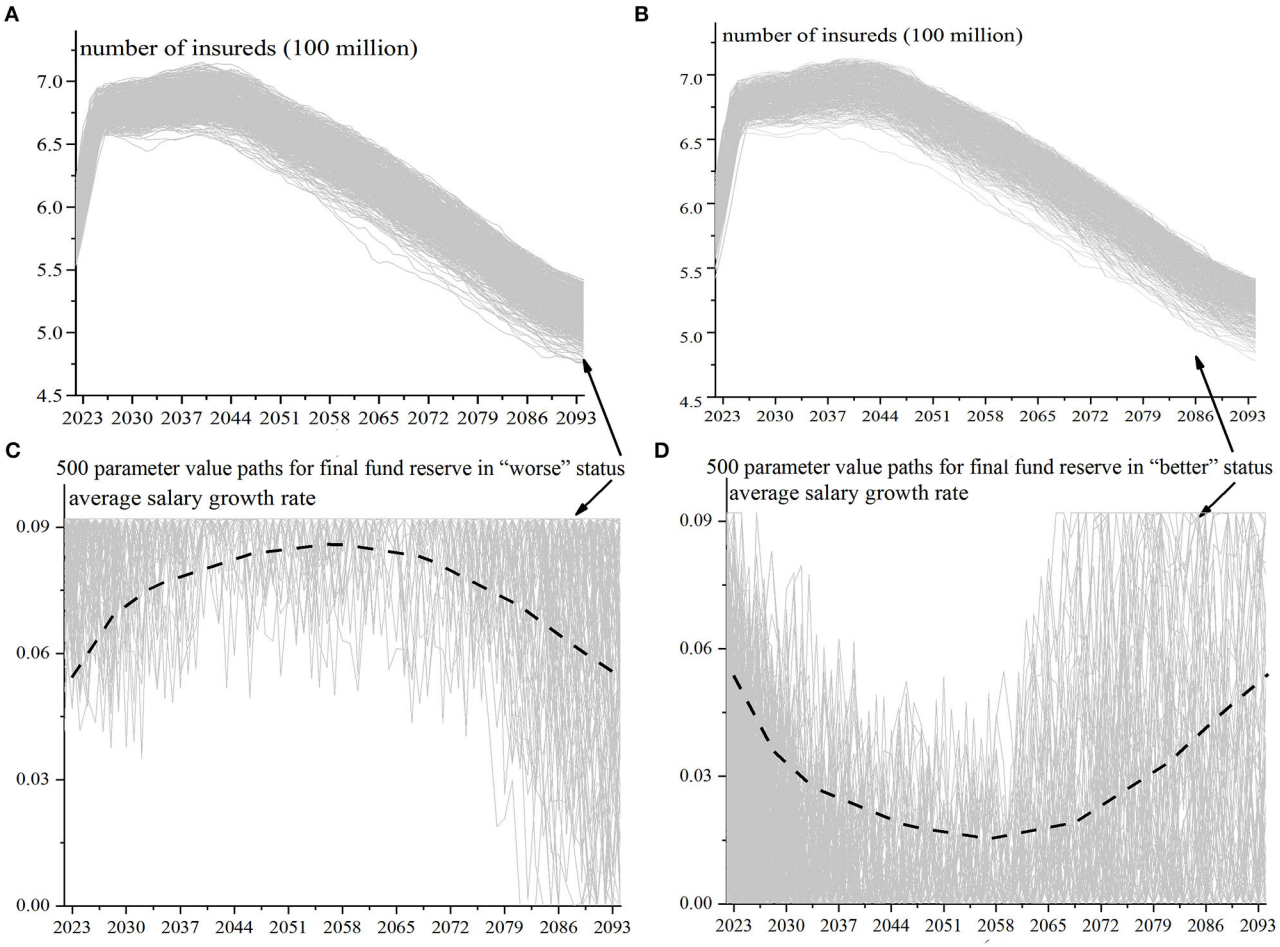

FIGURE 7 | (A–D) Feature search of value paths for the number of insureds and average salary growth rate.

contributions and expenditures), Indicator 3 (current year's payment gap as a proportion of current year's contributions), Indicator 4 (accumulated balance), Indicator 5 (fund ratio), and Indicator 6 (accumulated payment gap as a proportion of current year's contributions) are in the range of [0.73%, 1.80%], [−12.05, −0.12] trillion yuan, [0.29%, 3.89%], [−133.39, −5.62] trillion yuan, [2032, 2043] and [6.72%, 215.63%] with 95% probability respectively. What is more, under the harsh environment of not considering the transfer of state-owned capital, delaying retirement, and financial subsidies, the final fund reserve of the basic pension insurance will be seriously insufficient.

To improve the ability to consolidate the fund reserves, we analyze the influence of the main parameters on the fund reserves, their random fluctuations, and the influence of the parameter-value paths on the final status of the fund reserves. Sensitivity analysis identified three distinct categories of parameters affecting the direction of the fund reserves. In the first category, the parameters that make the accumulated balance change in the same direction include mortality, urbanization rate, ROI, enterprise contribution rate, and individual contribution rate. The second category is the parameters that make the accumulated balance change inversely, including unemployment rate, pension growth rate, and bookkeeping interest rate. The third category is the average salary growth rate for the parameters that make the accumulated balance change in the same direction and then in the opposite direction. Under the random fluctuation environment of future parameters, it is found that the influence degree of the fluctuation of main parameters on the fund reserves from large to small is the average salary growth rate, pension growth rate, unemployment rate, enterprise contribution rate, bookkeeping interest rate, mortality, individual contribution rate, ROI, and urbanization rate. The backtracking found that if the value path of the average salary growth rate showed a trend of rising first and then falling, the final reserve status would be "worse;" if it showed a trend of first falling and then rising, the final reserve status would be "better."

According to the above research conclusions, in order to actively respond to the aging population and consolidate the fund reserves of basic pension insurance, the following inspirations can be obtained. First, to improve the long-term fund reserves of the basic pension insurance, the average salary growth rate should preferably show a trend of "falling first and then rising."

The above conclusions show that when the value path of the average salary growth rate in each year of the forecast period is "first fall and then rise," the final fund reserve status will be "better." The average salary growth rate belongs to the parameter of economic development, and the government has weak control over it. The overall future growth rate of China's economy may just show a trend of first falling and then rising. Although the current economic growth rate of China is gradually declining, the purpose of turning to high-quality economic development is to obtain a relatively high-speed and stable economic growth in the future, so it may show a downward trend and then an upward trend. Related studies show that the average salary growth rate and the economic growth rate fluctuate closely in tandem (8, 24). Thus, it is necessary to further strengthen the close link between the average salary growth rate and the economic growth rate and establish an adjustment mechanism in which the average salary growth rate fluctuates closely with the fluctuation of the economic growth rate.

Second, to steadily consolidate the fund reserves of basic pension insurance, the government should control the parameters of the basic pension insurance in a combined manner. The sensitivity analysis shows that the enterprise contribution rate and the individual contribution rate change in the same direction with the accumulated balance, while the pension growth rate and the bookkeeping interest rate change in the opposite direction with the accumulated balance. Thus, if the government wants to further reduce the payment burden of the basic pension insurance for enterprises without affecting the consolidation progress of basic pension insurance fund reserves, the government can try to take a combination of measures, such as moderately increasing individual contribution rate, reducing the pension growth rate, and bookkeeping interest rate.

Third, the ROI of pension is increased and the accumulated fund reserves of the basic pension insurance are consolidated. Sensitivity analysis shows that increasing the ROI will increase the accumulated balance in the same direction and enhance the pension payment ability to cope with the aging of the population. According to the "Basic Pension Insurance Fund Entrusted Operation Annual Report 2020", the basic pension has been invested since 2016, and its annual average investment rate of return is 6.89%, but it fluctuates greatly. The lowest investment rate of return is 2.56% in 2018. Thus, it is urgent to actively study the investment strategies, investment fields, and investment supervisions of basic pension in order to stabilize its ROI.

Fourth, an actuarial reporting system of China's basic pension insurance should be established as soon as possible, and its fund reserve status should be regularly evaluated. Developed countries, such as the United Kingdom and the United States have already formed a mature financial evaluation system for pension funds. For example, the trustee of the "OASDI" fund in the United States submits the fund financial report to Congress every year, and the British government actuary reports the long-term financial report of the pension fund every 5 years. Under the background that the response to population aging has become a national strategy, relevant departments of China should regularly publish official actuarial reports on basic pension insurance or entrust relevant institutions to evaluate and monitor the fund reserves of basic pension insurance. By establishing the actuarial reporting system of China's basic pension insurance, we learn from the "OASDI" report of the United States and introduce stochastic technology to simulate the fund reserve situations in a complex and changeable environment as much as possible. At the same time, we try to introduce the concept of backtracking to find the possible path to improve the fund reserves of the basic pension insurance.

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

The author confirms being the sole contributor of this work and has approved it for publication.

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Bilateral effect of aging population on consumption structure: Evidence from China

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The deepening of aging population inevitably in China will exert a far-reaching influence on national consumption and economic transformation. Based on interprovincial panel data in 2000–2018, this paper measured the ratio of five survival and enjoyment consumptions in disposable incomes, reconstructed the indicators for upgrading the consumption structure, used the bilateral stochastic cutting-edge model, and decomposed the aging population to realize the net effect from the positive and negative effects generated by the consumption structure. The findings indicated that (1) aging population played a positive and negative bilateral effect on upgrading the consumption structure, in which the positive effect upgraded 14.04% of the consumption structure while the negative effect degraded 6.18% of the consumption structure. The comprehensive net effect upgraded 7.86% of the consumption structure. (2) From the perspective of the time effect, under the positive and negative effects of aging population, the consumption structure was upgraded 7.861% on average every year. (3) Regarding the regional effect, the promotion role of aging population was the highest in the eastern region, followed by the west. The middle was the lowest. By combining with estimation results of each province, the promotion role brought by aging population in the northeast and southwest was lower. Based on the above-mentioned research results, this paper proposed some advice for positively developing silver hair economy, promoting the improvement on the consumption structure according to circumstances, developing the perfect aging consumption market, exploring the consumption potential of the elderly, accelerating the urbanization development progress, and stimulating consumption growth relying on the Internet.

KEYWORDS

aging population, upgrade of the consumption structure, bilateral stochastic cutting-edge model, panel data, regulate economy

Introduction

To dialectically consider the effect of aging population, exploring how to relieve the demographic structure dividend under the background of keeping deepening aging population, promoting growth of domestic demands, and accelerating the domestic circulation, the following questions should be answered: first, what is the effect of aging population for the upgrade of the consumption structure; second, what is the size

of aging population on the upgrade effect of the consumption structure; third, what are time distribution characteristics and regional distribution features for the upgrade effect of aging population consumption structure. On this basis, this paper selected demographic and consumption data of 31 provinces in 2000–2018 and explored the upgrade effect of the aging population consumption structure, for the sake of proposing some effective advice.

In 2020, the "14th 5-Year Plan" specially proposed to depend on the powerful domestic market, insist on expanding domestic demands, and accelerate the domestic circulation. Meanwhile, China's population structure is undergoing a rapid transformation. In 2021, the 7th National Population Census data showed that the population of China over 60 years old occupied 18.70%, in which the population over 65 years old accounted for 13.50%. Compared with 2010, the ratio of older adults over 60 years old increased 5.44% during 10 years. At the same time, this ratio keeps growing. Relevant experts predict that in 2040, the elderly population over 65 years old in China will reach 27.8% and this value will be up to 32.2% in 2060 (1). Under the context of keeping increasing the elderly, it is of great significance to economic development by identifying whether it can effectively promote consumption growth and accelerate consumption transformation. The CPC Central Committee's Proposal on Formulating the 14th 5-Year Plan for National Economic and Social Development and the Long-term Goals for 2035 passed in the Fifth Plenary Session of the 19th Central Committee also emphasizes on positively implementing the national strategy to cope with aging population, positively changing aging risks into the "longevity dividend," accelerating the new industry, new state, and new pattern of silver hair economy, expanding silver hair consumption, continuously expanding domestic demands to enrich the domestic circulation, promoting the benign interaction of international double circulation, and cultivating the new power of economic growth.[1]

However, the current Chinese residents' consumption rate was present in the long-term downtrend. During the period 1978–2010, residents' consumption rate was reduced by percent points (2). At the same time, in 2019, the part with the biggest occupation in China's consumption structure still included food expenditure, occupying 28.22%, followed by housing expenditure which occupied 23.45%. The ratio of such expenditures has already exceeded 50% of the total expenditure. The total expenditure proportion of five terms including traffic communication, household equipment and energy service, medical healthcare, educational leisure, and entertainment, as well as services accounted for 42.13%. The consumption expenditure ratio of the five terms excluding basic necessities in the UK, Denmark, Finland, Japan, and the USA in the same period has already exceeded 50%. As a whole, the overall consumption structure of China should be improved. The resident consumption rate should be improved. Meanwhile, with the deepening of aging, on the one hand, aging population keeps growing, which undoubtedly will accelerate demands for medical healthcare, services for the aged, and facilities.

This is an important opportunity to promote the upgrade of China's consumption structure. On the other hand, aging population means the population reduction of laborers. The reduction of primary groups is not good for consumption growth and consumption transformation. As a result, the influence of accurately estimating aging population on the transformation of the consumption structure will better serve economic development.

Literature review

As an important aspect of economic growth, consumption is always the research key for domestic scholars. Particularly, with the growth of China's economy, research perspectives of scholars keep enriching from the consumption level and consumption structure to the upgrade of the consumption structure. According to existing studies, the main studies for the upgrade of the consumption structure are mainly concentrated on two aspects: On the one hand, they focus on discussing the current upgrade state of the consumption structure in China. Han and Xia (3), Shi et al. (4), and Gu and Xia (5), respectively, measured the upgrade state of the consumption structure in China from the perspectives of "developmental coefficient," consumption structure, and consumption habits, as well as the framework of "survival type—developmental type—enjoyment type," and demonstrated that the current consumption structure of China remained the upgrade state. Ye and Tang (6) further used the entropy weight method to measure the consumption upgrade index of each province in China and found that there was an obvious difference between regions. The provincial consumption upgrade index was successively decreasing from the east to the west. On the other hand, they concentrate on exploring the factors affecting the upgrade of the consumption structure. At present, scholars mainly study their relationship from the perspectives of social capital and consumption behavior (7), financial constraint (8), and Internet (9). However, so far, there have been fewer references analyzing the factors affecting the upgrade of the consumption structure from the demographic perspective. Particularly, with the constant deepening of aging population, the population structure transformation undoubtedly will exert an important influence on the upgrade of the consumption structure, showing the important significance to study their relationship.

First, aging population implies an increase in the elderly population ratio. The group is equipped with the significant features in consumption. As a whole, the consumption demands of the elderly in China are present in the trend of specialization and diversification. Moreover, the external dependency is

1 https://www.guancha.cn/politics/2020_11_03_570186.shtml

gradually enhancing (10, 11). Regarding consumption demands, older adults tend toward medical treatment and caring services. Moreover, the consumption concept of older adults is relatively mature and rational (12). The overall consumption level of the elderly is lower, which is even lower than the national average level (13). What is more, there is an obvious difference in the consumption quantity between urban–rural older adults (14); in terms of the consumption structure, after becoming elderly, the food expenditure ratio of older adults is rising (13). The expenditure of clothing expenditure and traffic consumption is present in the declining trend (15). The expenditure of medical healthcare is significantly growing (16). The special consumption features of the elderly undoubtedly will generate the special influence on the upgrade of the consumption structure.

From the combination between aging and consumption, the scholars Grunberg and Modigliani (1954) (17) put forward the life cycle theory and discussed the relationship between the population structure variation and consumption. This theory argues that rational consumers will be based on the utility maximization principle to deal with savings and incomes at different age stages. With the constant enhancement of China's aging and the consumption level, Chinese scholars also conduct lots of studies from the perspectives of aging and consumption structure. First, in terms of research methods, Li and Gao (18), Cha and Zhou (19), Yu and Sun (20), and Bao and Li (21) made use of the gray system theory and method to verify whether aging population exerted an influence on the consumption structure, but they did not specially clarify the role direction of aging population. After that, scholars established the unitary linear model based on the life cycle theory to demonstrate the effect direction of aging population. Speaking of the research framework, the current studies are based on the following three frameworks. The first one is based on eight consumption types used by the National Bureau of Statistics to measure the consumption upgrade effect of aging population. For example, based on panel data of 30 provinces in China, Zhang et al. (22) redivided eight consumptions[2] into "food and clothing consumption" and "other consumptions" to study the consumption upgrade effect of aging population. The second one is based on the survival materials, developmental materials, and enjoyment materials divided by Engels to measure the upgrade effect of the consumption structure for aging population. For instance, (23) measured the ratio of developmental and enjoyment expenditure in the total expenditure. Kou and Zhang (24) were based on the consumption framework of the type including survival—developmental—enjoyment. Tian (25) divided consumption into the health type, enjoyment type, and developmental type to measure the consumption upgrade effect of aging population. The third one is based on Stone's LES model and divided consumption into the basic consumption and developmental consumption to measure the upgrade effect of the consumption structure for aging population. For instance, Li (26) utilized the extended linear expenditure system (ELES) to divide the expenditure term in resident consumption structure into general commodities, and current research conclusions are mainly concentrated on the following two aspects: First, aging population is good for consumption structure upgrade (22–24); second, aging population is not good for upgrading the consumption structure (21, 25). Fewer scholars showed that the influence of aging population on the upgrade of the consumption structure was less significant (26).

On the whole, main conclusions of existing references for the upgrade effect of the consumption structure for aging population are mainly concentrated on the positive or negative unilateral effect but they have not noticed the simultaneous positive and negative bilateral effect for aging population changing with time and economic development. In the meanwhile, there are no relevant studies on time heterogeneity presented by aging population changing with time. In studies of different areas, scholars often make a comparison according to the eastern, middle, and western areas but cannot display the specific aging population effect of each province. Under the circumstance, through the bilateral stochastic boundary model, this paper conducted the estimation comparison on the positive and negative effects of aging population for the upgrade of the consumption structure and conducted quantitative estimation for the possible positive and negative effects on this basis, so as to evaluate the comprehensive influence of aging population on the upgrade of the consumption structure. What is more, this paper estimated the time development trend of the net effect for aging population and the upgrade effect of the independent consumption structure in each province, so as to propose more practical countermeasures.

Theoretical assumptions

After entering 21st century, China starts entering the aging society, and the aging degree keeps deepening. This aspect is attributed to the reduction of the young population and the increase in the elderly population brought by the reduction of birth rate and death rate, showing the aging population. Beyond that, due to expected lifetime dilation of population, the existing population age keeps growing. The number of the elderly in society is present in the gradually growing trend. The role of factors in two factors ultimately will increase the elderly population ratio. The social aging degree keeps deepening, while the change in both aspects will exert multiple influences on consumption.

2 It refers to eight categories of food expenditure, clothing expenditure, housing expenditure, traffic communication expenditure, educational cultural entertainment expenditure, medical expenditure, and daily consumption service expenditure used by National Bureau of Statistics.

On the one hand, aging population is possible to bring the promotion effect for the upgrade of the consumption structure: (1) The life cycle theory argues that most people prefer the lifetime balance consumption. The redundant income in the young stage will be often used for paying debts in their youth or saving money for pension. Hence, when the ratio of elderly population in society is increasing, the consumption of entire society tends to increase. (2) At the same time, after labor population quits the labor force market, they have more time to enjoy leisure time so that the opportunity cost of enjoying leisure will be reduced, so as to promote the increase in enjoyment consumption for such a group, driving consumption upgrade. (3) With the increase in age, people's body function keeps degeneration while people's self-caring ability keeps weakening. This inevitably will drive the demands for medical treatment, pension, and elderly caring. The deepening of aging undoubtedly will drive the social consumption in medical healthcare and aging service consumption. (4) After post-60s and post-70s generations gradually become elderly, the consumption concept of older adults will tend to premature consumption and enjoyable consumption. (5) The extensive use of the Internet will make consumption more convenient, reducing consumption barriers caused by inconvenient trip. Besides, the upgrade of the consumption structure brought by aging population may display the obstruction effect: (1) Aging population means that the ratio of young people in the total population is reduced, while young people are social labor participants and main consumer groups. The ratio reduction of young people inevitably will reduce each consumption part. (2) Expected lifetime keeps lengthening, so older adults should allocate the longer time period to realize utility maximization and reduce the current consumption expenditure. Meanwhile, the willingness of preventive savings in their youth will be increased, while they will reduce the current consumption for elderly pension. (3) With the growth of age, after they leave the operating post, people will have more time to make a comparison on the purchased commodities. Older adults tend toward purchasing commodities with high-performance cost ratio while reducing the impulsion consumption. (4) With age, people's ability to accept and learn new things is weakening while the consumption mode keeps updating and becomes more intelligent. The lagged consumption mode affects the diversified development of the consumption structure. (5) The older generation is affected by their long-term life habits, so their overall saving conception is stronger and their consumption willingness is lower. On this basis, this paper proposed the hypothesis 1: Aging population showed the positive and negative bilateral effect on the upgrade of the consumption structure.

Meanwhile, since the reform and opening-up, China has undergone earth-shaking changes in economy, politics, and culture. People's disposable incomes keep increasing. Relative to 2013, per capita disposal incomes of China in 2020 were increased by 75.79%; the industrial structure kept optimization. In 2000–2019, the GDP ratio of the primary and secondary industries was, respectively, reduced by 7.11 and 38.97% from 14.67 and 45.54%. The GDP ratio of the tertiary industry was increased to 53.92% from 39.79%; people's consumption concept kept changing, while the consumption environment was constantly optimizing. On this basis, this paper put forward the hypothesis 2: The positive promotion effect of aging population for the upgrade of the consumption structure will perform the trend of increasing over time.

China has a vast territory, and each area has significant differences in economic development and population structure. In this way, the upgrade effect of the consumption structure brought by aging population in each region inevitably shows some differences. As a whole, the overall aging population degree in east China is higher, while the economic development level is also higher. The consumption market development is relatively sound, and high-tech application degree is high. Also, people's consumption concept is relatively advanced. The west is situated in the remote area. The defects of the geographical environment make its economic development lag behind. The population is rare, while the consumption market development is unsound. Moreover, people's consumption concept is relatively lagging. On this basis, this paper came up with the hypothesis 3: There is heterogeneity of regions between aging population and the upgrade of the consumption structure. Moreover, the upgrade of the consumption structure in the east has the strongest positive effect.

Empirical model and data description

The description of the bilateral stochastic cutting-edge model

Through the above-mentioned analysis, it is concluded that there is the mutually exclusive effect of positive and negative directions in the upgrade of the consumption structure caused by aging population. Hence, based on the research idea of Kumbhakar and Parmeter (27), this paper constructed the bilateral stochastic cutting-edge model:

$$\begin{aligned} Upgrade_{it} &= i(x_{it}) + w_{it} - u_{it} + \varepsilon_{it} = i(x_{it}) + \xi_{it} \\ &= x_{it}\delta + \xi_{it} \end{aligned} \quad (1)$$

in which $Upgrade_{it}$ is the consumption structure level; x_{it} refers to a series of control variables affecting the upgrade of the consumption structure, including per capita disposable incomes, deposit balance, consumption tendency, child-rearing ratio, urbanization level, industrial development level, social safeguard level, Internet penetration rate, and telephone popularity rate. δ is the parameter vector to be estimated; $i(x_{it})$ refers to the cutting-edge industrial structure level; ξ_{it} denotes the compound

residual term, $\xi_{it} = w_{it} - u_{it} + \varepsilon_{it}$, in which, ε_{it} is the stochastic error term, showing the unobservable factors on the consumption structure level. Since compound residual term ξ_{it} is possible to be equal to 0, it will result in the bias in OLS estimation results. As $w_{it} \geq 0$, it means the aging population can promote the upgrade of the consumption structure; as $u_{it} \geq 0$, it means that aging population is not good for the upgrade of the consumption structure; as $w_{it} = 0$, $u_{it} \geq 0$ or $u_{it} = 0$, $w_{it} \geq 0$, the model means the bilateral stochastic cutting-edge model. As $w_{it} = u_{it} = 0$, the model is the OLS model.

Through the Formula (1), the actual effect of aging population for the upgrade of the consumption structure is the result under the combined action of positive and negative bilateral effect of aging population: Aging population promotes the upgrade of the consumption structure so that the consumption structure level is higher than the cutting-edge consumption structure level, while aging population obstructs the upgrade of the consumption structure so that the consumption structure level is lower than the cutting-edge consumption structure level. The net effect based on the combined influence of promotion and obstruction can measure the deviation degree of the practical consumption structure level.

Due to the bias in OLS estimation, to estimate parameter δ and residual terms w_{it} and u_{it}, this paper used the maximum likelihood estimation (MLE) to get the effective estimation results. To this end, ξ_{it} is the compound residual term and its distribution should satisfy the following conditions: the stochastic error term is mutually independent; ε_{it} observes normal distribution. In other words, $\varepsilon_{it} \sim$ iidN$(0,\sigma_\varepsilon^2)$, w_{it} and u_{it} observe the exponential distribution, namely $w_{it} \sim$ iidEXP$(\sigma_w\sigma_w^2)$,$u_{it} \sim$ iidEXP$(\sigma_u\sigma_u^2)$. The error term and upgrade characteristic of the consumption structure x_{it} are irrelevant. Based on the distribution assumption of the above-mentioned residual term, the probability density function of the compound residual term § it is deduced below:

$$f(\xi_{it}) = \frac{exp(\alpha_{it})}{\sigma_w + \sigma_u}\Phi(\gamma_{it}) + \frac{exp(\alpha_{it})}{\sigma_w + \sigma_u}\Phi(\gamma_{it})\int_{-\xi_{it}}^{\infty}\varphi(x)$$

$$= \frac{exp(\alpha_{it})}{\sigma_w + \sigma_u}\Phi(\gamma_{it}) + \frac{exp(\alpha_{it})}{\sigma_w + \sigma_u}\varphi(\zeta_{it}) \quad (2)$$

In Formula (2), $\Phi(\bullet)$ is the accumulative distribution function of the standard normal distribution. $\varphi(\bullet)$ is the probability density function and other parameters are set up as $\alpha_{it} = \frac{\alpha_v^2}{2\sigma_w^2} + \frac{\xi_i}{\sigma_w}$; $\beta_{it} = \frac{\alpha_v^2}{2\sigma_u^2} - \frac{\xi_i}{\sigma_u}$; $\gamma_{it} = \frac{\xi_i}{\sigma_v} - \frac{\sigma_v}{\sigma_u}$;$\delta_{it} = \frac{\xi_i}{\sigma_v} - \frac{\sigma_v}{\sigma_w}$. Furthermore, based on the estimation of the above-mentioned parameters, the MLE in n observational value samples can be written as follows:

$$\ln L(X,\pi) = -n\ln(\sigma_w + \sigma_v) + \sum_{i=1}^{n}\ln[e^{it}\Phi(\gamma_{it}) + e^{it}\Phi(\zeta_{it})] \quad (3)$$

in which $\pi = [\beta,\sigma_v, \sigma_w,\sigma_u]$, the maximum likelihood function (3) can be used to get all parameter values of MLE to further deduce the conditional density function of w_{it} and u_{it}:

$$f(w_{it}|\xi_{it}) = \frac{(\frac{1}{\sigma_u} + \frac{1}{\sigma_w})exp[-(\frac{1}{\sigma_u} + \frac{1}{\sigma_w})w_{it}]\Phi(\frac{w_{it}}{\sigma_v} + \zeta_{it})}{exp(\beta_{it} - \alpha_{it})[\Phi(\zeta_{it}) + exp(\alpha_{it} - \beta_{it})\Phi(\gamma_{it})]} \quad (4)$$

$$f(u_{it}|\xi_{it}) = \frac{(\frac{1}{\sigma_u} + \frac{1}{\sigma_w})exp[-(\frac{1}{\sigma_u} + \frac{1}{\sigma_w})u_{it}]\Phi(\frac{u_{it}}{\sigma_v} + \zeta_{it})}{\Phi(\gamma_{it}) + exp(\alpha_{it} - \beta_{it})\Phi(\gamma_{it})} \quad (5)$$

This paper focused on the positive and negative bilateral effect of aging population for the upgrade of the consumption structure. As a result, based on Formula (4) and Formula (5), the degree that aging population promotes or obstructs the upgrade of the actual consumption structure deviates the upgrade of the cutting-edge consumption structure. What is more, this paper changed the deviation degree's absolute value that aging population affects the consumption structure level into the percentage that is higher or lower than the upgrade level of the cutting-edge consumption structure. The transformed estimation value is estimated as follows:

$$E(1 - e^{-w_{it}}|\xi_{it}) = 1 - \frac{(\frac{1}{\sigma_u} + \frac{1}{\sigma_w})[\Phi(\gamma_{it}) + exp(\beta_{it} - \alpha_{it})exp(\frac{\sigma_{it}^2}{2} - \sigma\upsilon\zeta_{it})\Phi(\zeta_{it} - \sigma_\upsilon)]}{[1 - (\frac{1}{\sigma_u} + \frac{1}{\sigma_w})]exp(\beta_{it} - \alpha_{it})[\Phi(\zeta_{it}) + exp(\alpha_{it} - \beta_{it})\Phi(\gamma_{it})} \quad (6)$$

$$E(1 - e^{-u_{it}}|\xi_{it}) = 1 - \frac{(\frac{1}{\sigma_u} + \frac{1}{\sigma_w})[\Phi(\zeta_{it}) + exp(\beta_{it} - \alpha_{it})exp(\frac{\sigma_{it}^2}{2} - \sigma\upsilon\zeta_{it})\Phi(\gamma_{it} - \sigma_\upsilon)]}{[1 - (\frac{1}{\sigma_u} + \frac{1}{\sigma_w})][\Phi(\zeta_{it}) + exp(\alpha_{it} - \beta_{it})\Phi(\gamma_{it})} \quad (7)$$

Furthermore, the net effect (NE) of aging population for the upgrade of the consumption structure can be deduced from Formula (6) and Formula (7):

$$NE = E(1 - e^{-w_{it}}|\xi_{it}) - E(1 - e^{-u_{it}}|\xi_{it})$$
$$= E(e^{-u_{it}} - e^{-w_{it}}|\xi_{it}) \quad (8)$$

Variable selection and data source

Based on the above-mentioned measurement model and data availability, relevant variables can be set up as below:

Explained variable: The upgrade level of the consumption structure

It is believed that when residents' consumption demands are changed from the survival-oriented consumption of food, clothing, and housing to five developmental and enjoyable consumption transformation of traffic communication expenditure, leisure entertainment expenditure, educational expenditure, medical expenditure, and daily service expenditure, it is deemed as the residents' upgrade of consumption structure. Hence, by following and measuring residents' consumption level index—residents' average consumption

TABLE 1 Descriptive statistics of main variables ($N = 558$).

	Variables	Samples	Mean	Standard deviation	Min.	Max.
Dependent variables	Upgrade of consumption structure	558	0.263	0.209	0.014	1.427
Independent variables	Elderly population ratio	558	0.094	0.031	0.007	0.53
	Old-age dependency ratio	558	0.126	0.029	0.067	0.227
Control variables	Per capita disposable incomes	558	13,000	5844.743	5267.42	43,000
	Year-end balance	558	8188.708	8409.492	62.657	60,000
	Child population ratio	558	0.181	0.057	0.05	0.691
	Urbanization level	558	0.48	0.171	0.143	0.896
	Ratio of the tertiary industry	558	0.452	0.088	0.298	0.831
	Internet penetration rate	558	0.308	0.221	0.015	0.87
	Social safeguard level	558	0.027	0.021	0.001	0.178

Data source: Chinese Statistical Yearbook, Chinese Residents' Survey Yearbook, Yearbook of Chinese Population and Employment Statistics, and Statistical Report of Chinese Internet Development Status in previous years.

tendency (the ratio between residents' average consumption expenditure and disposable incomes in each region every year), this paper defined the ratio of traffic communication expenditure, leisure entertainment expenditure, educational expenditure, medical expenditure, and daily service expenditure in residents' disposable income (service product consumption tendency) as the index to measure residents' upgrade of the consumption structure.

Explaining variable: Aging population level

This paper applied the ratio of aging population over 65 years old in the total population. Meanwhile, to further verify the empirical results in this paper, the old-age dependency ratio variable could be used for the robustness test.

By learning from existing relevant studies, control variables selected in this paper mainly included (1) child-rearing ratio which can be measured by the ratio between child population below 14 years old and labor population; (2) urbanization level which can be measured by the ratio of urban population in total population; (3) residents' per capita disposable incomes; (4) residents' deposit balance; (5) social safeguard level; (6) industrial developmental level which can be measured by the ratio between the level of the tertiary industry and gross domestic product (GDP); (7) Internet penetration rate.

Data source and descriptive analysis

This paper selected panel data of 31 provinces in China from 2001 to 2018 as the research samples. Relevant data mainly came from annual data of each province from the National Bureau of Statistics, the Chinese Statistical Yearbook, the Chinese Residents' Survey Yearbook, the Yearbook of Chinese Population and Employment Statistics, and the Statistical Report of Chinese Internet Development Status in previous years. Some deficient data could be supplemented by calculating the annual average growth rate and combining with other relevant data. The main variable information is stated in Table 1.

Empirical results and analyses

The estimation of the bilateral stochastic cutting-edge model

The reference result

Based on the above-mentioned information, this paper estimated the bilateral effect of aging population for the upgrade of the consumption structure from the perspective of Formula (1). The estimation results can be shown in Table 2. Among them, model 1 in the second row refers to the simple OLS estimation. The values from third row to fifth row refer to MLE estimation results, in which the third row is the uncontrollable time and regional fixed effect. The fourth row is the controllable regional fixed effect, and the fifth row is the controllable time fixed effect. The sixth row is the simultaneous time and regional fixed effect. On this basis, the elderly population ratio over 65 years old was introduced while considering the effect of aging population for the upgrade of the consumption structure, in which the seventh row might only consider the unilateral estimation result of aging population for the negative effect of upgrading the consumption structure. The eighth row might be the unilateral estimation result of aging population for the positive effect of upgrading the consumption structure. The ninth row might be the estimation result that might simultaneously consider the bilateral effect of aging population for upgrading the consumption structure. By comparing the maximum likelihood ratio of each model in Table 2, it could be found that the estimation result of model 7 was the

TABLE 2 Basic estimation results of bilateral stochastic cutting-edge model ($N = 558$).

Variables	OLS	MLE (Uncontrollable time and regional effect)	MLE (Controllable regional effect)	MLE (Controllable time effect)	MLE (Controllable time and regional effect)	Negative effect of aging population	Positive effect of aging population	Bilateral effect of aging population
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
Child population ratio	−0.075* (−1.85)	0.0655* (1.89)	0.0704** (1.97)	−0.0801** (−2.06)	−0.0813** (−2.07)	−0.0749** (−1.97)	−0.0956** (−2.15)	−0.0956** (−2.11)
Per capita disposable incomes	−1.0092***	−0.9991***	−0.9994***	−0.9975***	−0.9975***	−0.9976***	−0.9995***	−0.9995***
	(−53.35)	(−61.35)	(−62.25)	(−72.61)	(−74.19)	(−74.05)	(−67.19)	(−67.19)
Year-end balance	0.09*** (7.77)	0.13*** (12.9)	0.12*** (12.24)	0.09*** (9.19)	0.08*** (8.41)	0.08*** (8.35)	0.07*** (7.12)	0.07*** (7.11)
Urbanization level	0.77*** (21.09)	0.87*** (25.58)	0.87*** (25.66)	0.84*** (25.661)	0.83*** (25.65)	0.83*** (26.38)	0.79*** (20.71)	0.79*** (20.68)
The development level of tertiary industry	0.69*** (5.48)	0.66*** (6.21)	0.55*** (4.86)	0.82*** (9.73)	0.71*** (7.59)	0.71*** (7.48)	0.63*** (7.88)	0.63*** (7.85)
Internet penetration rate	0.75*** (6.79)	1.16*** (16.78)	1.19*** (17.17)	0.51*** (5.97)	0.56*** (6.33)	0.57*** (6.47)	0.65*** (7.6)	0.65*** (7.47)
Social safeguard level	−1.57*** (−2.76)	0.48 (1.26)	0.68* (1.71)	−1.94*** (−3.77)	−1.75*** (−3.41)	−1.69*** (−3.44)	−1.61*** (−3.04)	−1.61*** (−2.99)
Regional fixed effect	YES	NO	YES	NO	YES	YES	YES	YES
Time fixed effect	YES	NO	NO	YES	YES	YES	YES	YES
Constant term	7.36*** (30.42)	6.73*** (34.82)	6.85*** (35.01)	7.26*** (40.67)	7.37***(41.1)	7.39*** (41.1)	7.47*** (44.59)	7.47*** (44.44)
Stochastic error term		−2.75*** (−10.35)	−2.82*** (-7.73)	−2.99*** (−11.28)	−3.04*** (−9.2)	−3.01*** (−9.57)	−4.79*** (−3.23)	−4.79*** (−3.23)
Negative effect								
Aging population							−1.54*** (−4.36)	−1.54*** (−4.33)
Constant term		−2.56*** (−18.1)	−2.55*** (−16.9)	−2.87*** (−17.7)	−2.87*** (−16.2)	−2.88*** (−15.9)	−6.49*** (−7.3)	−6.49*** (−7.2)
Positive effect								
Aging population						0.19 (1.13)		0.0006 (0.0033)
Constant term		−1.87*** (-25.2)	−1.86*** (−23.5)	−1.84*** (−28.3)	−1.84*** (−28.1)	−1.38*** (−3.4)	−1.81*** (−34.6)	−1.81*** (−4.4)
Likelihood ratio		3.28	5.79	100.82	108.02	109.32	134.46	134.46
P-value		0.000	0.016	0.000	0.000	0.000	0.000	0.000
Adjusted R	0.95							
Sample size	558	558	558	558	558	558	558	558

Data in the bracket refer to t-value. *, **, and ***, respectively, represent significance in 10, 5, and 1%.

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TABLE 3 Variance decomposition: the positive effect and negative effect of aging population ($N = 558$).

	Variable meaning	Symbols	Measurement coefficient
Influence of aging population	Stochastic error term	σ_v	0.0083
	Negative effect	σ_u	0.0727
	Positive effect	σ_w	0.1632
Variance decomposition	Total stochastic error term	$\sigma_v^2 + \sigma_u^2 + \sigma_w^2$	0.032
	The ratio with the combined influence of positive and negative effect in total variance	$\frac{\sigma_u^2+\sigma_w^2}{\sigma_v^2+\sigma_u^2+\sigma_w^2}$	0.9978
	Negative effect ratio	$\frac{\sigma_u^2}{\sigma_u^2+\sigma_w^2}$	0.1657
	Positive effect ratio	$\frac{\sigma_w^2}{\sigma_u^2+\sigma_w^2}$	0.8343

TABLE 4 Effect estimation of aging population's positive and negative effect affecting the upgrade of the consumption structure ($N = 558$).

Variables	Mean	Variation	25 percentiles	50 percentiles	75 percentiles
Positive effect	14.04	11.53	5.09	9.94	18.98
Negative effect	6.18	4.53	3.71	4.7	6.03
Net effect	7.86	13.65	−0.75	5.78	14.56

most robust (maximum likelihood ratio); thus, the subsequent variance decomposition and effect estimation should be based on model 7.

Variance decomposition: Measurement of the positive and negative effects

According to the regression result of model 8 in Table 2, the promotion and obstruction effect of aging population for the upgrade of the consumption structure is illustrated in Table 3. The estimation results show that aging population exactly shows the positive and negative bilateral effect for the upgrade of the consumption structure. This is consistent with the theoretical hypothesis in this paper, in which the positive effect's estimation coefficient of aging population for the upgrade of the consumption structure was 0.1632 and the negative effect's estimation coefficient was 0.0727, showing that the positive effect was obviously higher than the negative effect. The comprehensive net effect was 0.0905. The further analysis showed that in the influence ratio, the total variable of the stochastic error term that could not be explained by aging population was 0.032 while the ratio in the effect's total variable of the upgrade of the consumption structure to be explained by the bilateral effect of aging population was up to 99.78%, showing that the total utility of aging population explained most parts of the total variable in the upgrade of the consumption structure and verified that aging population exerted the influence on the upgrade of the consumption structure. In total utility of aging population for the upgrade of the consumption structure, aging population's positive effect ratio for the upgrade of the consumption structure was up to 83.43%. The negative effect ratio accounted for 16.57%. The overall results indicated that aging population's positive effect for the upgrade of the consumption structure was greater than that of the negative effect. In this way, the overall upgrade level of the consumption structure was higher than that of the cutting-edge upgrade level of the consumption structure.

The influence degree of aging population for the upgrade of the consumption structure. To further change aging population's deviation degree for the upgrade of the consumption structure level into the percentage that is higher than the cutting-edge upgrade level of the consumption structure level, based on Formulas (6)–(8), it, respectively, represented the positive and negative effects of aging population in this paper. The upgrade of the consumption structure deviated the cutting-edge upgrade level of the consumption structure's net effect percentage distribution characteristics. The results can be shown in Table 4. It can be found from the estimation results of Table 4 that on average, aging population promoted 14.04% for the upgrade of the consumption structure and obstructed 6.18% for the upgrade of the consumption structure. The net effect of their mutual influence made the actual upgrade level of the consumption structure slightly higher than 7.86% of the cutting-edge upgrade level of the consumption structure. In other words, if the cutting-edge upgrade level of the consumption structure is assumed as 100%, the ultimate actual level is 107.86%. Details from the fourth row to the sixth row reported the distribution status of the aging population's positive effect, negative effect,

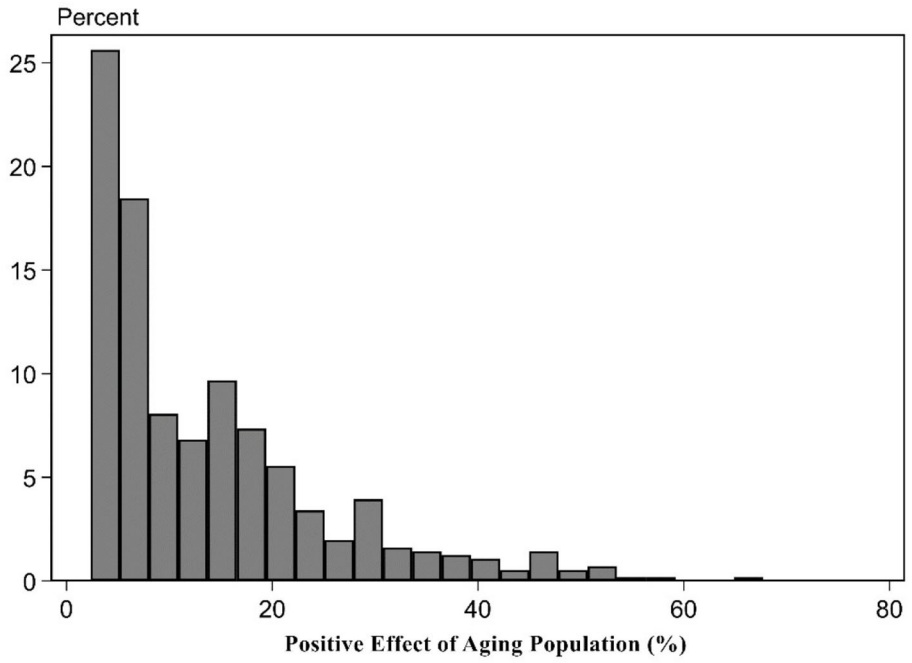

FIGURE 1
Positive effect of aging population.

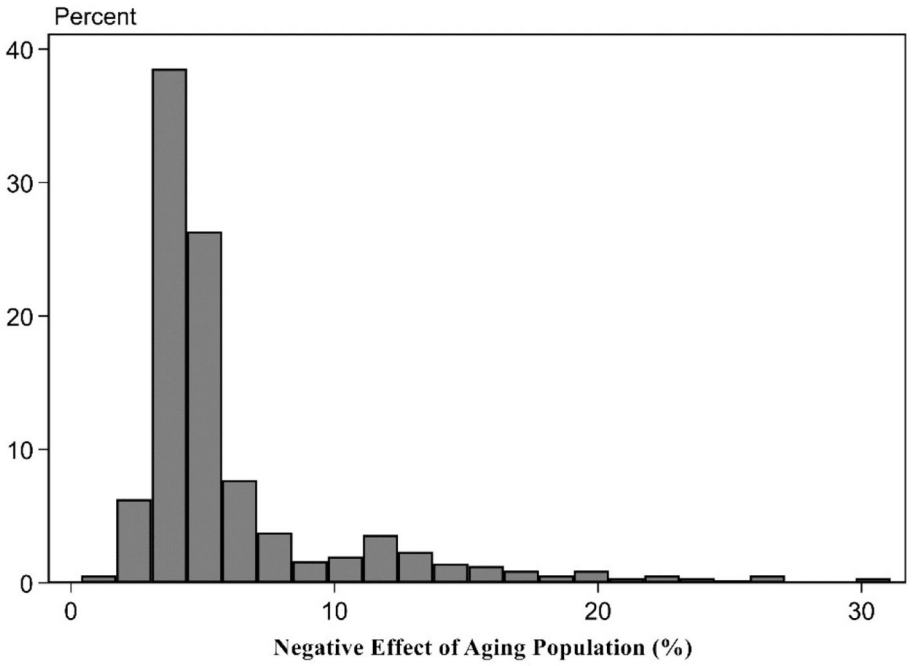

FIGURE 2
Negative effect of aging population.

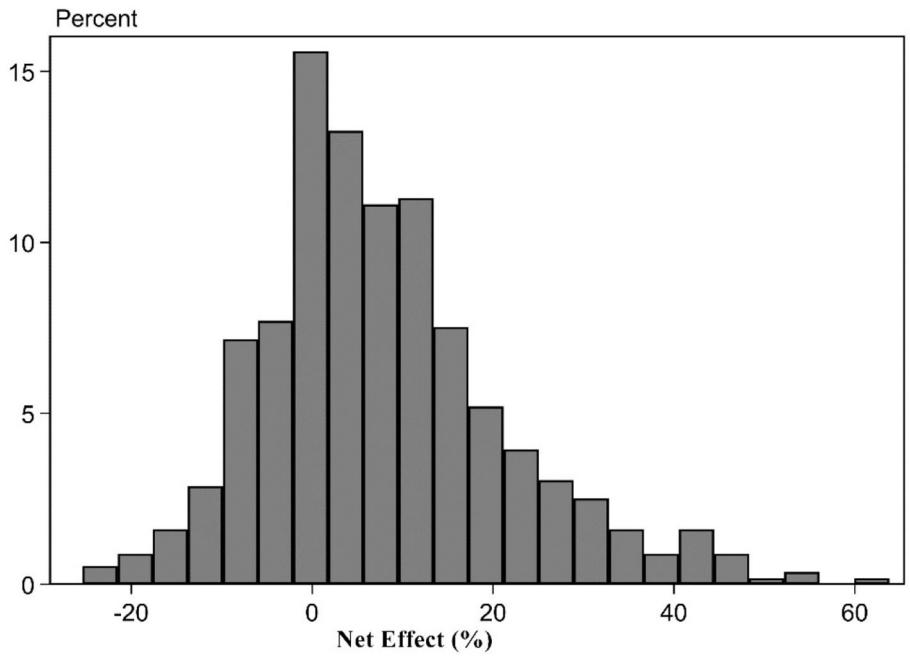

FIGURE 3
Net effect of aging population.

and their net effect. The findings showed the aging population's influence for the upgrade of the consumption structure showed the significant difference. Among them, the estimation results of 25 percentiles indicated that under the combined role of aging population's positive and negative effects, the upgrade of the consumption structure in 1/4 provinces was obstructed so that the actual net effect was lower than 0.75% of the cutting-edge level. The reason is that the economic development of 1/4 provinces lags behind and the industrial development is unsound, showing the small stimulation role for the elderly population consumption. For 50 percentiles, the positive effect of 1/4 provinces exceeded the negative effect so that the ultimate net effect was positive. The actual net effect was higher than 5.78% of the cutting-edge level. For 75 percentiles, the positive effect of 1/4 provinces surpassed the negative effect so that the positive net effect was further improved. The ultimate actual net effect was higher than 14.56% of the cutting-edge level.

This paper displayed the chart of frequency distribution among three of them to intuitively display the positive, negative, and net effect distribution situations for aging population affecting the upgrade of the consumption structure (Figures 1–3). Figures 1, 2 indicated the positive effect and negative effect of aging population performing the distribution characteristics of rightward trailing. Among them, Figure 2 stated that aging population's negative obstruction effect should disappear around 30%. Figure 1 showed that the positive promotion effect of aging population still showed the trailing phenomenon around 50%, showing that the promotion role of aging population for the upgrade of the consumption structure was slightly large. Figure 3 indicated that according to the distribution comparison of positive effect and negative effect of aging population, aging population's negative effect was obviously larger than the ratio of the positive effect.

The time characteristic analysis of aging population net effect

Table 5 exhibits the time distribution characteristics of aging population for the upgrade of the consumption structure. As shown in Table 5, after entering the 21st century, China has entered aging population society. The estimation results of 2001–2008 displayed that the net effect of aging population always showed the positive value, showing the gradually rising trend. However, in the stage of the global financial crisis in 2008, the net effect of aging population dropped. Moreover, since 2008, the net effect of aging population was rising with fluctuations. However, affected by the economic crisis trauma, the growth speed of the overall net effect had the slow speed. However, the overall net effect in previous years always remained the positive value, showing that aging population's promotion effect for the upgrade of the consumption structure always occupied the advantageous position. Meanwhile, according to the quantile results, when each year remained the low quantile

TABLE 5 Annual estimation of aging population for the net effect of the upgrade of the consumption structure ($N = 558$).

Years	Mean	Variation	25 percentiles	50 percentiles	75 percentiles
2001	1.49	16.43	−10.38	0.1	11.05
2002	5.28	15.72	−1.18	5.21	16.95
2003	9.44	13.68	2.66	8.82	17.71
2004	21.67	15.94	12.68	21.23	32.32
2005	6.84	12.71	−2.54	5.23	13.62
2006	7.48	12.98	−2.5	3.1	16.58
2007	8.1	10.24	0.16	7	14.2
2008	0.81	9.32	−6.82	0.55	8.44
2009	3.75	8.73	−1.27	2.23	9.02
2010	3.24	9.08	−2.8	3.12	8.81
2011	4.14	8.2	−0.85	2.9	9.37
2012	5.33	8.64	−0.54	5.79	11.44
2013	33.75	10.11	28.53	33.25	42.66
2014	6.06	10.03	−1.93	4.49	11.96
2015	6.83	9.57	1.11	3.16	12.25
2016	7.9	9.92	0.6	6.66	14.92
2017	5.51	9.63	−0.74	4.28	12.13
2018	3.88	10.5	−3.96	3.62	11.61

level, aging population's upgrade of the consumption structure had the larger obstruction role. Below 25 percentiles, aging population's net effect in half of years should be the negative value. However, with the constant increase in aging population level, the promotion role of aging population for the upgrade of the consumption structure should be more advantageous. Below 75 percentiles, aging population's net effect should be the positive value, showing the aging population level kept enhancing and it would be good for upgrading the consumption structure as a whole.

The regional characteristic analysis of aging population's net effect

Table 6 exhibits the regional distribution characteristic of aging population for the upgrade of the consumption structure. As shown in Table 6, it displayed the aging population's net effect results in the east, the middle, and the west of China by regarding each province and geographical orientation as the foundation for division. According to the effect result comparison of three areas, it could be seen that aging population's net effect in the eastern areas reached the maximum, 9.93%, followed by 9.07% in the western areas, and 3.16% in the middle areas. On this basis, the specific aging population's net effect results in 31 provinces could be further gained. Among all provinces, Zhejiang Province had the maximum aging population's net effect which was 32.22%. Twenty-six provinces had the positive aging population's net effect, with the proportion over 4/5. Five provinces had the negative aging population's net effect, with the proportion <1/5. As a whole, aging population's net effect level performed by five provinces including Xinjiang, Jiangxi, Hebei, Hainan, and Heilongjiang remained the lower level. In other words, aging population's net effect level remained the negative or low level in the northeast and southwest.

By combining with 7th National Population Census Data Results, the elderly population ratio over 65 years old was 13.5%. Among provinces with the low aging population's net effect level, the elderly population over 65 years old in Liaoning (17.42%), Jilin (15.61%), Heilongjiang (15.61%), Hubei (14.59%), and Hebei (13.92%) was higher than the national level. The value of Shanxi (12.9%), Jiangxi (11.89%), Tibet (5.67%), and Hainan (10.43%) was lower than the national level. On the whole, except for Tibet, aging population degree of other provinces remained the relatively high level but did not gain the silver hair economic dividend brought by aging population. The reason is that the northeast including Shanxi is always the heavy industrial base, energy base, and granary of China. In the period before the foundation of China, it has contributed a huge power for China's development and it was once the most developed area in China, showing that northeast has had some economic foundation. However, the corresponding heavy industry occupies an important position in northeast. All the times, the northeast does not make a breakthrough progress in exploring economic transformation and development of the service industry is not perfect, so it cannot effectively develop the elderly market. This may restrict

TABLE 6 Regional estimation of aging population for the upgrade of the consumption structure's net effect ($N = 558$).

Provinces	Mean
Shanghai	15.77
Beijing	7.37
Tianjin	7.14
Shandong	8.96
Guangdong	12.45
Jiangsu	13.38
Hebei	0.9
Zhejiang	32.22
Fujian	11.06
Liaoning	−0.51
East	9.93
Jilin	−0.5
Anhui	1.36
Shanxi	−4.51
Jiangxi	1.79
Henan	7.08
Hubei	−0.03
Hunan	18.37
Heilongjiang	1.01
Middle	3.07
Yunnan	7.67
Inner Mongolia	11.61
Sichuan	5.2
Ningxia	16.38
Guangxi	8.54
Xinjiang	2.61
Hainan	0.48
Gansu	11.27
Tibet	−1.09
Guizhou	6.57
Chongqing	11.93
Shaanxi	12.86
Qinghai	16.33
West	9.16

the consumption structure development of elderly population. What is more, the northeast and southwest have the severe brain drain phenomenon. Particularly, in the southwest like Jiangxi, Tibet, and Hainan, lots of young talents stay outside, resulting in intensifying the difficulty of economic development in both areas. There are many adverse conditions in the geographical position and economic development environment. All of these are not good for the economic development consumption growth. Hubei's industrial strengths are mainly concentrated on the high-tech industry. Hebei's advantageous industry mainly includes agriculture. Relatively speaking, it has the benign foundation to develop the service industry, but the development of relevant industries is still unsound.

Bilateral effect estimation with different aging degrees

Through the above-mentioned empirical analysis, it could be observed that the aging population's positive promotion role for the upgrade of the consumption structure was greater than that of the obstruction role. On this basis, this paper further classified the aging population degrees and explored the constant deepening influence of the aging population degrees on the upgrade of the consumption structure. According to the international standard, when the elderly proportion ratio over 65 years old exceeds 7%, it means that the country enters the aging society. When this ratio surpasses 14%, it implies that the state enters the deep aging society. When this ratio exceeds 21%, it means that it enters the ultra-aging society. Since the maximum elderly population over 65 years old did not exceed 21%, this paper divided aging degrees into 0–7, 7–14%, and 14–21%. It could be observed from the empirical results in Table 7 that as remaining the 0–7% interval of aging population degrees, aging population could positively promote the upgrade of the consumption structure (1%). With the deepening of aging population, when the aging degrees reached 14–20%, aging population positively facilitated the upgrade of the consumption structure (9.05%), showing that the constant deepening of the aging degrees, the aging population's promotion role on the upgrade of the consumption structure kept enhancing.

Bilateral effect degree of different urbanization degrees

Generally speaking, with the enhancement on the urbanization level in an area, on the one hand, it is good for young people to gather to drive consumption growth in this area, improve the regional consumption structure, and reversely neutralize the negative effect brought by aging population. On the other hand, the enhancement on the urbanization level means the comprehensive enhancement of the regional economic developmental level, the developmental level of tertiary industry, and elderly product development degree. The enhancement on the urbanization level can provide more convenient, safer, and more abundant consumption experience for older adults. This can positively stimulate consumption growth of older adults and upgrade the consumption structure for the elderly. To verify this guess, this paper divided the urbanization degree into three levels and verified aging population's effect for the upgrade of the consumption structure under different urbanization degrees.

TABLE 7 Bilateral effect estimation of different aging degrees ($N = 558$).

Elderly population ratio over 65 years old	Mean	Variance	25 percentiles	50 percentiles	75 percentiles
0–7%	1	14.03	−9.62	1.03	10.26
7–14%	8.72	13.35	−0.49	6.69	15.36
14–21%	9.05	10	2.34	4.77	15.35
Total	7.77	13.54	−0.78	5.77	14.51

TABLE 8 Bilateral effect estimation of different urbanization levels ($N = 558$).

Urbanization level	Mean	Variance	25 percentiles	50 percentiles	75 percentiles
0–30%	1	14.03	−9.62	1.03	10.26
30–70%	8.72	13.35	−0.49	6.69	15.36
70%–1	9.05	10	2.34	4.77	15.35
Total	7.77	13.54	−0.78	5.77	14.51

As illustrated in Table 8, under the circumstance with the low urbanization level, aging population's promotion role for the upgrade of the consumption structure was only 1%. With the enhancement of the urbanization level, when the regional urbanization level reached 30–70%, aging population promoted the upgrade of the consumption structure (8.72%); when regional urbanization level surpassed 70%, aging population's promotion role for the upgrade of the consumption structure was 9.05%, showing that with the constant enhancement on the urbanization level, aging population's promotion role for the upgrade of the consumption structure was enhanced accordingly. Improving the urbanization rate could effectively improve aging population's promotion role for consumption and reduce the inhibition role for aging population.

Robustness test

Old-age dependency ratio refers to the specific value between the elderly in non-labor age population and labor age population or it is called the elderly burden coefficient, showing the number of the elderly to be burdened by labor age population in society. This can reveal the social aging degree to some extent. To verify robustness of estimation results, on the basis of the original estimated results, the elderly population ratio above 65 years old was replaced as old-age dependency ratio. Then, the bilateral effect of aging population for the upgrade of the consumption structure was estimated again.

The paper exhibited the estimation result for upgrading the consumption structure by regarding old-age dependency ratio as the main explaining variable. To save the length, the paper directly displayed the bilateral effect result after variance decomposition, as shown in Table 9. The estimation results indicated that old-age dependency ratio showed the positive and negative bilateral effect for the upgrade of the consumption structure, in which old-age dependency ratio showed 0.158 positive effect estimate coefficient for the upgrade of the consumption structure while the negative estimate coefficient was 0.0473. Such a result remained the same with the reference result, verifying the above-mentioned results. Regarding the net effect of old-age dependency ratio, the negative effect of old-age dependency ratio was smaller than that of the positive effect. Similarly, it showed that aging population should be good for 91.68% of the upgrade of the consumption structure. The positive effect of old-age dependency ratio accounted for 91.76%, while the negative effect accounted for 8.24%, showing that old-age dependency ratio's positive role played a dominant role, making the upgrade of the consumption structure positively deviate from the cutting-edge level.

Table 10 shows the positive effect, negative effect, and net effect of old-age dependency ratio for the upgrade of the consumption structure. The findings indicated that with the continuous enhancement on old-age dependency ratio, the positive effect of old-age dependency ratio promoted the upgrade of the consumption structure by 13.61%. The negative effect of old-age dependency ratio reduced the upgrade of the consumption structure by 4.42%. The comprehensive net benefits promoted the actual upgrade of the consumption structure to be higher than that of cutting-edge level by 9.19%.

Conclusion and advice

On the grounds of the above-mentioned analysis, this paper drew the following conclusions: (1) Aging population showed a certain negative and negative bilateral effect for the upgrade of the consumption structure. Moreover, the positive effect of aging population was greater than that of the negative effect. (2)

TABLE 9 Variance decomposition: the positive effect and negative effect of old-age dependency ratio.

	Variable meaning	Symbols	Measurement coefficient
Influence of aging population	Stochastic error term	σ_v	0.0497
	Negative effect	σ_u	0.0473
	Positive effect	σ_w	0.158
Variance decomposition	Total stochastic error term	$\sigma_v^2 + \sigma_u^2 + \sigma_w^2$	0.0297
	Ratio of combined influence of positive effect and negative effect in total variance	$\frac{\sigma_u^2+\sigma_w^2}{\sigma_v^2+\sigma_u^2+\sigma_w^2}$	0.9168
	Negative effect ratio	$\frac{\sigma_u^2}{\sigma_u^2+\sigma_w^2}$	0.0824
	Positive effect ratio	$\frac{\sigma_w^2}{\sigma_u^2+\sigma_w^2}$	0.9176

TABLE 10 Positive effect, negative effect, and net effect estimation of old-age dependency ratio for the upgrade of the consumption structure (N = 558).

Variables	Mean	Variance	25 percentiles	50 percentiles	75 percentiles
Positive effect	13.61	11.15	5.48	9.38	17.84
Negative effect	4.42	3.88	2.13	3.39	5.18
Net effect	9.19	12.53	1.56	6.35	14.27

From the perspective of time effect, under the combined role of aging population's positive and negative effects, the upgrade of the consumption structure was promoted by 7.861% on average every year. (3) Aging population's effect for the upgrade of the consumption structure showed regional heterogeneity. The aging population's positive promotion role in the eastern areas reached the maximum, followed by the western areas, and middle areas were the minimum. The reason is that aging population's net effect of middle areas and western areas includes three provinces of northeast and southwestern areas. (4) With the continuous enhancement of aging population and urbanization level, aging population's promotion effect for the upgrade of the consumption structure enhanced with it. For this reason, the paper put forward the following advice:

First, it is necessary to positively develop economy and promote improvement of the consumption structure according to the circumstances. By estimating net effect of aging population in different provinces, it could be found that provinces with the relatively significant aging population's positive effect mainly included areas with the higher economic developmental level including Zhejiang, Shanghai, Guangdong, and Jiangsu. Hence, it is necessary to facilitate consumption growth under the circumstance of keeping deepening aging population, construct domestic circulation, and promote consumption growth. Under the circumstance, it is essential to develop national economy. Only by remaining faster and better economic development, it can effectively facilitate consumption upgrade. The dramatic drop of aging population's negative effect brought by the economic crisis in 2008 also verified the importance of economic development. What is more, economic development and industrial upgrade of each area should be promoted to the point which is reinforced according to circumstances. On the basis of estimating aging population's net effect of each province, aging population's net effect in southwest and northeast should be dominated by the lower net effect or negative effect. For the southwest with the relatively lagging economy, the regional characteristic economy should be developed. Meanwhile, northeast and Shanxi that have been equipped with favorable industrial foundation should drive development of tertiary industry and realize economic transformation. Hubei can depend on the high-tech industrial strength to realize the organic combination of the pension industry and high-tech industry and help to develop silver hair economy.

What is more, it is essential to develop the perfect elderly consumption market and explore the consumption potential of old groups. China has the large population base and fast aging speed (28). The "silver hair economy" inevitably will become the key of future service industry development. Also, the empirical results also indicated that with the continuous enhancement on aging degree, aging population's promotion role for the upgrade of the consumption structure kept enhancing, showing that aging population contains the huge consumption growth potential. Hence, developing elderly caring products and services, spiritual caring, tourist industry, and leisure products for older adults could be developed with pertinence. Meantime, based on medical healthcare, it is essential to develop products with the cross integration of medical pension combination, medical food combination, medical use combination, and medical accommodation combination, so as to promote growth of other consumption expenditure with medical healthcare.

Lastly, it is necessary to accelerate the urbanization development progress and depend on the Internet to comprehensively stimulate consumption growth. The estimation results of Table 2 found that the urbanization level, Internet penetration rate, and developmental level of tertiary industry showed the significant positive promotion role for the upgrade of the consumption structure. The empirical results also indicated that with the continuous enhancement on the urbanization level, aging population's promotion role for the upgrade of the consumption structure was enhanced. As a result, in future development process, the elderly consumption could be stimulated by keep improving the urbanization level and developmental level of tertiary industry. Meanwhile, the Internet utilization can make consumption realize rapid development through digitalization and networking (29, 30), so as to make safe, convenient, and reliable elderly services. Depending on the Internet technology, safer and more sustainable consumption channels could be created to develop characteristic features of online purchase and door-to-door old consumption and to stimulate elderly consumption growth depending on the sound consumption environment.

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/s.

Author contributions

YW contributed to conception, design of the study, and wrote the first draft of the manuscript. WZ organized the database. WM performed the statistical analysis. All authors contributed to manuscript revision, read, and approved the submitted version.

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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.

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Prediction models and associated factors on the fertility behaviors of the floating population in China

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The floating population has been growing rapidly in China, and their fertility behaviors do affect urban management and development. Based on the data set of the China Migrants Dynamic Survey in 2016, the logistic regression model and multiple linear regression model were used to explore the related factors of fertility behaviors among the floating populace. The artificial neural network model, the naive Bayes model, and the logistic regression model were used for prediction. The findings showed that age, gender, ethnic, household registration, education level, occupation, duration of residence, scope of migration, housing, economic conditions, and health services all affected the reproductive behavior of the floating population. Among them, the improvement duration of post-migration residence and family economic conditions positively impacted their fertility behavior. Non-agricultural new industry workers with college degrees or above living in first-tier cities were less likely to have children and more likely to delay childbearing. Among the prediction models, both the artificial neural network model and logistic regression model had better prediction effects. Improving the employment and income of new industry workers, and introducing preferential housing policies might improve their probability of bearing children. The artificial neural network and logistic regression model could predict individual fertility behavior and provide a scientific basis for the urban population management.

KEYWORDS

floating population, fertility behaviors, prediction, artificial neural network, logistic regression, associated factors

Introduction

The reform and opening-up policy implemented in 1979 promoted China's economic development, and the shifting population driven by the booming economy also expanded swiftly. The floating population referred to new industry workers without local household registration. It was a concept under the household registration system

in China (1). According to a report on the development of the floating population in China, the total number reached 121 million in 2000, accounting for 10 percent of the whole country population at the time, and increased to 245 million in 2016 (2). Most new industry workers moved from rural areas to urban areas or from central and western regions to eastern coastal areas for better job opportunities and living conditions (3).

According to the 2010 census in China, 53.6 percent of the floating population was born in 1980 or later, indicating a high proportion of new industry workers in their reproductive age (15–49 years) (4). The urban fertility rate has been below the replacement level since 1990 in China (5). However, the fertility rate of the floating population was lower than that of those living in both rural and urban areas (4). In the context of low fertility in China, decreasing birth rates would lead to labor constraints (6), economic slowdown (7), lack of innovation, and population aging (8). The floating population was an important labor force in urbanization construction (9). Promoting their fertility behaviors can well-alleviate their poor psychological and social health (10), poor sense of belonging (11, 12), and poor understanding of reproductive health (13), which are closely related to the stability and development of cities. An analysis of married women in China between 1980 and 1992 showed that residence, education level, and coincident marriage affected the first birth interval (14). A study on willingness of the floating population to have a second child in Hunan Province found that the relevant factors of fertility willingness included gender, age, occupation, education level, and marital status (15). Logistic regression, neural networks, and other machine learning models had been used to predict the birth results of pregnant women (16) and live birth results of embryos (17). However, there was still a lack of model research used to predict the fertility behavior of the floating population.

The one-child policy was enacted in 1979 to slow population growth at a time when productivity in China was relatively low, and its population was growing too fast (18). Violators of the policy, which was mainly enforced in cities and densely populated rural areas, could be fined and forced to undergo abortions or sterilizations (19). For nearly 40 years, late marriage, late childbirth, and strict population control became the main tone of fertility policy in the long term. However, with the economic development, the fertility level of China continued to be low, resulting in the imbalance of gender ratio, the weakening of the demographic dividend (20), and the acceleration of population aging (21), which made the transition of fertility policy urgent. On 29 October 2015, China implemented the universal two-child policy (20). However, the response of young couples to the "two-child policy" was not positive, and their willingness to have a second child was not high (22). By 2018, the birth rate of China dropped to its lowest level in 7 decades (23). China might be entering an era of negative population growth, with serious demographic and economic consequences (24). So China introduced the three-child policy in 2021 (25). Population trends were usually defined by fertility rates, which continued to increase after reaching replacement fertility rates (26). In the context of the low fertility rate of China, encouraging marriage and childbearing could increase the fertility rate. The proportion of newborns would gradually increase, while the proportion of the elderly would correspondingly decrease, alleviating the degree of population aging (27). The increase in the fertility rate could provide support for future labor stock, and the goal of sustainable economic development would be achieved (28, 29). The demographic dividend brought by the large proportion of the working-age population could be extended (30, 31).

The Chinese government has been encouraging couples to have more children to curb negative population growth and the aging population, but the implementation of the "two-child policy and three-child policy" requires the cooperation of families and individuals. Given the floating population, a group with a low fertility rate, this study explored the factors affecting the fertility behavior of the floating population, which could be helpful for relevant departments to formulate corresponding policies and measures to promote their fertility behavior, increase the future labor population of the city, and accelerate its construction and development.

According to the 14th Five-Year Plan of the Communist Party of China Central Committee, it is necessary to strengthen the construction of the digital society and digital government and improve the digital intelligence of public services and social governance. Urban population management includes the management of the floating population, family planning, and the quantity and quality of citizens. It could further strengthen the digital construction by relying on the original population information management system. By comparing the effects of three kinds of mathematical models applied to the individualized prediction of the fertility behavior of the floating population, this study selected scientific models to help relevant departments predict the potential population increment brought by new industry workers after they settled down in the local area, identify the individuals with low fertility possibility of the floating population, and take corresponding measures.

Data and methods

Data source and sample

The data used in this study were obtained from the China Migrants Dynamic Survey in 2016, which used a stratified three-stage random sample proportional to the population and collected information in the form of anonymous questionnaires (32). It was a large-scale national sample survey of the floating population conducted by the National Health Commission of China, covering 31 provinces (autonomous regions and municipalities directly under the central government) and

the Xinjiang Production and Construction Corps, where the floating population was highly concentrated, with a sample size of nearly 200,000 households per year. The data covered basic information about the floating population and family members, the extent and length of migration, employment and social security, income and expenditure, residence, basic public health services, marriage, and family planning services and management. This data set was the secondary data collected from the questionnaire survey of the floating population. After removing the samples with unreasonable data and blank data, 168,993 valid questionnaires were obtained. The analyses were in an anonymized form and, consequently, would not be offensive to any individual or community.

Dependent variable

In the research on the correlative factors of fertility behavior, since the data did not meet the conditions of the ordered multi-category logistic regression, it was divided into two binary logistic regressions. In logistic regression of all samples, the question "Do you have children?" was the outcome variable. Then, the samples with children were screened out, and a logistic regression analysis was conducted with the question "Do you have two or more children?" as the outcome variable. The dependent variable was a categorical variable, where "yes" was marked as "1" and "no" as "0."

A multiple linear regression model was applied to study the related factors of the age of first childbearing and birth spacing of the floating population. The time of first birth and the birth interval were used as the dependent variables, which were the continuous variables.

Independent variable

The basic information of the respondents, such as gender and age, were generally included in the model as control variables (33). Some studies suggested that the education level (34) and occupation (35) might affect the fertility behavior of residents. The object of observation in this study was the floating population, so the scope of migration and the duration of residence were also worth noting. Studies showed that new industry workers could change the original fertility pattern and move closer to the fertility behavior of residents in the destination (36, 37). The precondition for new industry workers to settle down was to acquire sufficient material basis, which was closely related to new industry workers' occupation, income (35), and housing (38). In addition, some economists believed that the introduction of social insurance might reduce the population's fertility rate (39). The involvement of healthcare services was required during the reproductive process (40).

Therefore, the independent variables in this study were divided into four aspects: personal information, migration situation, economic conditions, and social services. The study encoded the relevant variables (Table 1). Personal information included gender, ethnic group, registered permanent residence, education level, and occupation. The migration situation included the duration of residence after migration and the migration range of the investigation object. Economic conditions were measured by the level of the city the respondents lived in, their monthly income in the past year, and their real estate, which was measured by whether they bought a house locally. Social services referred to those obtained by the subjects themselves, including insurance services and health services. The former included whether to participate in endowment insurance, unemployment insurance, industrial injury insurance, maternity insurance, and medical insurance. The latter referred to the establishment of residents' health records and whether they have received health education related to occupational diseases, infectious diseases, and mental diseases.

Methods

This study grasped the overall distribution characteristic of the floating population based on the related statistical descriptions. For univariate analysis, logistic regression and multiple linear regression models were used to analyze the influencing factors of fertility behaviors.

In the univariate analysis, the sample was grouped according to whether or not they had children. For the continuous variables with a non-normal distribution and the ordered categorical variable, the rank-sum test was used for comparison between groups. If the independent variable was an unordered categorical variable, the chi-square test was used for comparison between groups.

The aforementioned statistically significant associated factors were incorporated into the logistic regression model for multivariate analysis of fertility behavior. Logistic regression was often used to analyze the related factors of dichotomous outcomes (41, 42):

$$\log\left(\frac{\Pr\left(y=1\right)}{1-\Pr\left(y=1\right)}\right)=\alpha_0+b_1x_1+b_2x_2+\cdots+b_nx_n \quad (1)$$

where $y = 1$ means "yes" and $y = 0$ means "no." $x_1, x_2, \cdots, x_n$ represent the n independent variables in this study; $b_1, b_2, \cdots, b_n$ are the coefficients of each variable; and e^b is equal to the odds ratio (OR). The estimated effect was expressed by OR with 95% confidence interval (CI).

When studying the associated factors of the age of the first birth and birth interval, the multiple linear regression model was established (43–45) with the associated factors as independent

TABLE 1 Coding of categorical variables.

Variable	Code
Duration of settlement	<1 year = 1, 1–2 years = 2, 3–4 years = 3, 5–9 years = 4, 10–14 years = 5, 15–19 years = 6, 20–29 years = 7, ≥30 years = 8*
Scope of migration	Across the county = 1, Across the city = 2, Across the province/nation = 3*
City	Non-first-tier cities = 0, First-tier cities = 1*
Gender	Male = 0, Female = 1*
Ethnic	Non-Han = 0, Han = 1*
Household registration	Non-agriculture = 0, Agriculture = 1*
Marital status	Unmarried = 0, Married = 1*
Education level	No formal education = 1, Primary school = 2, Junior high school = 3, High school = 4, Junior college = 5, Undergraduate = 6, Postgraduate = 7*
Occupation status	Unemployed = 1, Employee = 2, Employer = 3, Self-employed worker = 4, Blue-collar worker = 5*
Housing	Rent or others = 0, Self-occupation = 1*
Having children	No = 0, Yes = 1
Having two or more children	No = 0, Yes = 1

*Control group.

variables, and the age of the first birth or birth interval as dependent variables.

According to the aforementioned factors, the artificial neural network and naive Bayes models could be established. The first M = 90,000 samples were selected as the training set, and the remaining samples as the test set. The correlation coefficients of each model were trained to the optimal by using the training set.

The artificial neural network (ANN) (46) could be regarded as the simulation of the human brain nervous system. Dendrites were responsible for receiving input signals, and neurons were responsible for processing input signals. Then, they were transmitted to the next layer of neurons through synapses and continued to output after processing. The ANN model constructed in this study included input, two-layer activation function (hyperbolic tangent S-shaped function and linear function), and output (Figure 1).

The naive Bayes model (47, 48) was based on the Bayes theorem to calculate the possibility of each outcome in the case of fixed features to select the outcome with the highest possible as the predicted value. The logistic regression model (49) could estimate the probability that samples with various attribute values belonging to a certain category. Logistic regression used the likelihood function as the training function, and the maximum likelihood estimate obtained was the predicted value of model coefficients (50).

For each model with the best parameters obtained by training, feature vectors of the test set were inputted to output its prediction results, and the accuracy rate (ACC), precision rate (PRE), and recall rate (REC) of the model were calculated to measure the prediction effects of models to select the optimal model.

where TP is the number of true-positive cases, TN is the number of true-negative cases, FP is the number of false-positive cases, and FN is the number of false-negative cases.

Statistical analysis methods

Continuous data with normal distribution were described by the mean and standard deviation. Continuous data with non-normal distribution were represented by the median and inter-quartile range (IQR). Classified data were described by using relative numbers. The rank-sum test of independent samples was used to process univariate analysis of continuous data with the non-normal distribution. Logistic regression and multiple linear regression models were used to analyze the related factors of fertility behaviors. The univariate analysis and multivariate analysis were processed by IBM SPSS Statistics 24. The artificial neural network and naive Bayes models could be conducted by MATLAB R2020a. The $P \leq 0.05$ was considered statistically significant.

Results

Basic information

A total of 168,993 valid questionnaires were obtained in this study. The average age of the subjects was 39 years, with an inter-quartile range of 15 years. The local average monthly income in the previous year was 5500 CNY, with an inter-quartile range of 4000 CNY. The average insurance points was 2, with an inter-quartile range of 1. The average health service points was 6, with an inter-quartile range of 6. Descriptive statistics about the geographic location and demographic characteristics showed that 82.19% of subjects were residents from rural zones; 52.12% were male; 83.07% were married; 91.78% were Han; 61.71% had a junior high school education or less; 73.86% of the new industry workers had been away for <10 years; 46.95% were employees; 48.40% of the new industry workers crossed provinces or nations; and 72.32% of new industry workers rent houses in their city of residence (Table 2).

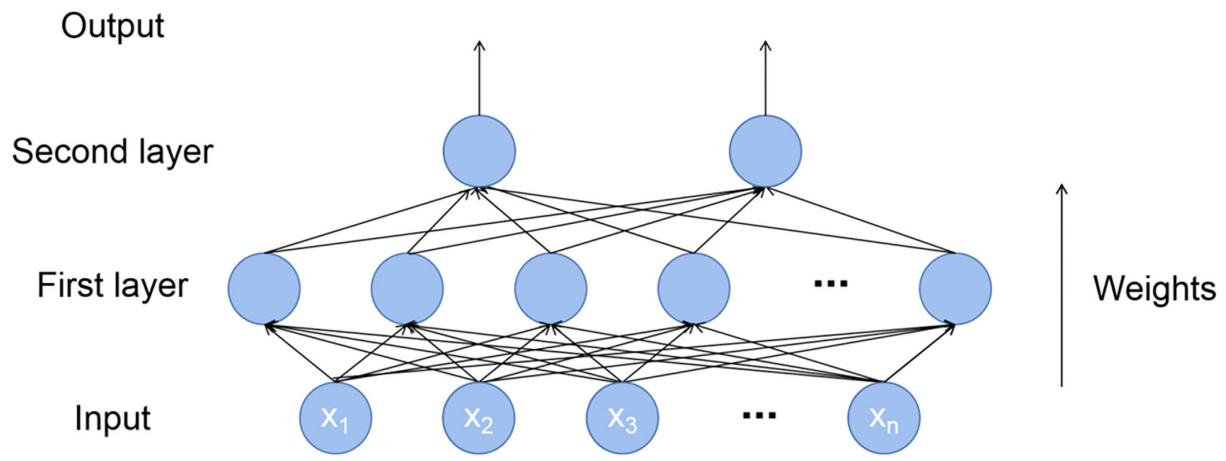

FIGURE 1
Structure of artificial neural network model (ANN).

Univariate analysis

The findings showed that the distribution of the variables mentioned earlier was different between the populace without children and with children, and the difference was statistically significant, including age ($u = -215.36$, $P < 0.05$), monthly income ($u = -78.39$, $P < 0.05$), insurance services ($u = -4.91$, $P < 0.05$), and health services ($u = -7.03$, $P < 0.05$). The duration of settlement ($u = -88.48$, $P < 0.05$), scope of migration ($u = -13.48$, $P < 0.05$), settlement ($\chi^2 = 33.47$, $P < 0.05$), ethnic ($\chi^2 = 199.40$, $P < 0.05$), household ($\chi^2 = 374.25$, $P < 0.05$), marital status ($\chi^2 = 106641.67$, $P < 0.05$), education ($u = -133.30$, $P < 0.05$), occupation ($u = -49.16$, $P < 0.05$), and housing ($\chi^2 = 1718.00$, $P < 0.05$) statistically correlated with fertility behaviors of the floating population (Table 3).

Multivariate analysis

The number of biological children born in the floating population was taken as the outcome variable in this model. However, this model did not pass the test of parallel lines. Therefore, two binary logistic models were chosen to analyze the related factors. In the model of one-birth behavior, the sample range was all the respondents, and the model was established with whether they had biological children as the outcome variable. The survey scope in the model of the second-child fertility behavior was all the survey subjects who had children, and the model was established with whether they were to have a second child as the dependent variable.

Factors related to fertility behavior of the floating population include age ($\chi^2 = 2578.01, P < 0.05$), gender ($\chi^2 = 62.07, P < 0.05$), ethnic group ($\chi^2 = 27.22, P < 0.05$), household registration ($\chi^2 = 156.61, P < 0.05$), marital status ($\chi^2 = 15581.80, P < 0.05$), education level ($\chi^2 = 1908.52, P < 0.05$), occupation ($\chi^2 = 308.26, P < 0.05$), duration of residence ($\chi^2 = 1355.19, P < 0.05$), scope of migration ($\chi^2 = 91.13, P < 0.05$), settlement ($\chi^2 = 107.82, P < 0.05$), and monthly household income ($\chi^2 = 109.53, P < 0.05$) (Table 4). In particular, female new industry workers were more likely to have children than men (OR = 0.85, 95% CI: 0.81–0.88). The odds of new industry workers having children increased with age (OR = 1.08, 95% CI: 1.077–1.084). The odds of non-Han new industry workers bearing children were less than those of Han new industry workers (OR = 0.83, 95% CI: 0.77–0.89). The odds of the new industry workers with non-agriculture household registration had less active reproductive behavior than those with agriculture household registration (OR = 0.72, 95% CI: 0.68–0.76). In addition, new industry workers with better economic conditions (OR = 1.24, 95% CI: 1.19–1.29) were more likely to have children. Fertility behavior and education level show an inverted U-shaped distribution. Under junior high school, the higher the education level, the more the childbirth. However, for the new industrial workers whose education level is junior high school or above, the higher the education level, the fewer the childbirth. New industrial workers with junior high school education had 6.07 times as many children as those with postgraduate (OR = 6.07, 95% CI: 5.06–7.29).There is no statistical difference in the fertility behavior of employee and blue-collar workers (OR = 1.08, 95% CI: 0.93–1.25), but the fertility behavior of employers (OR = 1.29, 95% CI: 1.09–1.52), self-employed workers (OR = 1.77, 95% CI: 1.51–2.07), and the unemployed (OR = 1.41, 95% CI: 1.21–1.65) is higher than that of blue-collar workers. The number of children born to new industrial workers living in non-first-tier cities was 1.4 times that

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TABLE 2 Basic information of the floating population.

Variables		*n*	Constituent ratio (%)
Age			39 (15)*
Gender	Male	88,085	52.12
	Female	80908	47.88
Ethnic	Non-han	13,883	8.22
	Han	155,110	91.78
Household	Non-agriculture	30,106	17.81
	Agriculture	138,887	82.19
Marital status	Unmarried	28,604	16.93
	Married	140,389	83.07
Education level	No formal education	3,114	1.84
	Primary school	21,735	12.86
	Junior high school	79,443	47.01
	High school	37,680	22.30
	Junior college	16,509	9.77
	Undergraduate	9,704	5.74
	Postgraduate	808	0.48
Occupation	Unemployed	30,828	18.24
	Employee	79,349	46.95
	Employer	12,042	7.13
	Self-employed worker	44,213	26.16
	Blue collar worker	2,561	1.52
Duration of settlement (year)	<1	15,480	9.16
	1-	30,538	18.07
	3-	30,803	18.23
	5-	47,992	28.40
	10-	23,616	13.97
	15-	13,074	7.74
	20-	6,858	4.06
	30-	632	0.37
Scope of migration	Across the county	29,767	17.61
	Across the city	57,431	33.98
	Across the province/nation	81,795	48.40
Settlement	Non-first-tier cities	150,995	89.35
	First-tier cities	17,998	10.65
Housing	Rent or others	122,215	72.32
	Self-occupation	46,778	27.68
Monthly income			5,500 (4,000)*
Insurance services			2 (1)*
Health services			6 (6)*

*Value with an asterisk was median (IQR).

of those living in first-tier cities (OR = 1.40, 95% CI: 1.31–1.49) (Table 4).

Further analysis findings showed that the migrant population with non-agricultural household registration has about half the number of second children as the migrant population with agricultural household registration (OR = 0.51, 95% CI: 0.49–0.53). New industry workers with lower education levels were more motivated to have a second child. Age (OR = 1.04, 95% CI: 1.040–1.043) and household income (OR = 1.07, 95% CI: 1.05–1.09) were positively correlated with the likelihood of having a second child among the floating population. Meanwhile, the odds of the non-Han floating population giving birth to a second child was 1.42 times that of the Han floating population (OR = 1.42, 95% CI: 1.36–1.49). New industry workers living in non-first-tier cities were more likely to have a second child than those dwelling in first-tier cities (OR = 1.12, 95% CI: 1.08–1.17) (Table 5).

Related independent variables were included in the multiple linear regression model, and it was found that there was no statistical relationship between monthly income and outcome variables. The factors that were positively correlated with the age of the first childbearing were insurance, health service, age, education, and housing property (Table 6). The age of first birth increased by 0.98 (95% CI: 0.95–1.00) years on average for each rank of education. The duration of settlement after migration (b = −0.03, $P < 0.05$) and the migration scope (b = −0.07, $P < 0.05$) were negatively correlated with the age of the first childbearing significantly. The first childbearing age of new industry workers living in first-tier cities was 0.338 years later than that of non-first-tier cities on average. The initial childbearing age of agricultural accounts was 0.62 (95% CI: 0.56–0.67) years earlier than that of non-agricultural accounts. Han new industry workers had one child 0.35 (95% CI: 0.28–0.43) years earlier than non-Han new industry workers on average. The age of the first birth of the female floating population is 1.49 (95% CI: 1.45–1.53) years earlier than that of the male floating population.

Insurance, health service, the duration of settlement after migration, age, and education were positively correlated with birth interval. In addition, the interval between multiple births of the floating population living in first-tier cities was 0.19 (95% CI:0.09–0.29) years shorter than that living in non-first-tier cities on average. The range of migration was a significant negative correlation factor, and the birth interval decreased by 0.05 (95% CI: 0.02–0.09) years for every one unit of migration scope increase (Table 6).

Prediction model

The statistically significant factors mentioned previously were incorporated into the prediction models of fertility behavior of the floating population. A total of 90,000 samples

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TABLE 3 Univariate analysis on fertility behavior of the floating population.

Variable		Having children	Childless	Statistic	P
Age		45 (13)	30 (8)	−215.36*	<0.001
Gender	Male	31,008	57,077	0.77	0.379
	Female	26,545	54,363		
Ethnic	Non-han	5,234	8,649	199.40	<0.001
	Han	52,319	102,791		
Household registration	Non-agriculture	5,897	24,209	374.25	<0.001
	Agriculture	51,656	87,231		
Marital status	Unmarried	189	28,415	106,641.67	<0.001
	Married	57,364	83,025		
Education level	No formal education	2,068	1,046	−133.30*	<0.001
	Primary school	12,736	8,999		
	Junior high school	31,557	47,886		
	High school	8,722	28,958		
	Junior college	1,771	14,738		
	Undergraduate	641	9,063		
	Postgraduate	58	750		
Occupation	Unemployed	11,028	19,800	−49.16*	<0.001
	Employee	19,873	59,476		
	Employer	4,918	7,124		
	Self-employed worker	20,877	23,336		
	Blue collar worker	857	1,704		
Duration of settlement (year)	<1	3,147	12,333	−88.48*	<0.001
	1-	6,946	23,592		
	3-	8,843	21,960		
	5-	17,088	30,904		
	10-	10,662	12,954		
	15-	6,699	6,375		
	20-	3,809	3,049		
	30-	359	273		
Scope of migration	Across the county	10,102	19,665	−13.48*	<0.001
	Across the city	17928	39503		
	Across the province/nation	29,523	52,272		
Settlement	Non-first-tier cities	52,331	98,664	33.47	<0.001
	First-tier cities	5,222	12,776		
Housing	Rent or others	42,871	79,344	1,718.00	<0.001
	Self-occupation	14,682	32,096		
Monthly income		5,800 (4,000)	4,500 (4,000)	−78.39*	<0.001
Insurance services		2 (1)	2 (3)	−4.91*	<0.001
Health services		6 (5)	6 (6)	−7.03*	<0.001

*Value with an asterisk was u *value*, and the others were χ^2 value.

were retained as training data sets to fit the models, and the remaining samples were used as validation data sets to measure the prediction accuracy of the models. The results showed that the accuracy of the naive Bayes model was slightly inferior to that of the artificial neural network and logistic regression models. The artificial neural network and logistic regression models had better prediction effects, with an accuracy of 93.3% and a recall rate higher than 92.0% (Table 7). Therefore, it was more accurate to predict the fertility behavior of the floating population by using the artificial neural network model and the logistic models,

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TABLE 4 Associated factors of the one-birth fertility behaviors of floating population.

Variable		*b*	$s_{\bar{x}}$	Wald χ^2 Value	*P*	OR (95%CI)
Age		0.077	0.002	2,578.014	0.000	1.08 (1.08–1.08)*
Gender						
	Female					1.00
	Male	−0.169	0.021	62.065	0.000	0.85 (0.81–0.88)
Ethnic						
	Han					1.00
	Non-han	−0.190	0.036	27.222	0.000	0.83 (0.77–0.89)
Household registration						
	Agriculture					1.00
	Non-agriculture	−0.331	0.026	156.607	0.000	0.72 (0.68–0.76)
Marital status						
	Married					1.00
	Unmarried	−5.686	0.046	15,581.804	0.000	0.00 (0.00–0.00)$
Education				1,908.521	0.000	
	Postgraduate					1.00
	Undergraduate	0.302	0.090	11.162	0.001	1.35 (1.13–1.62)
	Junior college	0.644	0.091	50.402	0.000	1.91 (1.59–2.28)
	High school	1.213	0.092	174.238	0.000	3.36 (2.81–4.03)
	Junior high school	1.804	0.093	376.859	0.000	6.07 (5.06–7.29)
	Primary school	1.678	0.101	278.739	0.000	5.36 (4.40–6.52)
	Uneducated	0.925	0.127	53.000	0.000	2.52 (1.97–3.24)
Occupation				308.264	0.000	
	Blue-collar worker					1.00
	Self-employed worker	0.571	0.080	51.170	0.000	1.77 (1.51–2.07)
	Employer	0.253	0.085	8.763	0.003	1.29 (1.09–1.52)
	Employee	0.075	0.077	0.960	0.327	1.08 (0.93–1.25)
	Unemployed	0.345	0.080	18.503	0.000	1.41 (1.21–1.65)
Duration of residence (year)				1,355.192	0.000	
	≥30					1.00
	20–29	0.583	0.257	5.137	0.023	1.79 (1.08–2.97)
	15–19	0.709	0.250	8.022	0.005	2.03 (1.24–3.32)
	10–14	0.741	0.248	8.949	0.003	2.10 (1.29–3.41)
	5–9	0.395	0.247	2.562	0.109	1.48 (0.92–2.41)
	3–4	0.140	0.247	0.322	0.570	1.15 (0.71–1.87)
	1–2	−0.218	0.247	0.781	0.377	0.80 (0.50–1.30)
	<1	−0.504	0.248	4.134	0.042	0.60 (0.37–0.98)
Scope of migration				91.127	0.000	
	Across the province/nation					1.00
	Across the city	−0.011	0.024	0.227	0.634	0.99 (0.94–1.04)
	Across the county	0.269	0.031	73.556	0.000	1.31 (1.23–1.39)
Settlement						
	First-tier cities					1.00
	Non-first-tier cities	0.336	0.032	107.818	0.000	1.40 (1.31–1.49)
Housing						
	Self-occupation					1.00
	Rent or others	−0.002	0.024	0.010	0.920	1.00 (0.95–1.05)
Monthly income ($y10^4 yuan$)		0.217	0.021	109.530	0.000	1.24 (1.19–1.29)
Insurance services		0.001	0.006	0.056	0.813	1.00 (0.99–1.01)
Health services		0.004	0.002	3.288	0.070	1.00 (1.00–1.01)
Constant		−2.735	0.286	91.234	0.000	-

*1.081 (1.077–1.084), $0.003 (0.003–0.004).

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TABLE 5 Associated factors of the two-children fertility behaviors of floating population.

Variable		*b*	$s_{\bar{x}}$	Wald χ^2 Value	*P*	OR (95%CI)
Age		0.041	0.001	3,420.320	0.000	1.04 (1.04–1.04)*
Gender						
	Female					1.00
	Male	0.021	0.013	2.620	0.106	1.02 (1.00–1.05)
Ethnic groups						
	Han					1.00
	Non-han	0.352	0.023	234.117	0.000	1.42 (1.36–1.49)
Household registration						
	Agriculture					1.00
	Non-agriculture	−0.672	0.019	1,194.058	0.000	0.51 (0.49–0.53)
Marital status						
	Married					1.00
	Unmarried	−0.365	0.095	14.826	0.000	0.69 (0.58–0.84)
Education				2,402.741	0.000	
	Postgraduate					1.00
	Undergraduate	−0.241	0.149	2.600	0.107	0.79 (0.59–1.05)
	Junior college	0.051	0.146	0.123	0.726	1.05 (0.79–1.40)
	High school	0.518	0.145	12.803	0.000	1.68 (1.26–2.23)
	Junior high school	0.925	0.145	40.764	0.000	2.52 (1.90–3.35)
	Primary school	1.277	0.146	76.648	0.000	3.59 (2.69–4.77)
	Uneducated	1.528	0.152	101.060	0.000	4.61 (3.42–6.21)
Occupation				833.195	0.000	
	Blue-collar worker					1.00
	Self-employed worker	0.242	0.051	22.037	0.000	1.27 (1.15–1.41)
	Employer	0.181	0.055	10.909	0.001	1.20 (1.08–1.33)
	Employee	−0.183	0.051	12.745	0.000	0.83 (0.75–0.92)
	Unemployed	−0.017	0.052	0.105	0.745	0.98 (0.89–1.09)
Duration of residence (year)				1,137.891	0.000	
	≥30					1.00
	20–29	0.233	0.092	6.477	0.011	1.26 (1.06–1.51)
	15–19	0.337	0.090	14.047	0.000	1.40 (1.18–1.67)
	10–14	0.234	0.089	6.861	0.009	1.26 (1.06–1.50)
	5–9	0.024	0.089	0.075	0.785	1.03 (0.86–1.22)
	3–4	−0.155	0.089	3.005	0.083	0.86 (0.72–1.02)
	1–2	−0.314	0.090	12.318	0.000	0.73 (0.61–0.87)
	<1	−0.228	0.091	6.220	0.013	0.80 (0.67–0.95)
Scope of migration				132.464	0.000	
	Across the province/nation					1.00
	Across the city	−0.161	0.014	127.673	0.000	0.85 (0.83–0.88)
	Across the county	−0.110	0.017	40.266	0.000	0.90 (0.87–0.93)
Settlement						
	First-tier cities					1.00
	Non-first-tier cities	0.117	0.022	28.577	0.000	1.12 (1.08–1.17)
Housing						
	Self-occupation					1.00
	Rent or others	0.294	0.014	422.766	0.000	1.34 (1.30–1.38)
Monthly income ($\times 10^4$ *yuan*)		0.071	0.010	50.731	0.000	1.07 (1.05–1.09)
Insurance services		−0.005	0.005	1.060	0.303	1.00 (0.99–1.00)
Health services		−0.002	0.001	2.417	0.120	1.00 (1.00–1.00)
Constant		−3.033	0.182	278.380	0.000	-

*1.042 (1.040–1.043).

TABLE 6 Associated factors of age at first childbearing and birth interval of floating population.

	Age at first childbearing					Birth interval				
	b	$s_{\bar{x}}$	*t*	*P*	95%CI	*b*	$s_{\bar{x}}$	*t*	*P*	95%CI
Constant	19.882	0.098	202.133	0.000	19.69–20.08	2.721	0.142	19.223	0.000	2.44–3.00
Age (year)	0.090	0.001	80.190	0.000	0.089–0.092	0.016	0.002	10.057	0.000	0.01–0.02
Gender	−1.492	0.021	−72.791	0.000	−1.53– −1.45	0.065	0.029	2.214	0.027	0.01–0.12
Ethnic groups	−0.351	0.038	−9.234	0.000	−0.43– −0.28	0.430	0.050	8.580	0.000	0.33–0.53
Household	−0.615	0.030	−20.422	0.000	−0.67– −0.56	0.128	0.050	2.555	0.011	0.03–0.23
Education	0.976	0.012	79.792	0.000	0.95–1.00	0.100	0.019	5.309	0.000	0.06–0.14
Duration of settlement	−0.034	0.007	−4.915	0.000	−0.05– −0.02	0.120	0.009	12.909	0.000	0.10–0.14
Scope of migration	−0.066	0.014	−4.746	0.000	−0.09– −0.04	−0.054	0.020	−2.766	0.006	−0.09– −0.02
Settlement	0.338	0.035	9.599	0.000	0.27–0.41	−0.186	0.052	−3.607	0.000	−0.29– −0.09
Monthly income($\times 10^4$ *yuan*)	−0.005	0.005	−0.906	0.365	−0.02–0.01	0.001	0.005	0.095	0.924	−0.01–0.01
Housing	0.112	0.023	4.815	0.000	0.07–0.16	0.272	0.034	7.997	0.000	0.21–0.34
Insurance services	0.097	0.007	14.442	0.000	0.08–0.11	0.044	0.011	3.995	0.000	0.02–0.07
Health services	0.009	0.002	3.834	0.000	0.00–0.01	0.011	0.003	3.301	0.001	0.00–0.02

TABLE 7 Comparison of the prediction effect on three models.

Model	ACC	PRE	REC
Artificial neural network	0.933	0.920	0.997
Naive bayes	0.909	0.933	0.947
Logistic regression	0.933	0.921	0.996

which included the independent variables of personal status, the duration of settlement after migration, migration scope, economic conditions, and social services.

Discussion

As the total fertility rate of China had been declining, the family planning policy was changed into a two-child policy and, subsequently, three-child policy, which has become a current hot topic in society (51). In addition, the fertility rate of the floating population was lower than that of residents, so it was necessary to pay attention to the fertility situation of the floating population. The birth of the floating population was related to the urban construction and development. However, at present, there are few research studies on the factors affecting the fertility of the floating population, and the corresponding prediction models are also relatively lacking.

This study showed that personal status, the duration of settlement, scope of migration, economic conditions, and social services all influence the reproductive behavior of the floating population. For details, Han new industry workers were more likely to give birth to one child and less likely to give birth to two children than non-Han new industry workers. Migrant farmers were more active in childbearing and have children earlier on average. People with junior high school education were the most likely to have a child, showing a U-shaped pattern that first increased and then decreased. However, in terms of having a second child, the less educated new industry workers were more motivated to give birth. Higher educational attainment was associated with a later age at first birth and a larger spacing between births. Employers were much more likely to have children than blue-collar workers.

New industry workers who had settled for more than 10 years after emigration were more active in their reproductive behavior. The improvement of family economic conditions had a positive influence on the fertility behavior of new industry workers. The influence of monthly income on the second child was less than that of the first child. The new industry workers in first-tier cities were less likely to give birth to a kid and more likely to delay childbearing. New industry workers who owned property locally were far less likely to have a second child. Improvements in insurance and health services might be associated with later age at first birth and longer intervals between births.

A study of women's health in Texas found that an increase in clinics around the house would lead to an increase in fertility (52). At the first International Symposium on West African Studies, experts pointed out that improving the current situation of maternal and child health service supply in China could improve the fertility desire of the population of childbearing age (53). Combined with these studies, it could be concluded that the fertility desire of residents could be improved by bettering social medical services.

The health insurance reform has reduced the cost of pregnancy, which might increase the fertility rate of married

women aged 20–34 years by about 1% (54). Insurance services in this study did not have a statistically significant effect on the fertility rate of new industry workers. This might be related to the unsatisfactory social security coverage of Chinese new industry workers (55) and the geographical limitations of some medical insurance (56, 57). Household income correlated closely with the number of children in metropolitan areas of the United States (58). People with better personal economic conditions expected more children. Also, in countries and regions with high economic status, the fertility rate of local women was relatively higher (59). Therefore, it supported the result that the increase in family income could promote reproductive behavior. People with higher education would delay marriage to some extent, resulting in a lower fertility rate (60). The human capital theory suggested that investment in education might produce marriage market returns (61). However, the higher demand for marriage partners among highly educated people, coupled with the huge cost of marriage caused by soaring property prices in China, might have reduced the desire of this group to get married, thus lowering the fertility rate. Consistent with this conclusion, people with higher education backgrounds were less likely to get married than those with a high school diploma, according to the Chinese Family Group Study (62).

A study on the ex-pat effect of a Maya Population from rural Guatemala found that new industry workers had their first babies earlier but had lower fertility rates, which could be attributed in part to stress (63), which explained the negative correlation between the migration range and the age of the first childbearing in this study, to some extent. After settling down for more than 10 years after migration, the immigrants' reproductive behavior was more active. This might be related to their wealth accumulation and improved quality of life.

First-tier cities and high housing prices might be important factors in decreasing fertility rates and delaying childbirth (64, 65). New industry workers who had their own houses in first-tier cities had spent longer time accumulating wealth in the past, thus delaying their childbearing. A study on Korean couples found that families living in non-metropolitan areas and renting houses had more active fertility behavior, which might be related to the family's housing requirements and the length of time spent to meet these demands (65). It was also confirmed by the results of our study. More preferential policies for renting or buying property might provide economic stability for new industry workers' initial settlement and meet their housing needs to promote the fertility rate. The difference between the rural floating population and non-agricultural fertility behavior might be related to the one-child policy of China announced in 1979. The policy was first strictly carried out in Shanghai and other big cities, while the implementation strategy was relaxed in the rural population with certain flexibility (66). Moreover, the concept of "raising children for old age" was deeply rooted in the rural population, and its fertility desire was stronger than that in the urban population.

In terms of employment, employment opportunities in first-tier cities were more attractive to the floating population (67), and it was more necessary to protect the basic rights and interests of new industry workers, such as income, and maintain their employment stability by building harmonious labor relations (68). In addition, it was necessary to improve the affordability of urban housing (69) and bring more new industry workers into the security scope of public rental housing and the community service system. Moreover, welfare policies such as housing subsidies could promote the settlement of the floating population (70). It was also suggested that their enthusiasm be increased to participate in insurance by expanding the coverage of work-related injury insurance (71), endowment insurance (72), and medical insurance (73, 74). Referring to medical and health services, integrating the floating population into the community health services, strengthening the maternal healthcare system, and adjusting the number of subsidies could improve the fertility rate of the floating population (75).

According to the associated factors obtained by the regression models, neural network, naive Bayes, and Logistic regression models were applied to predict the fertility behavior of the floating population. It was found that artificial neural networks and logistic regression could predict marriage and childbearing behavior of the floating population more effectively. This might be related to the assumption that the naive Bayes model needed to satisfy the independence of each feature vector (76).

Logistic regression used the logic function of a linear combination of numerical features to model the logarithmic probability of each category (77). Neural networks had low requirements for data. An artificial neural network consisted of an input layer, a hidden layer, and an output layer, with each linked to an earlier layer and each layer linked to another layer. In this study, we specified a hidden layer, a hyperbolic tangent, as the activation function and the identity activation function of the output layer and determined the model when the optimal difference of fitting conditions between the training set and test set was obtained (78). Among them, the performance of the ANN was superior to other networks in the field of medical prediction tasks (79). Accurate prediction of population fertility could reveal the trend of urban population growth, facilitate urban population management and construction, and benefit social stability and prosperity. Therefore, based on the information on the floating population's identity, the duration of settlement and migration scope, economic conditions, and social services, it was suggested that an artificial neural network and logistic regression be applied to predict fertility behavior, and the model coefficients be updated in time according to real-time data.

The study also had some limitations. The data set of Floating Population Dynamic Monitoring Survey of China in 2016 needed to be further supplemented by longitudinal follow-up data. In the analysis of related factors, regression analysis was used in this study, focusing on the dependence between variables. The causal relationship should be further explored to guide practical application.

In conclusion, the factors related to the reproductive behavior of the floating population were complex, such as social health services, family income, and urban living burden. We recommend the expansion of social health and insurance services, the promotion of employment and income levels of new industry workers, and the introduction of preferential policies for settling down. Furthermore, we should not blindly stimulate marriage and childbearing for the sake of urban population development. Due to the promotion of eugenics and the improvement of social construction such as insurance, people would no longer emphasize the number and speed of birth. Instead, they might pay more attention to the education and cultivation of the next generation. By incorporating the multi-factor analysis, the statistically significant correlation factors of personal status, the duration of settlement after migration and migration scope, economic conditions, and social services could be obtained. The artificial neural network model and logistic model with better performance might be used to make individual predictions. The prediction model of the population's childbearing behavior with high accuracy could help relevant departments to better predict and intervene in the development of the floating population, screen the population with low fertility possibility, and improve their fertility rate, ultimately to alleviate population aging and promote economic development.

Data availability statement

The data analyzed in this study is subject to the following licenses/restrictions: Application to data provider is required. Requests to access these datasets should be directed to Floating Population Service Center of China National Health Commission, China's Floating Population Dynamic Monitoring Survey Data Set (2016), http://hdl.handle.net/20.500.12291/10227.

Author contributions

XL and XZ designed the research study. XZ performed the research and wrote the manuscript. XL, XZ, ZZ, LG, LC, YZ, CH, JX, and JL offered help and advice on data collection and analysis. All authors have contributed to editorial changes in the manuscript, read, and approved the final manuscript version.

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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

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Can supplementary private health insurance further supplement health

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Background: China advocates a health insurance system with social health insurance (SHI) as the main body and private health insurance (PHI) as the supplement. The study of PHI's complementary role in health is conducive to providing evidence for PHI's policy expansion and encouraging the public to participate in PHI, which is insufficient in China.

Methods: We used the three-wave balanced panel data of the China Health and Retirement Longitudinal Survey (CHARLS). Taking the ownership of supplementary PHI as the independent variable and EQ-5D index scores as the dependent variable, the panel instrumental variable (IV) method was used to analyze the impact of participation in PHI on health. We also assessed the heterogeneity of the health effects of PHI between chronic and non-chronic disease groups and between low- and high-income groups.

Results: The coverage rate of PHI at baseline was 10.53%. The regression results showed that participating in PHI on the basis of SHI could result in an additional 8.21% health gain ($p < 0.001$). At the same time, PHI had greater health gain for chronic disease population than for healthy population (9.25 vs. 6.24%, $p < 0.001$), and greater health gain for high-income population than for low-income population (8.32 vs. 5.31%, $p < 0.001$).

Conclusion: Participating in supplementary PHI can effectively enhance the health status of the insured, and has a more significant effect on patients with chronic diseases. The development of PHI should be further supported, while the health inequality in different income groups should be paid attention to.

KEYWORDS

private health insurance, social health insurance, health promotion, EQ-5D, instrumental variable

Introduction

As a financial sharing mechanism of medical expenses, medical insurance can alleviate the economic losses caused by medical risks and make those who do not have the ability to seek medical treatment get timely services. Therefore, a good insurance system is crucial to obtain high-quality medical services and improve health (1). China has developed the world's largest medical security system, with government-led SHI covering

1.36 billion people, accounting for over 95% of the country's population (2, 3). However, due to the limited pool of SHI funds, the National Healthcare Security Administration haslimited the scope of SHI reimbursement for drugs, treatment items and medical service facilities, and formulated the deductibles, copayments, and maximum allowable costs (4, 5), making it difficult for SHI to meet the growing health needs of the population and limiting the ability of SHI to withstand catastrophic health expenditure. In 2021, the personal health expenditure accounted for 27.7% of the total health expenditure in China, much higher than the proportion of poverty control expenditure proposed by the World Health Organization of 15–20% (6). In this context, the Chinese government clearly proposes to take PHI as a supplement to SHI. PHI adopts the voluntary principle and relies on contracts to cover expenses and high-quality services beyond the reimbursement scope of SHI. The mainstream PHI products in China are currently characterized by reimbursing expensive services such as hospitalization for critical illness that are not part of SHI benefits. It can effectively compensate for the shortage of SHI, reduce the high medical expenses of individuals, enhance residents' ability to invest in health, and guarantee residents' higher health needs (7, 8).

Although the Chinese government is paying more attention to the role of PHI as a source of funding for the health system and giving policy support (4), the current coverage rate of PHI in China remains extremely low, only roughly 10%, whereas the proportion of PHI in in developed countries are range from 20 to 30% (9). As a supplementary role to the national health insurance system, PHI plays a limited supporting role at present, and the huge market space for PHI in China requires further development (10). As the development of PHI in China remains in its infancy, only few studies have systematically evaluated the impact of PHI on the health of insured Chinese residents. The existing studies on the role of PHI on health are controversial. While some studies have demonstrated the effect of PHI in promoting health by guaranteeing health service utilization (11, 12), others disagree. They claim that the causality may be an illusion because factors such as adverse selection by purchasers and cream skimming by insurers may lead to reverse causality of the insured's health status on PHI participation behavior, i.e., there is an endogeneity problem that is not addressed (13, 14). In addition, the effects of insurance on health service utilization and health expenditure are confirmed to vary among different populations, such as across age (15, 16), gender (17, 18), income (19, 20), or ethnic subgroups (21), between sick and healthy people (22), and across geographical locations (23–25), which is less considered in the studies of PHI's effects on health.

Therefore, we try to solve the endogeneity problem by using the panel IV method, estimate the health effect of PHI on the insured, and test the heterogeneity of this effect among different populations, aiming to supplement the real-world evidence for the effect of PHI and provide the basis for the improvement of PHI policy. Based on the previous studies, we hypothesize that: ①compared with residents with only SHI, residents with supplementary PHI can further improve their health level; ② PHI provides greater health gains for people with chronic diseases than for people without chronic disease; and ③ PHI provides greater health gains for high-income people than for low-income people.

Materials and methods

Data source

The data used in this study were obtained from the CHARLS database (http://charls.ccer.edu.cn/zh-CN), which attempts to create a high-quality public micro-database that can provide a wide range of information on Chinese residents, from socioeconomic status to health status. The national baseline survey was conducted in 2011–2012, with wave 2 in 2013, wave 3 in 2015, and wave 4 in 2018.

Data from waves 2, 3, and 4 were selected for analysis in this study, and balanced panel data were formed based on the following criteria: (1) the sample was fully traceable in all three periods and (2) no explanatory variables or key explanatory variables were missing. Samples that did not meet the criteria were excluded, resulting in 14,799 data for each period, for a total of 44,397 data.

Study variables

Dependent variables

All questions in the CHARLS database were self-reported by respondents. To minimize individual reporting errors, we planned to combine various self-reported conditions into a comprehensive health index and finally decided to use the three-level EuroQol 5-dimension (EQ-5D) index scores as the dependent variable (26, 27). EQ-5D is a standardized instrument for measuring health states, and it is widely used internationally because of its simplicity, ease of use, and high reliability. It consists of five dimensions (i.e., mobility, self-care, usual activities, pain/discomfort, and anxiety/depression) and three levels for each dimension (i.e., 1 = no problems, 2 = some/moderate problems, and 3 = extreme problems). The five dimensions and three levels can describe 243 unique health states after permutation and combination (28). Liu Guo-en et al. (29) firstly constructed the utility value integral system of EQ-5D based on Chinese population preference by using the time trade-off method. The

TABLE 1 The utility value integral system of EQ-5D scale based Chinese residents.

Variables	Definition	Coefficient
C	Constant term	0.039
Mobility		
MO2	Dimension at level 2	0.099
MO3	Dimension at level 3	0.246
Self-care		
SC2	Dimension at level 2	0.105
SC3	Dimension at level 3	0.208
Usual activities		
UA2	Dimension at level 2	0.074
UA3	Dimension at level 3	0.193
Pain/discomfort		
PD2	Dimension at level 2	0.092
PD3	Dimension at level 3	0.236
Anxiety/depression		
AD2	Dimension at level 2	0.086
AD3	Dimension at level 3	0.205
N3	At least one dimension is at level 3	0.022

formula for calculating EQ-5D index scores in the system is as follows.

$$U = 1 - \left(0.039 + 0.099^{*}MO2 + 0.105^{*}SC2 + 0.074^{*}UA2 + 0.092^{*}PD2 + 0.086^{*}AD2 + 0.246^{*}MO3 + 0.208^{*}SC3 + 0.193^{*}UA3 + 0.236^{*}P + 0.205^{*}AD3 + 0.022^{*}N3\right) \quad (1)$$

According to Table 1, the score of all 243 health states can be calculated. If all the five dimensions are at level 1, it is 11,111, indicating no health problem and a score of 1. If all the five dimensions are at level 3, it is 33,333, indicating that health is in the worst state and a score of [−0.149, 1].

Key variables

The core explanatory variable was the ownership of PHI. It was a binary variable, which was assigned a value of 0 to the sample that only participated in SHI, and 1 to the sample that purchased supplementary PHI on the basis of SHI.

Control variables

Based on the existing research results, we selected control variables including socioeconomic characteristics, health behavior and disease status. The definition and codes of variables were shown in the Supplementary File.

Statistical analysis

We mainly used panel regression method for analysis, and the model is as follows.

$$Y_{it} = \alpha_0 + \alpha_1^{*}X_{it} + \alpha_2^{*}Z_{it} + u_i + \varepsilon_{it} \quad (2)$$

Y_{it} represents the EQ-5D index scores of the subject, the core explanatory variable X_{it} represents whether individual I purchased PHI in year T, and Z_{it} represents a series of individual characteristic variables and health behavior variables (In the model 3 and model 4 is the same). The perturbation term is composed of (u_i+ ε_{it}), where u_i is an unobtainable random variable to measure individual heterogeneity, and ε_{it} is the error term that varies with individual and time. α_1 is the core parameter we focused on, indicating the extent of PHI's effect on individual health.

PHI is voluntary, so individuals may decide whether to join PHI by taking into account their income, personality preference, physical conditions, social and cultural environment, and other factors. The omission of these unobtainable variables can lead to the correlation between PHI and disturbance terms. At the same time, "adverse selection" exists in the insurance market. People with high health risks may be more inclined to buy PHI, resulting in two-way causality between explanatory variables and explained variables, which leads to biased results estimation. Therefore, we tried to find an appropriate IV to correct bidirectional causality due to the omission of individual heterogeneity over time and bidirectional causality. Two criteria should be followed when selecting the IV. First, the IV is related to endogenous explanatory variables. Second, the IV is exogenous and unrelated to the disturbance term. A large number of studies identify regional variables related to public policy changes as effective IV (30). Therefore, we chose the average participation rate of PHI in the community as the IV of this study. It may be highly correlated with whether the respondents participate in PHI through the advertising efforts of insurance companies and the externalities of consumption. The insurance coverage in the region has nothing to do with the unobservable information of individuals at the micro level, so it can only affect individual health by influencing the purchase decisions of PHI (31). On this basis, we modified model 2 and constructed a two-stage least-square regression model of the IV and further tested and reported the effectiveness of the IV in subsequent studies.

$$X_{it} = \pi_1^{*}Z_{it} + \pi_2^{*}C_{it} + u_i + \varepsilon_{it} \quad (3)$$

$$Y_{it} = \alpha_0 + \alpha_1^{*}\hat{X}_{it} + \alpha_2^{*}Z_{it} + u_i + \varepsilon_{it} \quad (4)$$

C_{it} represents the IV, Z_{it} represents the control variable, and $_{it}$ represents the predicted value of X_{it} obtained from regression of model 3 in the first stage.

To verify the robustness of the results, we replaced the explained variables and used the self-assessed health status of

TABLE 2 Sample characteristics of the selected respondents at baseline.

Variables	With PHI 1,558 (10.53)	Without PHI 13,241 (89.47)	Total	*p*
EQ-5D index scores	0.8289 (0.191)	0.8151 (0.2037)	0.8166 (0.2025)	<0.001[a]
Gender = 1	756 (48.52)	6,250 (47.20)	7,006 (47.34)	0.323[b]
Age				0.832[b]
18–44 years	127 (8.15)	1,000 (7.55)	1,127 (7.62)	
45–59 years	745 (47.82)	6,363 (48.06)	7,108 (48.03)	
60–74 years	548 (35.17)	4,733 (35.75)	5,281 (35.68)	
≥75 years	138 (8.86)	1,145 (8.65)	1,283 (8.67)	
Marital Status = 1	1,353 (86.84)	11,514 (86.96)	12,867 (86.95)	0.899[b]
Education				0.043[b]
Junior high school and below	1,399 (89.79)	11,640 (87.91)	13,039 (88.11)	
Vocational/technical secondary school/high school	137 (8.79)	1,311 (9.90)	1,448 (9.78)	
Junior college and above	22 (1.41)	290 (2.19)	312 (2.11)	
Non-rural household registration	1,168 (74.97)	10,270 (77.56)	11,438 (77.29)	0.021[b]
Smoke = 1	547 (35.11)	4,557 (34.42)	5,104 (34.49)	0.586[b]
Drink = 1	545 (34.98)	4,486 (33.88)	5,031 (34.00)	0.385[b]
Social contact = 1	958 (61.49)	8,076 (60.99)	9,034 (61.04)	0.704[b]
Chronic disease = 1	985 (63.22)	8,076 (60.99)	9,460 (63.92)	0.542[b]
Household incomes per capita	8.6476 (2.0577)	8.4639 (1.9319)	8.4832 (1.9463)	<0.001[a]

The descriptive results of "EQ-5D index scores" and "Household incomes per capita" were represented by mean (standard deviation), while the descriptive results of other indexes were represented by quantity (proportion).
[a]Outcomes of Student-*t*-test.
[b]Outcomes of Chi-square test.

residents in the questionnaire to replace EQ-5D index scores to measure the health level of residents. This variable was measured in the questionnaire with the question "How do you think your health is?", which was answered using a 5-point Likert scale. We assigned a score of 1, 2, 3, 4, and 5 to "very bad," "not good," "fair," "good," and "very good," respectively, and the better the self- assessed health, the higher the score.

All data compilation and statistical analysis were performed using STATA 15.0.

Results

Basic characteristics of participants

A total of 14,799 participants in the baseline data in 2013 were all covered by SHI, of which 1,558 were also covered by PHI, accounting for 10.53%. The mean value of EQ-5D index scores for the group with PHI was 0.8289, and that for the group without PHI was 0.8151, with a significant difference in health status between the two groups ($p < 0.001$). Those with supplemental PHI were more likely to be rural ($p < 0.05$) and have a relatively higher per capita household income ($p < 0.001$) (Table 2).

Analysis of the effects of PHI on health status by panel regression model

Columns 1, 2, and 3 of Table 3 respectively reported the estimation results of the panel pooled model, fixed-effect (FE) model, and random effect (RE) model. The *p*-values of the *F* test of FE and RE were both < 0.001, which strongly rejected the null hypothesis that "pooled regression is acceptable". That is, individual effect existed, and FE and RE were significantly better than pooled regression. The results of Hausman's test were significant at the 1% significance level ($p < 0.001$), which rejected the null hypothesis that explanatory variables and residuals were not correlated. It was more appropriate to adopt the FE model rather than the RE model. Therefore, we took the regression results of FE model as the analysis standard and the regression results of other two methods as the reference.

The regression results of the FE model in column 2 revealed a significant positive correlation between the purchase of supplementary PHI and the health level of residents. The results of the three methods showed an effect coefficient of approximately 0.01, indicating that participating in PHI on top of SHI could bring a health utility return of 1% (Table 3).

TABLE 3 Panel regression results of the effect of having PHI on the health state of residents.

Variables	Pooled model (1)	FE model (2)	RE model (3)
The ownership of PHI	0.0101 *** (0.0031)	0.0116 *** (0.0040)	0.0101 *** (0.0031)
Gender	−0.0018 (0.0017)	—	−0.0018(0.0017)
Age	−0.0063*** (0.0012)	−0.0403*** (0.0034)	−0.0063*** (0.0012)
Marital status	0.0018 (0.0025)	0.0039 (0.0030)	0.0018 (0.0025)
Education	0.0033 (0.0022)	0.0024 (0.0035)	0.0033 (0.0022)
Registered permanent residence	−0.0078*** (0.0021)	−0.0121*** (0.0032)	−0.0078*** (0.0021)
Smoke	−0.0058*** (0.0018)	−0.0319*** (0.0054)	−0.0058*** (0.0018)
Drink	0.0424*** (0.0017)	0.0434*** (0.0022)	0.0424*** (0.0018)
Social contact	0.0436 *** (0.0018)	0.0451*** (0.0021)	0.0436*** (0.0017)
Disease	−0.0622*** (0.0017)	−0.0603 *** (0.0021)	−0.0621*** (0.0017)
Household income per capita	0.0010 *** (0.0003)	0.0008** (0.0003)	0.0010*** (0.0003)
F test: *F*	0.0000*	195.09***	38.68***
Hausman test: χ^2		194.50***	
Observations		44,397	

Regression results were expressed by coefficients (standard error).
***, ** and * represented significant at 1%, 5% and 10% levels respectively.
"—", The binary variable "Gender" was automatically missing in the panel regression.
The following analysis results were presented in the same way.

Analysis of the effects of PHI with excluding endogenous

The use of IV presupposes the existence of endogenous explanatory variables, for which a Hausman test was conducted. The results showed that the original hypothesis of "all explanatory variables are exogenous" could be rejected at the 1% significance level. That is, ownership of PHI is an endogenous variable, which required unbiased estimation using IV. Next, the correlation between the IV and the endogenous explanatory variables was determined. The *F* value of the first stage regression was 69.25, which was much larger than the conventional critical value of 10. This outcome implied that there was no weak IV and that the IV we chose had strong explanatory power for the endogenous variables. In addition, given that there was only one IV, it was exactly identified.

The results of the second stage regression showed that after introducing the IV to adjust for the estimation bias, participation in PHI still had a positive effect on the health status of the population and the return grew to 8.21% (Table 4). The influence coefficient estimated by FE model with IV was more than seven times that of the FE model, indicating that the FE model had a large deviation. The traditional panel regression analysis ignored the possible endogenous problems, thus weakening the health promotion effect of participating in PHI on residents.

Results of robustness test by changing the dependent variable

The test results of the IV showed that "participation rate of PHI in the community" passed the endogeneity test ($\chi^2 = 80.42$, $p < 0.001$) and the weak IV test ($F = 45.42$, $p < 0.001$). The results of robustness analysis showed that participating in PHI could significantly improve residents' self-assessed health status by 60%, which was basically consistent with the previous conclusion with "EQ-5D index scores" as the explained variable (Table 5). The result was relatively robust.

Heterogeneity analysis of the effects of PHI on different populations

Considering that chronic disease might affect the health utility gain of PHI, the samples were divided into those with and without chronic diseases, and the FE model with IV was used for regression analysis. The results showed that, consistent with the full-sample analysis, participating in PHI had a significant positive effect on both sub-samples. However, the health gain of participating in PHI was 9.25% for the sample group with chronic disease and 6.24% for the non-chronic disease group, indicating that the effect of participating in PHI on residents' health had the heterogeneity on the group with and without chronic diseases, especially for the group with chronic disease (Table 6).

TABLE 4 The FE model with IV results of the effect of having PHI.

Variables	FE+IV	
	The first stage	The second stage
The ownership of PHI	—	0.0821***(0.0102)
Gender	—	—
Age	−0.0024 (0.0045)	−0.0400(0.0034)
Marital status	0.0051 (0.0040)	0.0035*** (0.0030)
Education	−0.0041 (0.0046)	0.0022 (0.0035)
Registered permanent residence	−0.0008 (0.0042)	−0.0105*** (0.0032)
Smoke	−0.0103 (0.0072)	−0.0305*** (0.0055)
Drink	0.0049* (0.0030)	0.0429*** (0.0022)
Social contact	−0.0016 (0.0028)	0.0446*** (0.0022)
Disease	0.0044 (0.0028)	−0.0606*** (0.0021)
Household income per capita	0.0013 *** (0.0004)	0.0004 (0.0003)
IV	1.0793*** (0.0146)	—
F test: *F*	83.07***	
Hausman test: χ^2	69.25***	
Observations	44,397	

TABLE 5 The effects of having PHI on the self-assessed health of residents.

Variables	FE+IV	
	The first stage	The second stage
The ownership of PHI	—	0.6006 (0.0879)
Gender	—	—
Age	−0.0059 (0.0066)	0.6438 (0.0284)
Marital Status	0.0085 (0.0060)	−0.0119 (0.0257)
Education	0.0000 (0.0066)	0.0242 (0.0282)
Registered permanent residence	−0.0013 (0.0058)	0.0195 (0.0250)
Smoke	−0.0100 (0.0111)	0.5543 (0.0477)
Drink	−0.0001 (0.0045)	0.1894 (0.0192)
Social contact	−0.0062 (0.0043)	0.0781 (0.0183)
Disease	−0.0015 (0.0042)	−0.6226 (0.0181)
Household income per capita	0.0008 (0.0007)	0.0503 (0.0029)
IV	1.0870*** (0.0223)	—
F test: *F*	80.42***	
Hausman test: χ^2	45.42 ***	
Observations	23,726	

We also assessed the effect of PHI on the insured at different income levels. The median annual household income per capita of all samples was calculated. Samples with annual household income per capita equal to or above the median were classified as the high-income group, and samples with annual household income per capita below the median were classified as the low-income group. The results of sub-sample regression showed that owning PHI had a significant effect on individual health in different income groups. However, such an effect was significantly different between low- and high-income income groups. PHI improved the EQ-5D index scores of the high-income group by 8.32%; low-income group, 5.31%. The health effect of PHI was particularly obvious in high-income groups with better economic status, and relatively small in low-income groups (Table 7).

TABLE 6 The effects of PHI on health status of residents with and without chronic diseases.

Variables	With chronic diseases	Without chronic diseases
The ownership of PHI	0.0925*** (0.0182)	0.0624*** (0.0179)
Gender	—	—
Age	−0.0399*** (0.0062)	−0.0411*** (0.0058)
Marital status	0.0020 (0.0054)	−0.0026 (0.0053)
Education	0.0022 (0.0065)	0.0060*** (0.0059)
Registered permanent residence	−0.0082 (0.0061)	−0.0158*** (0.0053)
Smoke	−0.0356*** (0.0104)	−0.0301*** (0.0091)
Drink	0.0560*** (0.0041)	0.0250*** (0.0038)
Social contact	0.0503*** (0.0038)	0.0342*** (0.0038)
Household income per capita	0.0004 (0.0006)	0.0009 (0.0006)
IV	Yes	Yes

TABLE 7 The effects of PHI on health status of low- and high-income residents.

Variables	Low income	High income
The ownership of PHI	0.0531*** (0. 0185)	0.0832*** (0.0178)
Gender	—	—
Age	−0.0369*** (0.0067)	−0.0470*** (0.0058)
Marital status	0.0074 (0.0056)	0.0022 (0.0055)
Education	0.0074 (0.0077)	0.0016 (0.0059)
Registered permanent residence	−0.0182* (0.0071)	−0.0116** (0.0052)
Smoke	−0.0316*** (0.0104)	−0.0249*** (0.0095)
Drink	0.0435*** (0.0041)	0.0472*** (0.0038)
Social contact	0.0430*** (0.0040)	−0.0479*** (0.0039)
Disease	−0.0653*** (0.0040)	−0.0585*** (0.0039)
IV	Yes	Yes

Discussion

Based on the "choice hypothesis", healthier people are more likely to purchase supplemental PHI, so the role of PHI for health promotion is controversial (32, 33). Using the quasi-experimental method, we excluded the endogenous interference of insurance adverse selection. We found that PHI could still significantly improve the comprehensive health

status of residents, which verified our first hypothesis. This is because benefits of PHI tend to be better than SHI (34), with higher cost sharing and a wider range of services, thus influencing health through the mediating effect of health-care service utilization. Two possible paths of action exist for this mediation. Some scholars believe that PHI has fewer treatment thresholds than SHI, and PHI covers medical expenses not included in SHI, allowing the insured to actively accept outpatient and inpatient treatment services when they experience health problems (35–37). However, many studies showed that the insured tends to utilize services that are exclusively covered by PHI, such as physical examinations, cancer screening, innovative drugs, and so on (38, 39), to better manage their current health conditions. The results revealed that although the use of relatively expensive services such as hospitalization did not increase (40), the insured received more valuable health services and reduced financial risks (41, 42). Contrastingly, the second path is more cost effective, consistent with the current popular and advanced concept of value-based insurance design (VBID) (30). VBID promotes the utilization of high-value preventive services by reducing or eliminating cost sharing for the insured for high-value services and increasing out-of-pocket costs for low-value services, resulting in higher health benefits at less cost (43, 44). Currently, domestic scholars are paying less attention to the coverage of preventive health care services of PHI and the incentives for patients to use such services, and pay more attention to medical services. It is necessary for scholars to change their research perspective. The government should strengthen the guidance of commercial insurance companies to explore VBID, which is highly significant to the cost control of insurance companies, the health of patients, and the resource saving of the health system.

We also found that participation in PHI had greater health gains for people with chronic diseases, verifying hypothesis 2 as well. Chronic diseases are associated with multiple health risks such as poor functional status, poor quality of life and increased psychological distress (45, 46). Chronic patients often suffer huge economic burden accompanied by continuous expenditure of long-term health service needs (41, 47). The economic pressure may force patients to reduce other expenditures in their lives to pay for health care or delay their visits, thus further endangering their health, which is unsolvable by SHI (48). Compared with the general population, health insurance plays a more significant role in dispersing the risk of medical expenses for patients with chronic diseases. As discussed above, PHI can increase the access of patients with chronic diseases to diagnostic and preventive services before complications occur (49), preventing greater damage to their health. At present, about 180 million elderly people in China suffer from chronic diseases (50), and deaths caused by chronic diseases have accounted for 86.6% of the total number of deaths in the country (51). Moreover, the total economic burden of chronic diseases is on the rise, and its growth rate has outpaced the growth rate of GDP. The rapid growth of health costs and the risk of life and health caused by chronic diseases have become an important issue of high concern to all countries. The role of PHI may be conducive to alleviating the threat of chronic diseases. However, PHI suffers from market failure, as evidenced by its "skimming" behavior. Commercial insurance companies that are profit drive, would cherry pick the young and healthy and exclude or impose onerous conditions on the elderly and infirm (52). The government ought to carry out strict supervision to prohibit commercial insurance companies from selectively selling insurance products by means of the so-called "actuarial calculation" on the basis of consumers' personal information such as health status, resulting in the exclusion of patients with chronic and serious illnesses who really need PHI and undermining the risk diversification mechanism of health insurance.

Finally, our hypothesis 3 was also verified that PHI provided less health gain to low-income groups than to high-income groups. This difference is because low-income groups, limited by their ability to pay, tend to choose PHI with lower premiums and lower levels of protection. Buchmueller also reported that consumers who purchased PHI are much more likely to purchase other types of insurance (53). Even if the medical expenses are shared by PHI, low-income groups still worry about their out-of-pocket expenses. Lee et al. pointed out that low-income families have more unmet medical service experience (54). Higher incomes increase the likelihood of seeking more health care and paying for it. In addition, low-income groups face more health threats such as increased psychological distress, less social support, higher intensity of work, and less healthy diets (55, 56), which may lead to less significant health gains from supplementary PHI. For China, the low-income population, especially the rural population, is relatively large and faces huge risks. The security of the low-income group is the core of the social security system and plays a positive role in promoting economic development and social stability (57). Based on the national conditions, PHI providers should prioritize the protection of low-income people and promote the inclusive innovation of PHI, especially the inclusive products aimed at low-income groups. In addition, PHI providers should lower the premium threshold for low-income people to expand the coverage and level of insurance.

Advantages and limitations

On the basis of eliminating endogeneity, we analyzed the value of PHI in improving residents' health and explored the heterogeneity of this effect in different groups of populations. This study provides supportive evidence for the improvement

of PHI policy and the development of PHI in China and encourages the public to actively participate in PHI.

The study also had several limitations. Firstly, the data we used came from the public database of the survey conducted by Peking University rather than our own survey. Due to data limitations and other factors, we only selected an IV, and some key control variables, such as the classification of SHI and the utilization of outpatient or inpatient visits, were not included. Secondly, we only discussed the results of the effect of the insurance on health. The mediating effect and other influencing mechanisms were not studied. These issues will be considered in future studies. Thirdly, although we used composite health indicators as dependent variables to minimize self-reported bias, it was still impossible to completely avoid bias.

Conclusion

After excluding the possible two-way causal relationship between insurance and health status, we found that PHI still promoted health status and had a more significant effect on patients with chronic diseases. This finding proves the health value of PHI. However, PHI can bring health inequality to different income groups. Therefore, PHI should be developed on the basis of SHI. The government can support the development of PHI by providing insurance incentives for individuals who buy PHI and doing a good job in connecting SHI and PHI systems. In addition, PHI providers are encouraged to actively develop health insurance products exclusively for the elderly to meet the insurance needs of senior citizens. Moreover, the threshold for low-income people to participate in PHI should be lowered to expand the scope and level of insurance.

Data availability statement

Publicly available datasets were analyzed in this study. This data can be found at: http://charls.pku.edu.cn.

Author contributions

XinlinC, DG, HT, and YC conceived and designed the study, YZ, YL, and XinlanC cleared up and analyzed the data. XinlinC, YC and DG wrote the first draft. All authors supplied critical revisions to the manuscript and gave final approval of the version to be published.

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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.2022.961019/full#supplementary-material

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Nomenclature

Countries around the world are trying to improve their health care systems. Some countries such as China, France and Belgium are developing a system with social health insurance as the main body and private health insurance as the supplement. We explored the effect of private health insurance on residents' health, which is conducive to providing scientific basis for the formulation of policies related to private health insurance. Secondly, it is controversial whether private health insurance can improve the health of the insured. Our study confirmed that participating in private health insurance on the basis of social health insurance can indeed further improve the health level of the insured, and provide greater health gain for the chronic disease population, which provides guidance and incentive for residents to participate in insurance. In addition, we explore the differences in the impact of private health insurance on the health of different populations with a view to providing evidence for promoting health equity.

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Application value of joint STOP-Bang questionnaire and Epworth Sleepiness Scale in screening for obstructive sleep apnea

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Objective: This paper evaluates the application value of the STOP-Bang questionnaire combined with the Epworth Sleepiness Scale (ESS) in screening for obstructive sleep apnea (OSA) in the population.

Method: Thousand-six hundred seventy-one patients with suspected OSA who visited the Sleep Medicine Center of the First Affiliated Hospital of Guangzhou Medical University from August 2017 to August 2020 were monitored by overnight polysomnography (PSG) after completing the ESS scale and STOP-Bang questionnaire. The sensitivity, specificity, positive predictive value, negative predictive value and receiver operating characteristic (ROC) curves of the two scales were calculated, and the accuracy in predicting OSA of the STOP-Bang questionnaire combined with ESS was analyzed.

Results: With Apnea Hypopnea Index (AHI) cutoffs of ≥5, ≥15 and ≥30 events/h, the areas under the ROC curve scored by STOP-Bang were 0.724, 0.703 and 0.712, and those of ESS were 0.632, 0.634 and 0.695; the diagnostic odds ratio (DOR) values of STOP-Bang for OSA, moderate to severe OSA, and severe OSA were 3.349, 2.651 and 3.189, and those of ESS were 2.665, 2.279 and 3.289. The STOP-Bang score of three was used as the cut-off point for OSA diagnosis with higher sensitivity and lower specificity, while ESS had higher specificity. STOP-Bang (≥3) combined with ESS significantly improved its specificity for predicting OSA.

Conclusion: The STOP-Bang questionnaire is a simple and effective new tool for screening patients for OSA, while a STOP-Bang score of ≥3 combined with

ESS can further improve its specificity. Thus, we suggest further screening with ESS after a STOP-Bang score of ≥3 in suspected patients.

KEYWORDS

obstructive sleep apnea, Epworth Sleepiness Scale, STOP-Bang questionnaire, diagnostic, polysomnography

Introduction

Obstructive sleep apnea (OSA) is a recurring narrowing or partial or complete collapse of the airway, snoring/apnea and low ventilation during sleep, leading to frequent hypoxemia, hypercapnia and common sleep-related breathing disorders. And as we know the Editorial Board of The AASM Manual for the Scoring of Sleep and Associated Events: Rules, Terminology and Technical Specifications (AASM Scoring Manual) would like to notify the membership and the sleep community that an update for the AASM Scoring Manual (Version 2.4) was released April 1, 2017 (1). The prevalence of OSA is about 1–5% in children, 9% in adult women and 24% in adult males (2, 3). OSA is harmful, can even lead to death and is associated with the increased mortality of patients (4, 5). Although the connection remains debated, several mechanisms such as intermittent hypoxemia, sleep deprivation, hypercapnia disruption of the hypothalamic-pituitary-adrenal axis have been associated with poor neurocognitive performance. Different treatments have been proposed to treat OSAS patients as continuous positive airway pressure (CPAP), mandibular advancement devices (MAD), surgery; however, the effect on neurocognitive functions is still debated. CPAP treatment seems to improve cognitive defects associated with OSA. Limited studies have evaluated the effects of the other therapies on cognitive function as oral appliance or barbed surgery (6). The scary thing is that a lot of OSA in the population goes undiagnosed (7, 8). As we all know, polysomnography (PSG) is the gold standard for the diagnosis of OSA, but it is difficult to apply PSG widely in primary hospitals as sleep rooms and professional and technical personnel are required, while PSG examination is expensive, complicated and time-consuming. The STOP-Bang questionnaire is a simple and effective screening tool for the risk assessment of suspected sleep disordered breathing (9–11) which includes eight indicators: snoring (S), tiredness (T), observed apnea during sleep (O), blood pressure (P), BMI, age, neck circumference and gender; scores ≥3 are 93% sensitive and 43% specific for moderate OSA, and 100% sensitive and 37% specific for severe OSA (12). It is not difficult to see that although the STOP-Bang questionnaire has good sensitivity, its specificity is poor. A meta-analysis confirms the high performance of the STOP-Bang questionnaire in the sleep clinic and surgical population for screening of OSA. The higher the STOP-Bang score, the greater is the probability of moderate-to-severe OSA (13). It was recently found that STOP-Bang combined with serum bicarbonate can significantly improve the diagnostic value of STOP-Bang for OSA patients (14). Considering that blood drawing tests are troublesome and time-consuming, while the Epworth Sleepiness Scale (ESS) is relatively easy to perform, this study evaluated STOP-Bang and ESS for suspected OSA patients, and then the statistical analysis of the PSG data was completed to further evaluate the application value of STOP-Bang combined with ESS for screening for OSA in the population. We hypothesized that the combination of ESS would significantly improve the specificity of STOP-Bang in predicting OSA.

Materials and methods

Study subjects

All participants were recruited from the Sleep Medical Center of the First Affiliated Hospital of Guangzhou Medical University, Guangzhou, China, from August 2017 to August 2020. From a total of 1,861 patients, 1,671 were eventually included: 1,300 males and 371 females; mean age of 47.45 ± 13.90 years; average neck circumference of 38.36 ± 3.93 cm; and mean BMI of 26.49 ± 4.20 kg/m^2. This study was approved by the Ethics Committee of the First Affiliated Hospital of Guangzhou Medical University with Ethical Approval No. 05, 2017, and all patients gave and signed their informed consent. The inclusion criteria were: (1) older than 18 years; (2) total sleep time of >4 h; (3) autonomous behavior and cognitive ability; and (4) able to answer the questionnaire. The exclusion criteria were: (1) history of various mental and psychological diseases; (2) brain tumors or epilepsy; (3) long-term or current use of benzodiazepines, barbiturates or other sedative and sleeping drugs; (4) severe organ failure leading to an inability to complete the examination; (5) previously diagnosed or treated; (6) did not complete the questionnaire; (7) total sleep time of < 4 h; and (8) OSA dominated by central or mixed events.

Methods

In our study, we collected the basic data of the 1,671 suspected patients: (1) basic anthropological data; (2) basic demographics (e.g., gender, age, occupation); (3)

anthropometric parameters (height, weight, neck circumference, waist circumference, etc.); (4) previous history (history of hypertension, diabetes, cardiovascular and cerebrovascular diseases, and other related diseases); (5) personal history (smoking and drinking); and (6) sleep-related breathing events (e.g., snoring, apnea, sleep suppression). Patients were asked to complete ESS and STOP-Bang 1 h before the PSG examination. According to the PSG monitoring results, the patients were divided into the normal group [AHI $<$ 5 events/h (n = 470)], mild OSA group (AHI $\geq$5 and $<$15 events/h [n = 378)], moderate OSA group [AHI $\geq$ 15 and $<$30 events/h (n = 320)] and severe OSAHS group [AHI $\geq$30 events/h (n = 503)].

Questionnaire

The STOP-Bang questionnaire has eight questions on snoring, tiredness, observed apnea, hypertension, body mass index $>$35 kg/m^2, age $>$50, neck circumference $>$40 cm and male that are answered with "yes" or "no." It adds one point for "yes" and zero points for "no." When the total points are $>$3, this indicates that the patient is at high risk for OSA. ESS, which includes 8 questions, asks respondents to rate their sleepiness from zero to three in eight daily situations. For each question, a score of zero indicates no lethargy, and one, two and three indicate light, moderate and heavy lethargy respectively. The highest score of ESS is 24 (the most excessive daytime sleepiness), with a threshold for daytime sleepiness of 10 points or more.

Polysomnography

All patients were synchronously monitored with an Alice 5 PSG (Philips Wellcome, USA) for at least 7 h, and the use of alcohol, coffee, sedatives and hypnotics was prohibited on the same day. The monitoring indicators included electro-encephalogram, electromyography, blood oxygen saturation, electro-oculogram, electrocardiogram, snoring, mouth airflow, nasal airflow, chest breathing and body position. The raw data was automatically read by the instrument, then manually analyzed by trained sleep professionals for parameters such as sleep duration and sleep breathing events based on the *Manual for the Scoring of Sleep and Associated Events* published by the American Academy of Sleep Medicine (AASM) in 2012, and finally corrected by the same physicians (15). According to the guidelines for the diagnosis and treatment of OSA, patients were defined as having OSA when their obstructive apnea was dominated by respiratory events and their Apnea Hypopnea Index (AHI) was not below five events/h. Patients with suspected OSA were classified into four groups based on AHI: AHI $<$ 5 events/h, AHI $\geq$ 5 and $<$15 events/h, AHI $\geq$ 15 and $<$30 events/h and AHI $\geq$ 30 events/h.

Sample size calculation

We take all the data into study and the sample size was not calculated.

Reduce the potential for bias

Firstly, it was not the same person who conducted the questionnaire and the PSG and they don't know the patient's condition. Secondly, the sample size is very huge in our study. Lastly, there are fewer interference factors in our study because both the questionnaire and PSG data were obtained from the same patient.

Statistical analysis

Statistical analysis was performed using SPSS v16.0. One-Way ANOVA was adopted for the normal distribution of data. *Post-hoc* analysis was conducted for comparison between the two groups. The chi-square test was used for comparison between count data groups. The diagnostic results of each scale and PSG were calculated as the sensitivity, specificity, positive predictive value and negative predictive value of each scale in a four-grid scale form. The diagnostic results of PSG and each scale were analyzed in a four-fold table, and the sensitivity, specificity, positive predictive value and negative predictive value of each amount was calculated. The ROC curves were used to analyze the OSA diagnostic performance of STOP-Bang combined with ESS.

Results

General data

A total of 1,671 suspected patients (including 1,300 males) were recruited for this study (Figure 1). The mean age of the subjects was 47.45 $\pm$ 13.90 years old, the mean BMI was 26.49 $\pm$ 4.20 kg/m^2 and the mean neck and waistline circumferences were 38.36 $\pm$ 3.93 and 95.37 $\pm$ 13.90 cm respectively. The mean AHI of the subjects was 26.64 $\pm$ 27.69 events/h, and the mean lowest oxygen saturation (LSpO2) was 77.29 $\pm$ 14.60%. The mean ESS and STOP-Bang scores were 8.12 $\pm$ 5.79 and 3.54 $\pm$ 1.50 respectively. There were no statistically significant differences in age and ESS scores between the mild and moderate OSA groups. In addition, there were statistically significant differences in other items among the four groups. The proportion of males in the mild group was higher than in the normal group, higher in the moderate group than the mild group, and higher in the severe group than the moderate group, and the differences were statistically significant (P $<$ 0.05). Similarly, these differences were reflected in the indicators

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TABLE 1 Baseline characteristics of study subjects.

	All	AHI<5	5≤AHI<15	15≤AHI<30	AHI≥30	F/χ2	*P*
n	1,671	470	378	320	503		
Male (*n*, %)	1,300	306	282	253	459	99.075	<0.001
Age (years)	47.45 ± 13.90	47.51 ± 15.05	49.60 ± 13.41	49.76 ± 13.96	44.33 ± 12.49	14.748	<0.001
BMI (kg/m^2)	26.49 ± 4.20	24.64 ± 4.06	25.92 ± 3.42	26.45 ± 3.74	28.65 ± 4.18	88.288	<0.001
NC (cm)	38.36 ± 3.93	36.17 ± 3.82	37.90 ± 3.43	38.48 ± 3.26	40.69 ± 3.47	136.057	<0.001
WC (cm)	95.37 ± 13.90	89.34 ± 11.17	93.80 ± 9.85	95.47 ± 9.78	102.11 ± 17.64	80.49	<0.001
AHI (events/h)	26.64 ± 27.69	1.64 ± 1.62	9.26 ± 2.99	20.56 ± 3.55	65.60 ± 13.30	6,751.75	<0.001
MinSPO$_2$	77.29 ± 14.60	88.62 ± 6.11	82.73 ± 9.15	78.23 ± 8.58	62.04 ± 13.72	628.22	<0.001
ESS	8.12 ± 5.79	6.27 ± 5.20	7.36 ± 5.23	7.26 ± 5.27	10.98 ± 5.99	68.702	<0.001
STOP-Bang	3.54 ± 1.50	2.69 ± 1.34	3.41 ± 1.26	3.73 ± 1.49	4.32 ± 1.36	119.69	<0.001

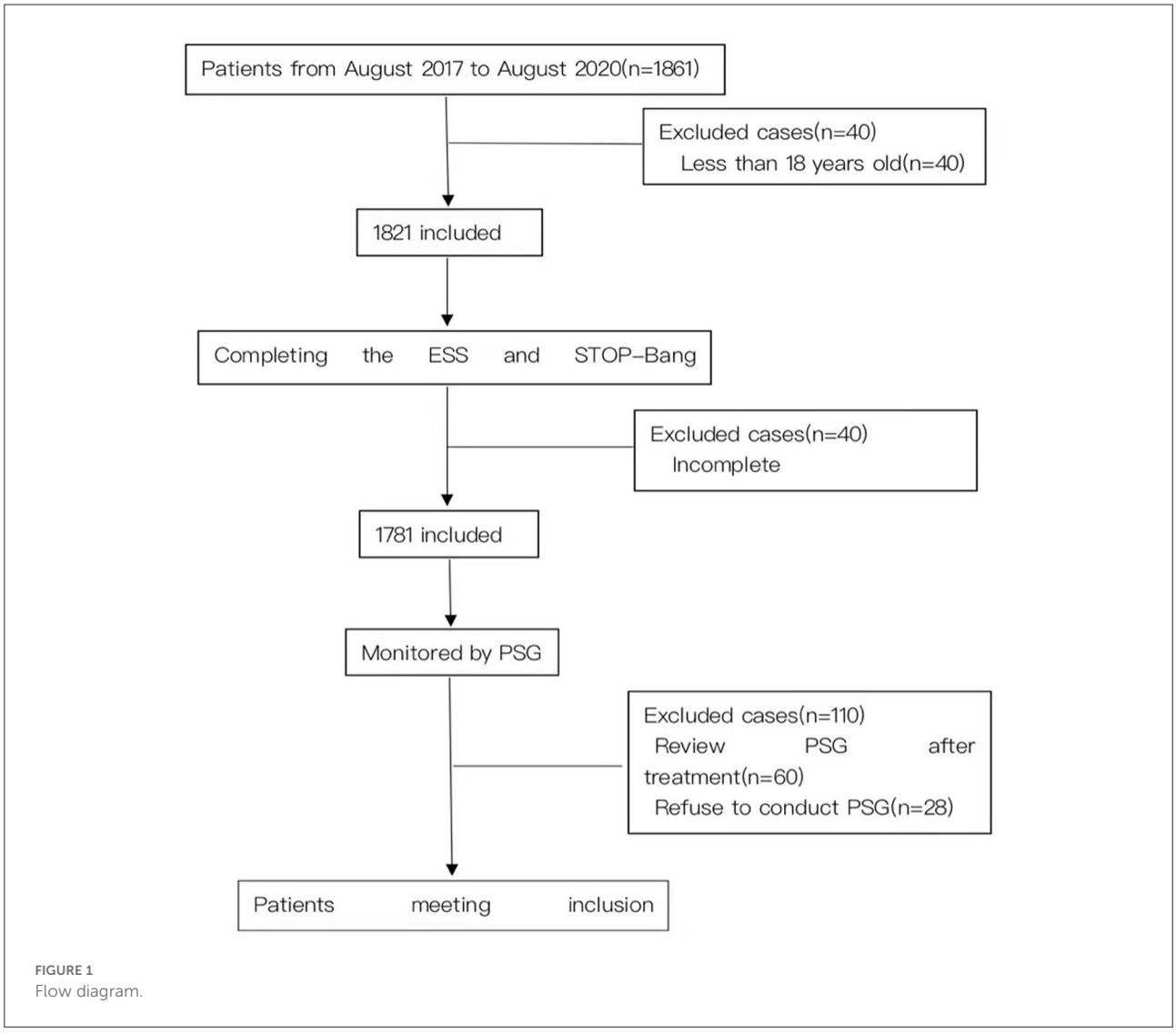

FIGURE 1
Flow diagram.

TABLE 2 The area under the receiver operating curve of various scales.

AHI	ESS	STOP-Bang
≥5	0.632 (0.603–0.661)	0.724 (0.697–0.751)
≥10	0.618 (0.591–0.644)	0.704 (0.679–0.729)
≥15	0.634 (0.607–0.660)	0.703 (0.679–0.728)
≥20	0.653 (0.626–0.680)	0.702 (0.677–0.728)
≥25	0.686 (0.658–0.713)	0.708 (0.682–0.735)
≥30	0.695 (0.667–0.723)	0.712 (0.686–0.739)

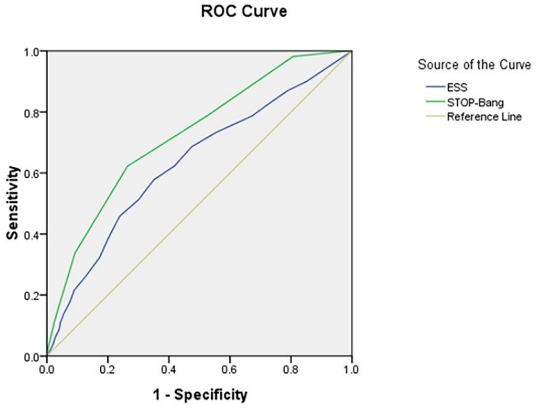

FIGURE 2
ROC curve of the ESS and STOP-Bang at AHI cutoff of ≥5 events/h (At an AHI cutoff of ≥5 events/h, the diagnostic performance of the STOP-Bang is better than the ESS. AHI, apnea-hypopnea index; ESS, Epworth Sleepiness Scale; STOP-Bang, STOP-Bang questionnaire; ROC, receiver operating characteristic).

of BMI, neck circumference, waist circumference, AHI, ESS and STOP-Bang (Table 1).

Area under ROC curve

The area under the curve (AUC) of the two scales was compared using AHI cutoffs of 5, 10, 15, 20, 25, and 30 events/h, respectively: STOP-Bang was 0.724, 0.704, 0.703, 0.702, 0.708, and 0.712, and ESS was 0.632, 0.618, 0.634, 0.653, 0.686, and 0.695. It was found that the AUC of STOP-Bang was higher than that of ESS (Table 2; Figures 2–4).

Sensitivity and specificity of STOP-Bang

Using the STOP-Bang score of three as the cutoff, the sensitivity and specificity of STOP-Bang for OSA, moderate to severe OSA, and severe OSA were 0.788, 0.812, and 0.857, and 0.474, 0.381 and 0.348, respectively (Table 3).

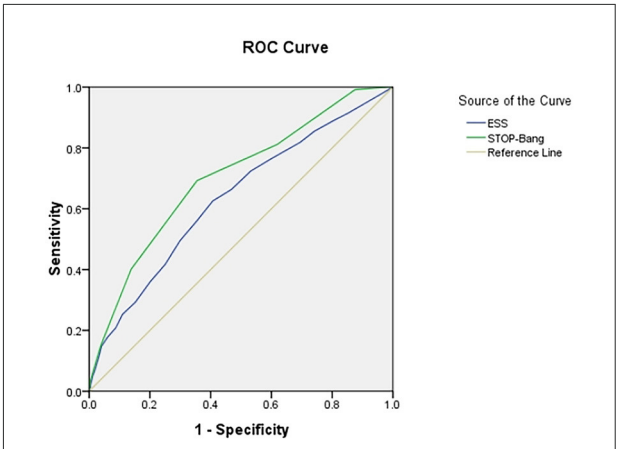

FIGURE 3
ROC curve of the ESS and STOP-Bang at AHI cutoff of ≥15 events/h (At an AHI cutoff of ≥15 events/h, the diagnostic performance of the STOP-Bang is better than the ESS. AHI, apnea-hypopnea index; ESS, Epworth Sleepiness Scale; STOP-Bang, STOP-Bang questionnaire; ROC, receiver operating characteristic).

Specificity of STOP-Bang combined with ESS

The specificity of STOP-Bang (3) for OSA, moderate to severe OSA, and severe OSA was 0.474 (0.429–0.520), 0.381 (0.348–0.414) and 0.348 (0.320–0.375). When combined with ESS, the specificity increased to 0.668 (0.609–0.727), 0.598 (0.556–0.640) and 0.592 (0.557–0.627) (Table 4).

Two-step screening procedure screens for OSA risk

According to the above analysis, a two-step screening method can be formed. In the first step, STOP-Bang was used to screen all 1,671 patients; the risk of OSA, moderate to severe OSA, and severe OSA in patients with scores lower than 3 was 0.53 (0.49–0.58), 0.32 (0.28–0.37) and 0.15 (0.12–0.18), indicating that these patients were less likely to have OSA.

For 1,193 patients (STOP-Bang score ≥3), the risk of OSA was further evaluated by ESS. For patients with an ESS score ≥10, the risk of OSA, moderate to severe OSA, and severe OSA was 0.86 (0.84–0.89), 0.65 (0.61–0.69) and 0.48 (0.44–0.52). The risk was significantly higher

than that of patients with ESS < 10; in particular, the risk of severe OSA was as much as 2.0 times higher (Figure 5).

Discussion

In this study, 1,201 of the 1,671 patients suspected of OSA were confirmed, and the proportion of men was far higher than that of women, in line with the epidemiological characteristics of OSAHS. Scholars all over the world have developed a variety of OSA screening tools, among which a large number of scales are complex, requiring the use of computers and complicated mathematical calculations, making it difficult to promote the use of such tools in clinical practice (16–18). STOP-Bang is a relatively new questionnaire used for screening OSA. In this study, the STOP-Bang questionnaire showed an increasing trend with the aggravation of OSA, the comparison between the normal group and mild, moderate and severe OSA groups was statistically significant, and differences among OSA groups were also statistically significant. Similarly, these differences were reflected in ESS. However, there was no statistical difference between the mild and moderate OSA groups, suggesting that STOP-Bang is better than ESS at distinguishing severe OSA. As can be seen from the AUC, STOP-Bang was higher than ESS for OSA, moderate to severe OSA, and severe OSA, showing good predictive value for OSA patients. The results of this study are similar to those of other studies (19, 20), which show that the STOP-Bang questionnaire is a simple, effective and easy tool for risk assessment in patients with suspected OSA.

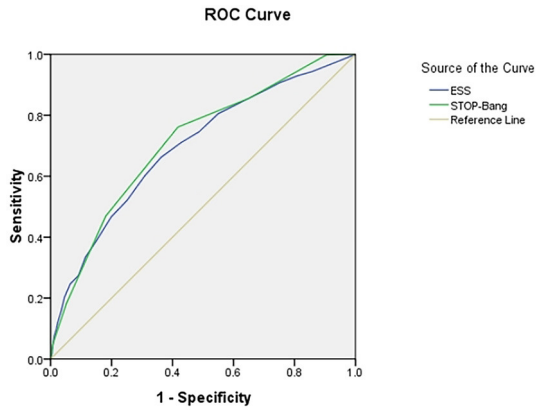

FIGURE 4
ROC curve of the ESS and STOP-Bang at AHI cutoff of ≥30 events/h (At an AHI cutoff of ≥30 events/h, the diagnostic performance of the STOP-Bang is better than the ESS. AHI, apnea-hypopnea index; ESS, Epworth Sleepiness Scale; STOP-Bang, STOP-Bang questionnaire; ROC, receiver operating characteristic).

Diagnostic odds ratio (DOR) was applied in the meta-analysis to compare the accuracy of various prediction models and questionnaires for sleep-disordered breathing (21). In this study, the DOR values of STOP-Bang for OSA, moderate to severe OSA, and severe OSA were 3.349, 2.651, and 3.189 respectively, and the DOR values of ESS for OSA, moderate to severe OSA, and severe OSA were 2.665, 2.279, and 3.289 respectively. It can be seen that the DOR values of STOP-Bang in diagnosing OSA and moderate severe OSA are higher than those of ESS, while the DOR value of STOP-Bang in diagnosing severe OSA is similar to that of ESS. Therefore, STOP-Bang has better predictive value for OSA than ESS.

The lack of awareness of OSA among the public and health professionals leads to a failure in the timely diagnosis of OSA patients, and studies have found that the vast majority (>80%) of patients with moderate to severe OSA remain undiagnosed (22). Untreated OSA patients are at increased risk for metabolic syndrome, cardiovascular disease and impaired neurocognitive function and mental health (23–26), and the disease significantly reduces the quality of life of patients (27, 28) and even contributes to their premature death (29–31). The adverse health effects of OSA can significantly increase economic costs (32, 33), while the treatment of OSA can bring economic benefits (34). Although PSG is the gold standard for diagnosing OSA, it is time-consuming and

TABLE 3 The scale predictors of each group patients [percentage (95%CI)].

Scale	Sensitivity	Specificity	PPV	NPV	DOR
AHI≥5 events/h					
ESS	0.455 (0.426–0.483)	0.762 (0.723–0.800)	0.830 (0.801–0.859)	0.353 (0.324–0.383)	2.665
STOP-Bang	0.788 (0.765–0.811)	0.474 (0.429–0.520)	0.793 (0.770–0.816)	0.467 (0.422–0.511)	3.349
AHI≥15 events/h					
ESS	0.492 (0.458–0.526)	0.702 (0.671–0.732)	0.616 (0.578–0.653)	0.587 (0.557–0.618)	2.279
STOP-Bang	0.812 (0.785–0.838)	0.381 (0.348–0.414)	0.560 (0.532–0.588)	0.676 (0.634–0.718)	2.651
AHI≥30 events/h					
ESS	0.592 (0.550–0.635)	0.693 (0.667–0.720)	0.454 (0.416–0.492)	0.798 (0.773–0.823)	3.289
STOP-Bang	0.857 (0.826–0.887)	0.348 (0.320–0.375)	0.361 (0.334–0.389)	0.849 (0.817–0.881)	3.189

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TABLE 4 Compare STOP-Bang combine ESS with STOP-Bang the scale predictors of each group patients [percentage (95%CI)].

Scale	Sensitivity	Specificity	PPV	NPV
AHI≥5 events/h				
STOP-Bang	0.788 (0.765–0.811)	0.474 (0.429–0.520)	0.793 (0.770–0.816)	0.467 (0.422–0.511)
STOP-Bang combine ESS	0.550 (0.518–0.581)	0.668 (0.609–0.727)	0.864 (0.836–0.891)	0.279 (0.243–0.315)
AHI≥15 events/h				
STOP-Bang	0.812 (0.785–0.838)	0.381 (0.348–0.414)	0.560 (0.532–0.588)	0.676 (0.634–0.718)
STOP-Bang combine ESS	0.585 (0.548–0.623)	0.598 (0.556–0.640)	0.650 (0.611–0.688)	0.531 (0.491–0.572)
AHI≥30events/h				
STOP-Bang	0.857 (0.826–0.887)	0.348 (0.320–0.375)	0.361 (0.334–0.389)	0.849 (0.817–0.881)
STOP-Bang combine ESS	0.675 (0.631–0.719)	0.592 (0.557–0.627)	0.483 (0.443–0.523)	0.763 (0.729–0.797)

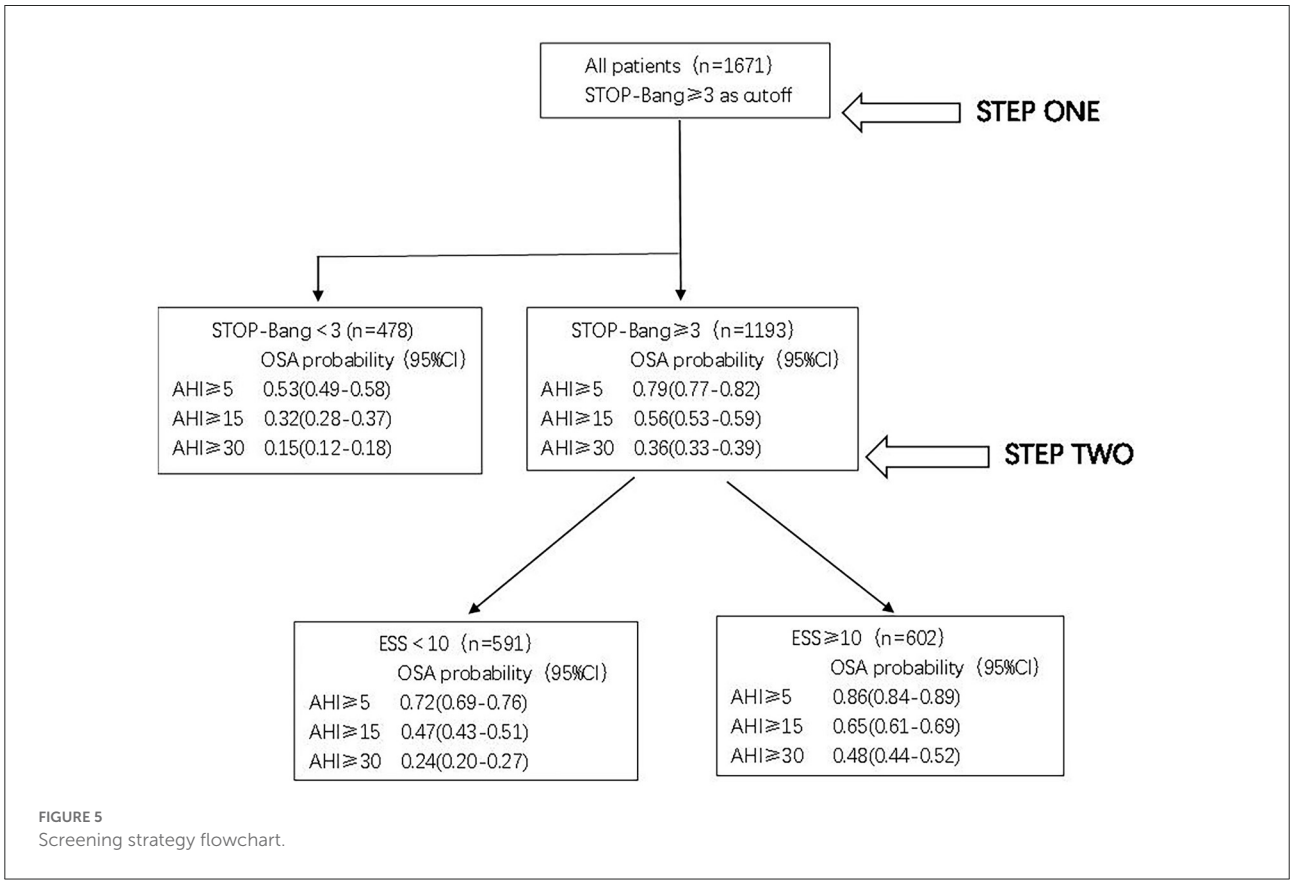

FIGURE 5
Screening strategy flowchart.

expensive, and has long waiting times, making timely diagnosis difficult to achieve. Tools for screening patients at high risk for OSA are becoming increasingly important in order to identify patients with OSA early and schedule further diagnosis and treatment.

The results of this study provide a simple and effective program for screening suspected OSA patients. We recommend a two-step screening. The first step is preliminary screening with the STOP-Bang questionnaire. Those with scores lower than three have a low risk of OSA, but its low specificity can easily cause a high false positive rate, so it is necessary to conduct the second step screening for those with scores of three or above.

The ESS score is mainly based on the patients' own cognitive score, which is completely subjective, while the STOP-Bang questionnaire is mainly based on objective factors. The combination of the two scales can complement each other to improve the predictive value of OSA. In this study, when combined with ESS, the specificity of the STOP-Bang questionnaire in predicting OSA, moderate to severe OSA, and severe OSA in patients was 0.668, 0.598, and 0.592. It can be seen

that the specificity of the STOP-Bang questionnaire combined with ESS in predicting OSA patients can be significantly improved. Therefore, we suggest that the second step of screening should be carried out in combination with ESS for people with a STOP-Bang questionnaire of three or more. For patients at high risk for OSA, we suggest a PSG examination followed by stratified management according to the examination results, including behavior adjustment, weight loss, drugs, continuous positive airway pressure ventilation, oral appliances, surgery and other individualized treatments. With the deepening of public understanding of OSA and the formation and efforts of multidisciplinary teams, the layered management of OSA is becoming increasingly important, and the rational diagnosis and treatment of OSA can be expected in the future.

Like many studies, this study has several shortcomings. The single-center cohort study mainly includes subjects from Guangzhou, but as the National Respiratory Medicine Center, our unit accepts a large number of research subjects from all over the country and should represent the Chinese population to a certain extent; and the members of the normal and severe OSAHS groups were younger than those of the mild and moderate groups, which may have had a certain impact on the results.

In conclusion, combining ESS with the STOP-Bang score improves its specificity at the cost of reducing its sensitivity in predicting OSA. As such, we recommend a two-step screening process for suspected OSA patients: the initial screening using the highly sensitive STOP-Bang score (three points), and then combining it with ESS to improve the specificity. This screening approach can assist doctors in conducting stratified management according to the OSA risk levels of patients, identifying high-risk patients and having them undergo PSG examination as soon as possible, and carrying out early intervention for patients with a definite diagnosis, thereby minimizing the harm caused by OSA.

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 human participants were reviewed and approved by Medical Ethics Committee of the First Affiliated Hospital of Guangzhou Medical University. Written informed consent for participation was not required for this study in accordance with the National Legislation and the Institutional requirements. Written informed consent was not obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

Author contributions

YZ, ZZh, CL, MC, and CW are the guarantor of the manuscript and take responsibility for the content of this manuscript. YZ, ZZh, RC, and XC contributed to the design of the study. JZ, JL, and XO were involved in the data analysis. ZZo, XO, and RC contributed to the acquisition of primary data. JL and RC wrote the initial draft of the manuscript. ZZh, RC, JD, and XC contributed significantly to the revision of the manuscript. All authors contributed to the article and approved the submitted version.

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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

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Intergenerational support and depressive symptoms in old age: The difference between urban and rural China

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Objectives: Intergenerational support is associated with fewer depressive symptoms in old age. Uneven development has resulted in huge urban–rural disparities in China, which could lead to different intergenerational relationships. The present study aimed to examine whether intergenerational support was associated with depressive symptoms differently among urban and rural Chinese older participants.

Methods: A sample of 3,498 participants from nine pairs of urban subdistricts and rural villages were included in the present study. Depressive symptoms were measured by the 10-item Center for Epidemiological Studies Depression Scale, and the intergenerational support mechanisms (financial, instrumental, and emotional) were assessed with a self-designed questionnaire.

Results: Significant areas by support effect for depressive symptoms indicated different associations between intergenerational financial and emotional support and depressive symptoms in urban and rural areas. Specifically, urban older participants receiving emotional support from adult children and rural older participants receiving financial support from adult children showed fewer depressive symptoms. In both areas, participants receiving instrumental support showed fewer depressive symptoms.

Conclusion: Our study is the first to compare the urban–rural disparity in association between intergenerational support and depressive symptoms in a developing country, China. The results support modernization theories proposing weakened economic function but intensified emotional ties in societies with higher level of development. Communication-based intergenerational emotional support should be promoted in urban areas, and formal support systems should provide financial and instrumental support to the vulnerable rural older population.

KEYWORDS

intergenerational support, depression, older adults, urban China, rural China

Introduction

Intergenerational support is a well-documented protective factor against depression in old age (1, 2), and this protective effect also holds true in China (3–5). During the last several decades, uneven development in China has led to great urban–rural disparities in economics, industries, living standard, and even social norms (6–8). Intergenerational relationship is closely linked to social development (9), and it is therefore intriguing whether intergenerational support and its association with depressive symptoms among older adults differ in the unevenly developed urban and rural areas in this developing country.

The most significant gap between urban and rural China is in economic development, with households' disposable income per capita in urban areas being 2.8 times the figure in rural areas through 1997 to 2015 (10). Urban areas have more secondary and tertiary industries, and urban residents enjoys better housing, education, and public services (8, 11). Furthermore, the social security system benefits urban older residents much more than their rural counterparts. The majority of rural older adults are covered by the Urban-Rural Resident Social Pension, the average of which being only 119 CNY per month at the time the present study was conducted, 5% of the Enterprise Employee Basic Pension, which covers most urban residents (12).

Such urban–rural disparities could lead to difference in intergenerational relationships. In agrarian societies with an economy based on land owned by the older generations, parents have authority over their children, and adult children are responsible for providing financial support to the older adults (13). In urban societies with a market economy, in contrast, the younger generation relies less on their parents to make a living, and the economic tie within a family is weakened (14, 15). At the same time, the improved pension system makes it possible for the older adults to support themselves (16). Consequently, adult children are no longer obliged to support their aged parents financially (17), and instead tend to maintain a strong emotional bond with their parents (18). Supporting this theory, empirical studies have found that in rural China, up to 60% of older adults receive financial support from their adult children (19, 20), while in developed countries (USA, European countries, and Japan) and urban China, the figure ranges from 1.3% to 22% (16, 19, 21, 22). Communication-based emotional support, on the other hand, is gaining importance and has become the leading form of intergenerational support expected by and provided to older adults in more developed areas such as Hong Kong, New Zealand, and Japan (22–24).

Intergenerational support has been found to be associated with few depressive symptoms in old age (25–28), but the contributions of different types of support are controversial. For example, with older participants from Myanmar, Vietnam, and Thailand, researchers found that financial but not emotional support from adult children predicted fewer depressive symptoms (27). In contrast, with participants from urban China, emotional but not financial support from adult children predicted fewer depressive symptoms in old age (4). Other studies in Japan and Spain found that both emotional and instrumental support from adult children was linked to fewer depressive symptoms (28, 29). These studies were conducted in areas with varied levels of social development, but it remains to be examined directly whether such difference has contributed to the inconsistent findings.

The present study aimed to test whether the association between three types of intergenerational support (financial, emotional, and instrumental) and depressive symptoms is different among urban and rural Chinese older participants. Basing on the above-described modernization theories and empirical studies, it was hypothesized that (1) in rural but not urban areas, older participants receiving financial support from adult children would show fewer depressive symptoms (H1), and (2) in urban but not rural areas, older participants receiving emotional support from adult children would show fewer depressive symptoms (H2). No hypothesis was made for instrumental support.

Methods

Sample and procedure

The present study is part of the Science and Technology Service Network Initiative and was initiated in 2015. The study was approved by the Ethics Committee of the Institute of Psychology of the Chinese Academy of Sciences (IPCAS), and informed consent was obtained from all participants.

Data were collected from permanent resident older adults in Ningde, Fujian Province, and multistage sampling was used in the present study. At the first stage, purposive sampling was adopted to ensure differences in the sampling sites. From each of the nine county-level units in Ningde, one pair of rural village and urban subdistrict were chosen. The villages were far from the county town center, while the subdistricts were sampled in the towns (Figure 1). At the second stage, participants were sampled during an annual physical examination offered to all older adults (aged 60 or more). The physical examination lasted for a month and residents can take it on any day that they were available. For each site, on three pre-determined days during this period, older adults taking the physical examination on those days were consecutively enrolled until a sample size of 200 was reached.

Note that three or four decades ago, these rural and urban sampling sites were all traditional agricultural societies and shared similar agricultural economic structure and culture. However, because the latter type of sampling sites was close to the old town, they gradually evolved from the traditional agricultural villages to part of the towns due to urbanization. Therefore, this purposive sampling method

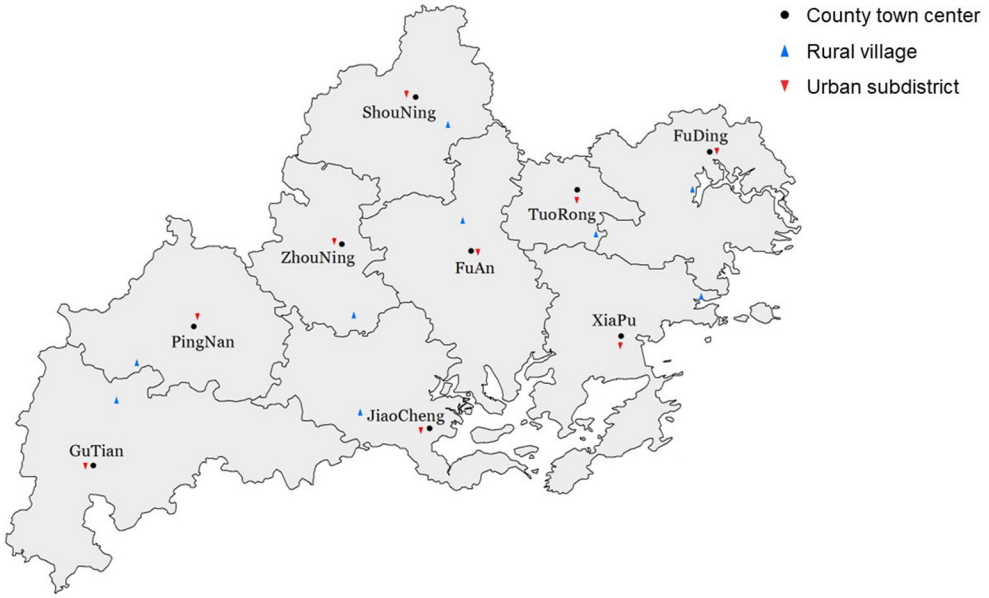

FIGURE 1
Sampling sites of the present study.

provides us high-quality paired samples to compare the pattern of intergenerational support and its association with emotional well-being in old age at different levels of social development.

Data were collected through face-to-face interviews conducted by trained local healthcare workers using a structured questionnaire. The training of the interviewers consisted a key member training and a project training. Seven local healthcare workers with work experience in public health and health promotion participated the key member training, which was held at the IPCAS. Lectures on psychological well-being in old age were delivered, and the present study were introduced. The seven key members were responsible for coordinating the project, recruiting participants, and interviewing the participants. Another 15 local healthcare workers, together with the key members, participated in the project training, which was held at a local venue. Instructions on how to implement the interview were given by an experienced researcher. The healthcare workers discussed how to explain the items in local dialect, and practiced the interview through role playing. These 15 healthcare workers were responsible for interviewing the participants. The questionnaire contained 135 questions, and on average it took an hour for a participant to finish it.

A total of 3,620 participants completed the survey, of which 46 were excluded, being below the age of 60, and a further 76 were excluded due to missing data on one or more variables included in the regression models. The participants with missing data accounted for only 2.0% of all participants, and in both urban and rural areas, there was no significant difference in core variables (depressive symptoms and intergenerational support) between participants with or without missing data. Ultimately, data from 3,498 participants (1,675 from traditional villages and 1,823 from urban subdistricts) were used in analyses.

Measures

Depressive symptoms

The 10-item version of the Center for Epidemiological Studies Depression Scale (CES-D) was used to measure depressive symptoms, requiring participants to indicate the frequency of depressive symptoms experienced during the past weeks on a 4-point scale from 0 (rarely or none) to 3 (most of the time) for each item. The total score ranges from 0 to 30, with higher scores indicating higher levels of depressive symptoms. The Chinese version of this scale has been validated in a previous study (30). The Cronbach alpha was 0.80 in the present sample.

Intergenerational support

The measurement of intergenerational support includes financial support, instrumental support, and emotional support. To assess financial support, participants were asked to identify at least one major source of income from the following options: (A) retirement pension, (B) spouse, (C) adult children, (D) adult grandchildren, (E) other relatives, (F) government subsidies, (G) labor income (working or farming), and (H) other sources. Answers were recoded into the variable "financial support from

adult children." Participants were coded as 1 if their choices included (C).

To measure instrumental and emotional support, participants were first asked to nominate up to three family members who provided the most support, then rate the support that each nominated child provided on a five-point Likert scale (1 = never to 5 = always), following the procedure of the Berlin Aging Study (31). The items of instrumental support were: (a) When you are sick, does he (or she) take care of you? (b) Does he (or she) help you to resolve difficulties? The items of emotional support are: (a) Do you confide in him (or her)? (b) Does he (or she) care for and comfort you? These questions were adapted from the Chinese Longitudinal Healthy Longevity Survey (32). For each item, the maximum among the scores corresponding to the nominees was used to represent the highest level of intergenerational support the participants receive. The sum of the two items' scores was used as the final score for instrumental/emotional support. Since the distribution of these two measurements were zero-inflated and significantly negatively skewed, both scores were dichotomized. A score of 8 or higher was coded as receiving "sufficient instrumental/emotional support." This threshold value was chosen because a score of 8 means reporting "4-often" for both items or "5-always" for one item and "3-sometimes" for the other, which indicates intensive instrumental/emotional support.

Control variables

Demographic information (age, gender, marital status, living arrangement), socioeconomic status (education, personal income, perceived financial status), health condition (perceived health, physical function), and negative life events were assessed using a self-designed questionnaire.

Living arrangement was classified into three categories: with adult children (both with or without a spouse), with a spouse only, and alone. The variable "personal income" was recoded from the question "major source of income," to indicate income other than intergenerational support. Participants who chose (A) retirement pension, (B) spouse, (E) other relatives, (G) labor income, or (H) other sources were coded as 1. Government subsidies were not included because every resident aged 60 and over is eligible for them, and they are hardly enough to maintain a minimum standard of living. Perceived financial status was measured by the question "Do you have enough money to spend?" Options ranged from "always" to "never."

Perceived health was measured by a question asking participants to evaluate their health condition, with options ranging from "very good" to "very bad." Activities of daily living (ADL) and instrumental ADL (IADL) were used to indicate physical functions. Activities of daily living assessed six items: bathing, dressing, toileting, indoor transferring, continence, and feeding. Instrumental activities of daily living assessed eight items: visiting others, shopping, cooking, doing laundry, walking for 2 km, carrying weights of 5 kg, squatting, and taking a bus. Participants having difficulty in neither ADL nor IADL were coded as "active," those having difficulty only in IADLs as "mildly impaired," and those having difficulty in both ADL and IADL as "severely impaired." The negative life events variable assessed whether participants had experienced events such as bereavement or natural disaster during the past year.

Statistical analysis

Independent sample *t*-tests and Chi-square tests were used to compare depressive symptoms with intergenerational support of participants in the two areas. We then conducted a one-way analysis of variance (one-way ANOVA) for bivariate analyses of associations between depressive symptoms and demographical variables, financial situation, and health situation.

Multiple linear regression models were then conducted for analyses of associations between depressive symptoms and intergenerational support. In the first set of models, interactions between area and intergenerational support were examined for their effect on depressive symptoms, both with and without other control variables. After having identified a significant interaction between area and intergenerational support, another set of models were conducted separately for urban and rural areas, examining the contribution of different types of intergenerational support on depressive symptoms.

Results

Descriptive analysis

Independent sample *t*-tests/chi-square tests were conducted on the mentioned demographics of participants from the two different areas. The results indicated that there was no significant difference in age distribution, marital status, or experience of negative life events (Table 1), but the percentage of females was higher in urban (56.6%) than in rural areas (50.7%, $\chi^2 = 11.86$, $p < 0.001$). Participants in the two areas differed significantly in living arrangements ($\chi^2 = 75.32$, $p < 0.001$), the percentage of participants living with adult children being higher in urban (55.3%) than in rural areas (42.3%). A larger proportion of participants in rural than in urban areas did not receive formal education (63.5% vs. 55.1%, $\chi^2 = 106.61$, $p < 0.001$), and were in a poor financial situation (49.2% vs. 34.3%, $\chi^2 = 157.58$, $p < 0.001$) and health condition (45.1% vs. 30.6%, $\chi^2 = 90.79$, $p < 0.001$). In rural areas, a lower percentage of participants reported retirement pensions as their major source of income than those in urban areas (5.7% vs. 23.3%, $\chi^2 = 211.50$, $p < 0.001$). Hence, these demographic variables were treated as covariates in the final regression models to rule out the possible influence of an unbalanced distribution.

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TABLE 1 Sociodemographic characteristics of participants in the two areas.

Variables	Rural areas ($n = 1,675$) n (%)	Urban areas ($n = 1,823$) n (%)	χ^2	p
Age			0.90	0.639
60–69	757 (45.2)	847 (46.5)		
70–79	636 (38.0)	688 (37.7)		
≥80	282 (16.8)	288 (15.8)		
Female	849 (50.7)	1,031 (56.6)	11.86	<0.001
Married	1,111 (66.3)	1,263 (69.3)	3.36	0.067
Living arrangement			75.32	<0.001
With children	709 (42.3)	1,008 (55.3)		
With spouse only	619 (37.0)	596 (32.7)		
Alone	347 (20.7)	219 (12.0)		
Formal education			106.61	<0.001
0 years	1,057 (63.1)	1,004 (55.1)		
1–6 years	519 (31.0)	506 (27.8)		
6+ years	99 (5.9)	313 (17.2)		
Financial situation			157.58	<0.001
Never or hardly enough	824 (49.2)	626 (34.3)		
Half the time enough	638 (38.1)	666 (36.5)		
Always or usually enough	213 (12.7)	531 (29.1)		
Major personal income				
Retirement pension	96 (5.7)	425 (23.3)	211.50	<0.001
Labor income	691 (41.3)	311 (17.1)	248.81	<0.001
Government subsidies	905 (54.0)	761 (41.7)	52.33	<0.001
Perceived health			90.79	<0.001
Bad or very bad	755 (45.1)	558 (30.6)		
Fair	712 (42.5)	891 (48.9)		
Good or very good	208 (12.4)	374 (20.5)		
Physical function (ADL/IADL)			25.64	<0.001
Active	1,264 (75.5)	1,487 (81.6)		
Mildly impaired	263 (15.7)	244 (13.4)		
Severely impaired	148 (8.8)	92 (5.0)		
Negative life events	342 (20.4)	366 (20.1)	0.04	0.835
Intergenerational support				
Financial support	1,057 (63.1)	1,030 (56.5)	15.82	<0.001
Emotional support	605 (36.1)	986 (54.1)	113.65	<0.001
Instrumental support	750 (44.8)	1,100 (60.3)	84.87	<0.001

Depressive symptoms and intergenerational support in urban and rural areas

Participants in rural areas reported significantly higher levels of depressive symptoms ($M = 12.30$, $SD = 5.88$) than those in urban areas [$M = 9.67$, $SD = 6.10$, $t_{(3,496)} = 12.95$, $p < 0.001$]. Intergenerational support also differed significantly in the two areas (Table 1). A higher percentage of participants in rural areas reported financial support from adult children as their major source of income (63.1% vs. 56.5%, $\chi^2 = 15.82$, $p < 0.001$). The reporting rate was significantly lower in rural than in urban areas for emotional (36.1% vs. 54.1%, $\chi^2 = 113.65$, $p < 0.001$) and instrumental support (44.8% vs. 60.3%, $\chi^2 = 84.87$, $p < 0.001$).

Associations between depressive symptoms and control variables

Bivariate associations between depressive symptoms and control variables were then examined using the one-way

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TABLE 2 Bivariate analyses of association between depressive symptoms and related factors.

Variables	Rural areas ($n = 1,675$)			Urban areas ($n = 1,823$)		
	M (SD)	*F*	*p*	*M (SD)*	*F*	*p*
Age		5.51	0.004		5.44	0.004
60–69	12.05 (5.67)			9.62 (6.12)		
70–79	12.12 (5.93)			9.3 (5.86)		
≥80	13.35 (6.23)			10.7 (6.46)		
Gender		16.40	<0.001		10.06	0.002
Male	11.71 (5.76)			9.15 (6.06)		
Female	12.87 (5.95)			10.06 (6.1)		
Marriage		21.92	<0.001		11.01	0.001
Not currently married	13.23 (6.05)			10.38 (6.44)		
Currently married	11.82 (5.74)			9.35 (5.91)		
Living arrangement		7.84	<0.001		6.65	0.001
With children	12.26 (5.81)			9.4 (6.01)		
With spouse only	11.76 (5.58)			9.61 (5.86)		
Alone	13.31 (6.42)			11.05 (6.92)		
Formal education		25.92	<0.001		47.49	<0.001
0 years	12.99 (5.86)			10.74 (6.15)		
1–6 years	11.45 (5.84)			9.15 (5.79)		
6+ years	9.34 (4.8)			7.09 (5.5)		
Personal income		35.86	<0.001		123.93	<0.001
Yes	11.46 (5.81)			8.11 (5.89)		
No	13.16 (5.84)			11.19 (5.90)		
Financial situation		70.14	<0.001		130.57	<0.001
Never or hardly enough	13.82 (5.87)			12.46 (6)		
Half the time enough	11.34 (5.32)			9.04 (5.66)		
Always or usually enough	9.25 (5.77)			7.16 (5.39)		
Perceived health		103.22	<0.001		154.74	<0.001
Bad or very bad	14.08 (5.87)			12.6 (6.41)		
Fair	11.63 (5.33)			9.36 (5.39)		
Good or very good	8.1 (5.1)			6.03 (4.95)		
Physical function		43.257	<0.001		57.22	<0.001
Active	11.56 (5.71)			8.98 (5.67)		
Mildly impaired	14.23 (5.9)			12.31 (6.82)		
Severely impaired	15.12 (5.72)			13.83 (7.18)		
Negative life events		60.38	<0.001		130.89	<0.001
None	11.74 (5.63)			8.88 (5.64)		
At least one	14.46 (6.35)			12.82 (6.79)		

ANOVA method (Table 2). In both urban and rural areas, higher levels of depressive symptoms were associated with increased age ($F = 5.51$, $p < 0.01$; $F = 5.44$, $p < 0.01$), being female ($F = 16.40$, $p < 0.001$; $F = 10.06$, $p < 0.01$), being unmarried ($F = 21.92$, $p < 0.001$; $F = 11.01$, $p < 0.01$), a poor financial situation ($F = 70.14$, $p < 0.001$; $F = 130.57$, $p < 0.001$), poor health ($F = 103.22$, $p < 0.001$; $F = 154.74$, $p < 0.001$), and negative life events ($F = 60.38$, $p < 0.001$; $F = 130.89$, $p < 0.001$).

Hypothesis testing

A series of multivariate regression analyses were conducted to examine whether the association between depressive symptoms and intergenerational support is different in the two areas (Table 3). In Model 1 (M1), only area, three types of intergenerational support, and interaction terms of the two variables were included, and control variables were added in Model 2 (M2). Regardless of this addition, the coefficients of

TABLE 3 Interaction of intergenerational support and area on depressive symptoms.

Variables	Model 1			Model 2		
	B	*SE*	*β*	*B*	*SE*	*β*
Rural areas	2.33	0.37	0.19***	1.16	0.33	0.09***
Inter-generational support						
Financial support	1.96	0.28	0.16***	−0.06	0.28	−0.00
Emotional support	−1.40	0.35	−0.11***	−1.02	0.31	−0.08**
Instrumental support	−1.76	0.36	−0.14***	−1.21	0.32	−0.10***
Intergenerational support * Area						
Financial support * Rural areas	−1.94	0.42	−0.15***	−0.79	0.37	−0.06*
Emotional support * Rural areas	1.56	0.53	0.10**	1.16	0.47	0.07*
Instrumental support * Rural areas	0.68	0.53	0.05	0.21	0.46	0.01
Age (60–69)						
70–79				−0.60	0.20	−0.05**
≥80				−0.11	0.28	−0.01
Female				0.67	0.19	0.05***
Married				−0.27	0.25	−0.02
Living arrangement (Alone)						
With children				−0.51	0.28	−0.04
With spouse only				−0.47	0.33	−0.04
Education (0 years)						
1–6 years				−0.56	0.21	−0.04**
6+ years				−1.29	0.31	−0.07***
Personal income				−1.54	0.22	−0.13***
Financial situation (Always/usually enough)						
Half the time enough				1.06	0.25	0.08***
Never or hardly enough				2.75	0.26	0.22***
Perceived health (Good or very good)						
Fair				2.50	0.26	0.20***
Bad or very bad				3.88	0.28	0.31***
Physical function (Active)						
Mildly impaired				1.57	0.26	0.09***
Severely impaired				2.64	0.35	0.11***
Negative life events				2.34	0.22	0.15***

*$P < 0.05$, **$P < 0.01$, ***$P < 0.001$.

interaction terms between area and financial support (M1, $B = -1.94$, $SE = 0.42$, $p < 0.001$; M2, $B = -0.79$, $SE = 0.37$, $p < 0.05$, H1) and area and emotional support (M1, $B = 1.56$, $SE = 0.53$, $p < 0.01$; M2, $B = 1.16$, $SE = 0.47$, $p < 0.05$, H2), reached statistical significance. This first set of models thus demonstrates that a difference exists in associations between depressive symptoms and financial/emotional support in urban and rural areas. Furthermore, in Model 1, the coefficients of main effects reached statistical significance for all three types of support (financial support, $B = 1.96$, $SE = 0.28$, $p < 0.001$; emotional support, $B = -1.40$, $SE = 0.35$, $p < 0.001$; instrumental support, $B = -1.76$, $SE = 0.36$, $p < 0.001$), and in Model 2, those do for emotional support ($B = -1.02$, $SE = 0.31$, $p < 0.001$) and instrumental support ($B = -1.21$, $SE = 0.32$, $p < 0.001$).

To further examine the difference in associations between depressive symptoms and intergenerational support, as well as other associated factors in urban and rural areas, another set of regression analyses were conducted for the two areas separately (Table 4). In Model 1 (M1) and Model 3 (M3), only three types of intergenerational support are included. In Model 2 (M2) and Model 4 (M4), control variables are also included. In models without covariates, financial support (H1) does not predict depressive symptoms in rural areas ($B = 0.02$, $SE = 0.31$, $p > 0.05$), and even predicts higher levels of depressive symptoms in urban areas ($B = 1.96$, $SE = 0.28$, $p < 0.001$). In models with

TABLE 4 Multiple liner regression models of intergenerational support on depressive symptoms in the two areas.

	Rural areas						Urban areas					
	Model 1			Model 2			Model 3			Model 4		
Variables	***B***	***SE***	***β***	***B***	***SE***	***β***	***B***	***SE***	***β***	***B***	***SE***	***β***
Intergenerational support												
Financial support	0.02	0.31	0.00	−0.95	0.32	−0.08**	1.96	0.28	0.16***	0.05	0.30	−0.00
Emotional support	0.15	0.40	0.01	0.19	0.36	0.02	−1.40	0.35	−0.12***	−1.00	0.31	−0.08**
Instrumental support	−1.08	0.39	−0.09**	−1.12	0.35	−0.10**	−1.76	0.36	−0.14***	−1.03	0.32	−0.08**
Age (60–69)												
70–79				−0.48	0.30	−0.04				−0.67	0.27	−0.05*
≥80				−0.04	0.41	0.00				−0.16	0.39	−0.01
Female				0.74	0.28	0.06**				0.59	0.26	0.05*
Married				−0.47	0.37	−0.04				−0.05	0.34	−0.00
Living arrangement (Alone)												
With children				−0.06	0.38	−0.01				−1.01	0.41	−0.08*
With spouse only				−0.45	0.45	−0.04				−0.58	0.48	−0.05
Education (0 years)												
1–6 years				−0.52	0.30	−0.04				−0.56	0.29	−0.04
6+ years				−1.80	0.57	−0.07**				−1.06	0.38	−0.07**
Personal income				−1.49	0.32	−0.13***				−1.56	0.31	−0.13***
Financial situation (Always/usually enough)												
Half the time enough				1.29	0.42	0.11**				0.87	0.31	0.07**
Never or hardly enough				2.79	0.42	0.24***				2.87	0.34	0.22***
Perceived health (Good or very good)												
Fair				2.66	0.42	0.22***				2.39	0.32	0.20***
Bad or very bad				4.03	0.43	0.34***				3.79	0.37	0.29***
Physical function (Active)												
Mildly impaired				1.45	0.37	0.09***				1.71	0.37	0.10***
Severely impaired				2.36	0.46	0.11***				3.06	0.56	0.11***
Negative life events				1.95	0.32	0.13***				2.74	0.31	0.18***

*$P < 0.05$, **$P < 0.01$, ***$P < 0.001$.

covariates, financial support predicts lower levels of depressive symptoms in rural areas ($B = -0.95$, $SE = 0.32$, $p < 0.01$) and is no longer a significant predictor in urban areas ($B = 0.05$, $SE = 0.30$, $p > 0.05$). Emotional support (H2) predicts lower levels of depressive symptoms only in urban areas (M3, $B = -1.40$, $SE = 0.35$, $p < 0.001$; M4, $B = -1.00$, $SE = 0.31$, $p < 0.01$). Instrumental support, regardless of the variables considered, consistently predicts lower levels of depressive symptoms (M1, $B = -1.08$, $SE = 0.39$, $p < 0.01$; M2, $B = -1.12$, $SE = 0.35$, $p < 0.01$; M3, $B = -1.76$, $SE = 0.36$, $p < 0.001$; M4, $B = -1.03$, $SE = 0.32$, $p < 0.001$).

It is important to note other indicators of depressive symptoms identified by this study. In both urban and rural areas, the three variables with the largest standard coefficients were poor perceived health (M2, $B = 4.03$, $SE = 0.43$, $p < 0.001$; M4, $B = 3.79$, $SE = 0.37$, $p < 0.001$), poor financial situation (M2, $B = 2.79$, $SE = 0.42$, $p < 0.001$; M4, $B = 2.87$, $SE = 0.34$, $p < 0.001$), and severely impaired physical function (M2, $B = 2.36$, $SE = 0.46$, $p < 0.001$; M4, $B = 3.06$, $SE = 0.56$, $p < 0.001$), indicating that these factors are most intensively associated with depressive symptoms.

Discussion

The present study investigated whether the association between intergenerational support and depressive symptoms differed between urban and rural Chinese older adults. Given the important role intergenerational support plays in promoting emotional well-being in old age (1, 2), it is essential to find out which type of support benefits older parents more. Sociodemographic characteristics of the participants corroborated the difference of development in the two sets of sample sites. Participants in urban areas receive more

formal education, rely more on retirement pension as their major source of income, and are in better financial situations, indicating different social and economic development levels of the two areas.

Intergenerational support and depressive symptoms in old age

Consistent with the first hypothesis, results indicated that rural but not urban participants receiving financial support from adult children had fewer depressive symptoms, corroborating previous reports of contribution of financial support in rural China (33) and other developing countries (27). In addition, a higher percent of rural participants reported receiving intergenerational financial support than urban participants. In traditional Chinese societies, family is the most important source of old-age support, and adult children bear the responsibility to provide financial and material support for their aged parents (13). Older parents would feel ashamed and even consider it a personal failure in life if their children are unfilial and do not support them (34). However, financial support from adult children has gradually lost its psychological significance in societies with higher levels of development (23, 35, 36), as the role that a modern family plays as a productive unit declines (15, 37). Formal support systems have instead begun to address old-age security, reducing the dependence of older adults on their children, as is the case in urban China (38).

In the model for urban areas without covariates (Table 4, Model 3), participants relying on intergenerational financial support have more depressive symptoms. According to supplementary analyses, including the variable "personal income" in the model can lead to a change in the coefficient of financial support as in Model 4. We noticed that older adults without another income source are much more likely to depend on financial support from adult children than those with other incomes (85.2% vs. 28.1%, $\chi^2 = 604.84$, $p < 0.001$). Given that no other income is also a predictor of more depressive symptoms, it is reasonable that in Model 3, participants reporting intergenerational financial support, who were also less likely to have other incomes, had more depressive symptoms.

Consistent with the second hypothesis, urban but not rural participants receiving emotional support from adult children had fewer depressive symptoms, and a higher percent of urban participants reported receiving sufficient intergenerational emotional support than rural participants. This significance of emotional support from adult children corresponds with previous studies on older Chinese citizens (4, 39) and older adults (including Chinese immigrants) in developed countries (28, 29, 35). With economic function detached from modern families, intergenerational relationships are less structurally defined and more personal (18), and emotional ties are based more on "verbal communication, understanding, sharing thoughts, and showing feelings" (40). In the present study, items addressing emotional support focused on this intimacy-based emotional support, asking whether the participants "confide in" or "are cared for and comforted by" their adult children. In an East Asian traditional patriarchal society, however, where the parent-child relationship is asymmetric and obedience to parental authority is obligatory (41), mutual understanding was not valued. As the society modernizing, family ties still endure but are more likely driven by choice instead of obligation (42). Hence, in later life, emotional support from children contributes more to psychological well-being in urban areas.

It worth noting that less than half (44.8%) of the rural participants received sufficient intergenerational instrumental support, the figure significantly smaller than their urban counterparts. This lack of instrumental support in rural areas contradicts the obligation of adult children to provide old-age care to their parents, and it could be accounted for by the fewer proportion of participants living with adult children in rural (42.3%) than in urban (55.3%) areas. Traditionally, living with adult children is the most common and preferred living arrangement for older adults (43). Social development and changes in the last few decades, however, have shaken this tradition and led to an increase in nuclear families. In 2015, up to half of the older population do not live with adult children (44). Rural residents tend to seek more non-agricultural job opportunities and move to live in cities (45), leaving their older parents, while urban residents are more likely to work and live locally and hence, more possible to take care of their parents.

In both urban and rural areas, participants receiving sufficient instrumental support from adult children reported fewer depressive symptoms, consistent with previous nation-wide research (19). In China, with filial piety being an essential social norm and taking care of older parents prescribed by law, it is most prevalent that older adults live at home (23, 24, 46). Although the government has started to stimulate the expansion of residential care homes since this century, only <5% older adults living in such institutes, and existing institutes could not substitute care provided by adult children (47, 48). In addition, in modern societies, older adults need practical help from adult children with various additional things, including home repairs, transportation, and financial and legal matters (49). Under both social norms and legal requirements, intergenerational instrumental support still bears great significance in both urban and rural areas, and consequently, lacking intergenerational instrumental support could have contributed to the higher level of depressive symptoms among rural participants.

Furthermore, although it is not the primary concern, the present study identified other possible factors contributing to

the great difference in depressive symptoms between urban and rural Chinese older adults. For participants in both areas, the predominant indicators of higher depressive levels are poor health, poor financial condition, and negative life events, all well-documented risk factors for late-life depression (50–53). The health and financial conditions of participants in rural areas are remarkably worse, which may have contributed most to the difference in late-life depressive symptoms in the two areas. This disparity is rooted in the unbalanced development in urban and rural China (7), rendering older adults in rural China the most vulnerable group in the context of mental health problems.

Implications

The present study is the first to examine whether financial, emotional, and instrumental support from adult children is associated with depressive symptoms differently among urban and rural Chinese older adults. The results provided support for modernization theories proposing weakened economic function but intensified emotional tie in families in more developed societies (14, 18). To better meet the psychological needs of urban older adults, communication-based intergenerational emotional support should be promoted. Older adults in rural areas, on the other hand, are more vulnerable to depressive symptoms and need support from both formal and informal support systems. Economic development is fundamental to improving this situation; it can improve living conditions for rural older adults and create more local job opportunities, therefore alleviating rural-urban migration and the resulting lack of instrumental support from adult children. Further, formal support systems should provide better old-age security and life-care services to cover the basic needs of older residents in rural areas. These forms of formal support have started to be addressed (54).

Limitations and future directions

The major limitation of this study is its generalizability. China is a vast nation with significant regional disparities in family values (55), and our sample sites were only from one prefecture-level city on the southeast coast of China. Other developing countries also differ from China in norms and practice concerning intergenerational relationships. Data from nation-wide surveys and other developing countries can further test whether the results can be generalized to other regions. Furthermore, it is intriguing whether other important formal (such as access to health care) and informal (such as friend) support systems influence urban–rural disparity of the association between intergenerational support and mental health. However, the contribution of other sources of support is beyond the scope of the present study and needs future studies to further investigate whether the present results still hold after controlling for other support systems.

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 human participants were reviewed and approved by the Ethics Committee of the Institute of Psychology, Chinese Academy of Sciences. The patients/participants provided their written informed consent to participate in this study.

Author contributions

CW performed all statistical analyses and contributed to writing the paper. ZL and JW contributed to survey implementation and data collection. TC planned the study, supervised the data analysis, and wrote the paper. XZ and BH contributed to revising the manuscript. All authors contributed to the article and approved the submitted version.

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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.

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Health shocks, basic medical insurance and common prosperity: Based on the analysis of rural middle-aged and elderly groups

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Health is a major part of human welfare. The index system of common prosperity was constructed for middle-aged and elderly people in rural areas. Besides, the impart of health shocks and rural basic medical insurance on common prosperity was explored. The data for this study came from China Health and Retirement Longitudinal Survey (CHARLS) in 2013, 2015, and 2018. The finding shows that health shocks hindered the improvement of the common prosperity of the middle-aged and elderly in rural areas, among which daily activities produced the greatest negative effect. The heterogeneity analysis shows that health shocks have a stronger negative effect on the common prosperity of low-income groups than that of high-income ones. The shock of daily activity ability has the greatest influence on the middle-aged and elderly between 45 and 55 years old. However, acute health shocks have a strong negative effect on those aged above 56. The mechanism analysis shows that rural basic medical insurance can alleviate the health shocks to middle-aged and elderly people, but the effect is limited. In general, low-income groups benefit more. Therefore, China should speed up the promotion of the Healthy China Strategy and the reform of the rural basic medical insurance system, and prompt changes from an inclusive to a targeted policy to provide more precise safeguards for vulnerable groups.

KEYWORDS

health shock, aging population, common prosperity, basic medical insurance, China

Introduction

Aging is one of the major trends in the changing age structure of the population in the world, and it is a main economic and social issue against the development of all nations (1). China is also so. According to the prediction of the World Bank, the population of the elderly in China will exceed 400 million by 2,035, with an aging rate of about 28%, and most of them live in rural areas (2). Unlike other groups, elderly people are highly vulnerable to health shocks due to their weak social roles and poor physical conditions,

especially given the relative lack of family support and medical care facilities in rural China. Statistics show that around 66% of the elderly aged above 60 in rural areas suffer from chronic diseases, which is much higher than that of the elderly in urban areas. This requires China to face a challenge in the long term: the health of the rural elderly.

As clearly pointed out by the Fifth Plenary Session of the 19th Central Committee, "the common prosperity of all people will have achieved more obvious and substantial progress by 2,035". On par with the new concept of common prosperity by the World Bank, the concept of common prosperity is aimed at enabling poor people to benefit from economic growth (3). Common prosperity lays emphasis on social equity and justice and comprehensive and coordinated development. Health, an indispensable human capital, is an important factor in enhancing the earning power of individuals and the wellbeing of humans (4). Safeguarding the health of rural elderly people is an important part of achieving comprehensive health and an important step to realize common prosperity. This is because the health problems of elderly people in rural areas are related to their development and life quality, as well as the harmonious development of the entire family. They are also closely associated with the wellbeing of the whole society. On the one hand, health shocks reduce the labor supply of middle-aged and elderly people and other family members by generating unexpected medical expenditures, leading to a decline in household income and increased uncertainty about household income (5–15). On the other hand, from a social perspective, the physical health status of middle-aged and elderly people, especially the elderly, is directly related to the care burden and medical expenses of the whole society (16, 17).

The main way for families to deal with health shocks is to increase preventive savings and participate in medical insurance, and the latter is a more effective means of risk transfer (18). At present, rural areas have established a full coverage medical insurance and security system to guarantee that each individual has medical insurance. Through social welfare, the material and spiritual living conditions of rural residents have been continuously improved, enabling them to share the achievement of economic and social development. From the existing literature, some scholars believe that rural medical insurance helps to improve the physical and mental health of participants (19–23), reduce household medical expenditures and preventive savings (24, 25), and enhance the ability to cope with health shocks (26). Nonetheless, some scholars stated that rural basic medical insurance has little effect on the improvement of residents' health and economic welfare (27, 28). Despite the increase in the utilization of medical services by patients, the rapid growth of medical expenses has resulted in no decline in their costs (29), which partially impairs the protection function of medical insurance (30). The economic and health effects of medical insurance have been extensively explored in the above literature, but most of them use data from a single year or non-tracking surveys and focus on the average coverage function of medical insurance for various groups of people. In a rapidly aging society, we must focus on the elderly people and explore the function of rural medical insurance for the elderly. This will contribute to the reform of rural medical insurance system and further improve its welfare effects.

This study aims to analyze the impact of health shocks on the common prosperity of the rural middle-aged and elderly, and verify the effects of rural basic medical insurance in the face of health shocks. The data for this study came from China Health and Retirement Longitudinal Survey (CHARLS) in 2013, 2015, and 2018. Compared with existing research, this study made the following contributions. This study firstly focused on middle-aged and elderly people in rural areas, and then it builds a multi-dimensional coupled common prosperity index system for them. In addition, the people-oriented concept of common prosperity was comprehensively reflected. Second, multi-dimensional health indicators were selected. The impacts of different health shocks on the common prosperity of the middle-aged and elderly in rural areas were subdivided, finding that daily activities have a greater negative effect than other health shocks. Third, whether rural basic medical insurance can alleviate the negative impact of health shocks on the common prosperity of the middle-aged and elderly in rural areas was explored. Additionally, the beneficiary groups of rural basic medical insurance were further evaluated.

Data, variables, and empirical model

Data

The 2013, 2015, and 2018 three-phase tracking data of CHARLS were used, aiming to collect a nationally representative micro-data set of the Chinese population aged 45 and above to analyze the problem of Chinese population aging. The national baseline survey began in 2011, whose content covers personal basic information, health status, household income and consumption, medical insurance, etc. to meet the research needs of the middle-aged and elderly. This paper dealt with the data set as follows: Firstly, the samples whose household registration is agricultural were surveyed in 2013, 2015, and 2018, and retained; secondly, the samples with missing key information including individuals and families were eliminated, and the final balanced panel data is 20,256.

Variables

Dependent variable

Level of common prosperity (CP). Common prosperity is the continuation and expansion of poverty alleviation work (31). It emphasizes social fairness and justice and the all around

development of people, including material prosperity, spiritual life and sharing of social development achievements. It refers to the prosperity of all the people, which requires benefiting each individual. Rural middle-aged and elderly groups account for about 49.38% of the total rural population, which thus cannot be ignored in the process of promoting common prosperity. Previous studies focused on the development of middle-aged and elderly people in rural areas from material and spiritual dimensions (32, 33), embodying the "prosperity" dimension of common prosperity. The focus of common prosperity should be on "prosperity" and "common" dimensions. It should incarnate the fairness and equality of human development, narrow the urban-rural gap between middle-aged and elderly people in terms of income and living standards, and eliminate their insufficient access to medical resources. The disparity in basic public services is also an important part of promoting common prosperity. According to previous studies, an index evaluation system was constructed for the common prosperity of middle-aged and elderly people in rural areas from the three dimensions of material and spiritual wealth as well as social sharing. Subdivision indicators for dimensions including livable pension environment and active aging spirit were selected (see Table 1).

Referring to the previous literature (32–34), the dimension of material wealth is mainly measured from income, wealth, consumption and living environment. It mainly highlighted that a secure life for the middle-aged and elderly, a livable environment and other basic survival needs were met. The income included both indicators reflecting objective income (absolute and relative income) and subjective indicators reflecting the income gap. The absolute poverty line of CNY2300 per year (at 2010 prices; this is approximately USD361) will be used as set by the Chinese government, which was assigned a value of 1, and otherwise 0. For relative income, the median disposable income of rural residents in the country in the current year was selected as the critical value. The per capita annual income of households in the current year was not lower than the critical value, whose value was assigned as 1 and otherwise 0. The relative poverty line of the 3 years can be calculated as CNY 7,907(USD1,276.23), CNY10,291 (USD1, 652.27) and CNY13,066(USD1,976.16).[1] Regarding subjective relative income, the question on the measurement of relative income in the questionnaire "Do you think your standard of living is much better, better, similar, worse or much worse than the average living standard of your neighbors/village?" was used. It was assigned a value of 1 if the respondent's answer was similar, better or much better, and otherwise 0. Employment included agricultural and non-agricultural employment as long as the respondent was engaged in any of the two, and it was assigned a value of 1 and otherwise 0. The threshold value of consumption adopted the rural per capita consumption in the province where the respondent was located. It was assigned a value of 1 and otherwise 0 when the total per capita consumption of the household in the current year was not lower than the rural per capita consumption of the province in the current year. Each subdivision indicator was limited by space and would not be repeated one by one. Details are shown in Table 1.

Different from material wealth, spiritual wealth aims to reflect people's learning and development, protection of rights and interests as well as other aspects of a better life at a deeper level. The measure of the mental affluence dimension is difficult to define. The measurement of spiritual wealth mainly included culture, education and entertainment, political gain, etc. (1), while that of spiritual wealth included health, social security, education and culture (34). Limited by the availability of data, the latter definition was mainly drawn on. Health adopted self-assessment health, and good and above were assigned a value of 1 and otherwise 0. Education covered educational level and vocational training. The critical value of educational level was junior high school, and the value of junior high school and above was 1 and otherwise 0. For rural middle-aged and elderly people, labor participation is still an important basis for their survival and development (15), thereby suggesting that participation in vocational training is also crucial for their further improvement of human capital. Social security was measured by whether to participate in or receive any pension insurance. The cultural dimension covered social activities and subjective wellbeing. Social activities were represented by "Have you performed the following social activities in the past month" in the questionnaire, and the value was 1 if the respondent participated in any of them, and otherwise 0.

The social sharing dimension included group and regional differences into the social sharing dimension and covered the subdivision dimension of public service supply differences (34). Group differences included objective and subjective differences. Objective differences meant that the ratio of local urban-rural income did not exceed the sample median of the year as the critical value. However, subjective differences were based on the question on the measurement of relative income in the questionnaire "What do you think you are compared with the average living standard of people in this county/city/district? Is the standard of living much better, better, about the same, worse or much worse?" It was assigned a value of 1 when the respondent answered about the same or above, and otherwise 0. The supply of public services mainly reflected local medical resources. The median of the current year was selected as the critical value. When the number of local health institutions per 10,000 people was not lower than the median of the current year, the value was 1 and otherwise 0. Regional differences mainly considered the level of economic development. The sample region is the east, which was assigned a value of 1 and otherwise 0.

In addition, equal and entropy weight methods, analytic hierarchy processes, etc. were primarily used for determining

1 Notes: In 2018,1USD = 6.6118CNY; In 2015, 1USD = 6.2284CNY; In 2013, 1USD = 6.1956CNY.

TABLE 1 Common prosperity index system for middle-aged and elderly people in rural areas.

First-level indicators	Second-level indicators	Third-level indicators	Critical value
Material wealth	Income	Absolute income	If the per capita annual income of the family is not less than CNY2300, the value is 1; otherwise, 0
		Relative income	If the per capita annual household income is not lower than the national median disposable income of rural residents in that year, the value is 1; otherwise, 0
		Subjective relative income	Compared with the average living standard of the village/neighbor, if you think your living standard is similar or above, assign a value of 1; otherwise,0
	Employment	whether have a job	If the respondent is a business farmer or a worker, the assignment is 1; otherwise, 0
	Consumption	Per capita consumption	If the total per capita consumption is not lower than the rural per capita consumption of the province in that year, and the value is 1; otherwise, 0.
	Living environment	Tap water	Yes = 1, no = 0
		Internet	Yes = 1, no = 0
		Cooking fuel	Clean fuel = 1, no = 0
		Whether the toilet can be flushed	Yes = 1, no = 0
		Housing structure	Reinforced concrete or brick and wood structure, the value is 1; otherwise, 0
		Cleanliness of the house	Neat, assign a value of 1; otherwise, 0
Spiritual wealth	Health	Self-assessed health	The self-assessment of good health is assigned a value of 1; Otherwise, 0
	Education	Education level	1 for junior high school and above; otherwise, 0
		Vocational training	Whether to participate in vocational training, yes = 1, no = 0
	Social security	Endowment insurance	Whether to participate in or receive any pension insurance, yes = 1, no = 0
	Culture	Social interaction	Whether you have participated in social activities in the past month, yes = 1, no = 0
		Subjective wellbeing	Evaluation of life satisfaction, satisfaction = 1, otherwise 0
Social sharing	Group differences	Objective difference	If the ratio of local urban and rural income does not exceed the sample median of the year, assigned a value of 1; otherwise, 0
		Subjective difference	Compared with the average living standard of people in this county/city/district, if you feel that your living standard is about the same or above, assign a value of 1; otherwise, 0
	public service provision	Medical resources per capita	If the number of health institutions per 10,000 people is not lower than the sample median of the year, assigned a value of 1; otherwise, 0
	Regional differences	The level of economic development	If the region is the east, the value is 1; otherwise, 0

weights. Among them, the equal weight method has been recognized and widely used by numerous scholars at the level of micro-individual data (34, 35), which was thus employed to assign indicators. Notably, subjective relative income and subjective differences in subdivision indicators were only included in 2013, and vocational training indicators were only reflected in 2015 and 2018 because of data availability.

Independent variable

Health shock is widely defined as sudden health deterioration caused by diseases or accidents (11, 36). Some previous studies used self-reported health (37), sickness in the past 4 weeks (37) and hospitalization in the past year (38), the proportion of medical expenditures (39) and other indicators as standards. However, the measurement of these indicators did not subdivide the types of health shocks. This tends to exaggerate the effect of health shocks and leads to the difficulty in truly and objectively reflecting the true impact of health shocks on individuals. Zhang et al. (40) stated that health shocks could also be segmented into chronic (*Sick_1*) and acute health (*Sick_2*) as well as daily activity ability shocks (*ADLS*) utilized in this study. Among them, chronic and acute health shocks were defined by "Whether you have been told by a doctor that you have a certain disease" in the database. As classified by Yang et al. (14, 36), the samples with heart disease, cancer or stroke were defined as acute health shocks and assigned a value of 1 and otherwise. In addition, chronic health shocks were defined

as high blood pressure, stomach disease, rheumatoid arthritis, etc., and characterized according to the number of common chronic diseases the respondents suffered from. Middle-aged and elderly people were classified as acute health shock groups if suffering from two types of diseases simultaneously.

As regards the impact of daily activity ability, the questionnaire DB010-DB020 on 11 daily life behaviors such as dressing, bathing, eating, getting up and out of bed, and going to the toilet was used. Scores were summed up, with a value ranging from 11 to 44. The larger the value was, the greater the impact of its daily activity ability would be. The number of chronic diseases and the scores of daily activities of the respondents were standardized according to the following formula:

$$\hat{X} = \frac{X - \min(X)}{\max(X) - \min(X)} \quad (1)$$

Control variables

Control variables were mainly selected from personal and family characteristics according to previous literature (36, 37, 39). The level of personal characteristics included: (1) The age of the respondents (*age*) was a continuous variable; (2) Marital status (*marry*) was a binary variable. The value of marriage was 1, and that of divorce and widowhood was 0; (3) Whether it is a party member (*party*) was a binary variable; (4) Type of residence (*live*). Family residence was assigned a value of 1, and a nursing home or other elderly care institution was assigned a value of 0.The level of family characteristics covered: (5) Family size (*hsize*) was a continuous variable; (6) The existence of productive fixed assets (*invest*) was a binary variable, the family has productive fixed assets such as threshers, tractors, etc., was assigned a value of 1 and otherwise 0; (7) Whether to take care of grandchildren (*care*), two categorical variables; (8) per capita annual household income (*income*), a continuous variable, incorporating the logarithm of income into the regression equation.

Mediating variable

The role of basic medical insurance between health shocks and common prosperity among middle-aged and elderly people was explored in this study. Some areas in China have made a combination of new rural cooperative medical insurance and urban resident medical insurance collectively referred to as urban and rural resident medical insurance. Therefore, the value was 1 and otherwise 0 if the respondents participating in new rural cooperative medical care or basic medical insurance were considered to participate in basic medical insurance in rural areas. Additionally, individuals participating in both basic medical insurance and other types of medical insurance, including commercial medical insurance, urban employee medical insurance, etc. were deleted for better testing of the role of rural basic medical insurance.

The above variables and their descriptive statistics are shown in Table 2.

Empirical model

To explore the impact of health shocks on the common prosperity of rural middle-aged and elderly people, the benchmark model was constructed as follows:

$$CP_{it} = \beta_0 + \beta_1 X_{it} + \beta_i conrtols_i + \alpha_i + \lambda_t + \epsilon_{it} \quad (2)$$

Where *CP* represents the common wealth level of middle-aged and elderly people; *X* stands for three variables to measure health shocks: chronic and acute health shocks as well as daily activity ability shock; *conrtols* refers to a series of selected control variables; β_0 indicates the intercepted item; β_1 means the coefficient of interest; β_i is the coefficient of control variables; *i* represents middle-aged and elderly individual, and *t* stands for year; $\epsilon_{it}$is a normally distributed random error vector. Meanwhile, variables α_i without changing with time (individual effect) and other variables λ_t changing with time (year effect) were controlled as random disturbance terms to alleviate the endogenous problem caused by missing variables.

Empirical results and analysis

Benchmark regression results

The regression results of the impact of three types of health shocks on the common prosperity of the middle-aged and elderly are reported in Table 3 (1), (3), and (5) are the two-way fixed effects of the control year and individual, and (2), (4), and (6) are the regression results of adding control variables on this basis. Regression coefficients shrank, but the significance and none of the coefficient directions changed. Daily activity ability and acute health shocks were significant at the 1% level, and chronic health shocks were significant at the 5% level. It indicates that health shocks significantly negatively affected the common prosperity of the rural middle-aged and elderly. The regression coefficients of the three types of health shocks are −0.0854, −0.0142, and −0.0113. It can be seen that daily activities have the largest negative effect, followed by chronic and finally acute health shocks. For every 1% increase in the impact of daily activity ability, the common wealth level of the rural middle-aged and elderly can decrease by 8.54% on average. The possible reason is that the limited daily activities of middle-aged and elderly people will increase family expenditures compared with other health shocks for one thing. For another thing, other family members are required to

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TABLE 2 Descriptive statistics.

Variables	Symbols	2013		2015		2018	
		Mean	S.D.	Mean	S.D.	Mean	S.D.
Dependent variable							
Common prosperity for the middle-aged and elderly in rural areas	CP	0.4964	0.1429	0.5248	0.1294	0.5530	0.1367
Independent variable							
Activities of daily living shock	ALDS	0.0321	0.0836	0.0421	0.0974	0.0527	0.1126
Chronic health shock	Sick_1	0.1287	0.1886	0.1721	0.2153	0.2506	0.2523
Acute health shock	Sick_2	0.1401	0.3471	0.1881	0.3908	0.2922	0.4548
Control variables							
Age	Age	58.8520	8.4786	60.8520	8.4786	63.8520	8.4786
Marital status	Marry	0.9159	0.2776	0.9159	0.2776	0.9274	0.2595
Party member	Party	0.9285	0.2577	0.9285	0.2577	0.9362	0.2445
Type of residence	Live	0.9954	0.0676	0.9852	0.1208	0.9767	0.1507
Household population size	Hsize	3.5579	1.8617	2.5255	1.1743	2.7656	1.4851
Whether there are productive fixed assets	Invest	0.4391	0.4963	0.4084	0.4916	0.3152	0.4646
Whether to take care of grandchildren	Care	1.4797	0.4996	1.4612	0.4985	1.4335	0.6110
Logarithm of household income per capita	Income	8.4956	1.1977	7.9222	1.5583	8.0247	1.2792
Mediating variable							
Basic medical insurance	Insurance	0.9638	0.1866	0.9228	0.2668	0.9669	0.1787
Observations	–	6,752	6,752	6,752			

accompany and care for them, which not only affects the labor participation of middle-aged and elderly individuals but also restricts the labor participation of other family members. This impact may not be temporary, but long-term, which will greatly bring down the level of family economy and welfare. Besides, the regression coefficient of chronic health shocks was slightly larger than that of acute health shocks, which slightly differs from the conclusions of previous studies. This is because the number of middle-aged and elderly people with chronic diseases rather than whether they have chronic diseases was taken into consideration in this paper. Patients with chronic diseases and comorbidities in the sample occupied about 50%. The number of outpatient visits and the risk of catastrophic health expenditures will significantly increase with the increasing number of patients with comorbidities (41).

Endogeneity and robustness test

The regression in this study made use of a two-way fixed-effects model and could alleviate the endogeneity problem that may be caused by omitted variables. However, a reverse causality existed, given that the common wealth level of middle-aged and elderly people may affect their health status in terms of the micro level. Thus, this study referred to the practice of Tian (42) and Zhang et al. (40) to select physical health status before the age of 15 and whether to exercise regularly as the instrumental variables of health shock. The instrumental variable method for testing was also applied. The regression results are presented in Table 4. The coefficients of the three core explanatory variables characterizing health shock remained significantly positive at the 1% level. It indicates the reliability of the conclusion that health shock has a significant negative effect on the common prosperity of the rural middle-aged and elderly. Meanwhile, the method of replacing explained variables was adopted to test the robustness of benchmark regression. To be specific, the three-level indicators under first-level indicators were assigned equal weights and then summed up. The latent variable was assigned 0 if ≤ 1, 1 if >1 and ≤ 2, and 2 if >2 and <3. The panel Probit model was regressed [columns (4)–(6)], and the results all significantly supported the conclusions of this study.

Heterogeneity analysis

Different income groups and age structures may have different effects on common prosperity when suffering from health shocks. Therefore, heterogeneity analysis was conducted on the basis of the whole sample. The samples were classified into three groups (low-, middle- and high-income groups) according to the per capita annual income of households. Besides, age was classified into three groups (45–55, 56–64, and 65 years old and above).

The income group regression results are shown in Table 5. First, the three health shocks have the greatest impact on the common wealth level of middle-aged and elderly people among

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TABLE 3 The benchmark regression result.

Variables	(1)	(2)	(3)	(4)	(5)	(6)
ADLS	−0.0878***	−0.0854***				
	(0.0107)	(0.0101)				
Sick_1			−0.0183***	−0.0142**		
			(0.0071)	(0.0063)		
Sick_2					−0.0128***	−0.0113***
					(0.0034)	(0.0031)
Age		0.0145***		0.0145***		0.0145***
		(0.0003)		(0.0003)		(0.0003)
Live		−0.0011		−0.0016		−0.0014
		(0.0063)		(0.0063)		(0.0063)
Party		0.0014		0.0012		0.0016
		(0.0114)		(0.0114)		(0.0114)
Marry		−0.0241***		−0.0233***		−0.0239***
		(0.0089)		(0.0089)		(0.0088)
Hsize		0.0012**		0.0011*		0.0011**
		(0.0006)		(0.0006)		(0.0006)
Invest		0.0040**		0.0040**		0.0040**
		(0.0018)		(0.0018)		(0.0018)
Care		−0.0071***		−0.0073***		−0.0073***
		(0.0014)		(0.0014)		(0.0014)
Income		0.0268***		0.0268***		0.0268***
		(0.0005)		(0.0005)		(0.0005)
_cons	0.4992***	−0.5562***	0.4987***	−0.5549***	0.4982***	−0.5553***
	(0.0010)	(0.0317)	(0.0013)	(0.0329)	(0.0010)	(0.0322)
Year control	Yes	Yes	Yes	Yes	Yes	Yes
Individual control	Yes	Yes	Yes	Yes	Yes	Yes
Observations	20,256	20,256	20,256	20,256	20,256	20,256

***$p \leq 0.01$, **$p \leq 0.05$, * $p \leq 0.1$; Standard errors are in parentheses (the same below).

TABLE 4 Results of endogenous test and robustness test.

Variables	Endogenous test			Robustness test		
	(1)	(2)	(3)	(4)	(5)	(6)
ADLS	−0.8447***			−1.7437***		
	(0.0686)			(0.1462)		
Sick_1		−0.5542***			−0.2445***	
		(0.0392)			(0.0742)	
Sick_2			−0.2348***			−0.0966**
			(0.0142)			(0.0394)
_cons	0.4058***	0.3972***	0.3182***			
	(0.0168)	(0.0192)	(0.0157)			
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
Year control	Yes	Yes	Yes	Yes	Yes	Yes
Individual cnotrol	Yes	Yes	Yes	Yes	Yes	Yes
Observations	20,256	20,256	20,256	20,256	20,256	20,256

Due to space limitations, this study only reports the second-stage regression results. ***$p \leq 0.01$, **$p \leq 0.05$.

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TABLE 5 Results of income groups.

Variables	Low income (1)	Middle income (2)	High income (3)	Low income (4)	Middle income (5)	High income (6)	Low income (7)	Middle income (8)	High income (9)
ADLS	−0.0927***	−0.0969***	−0.0659**						
	(0.0204)	(0.0281)	(0.0326)						
Sick_1				−0.0206	−0.0138	0.0024			
				(0.0162)	(0.0166)	(0.0152)			
Sick_2							−0.0137*	−0.0175**	−0.0124*
							(0.0077)	(0.0085)	(0.0075)
_cons	−0.3346***	−0.3821***	0.0317	−0.3357***	−0.3782***	0.0393	−0.3253***	−0.3903***	0.0154
	(0.0650)	(0.0766)	(0.0632)	(0.0704)	(0.0801)	(0.0662)	(0.0667)	(0.0794)	(0.0647)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year control	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Individual control	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	6,749	6,386	7,121	6,749	6,386	7,121	6,749	6,386	7,121

***$p \leq 0.01$, **$p \leq 0.05$, * $p \leq 0.1$.

middle- and low-income groups across the board. Despite the insignificant coefficient of chronic health shocks, its sign remained negative. The impact of daily activities was taken as an example. The regression coefficients of low- and middle-income groups were −0.0969 and −0.0927, respectively, with a small difference, whose absolute value was significantly higher than that of the high-income group by about 3.1%. This indicates that low- and middle-income groups experienced a greater reduction in the level of common prosperity when suffering from health shocks compared with the high-income group. With a single source of income, low- and middle-income families mainly rely on wage income, including migrant workers, and have a relatively poor ability to resist risks. Therefore, their common wealth level drops significantly when they suffer from health shocks.

The age group regression results are shown in Table 6. The impact of different health shocks on different age groups varied across the board. First, the regression coefficient of daily activities of the first group (45–55 years old) was significantly higher than that of the other two groups, about twice that of the other two groups. The reason for this phenomenon is that the impact on both individuals and families has a longer time span than the other two groups when 45–55-year-old individuals are limited in their ability to perform daily activities during their lifespan. For this reason, the impact on common prosperity is also greater. Secondly, acute health shocks have a greater impact on the second (56–64 years old) and third groups (65 years old and above) than the first one. Finally, the influence coefficient of chronic health shocks has a greater impact on the latter two groups despite being not significant.

Mediating effect of rural basic medical insurance

Results of mediating effect of basic medical insurance

To further explore whether rural basic medical insurance can alleviate the negative impact of health shocks on the common prosperity of the middle-aged and elderly, the interaction term between basic medical insurance and health shocks was introduced. If basic medical insurance can mitigate the health shocks to the common prosperity of the middle-aged and elderly, the expected interaction term coefficient was positive. The regression results are presented in Table 7. It can be seen that the interaction coefficients of the three types of health shocks and medical insurance were all positive but insignificant, indicating that basic medical insurance can alleviate the negative effect of health shocks on the common prosperity of middle-aged and elderly people, but the effect is limited. In this case, hypothesis 3 was verified. Zhang et al. (40) also maintained that basic medical insurance plays a limited role in alleviating health shocks to the decline in income and increased expenditures of middle-aged and elderly families. The possible reason lies in the focus of current rural basic medical insurance on the most basic ones, the limited reimbursement ratio, the small scope of reimbursement and the limited ability to protect vulnerable groups (43). On top of this, the gap between urban and rural medical resources is extremely large, and the construction of basic medical services in rural areas is weak. People need to seek medical treatment in other places when generally suffering from major diseases.

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TABLE 6 Results of age groups.

Variables	45–55 years old (1)	56–64 years old (2)	>65 years old (3)	45–55 years old (4)	56–64 years old (5)	>65 years old (6)	45–55 years old (7)	56–64 years old (8)	>65 years old (9)
ADLS	−0.1351***	−0.0675***	−0.0649***						
	(0.0266)	(0.0204)	(0.0147)						
Sick_1				0.0018	−0.0139	−0.0110			
				(0.0135)	(0.0124)	(0.0112)			
Sick_2							−0.0050	−0.0147**	−0.0115**
							(0.0073)	(0.0065)	(0.0053)
_cons	−0.6450***	−0.5043***	−0.5594***	−0.6354***	−0.5066***	−0.5450***	−0.6422***	−0.5157***	−0.5545***
	(0.0641)	(0.0613)	(0.0623)	(0.0654)	(0.0626)	(0.0658)	(0.0644)	(0.0620)	(0.0642)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year control	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Individual control	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	6,028	7,331	6,897	6,028	7,331	6,897	6,028	7,331	6,897

***$p \leq 0.01$, **$p \leq 0.05$.

TABLE 7 Results of mediating effect of basic medical insurance.

Variables	(1)	(2)	(3)
ALDS	−0.0845***		
	(0.0101)		
ALDS*insurance	0.0141		
	(0.0313)		
Sick_1		−0.0142**	
		(0.0063)	
Sick_1*insurance		0.0231	
		(0.0140)	
Sick_2			−0.0112***
			(0.0031)
Sick_2*insurance			0.0016
			(0.0079)
Insurance	0.0079**	0.0091***	0.0088***
	(0.0033)	(0.0033)	(0.0033)
_cons	−0.5637***	−0.5633***	−0.5637***
	(0.0318)	(0.0330)	(0.0323)
Control variables	Yes	Yes	Yes
Year control	Yes	Yes	Yes
Individual control	Yes	Yes	Yes
Observations	20,256	20,256	20,256

***$p \leq 0.01$, **$p \leq 0.05$.

Benefits of rural basic medical insurance

To test the impact of rural basic medical insurance on different income groups under health shocks, all the middle-aged and elderly people participating in insurance were taken as a sample and divided into three groups according to per capita annual household income. The regression results are presented in Table 8. It was further found that low-income groups could benefit from health insurance, especially those suffering from daily activity and acute health shocks. In the regression of daily activity ability shocks, the regression coefficients of low-, middle- and high-income groups were −0.2028, −0.2445, and −0.2462, respectively. This means that medical insurance can reduce the common wealth level of the middle-aged and elderly in the low-income group by an average of 4.26% when they suffered from the impact of daily activities. In the group regression of acute health shocks, the regression coefficient of the low-income group was −0.0236, whose absolute value was significantly lower than that of middle- and high-income groups. It indicates that medical insurance can also effectively alleviate the common prosperity of the middle-aged and elderly in the low-income group in the event of acute health shocks. For chronic health shocks, the high-income group is more likely to benefit from health insurance, followed by the low-income one. Rural basic medical insurance was originally designed to alleviate the economic burden of farmers suffering from major diseases. In recent years, chronic diseases have been gradually included in the reimbursement scope. When suffering from chronic health shocks, the low-income group has less need for the utilization of medical services compared with the high-income one. In summary, the beneficiary group of rural medical insurance is the low-income group.

Discussion

This paper mainly aimed to construct an evaluation system for the common prosperity of rural middle-aged and elderly people under the background of the increasing aging in China. It also intends to systematically evaluate the impact of chronic

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TABLE 8 The mediating effect of medical insurance under different income groups.

Variables	Low income (1)	Middle income (2)	High income (3)	Low income (4)	Middle income (5)	High income (6)	Low income (7)	Middle income (8)	High income (9)
ADLS	−0.2028***	−0.2445***	−0.2462***						
	(0.0129)	(0.0144)	(0.0171)						
Sick_1				−0.0361***	−0.0378***	−0.0318***			
				(0.0069)	(0.0069)	(0.0071)			
Sick_2							−0.0236***	−0.0331***	−0.0304***
							(0.0036)	(0.0038)	(0.0039)
_cons	0.5801***	0.2423***	0.1205***	0.5967***	0.2540***	0.1359***	0.6006***	0.2544***	0.1416***
	(0.0266)	(0.0395)	(0.0383)	(0.0271)	(0.0402)	(0.0387)	(0.0271)	(0.0401)	(0.0386)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year control	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Individual control	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	6,399	6,130	6,739	6,399	6,130	6,739	6,399	6,130	6,739

***$p \leq 0.01$.

and acute health shocks as well as daily activity ability shocks on their common prosperity. On this basis, whether rural basic medical insurance can alleviate the influence of health shocks on the common prosperity of the middle-aged and elderly was further explored.

Unlike absolute poverty, common prosperity is not defined by clear criteria. Under the inspiration of previous studies, a common prosperity indicator system was constructed for rural middle-aged and elderly people from material, spiritual, and social sharing dimensions, covering income, consumption, labor supply, medical resources and other factors. Different from previous studies, this paper incorporates the social sharing dimension into the indicator system and better reflects efficiency and equity. The results indicate that heterogeneity exists in the impact of health shocks on middle-aged and elderly people in rural areas. Inconsistent with other studies (40), this paper showed that daily mobility shocks have a greater impact on rural middle-aged and elderly people, followed by major disease shocks (cancer, heart disease and stroke). After a major health shock, people are inclined to perceive limited benefits. Therefore, their willingness to extend their lifespan by making a wide range of behavioral changes across the board is weakened (36, 44). In other words, the impact of a major health shock may be more significant in the short run and insignificant in the long run. However, elderly people with limited capacity for daily living need the companionship and care of other family members. In addition, they increase household expenses, which will hinder the labor participation of middle-aged and elderly people themselves and other family members of the family. This effect may be long-term rather than temporary, which will ultimately reduce household economy and welfare to a large extent. Under the common prosperity strategy, more attention should be paid to the rural middle-aged and elderly as a vulnerable group. Moreover, it is necessary to attach importance to further improvement and refinement although this study largely revealed the impact of health shocks on the common prosperity of middle-aged and elderly people in rural areas. As for measures of health shocks, mental health is also included in an increasing number of studies in addition to physical and self-rated health (45). Subsequent research can also incorporate the dimension of mental health, construct dynamic changes in health indicators, and then refine its impact on middle-aged and elderly-people in rural areas. Medical insurance has different effects on people depending on their age and income group. This study focused on middle-aged and elderly groups in the greatest need of medical services. Basic medical insurance has a limited effect on middle-aged and elderly people, which is in line with prior studies (27–30, 46). The results of this study only show this possibility without implying the failure to implement social medical insurance in China. Reasons for the results are as follows: First, more emphasis is placed on social equity in the context of common prosperity, while medical development is uneven in China, with significant differences in medical resources and coverage levels between regions. In the future, it is pressing to achieve the equalization of basic public services. Second, primary medical facilities cannot satisfy the health needs of people anymore when their age increases to a certain degree. In this case, these elderly people have no choice but to bypass primary medical institutions by going to the hospital (24). In China, however, medical treatment is low in reimbursement rates in other places or even cannot be reimbursed, which will undermine the role of medical insurance. Like a many of studies, this study used whether one participates in medical insurance, but failed to delve into the effects of different levels of medical

coverage and types of insurance on middle-aged and elderly people. This is limited by data availability. The research method also focused on panel data and applied difference in difference (DID) and propensity score matching (PSM) models to explore the deeper economic relationship between the two objects (36, 47). How to integrate existing methods and conduct detailed research on medical insurance, health and common prosperity could be further investigated from multiple perspectives.

Conclusions and implications

For the middle-aged and elderly people, disease is the biggest risk in life. This study focuses on major development needs including "Healthy China". An indicator system was built for the common prosperity of the middle-aged and elderly in rural areas. Based on three-year tracking data, the impacts of health on the common prosperity of the middle-aged and elderly were discussed, and the effect of basic medical insurance was examined. The results show that: Frist, Health shocks hinder the improvement of and have different effects on the common prosperity of the middle-aged and seniors in rural areas. Among them, daily activity ability has the largest negative effect. Second, the impact of health shocks on different income and age groups is different. The negative effect on the common prosperity of the middle-aged and elderly in low- and middle-income groups is stronger than that in the high-income group. Daily activity ability has the greatest impact on the common prosperity of the middle-aged and elderly aged 45–55, while acute health shocks have a negative impact on the middle-aged and elderly aged above 56. Third, Rural basic medical insurance can alleviate the adverse impact of health shocks on the common prosperity of the middle-aged and elderly, but the effect is limited. In relative terms, low-income groups benefit more from it.

Based on the research conclusions, the following policy recommendations were put forward: First, the state should vigorously promote the Healthy China strategy and increase investment in the construction of rural medical infrastructure. Moreover, it shall also improve public health, and increase the breadth and depth of health service coverage. The reason is that health shocks are an important background risk in the process of promoting common prosperity. Second, the government should focus on solving the health problems of key groups including the elderly in rural areas, insist on health prevention, and regularly provide rural middle-aged and elderly people with free physical examination services. For middle-aged and elderly groups with limited daily life ability, it is necessary to increase policy preferences for them and strengthen bottom-line Protection. Third, the recommendation involves accelerating the reform of the rural basic medical insurance system, changing from an inclusive policy to a targeted one, classifying people, refining the top-level design of rural basic medical insurance, and providing more precise safeguards for vulnerable groups. In addition, the government is supposed to increase the reimbursement scope and proportion of basic medical insurance, gradually narrow the medical insurance gap between urban and rural residents and achieve the equalization of basic public services.

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

YZ, YS, and SC prepared the datasets. YZ performed the statistical analysis, drafted the manuscript, and contributed to study design. YS designed the study. SC, YZ, MX, and YS contributed to revision of the manuscript. MX, YZ, YS, and SC organized the study. All authors contributed to the article and approved the submitted version.

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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.

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Evaluation of potentially inappropriate medication in older patients with cardiovascular diseases—STOPP/START-based study

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Objective: This study aims to evaluate the use of STOPP/START criteria in the identification of Potentially inappropriate medication and potential prescribing omissions in older patients with cardiovascular diseases in Bulgaria. Excessive morbidity and mortality has been linked to drug-related problems and increased use of healthcare services and is an understudied problem for Bulgaria.

Materials and methods: A prospective, questionnaire-based study was conducted among 543 older patients across 25 pharmacies in Bulgaria. Socio-demographic characteristic, disease profile, symptoms, and medication data were collected. The questionnaire was developed for the purposes of the EUROAGEISM project. Out of all 543 patients, only those with documented cardio-vascular diseases were extracted and the medication profile per patient was evaluated for Potentially inappropriate medication (PIMs) and potentially prescribing omissions (PPOs) using STOPP/START criteria version 2. In addition, several risks for potentially inappropriate prescribing (PIPs), PPOs and PIMs were calculated with the focus being on the Odds and Risks to develop a PIP.

Results: Four hundred and twenty eight from 531 patients with known therapy for cardiovascular diseases (CVDs) were included in the analysis of PIP (40.52% aged 65–69 years, 61.88% female, 64% had up to 6 comorbidities, and 21.72% presenting with polypharmacy). A total of 71 PIMs in 64 patients with polypharmacy were identified during applying STOPP criteria. 56% of patients taking above five medicines daily had PIMs. The majority of PIMs (31%) were related to CVDs treatment, followed by PIMs in the treatment of endocrine diseases (22.54%), duplication of medicines (8.46%) and prolonged treatment with benzodiazepines (8.46%). Forty four PPOs were identified with START criteria. 22.72% were related to lack of proton pump inhibitors (PPI) in the presence of gastroesophageal disorders, and the same percentage was for lack of Calcium-vitamin D supplementation in osteoporosis. Applying the methodology of risks calculation the sample risk for PPO was 2.1% and for PIM

3.4%. At sample level the relative risk for PPO was 62% out of the risk for PIM and at population level varied between 42.8 and 89.8% and it is statistically significant. The number needed to treat for the event to happen is 77.5, meaning that at every 78 prescriptions there is a chance to appear PIP.

Conclusion: Application of methodologies for detection of potentially inappropriate prescribing is not part of routine clinical practice in Bulgaria. Our study demonstrates a high percentage of potentially inappropriate medication among older patients with polypharmacy. Along with the aging population in Bulgaria, economic burden of polypharmacy and the prevalence of cardiovascular diseases, it is especially important to address potentially inappropriate medication use in cardiovascular patients. There is a considerable necessity for implementation of measures for early detection of potentially inappropriate medication and potentially prescribing omission as a part of de-prescribing strategies in older patients.

KEYWORDS

elderly patients, inappropriate prescribing, cardiovascular diseases, STOPP/START criteria, polypharmacy, older patients

Introduction

Polypharmacy is considered as the concurrent use of multiple medications. There is no standard definition, but the most commonly accepted among authors is the routine use of five or more medications. The over-the-counter, prescription and/or traditional and complementary medicines used by a patient are also counted in the definition (1). Older people are at increased risk of polypharmacy due to the prevalence of chronic diseases, multiple prescribers, and simultaneous use of drugs, which can compromise their health performance, can lead to adverse drug reactions, drug interactions, non-adherence to therapy, hospitalizations, systemic disorders and increased mortality (2–4). When polypharmacy is unavoidable the key challenges are to achieve evidence-based appropriate use of medicines, especially in older people with multimorbidity.

Cardiovascular diseases (CVDs) are the leading cause of death worldwide, with an estimated 17.9 million lives each year. In Europe in 2017, above 20% of the population was aged $\geq$60 years, and the expected increase is to 35% by 2050. The incidence of CVDs increases with age. From 40% in adults aged 40–59 years, to 75% in those 60–79 years, and 86% in those >80 years, experienced CVDs (5). According to statistical data, Bulgaria ranks first in Europe and third in the world in mortality from cardiovascular diseases (6).

Older patients have a higher prevalence of CVDs, high rates of CV risk factors, and multiple age-related comorbidities. Drug prescribing in the older is complicated by comorbidity, polypharmacy and age-specific changes in pharmacokinetics and pharmacodynamics. All of these factors make managing efficacy and safety in older patients with CVDs a challenging and complex process, which poses an increased risk of potentially inappropriate prescribing (PIP) (7). PIP refers to prescribing medications that may not produce benefits relative to harm, or not prescribing medications that are recommended. PIP includes Potentially inappropriate medication (PIMs) and potential prescribing omissions (PPOs). PIMs are medications with a greater risk than benefit to a patient, while PPOs are failures to prescribe medications of potential benefit (8, 9).

In order to evaluate and avoid PIPs several methodologies have been developed to help physicians and health care professionals have the possibility to quickly check PIMs, as well as to detect PPOs. One of the well-known and used tool in Europe for detection of both PIMs and PPOs is the explicit STOPP (Screening Tool of Older Person's Prescriptions)/START (Screening Tool to Alert doctors to Right Treatment). STOPP/START criteria were first published in 2008 and later in 2015 were updated. They are designed as "evidence-based explicit criteria for common and/or important instances of PIMs (STOPP) and PPOs (START), arranged according to physiological systems as in drug formularies" (10).

Although the use of multiple drugs is part of recommended strategy for treatment of CVDs, it may increase the risk for PIMs (11).

The safety of prescribing in older patients is the subject of serious research regarding appropriate prescriptions, combinations, and drug-related issues.

In Bulgaria, drug related problems are not evaluated, namely the patterns of prescription and use of medicines in adults population over 65 years of age. Considering that CVDs are the leading cause of death among older patients, we intended to determine the prevalence of PIMs and PPOs, defined by

the STOPP/START criteria, and to investigate the relationship between the number of medications taken and the possibility of occurrence of PIPs.

Materials and methods

Study design and patient recruitment

A national representative, prospective questionnaire study among patients over 65 years of age was conducted in 25 pharmacies in Bulgaria.

Pharmacies were randomly selected, depending on the pharmacy manager's willingness to participate, throughout the whole country. Graduating pharmacy students conducted the interviews with patients after informed consent was obtained. The sample size of 384 people was considered as satisfying the 5% confidence level for a population 1.5 million older Bulgarian inhabitants in the country. Representativeness was ensured by selecting patients that agreed to participate and belongs to the selected geographical areas. Three main geographical centers were chosen as coordinating centers – Varna ($n = 7$ pharmacies), Sofia ($n = 11$ pharmacies), and Plovdiv ($n = 7$ pharmacies), corresponding to the eastern, middle and western parts of the country, with a total population of 3 million (50% of the population). Each center selected pharmacies from the main city and other settlements with the highest workload, in order to ensure sufficient recruitment options and representativeness. Pharmacies in Sofia recruited 29 patients per pharmacy, 19 in Varna and 12 in Plovdiv, respectively. Questioners were instructed to collect information for 1 patient per day for a period of 1 month at least.

The questionnaire was developed for the EUROAGEISM project, funded under the Horizon 2020 program (12). The questionnaire is rather detailed and included data on demographic characteristics, lifestyle, motor activity, laboratory tests performed by patients, patient health status, use of health services, existing diseases, symptoms of disease manifestation, pain and depression, medications taken and satisfaction with therapy.

Five hundred and forty three patients were recruited, and 531 had available and relevant prescription information extracted from the questionnaire. Evaluation of PIMs and PPOs was performed for 428 patients who have a CVDs prescription. Based on the information in the questionnaire all STOPP/START criteria were applied.

According to World health organization the "Global Atlas on Cardiovascular Disease Prevention and Control" cardiovascular disease (CVD) is a class of diseases that involve the heart or blood vessels (13) and include coronary artery diseases (CAD) such as angina and myocardial infarction, stroke, heart failure, hypertensive heart disease, rheumatic heart disease, cardiomyopathy, abnormal heart rhythms, congenital heart disease, valvular heart disease, carditis, aortic aneurysms, peripheral artery disease, thromboembolic disease, and venous thrombosis. In this study we analyzed only medicines prescribed for patients with cardiovascular diseases, presented on the second part of Table 2 because only those diagnoses were reported.

Inclusion and exclusion criteria

The survey included patients above 65 years old who received their medicines from the relevant pharmacy and agreed to participate. The age limit of 65 years was stated at the EuroAgeism project and corresponds with the definition of OECD that the older population are people aged 65 and over (14). The inclusion criteria were the age of patients, willingness to participate and answer the questions. No limitations were defined.

Ethics

Every patient was acquainted with the purposes of the study, and their informed consent was obtained. The study was approved by the ethics committees of the Medical Universities in Sofia (737/20.02.2019), Plovdiv (04.02.2019) and Varna

TABLE 1 Demographic characteristic of study population.

Characteristics of patients ($N = 543$)	
Gender	***n* (%)**
Male	189 (34.8)
Female	336 (61.88)
No information for medication therapy	18 (3.32)
Age groups	***n* (%)**
65–69 years	220 (40.52)
70–74 years	145 (26.7)
75–79 years	77 (14.18)
80–84 years	54 (9.95)
above 85 years	40 (7.37)
No data	7 (1.28)
Reported diseases and symptoms	***n* (%)**
1–3	178 (33)
4–6	166 (31)
7–10	134 (28)
11–15	63 (8)

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TABLE 2 Reported diseases.

Reported diseases	*N*
CVDs	816
Musculoskeletal	306
Endocrine and metabolic disorders	326
Respiratory disorders	60
Digestive system	317
Genitourinary	169
Blood disorders	44
Neurological	40
Psychiatric disorders	438
Infectious diseases	64
Cancer diseases	19
Vision and hearing	452
Skin diseases	29
Other diseases	50
CVD diseases	
Hypertension	383
Angina ischemic heart disease	97
Myocardial infarction	43
Heart failure	89
Stroke	44
AV blockage	7
Arrhythmia	97
Deep vein thrombosis	28
Pulmonary embolism	5
Ischemic leg disease	7
Bleeding history	16

TABLE 3 Prescribed type and number of medication therapy.

Type of medication	*N*
Medicinal products	2,004
Food supplements	88
Total	2,092
Mean	3.98
Number of medications	***N* of patients (%)**
1	71 (13.52)
2–5	340 (64.76) out of them 33% with five medicines
6–10	104 (19.81)
>10	10 (1.91)

(161/07.02.2019). The ethical approvals are available upon request from the authors.

Evaluation of PIPs, PPOs, and PIMs

PIP (potentially inappropriate prescribing) was evaluated as a drug related problem that encompasses potentially inappropriate medication (PIM) and Potential prescribing omissions (PPO) (15, 16).

$$PIP = PIM + PPO \text{ (17, 18)}.$$

The STOPP/START criteria version 2015 was used for the evaluation of PIMs and PPOs and then the resulting PIPs were calculated (15–20). All prescriptions for the CVDs under consideration were evaluated by two members of the research team for their correspondence with the definitions set by STOP/START system.

Risk for PIP, PPOs, PIMs calculation

The two events—PIMs and PIPs were evaluated for their risks, based on the recommendations illustrated by Sacket, Richardson, Rosenberg and Haynes in Evidence based medicine (21).

The main questions explored were which event was more likely to occur, a PIM or a PPO and what is the relationship between the risks and odds, using the following formulae.

$$\begin{aligned} \textit{Absolute risk reduction } (ARR) &= p2 - p1(\%) \\ \textit{Relative risk } (RR) &= p1/p2 \\ \textit{Risk reduction} &= 1 - RR(\%) \\ \textit{Odds ratio } (OR) &= r2(n2 - r2)/r2(n1 - r1). \end{aligned}$$

Where p2 and p1 are the proportions (%) of patients with a PIM or PPO, respectively. Number of patients in groups is n1 and n2, respectively and r1, r2 is the number of patients with event (PPO, or PIM).

Results

General characteristics

The demographic characteristics of patients are shown in Table 1. Majority of respondents were female (61.88%), with the highest proportion being patients between 65 and 69 years (40.52%). Polymorbidity is present in our observed sample as

well. A total of 3,130 diseases or symptoms were reported, an average of 6 per respondent, with 64 percent having up to 6 symptoms or diseases. It should be noted that some symptoms were related to an already reported disease. There was no patient who was disease free, which can be contributed to the fact that these patients were visiting the pharmacy to collect a valid prescription.

The most reported diseases and symptoms among respondents were; diseases of the cardiovascular system (n = 816), sensory organs (hearing and sight, n = 452) and mental diseases (n = 438). Hypertension was the leading diagnosis among cardiovascular diseases, with more than half of patients (n = 383) reporting being diagnosed (Table 2). Some patients reported multiple CVD diseases, which is accounted by the higher number of present CVDs than actual patients—due to multimorbidity.

Medication profile and identification of PIPs

On total, 2092 medications were reported by patients, including food supplements, with an average of 3.98 per patient. 64.76% took between 2 and 5 medications per day, while the percentage of patients with polypharmacy was 21.72%, with only 1.91% taking more than ten medications daily (Table 3).

A total of 71 PIMs in 64 patients with polypharmacy were identified when applying STOPP criteria. 56% of patients taking above five medicines daily had PIMs. 22 PIMs were related to prescriptions for CVD treatment; in terms of endocrine system diseases, there were 16 PIMs, followed by duplication of medicines (n = 6) and more prolonged treatment with benzodiazepines (n = 6) (Table 4).

Forty four PPOs in 44 patients were detected applying START criteria. The majority of PPOs were detected in the gastrointestinal system—lack of PPI in the presence of GERD (n = 10) and lack of fiber supplements when a patient had a history of constipation (n = 10). 15 PPOs were related to treatment omissions regarding the muscle-skeletal system, with the majority related to skipping Vitamin D as a supplement when the patient is with osteoporosis/osteopenia (n = 10) (Table 5).

PPOs were not identified regarding central nervous system and eyes, urogenital system and vaccines. In terms of vaccines, it is worth emphasizing that we cannot accurately detect these criteria since immunization with influenza and pneumococcal vaccines is not mandatory for older adults.

The potentially inappropriate prescribing was detected for 115 (71PIMs +44 PPOs) prescriptions. These numbers were included in the calculations of the risk for their appearance in prescriptions (Tables 6, 7).

Most PIMs (n = 22) were related to CVDs treatment.The most common detected PIMs in this class were related to prescription of Digoxin for heart failure, Furosemide, Torasemide as first line treatment for hypertension and the combination of Spironolactone with ACEIs and ARBs.

In terms of endocrine system there were 8 detected inappropriate prescriptions associated with glibenclamide or glimepiride in patients with diabetes type 2, as common comorbidity to hypertension. Eight PIMs are linked to beta blockers (metoprolol, bisoprolol). There were 6 patients who had duplication of drug class medications (simultaneous use of 2 NSAIDS - diclofenac, ibuprofen for pain relief). The prolonged use of bromazepam, alprazolam was also observed (n = 6).

The sample risk for PPO is 2.1%, and for PIM is 3.4%. The absolute risk reduction /ARR=p2-p1/ for PIM and PPO at sample level is 1.3% which means that patients have a 1.3% higher risk of being prescribed an inappropriate medication as opposed to having a prescription omission. Confidence intervals put the population risk to be between 0.301 and 2.281%. The relative risk between groups in our sample was calculated to be (for PPO) 62% out of the risk for PIMs, with the confidence interval putting the population risk between 42.8 and 89.8%, which was statistically significant. Based on these numbers, the combined risk of a PIP (PIM+PPO) will be 5.5%, varying between 4.562 and 6.565% at the population level.

The number needed to treat for the event to happen is 77.5, translating to a PIP once every 78 prescriptions.

Curiously, all 71 PIMs and 44 PPOs were unique, meaning that 115 individual patients experienced PIP which allows for similar risk calculations to be conducted at the patient level (n = 428), which allows us the risk of assessing the odds and risks for a PIP on an individual level, as opposed to per prescription. Importantly, what these calculations show is that a PIP could occur once every 15.8 patients (Table 7).

The PIP as a sum of the PIM and PPO proportions is 26.89% (10.29 + 16.6%). If we relate those results to the general country population of 1.73 million above the age of 65 years, we might expect that 457,130 adult will have PIP.

Discussion

This is the first study in Bulgaria assessing the potential inappropriate prescribing in older patients with CVDs. The assessment tools for PIPs are not used in Bulgarian practice, although various studies in Europe and worldwide prove their usefulness in clinical practice (11).

Recently the terms "appropriate polypharmacy" and "inappropriate polypharmacy" have gained a widespread use. 2019 WHO Medication Safety Technical report provides some clarification on both terms (22). Having in mind that the most commonly accepted among authors definition that polypharmacy is the routine use of five or more medications,

TABLE 4 Screening tool of older people's potentially inappropriate prescriptions (STOPP).

Indication of medication	*N*
Any duplicate drug class prescription e.g., two concurrent NSAIDs, SSRIs, loop diuretics, ACE inhibitors, anticoagulants (optimization of monotherapy within a single drug class should be observed prior to considering a new agent)	6
Cardiovascular system	
Digoxin for heart failure with normal systolic ventricular function (no clear evidence of benefit)	6
Loop diuretic as first-line treatment for hypertension (safer, more effective alternatives available)	4
Loop diuretic for treatment of hypertension with concurrent urinary incontinence (may exacerbate incontinence)	2
Centrally-acting antihypertensives (e.g., methyldopa, clonidine, moxonidine, rilmenidine, guanfacine), unless clear intolerance of, or lack of efficacy with, other classes of 2 antihypertensives (centrally-active antihypertensives are generally less well-tolerated by older people than younger people)	2
Aldosterone antagonists (e.g., spironolactone, eplerenone) with concurrent potassium conserving drugs (e.g., ACEI's, ARB's, amiloride, triamterene) without monitoring of serum potassium (risk of dangerous hyperkalaemia i.e., > 6.0 mmol/l – serum K should be monitored regularly, i.e., at least every 6 months)	8
Antiplatelet/anticoagulant drugs	
Aspirin with a past history of peptic ulcer disease without concomitant PPI (risk of recurrent peptic ulcer)	3
NSAID with concurrent antiplatelet agent(s) without PPI prophylaxis (increased risk of peptic ulcer disease)	2
Central nervous system and psychotropic drugs	
Benzodiazepines for ≥4 weeks (no indication for longer treatment; risk of prolonged sedation, confusion, impaired balance, falls, road traffic accidents; all benzodiazepines should be withdrawn gradually if taken for more than 4 weeks as there is a risk of causing a benzodiazepine withdrawal syndrome if stopped abruptly)	6
Renal System (The following drugs are potentially inappropriate in older people with acute or chronic kidney disease with renal function below particular levels of eGFR)	
Digoxin at a long-term dose >125 μg/day if eGFR <30 ml/min/1.73 m2 (risk of digoxin toxicity if plasma levels not measured)	1
Gastrointestinal system	
Drugs likely to cause constipation (e.g., antimuscarinic/anticholinergic drugs, oral iron, opioids, verapamil, aluminum antacids) in patients with chronic constipation where non-constipating alternatives are available (risk of exacerbation of constipation)	2
Oral elemental iron doses >200 mg daily (e.g., ferrous fumarate> 600 mg/day, ferrous sulfate > 600 mg/day, ferrous gluconate> 1,800 mg/day; no evidence of enhanced iron absorption above these doses)	1
Respiratory system	
Theophylline as monotherapy for COPD (safer, more effective alternative; risk of adverse effects due to narrow therapeutic index)	1
Musculoskeletal system	
NSAID with severe hypertension (risk of exacerbation of hypertension) or severe heart failure (risk of exacerbation of heart failure)	1
Long-term use of NSAID (>3 months) for symptom relief of osteoarthritis pain where paracetamol has not been tried (simple analgesics preferable and usually as effective for pain relief).	2
Long-term NSAID or colchicine (>3 months) for chronic treatment of gout where there is no contraindication to a xanthine-oxidase inhibitor (e.g., allopurinol, febuxostat) (xanthineoxidase inhibitors are first choice prophylactic drugs in gout)	1
COX-2 selective NSAIDs with concurrent cardiovascular disease (increased risk of myocardial infarction and stroke)	2
Oral bisphosphonates in patients with a current or recent history of upper gastrointestinal disease i.e., dysphagia, oesophagitis, gastritis, duodenitis, or peptic ulcer disease, or upper gastrointestinal bleeding (risk of relapse/exacerbation of oesophagitis, esophageal ulcer, esophageal stricture)	1
Endocrine system	
Sulphonylureas with a long duration of action (e.g., glibenclamide, chlorpropamide, glimepiride) with type 2 diabetes mellitus (risk of prolonged hypoglycaemia)	8
Beta-blockers in diabetes mellitus with frequent hypoglycaemic episodes (risk of suppressing hypoglycaemic symptoms)	8
Drugs that predictably increase the risk of falls in older people	
Hypnotic Z-drugs e.g., zopiclone, zolpidem, zaleplon (may cause protracted daytime sedation, ataxia)	3
Analgesic drugs	
Use of regular (as distinct from PRN) opioids without concomitant laxative (risk of severe constipation)	1
Total PIM	71

Cardiovascular system	Nr:
Antiplatelet therapy (aspirin or clopidogrel or prasugrel or ticagrelor) with a documented history of coronary, cerebral or peripheral vascular disease	1
Angiotensin Converting Enzyme (ACE) inhibitor with systolic heart failure and/or documented coronary artery disease	1
Beta-blocker with ischemic heart disease	2
Appropriate beta-blocker (bisoprolol, nebivolol, metoprolol or carvedilol) with stable systolic heart failure.	1
Respiratory system	
Regular inhaled b2 agonist or antimuscarinic bronchodilator (e.g., ipratropium, tiotropium) for mild to moderate asthma or COPD	1
Gastrointestinal system	
Proton Pump Inhibitor with severe gastro-esophageal reflux disease or peptic stricture requiring dilatation	10
Fiber supplements (e.g., bran, ispaghula, methylcellulose, sterculia) for diverticulosis with a history of constipation	10
Musculoskeletal system	
Vitamin D and calcium supplement in patients with known osteoporosis and/or previous fragility fracture(s) and/or (Bone Mineral Density T-scores more than−2.5 in multiple sites)	7
Vitamin D supplement in older people who are housebound or experiencing falls or with osteopenia (Bone Mineral Density T-score is > -1.0 but < -2.5 in multiple sites)	3
Xanthine-oxidase inhibitors (e.g., allopurinol, febuxostat) with a history of recurrent episodes of gout	3
Folic acid supplement in patients taking methotrexate	2
Endocrine system	
ACE inhibitor or Angiotensin Receptor Blocker (if intolerant of ACE inhibitor) in diabetes with evidence of renal disease i.e., dipstick proteinuria or microalbuminuria (>30 mg/24 h) with or without serum biochemical renal impairment	2
Analgesics	
Laxatives in patients receiving opioids regularly	1
Total PPO	44

while 10 or medications is defined as excessive polypharmacy, we used these values as cutoff points. However, in our sample we also observe patients taking various medications. 22% of the recruited patients receive more than 6 medicines and 65% take between 2 to 5, but out of them 33% take 5 medicines, which allows for the possibility of inappropriate prescribing within this population as well. This requires paying a special attention to older patients with polypharmacy and implementing a measure for tracking and evaluation of PIPs among older patients. We also have to clarify that 88 people take OTC and dietary supplements that are included in the definition.

A study among 28 countries using data from the WHO showed that multimorbidity is a global phenomenon that already affects middle- and low-income countries, with an estimated average prevalence of 7.8% for these countries, and among higher income countries, this percentage varies between 8.3 and 27% (23). An Australian study of 4,574 patients found that comorbid and polymorbid conditions were more common among the older over 60 years of age, with an average of 2.4 co-morbid conditions being the most frequent (24). These results are also confirmed in Canada (25), where in people over the age of 25, the frequency of comorbidity is only 10%, while in older patients over 65 this percentage rises to 62%, and in the USA, where the authors found that 65% of adult patients have more than 2 diseases (26). Similar are the results in our study where polymorbidity affects almost all of people above 65 years of age.

As was pointed above the OTC and dietary supplements intake have to be considered as part of the whole medication. An analysis of OTC drug utilization among the older population found that in 2011, about 67% took 5 or more drugs in combination with their standard treatment (27), with self-medication by these patients placing about 15.1% at risk of serious drug interactions, caused by a contraindication between the medicinal product and non-prescription drugs or nutritional supplements, and again, this trend is in a positive direction and continues to strengthen (28). The risk of the patient not reporting the supplements and OTC products they are taking is a complicating factor. Jou and colleagues estimated the percentage of patients who did not share with their treating physicians about their self-medication at 25% (29). In our study the reported use of supplements is relatively low. Because we have a very few data for OTC and dietary supplements intake, which might be underreported by patients, it stands to reason that the actual number of polypharmacy patients could be higher.

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TABLE 6 Risks for development of PIMs, and PPOs for the observed prescriptions.

Group 1	Group 2
Number of prescriptions with event PPO r1 (44)	Number of prescriptions with event PIM r2 (71)
Number of prescriptions in the group n1 (2092)	Number of prescriptions in the group n2 (2092)
Proportion (%) of prescriptions with event in group 1 PPO, (p1)	2.1
Proportion (%) of prescriptions with event in group 2, PIM (p2)	3.4
Absolute risk reduction (ARR)	1.3
Standard error (SE) of ARR	0.5
95% confidence interval (CI) for ARR	0.301–2.281
Number needed to treat (NNT)	77.5
95% confidence interval (CI) for NNT	43.85–332.68
Relative risk (RR)	0.62
95% confidence interval (CI) for RR	0.43–0.898
Relative risk reduction (RRR)	38
95% confidence interval (CI) for RRR	10.2–57.20
Odds ratio (OR)	0.612
95% confidence interval (CI) for OR	0.418–0.895

TABLE 7 Risks for PIMs, and PPOs at patient level.

Group 1	Group 2
Number of patients with event PPO r1 (44)	Number of patients with event PIM r2 (71)
Number of patients in the group n1 (428)	Number of patients in the group n2 (428)
Proportion (%) of patients with event in group 1 PPO, (p1)	10.29
Proportion (%) of patients with event in group 2, PIM (p2)	16.6
Absolute risk reduction (ARR)	6.3
Standard error (SE) of ARR	2.3
95% confidence interval (CI) for ARR	1.759–10.858
Number needed to tear (NNT)	15.852
95% confidence interval (CI) for NNT	9.21–56.855
Relative risk (RR)	0.62
95% confidence interval (CI) for RR	0.436–0.881
Relative risk reduction (RRR)	38
95% confidence interval (CI) for RRR	11.89–56.399
Odds ratio (OR)	0.576
95% confidence interval (CI) for OR	0.385–0.862

Latvian researchers showed that prevalence of PIM varies from 24 to 26 to 57% (30) depending on the version of Beers criteria used: 2003 or 2015, respectively (31, 32). A retrospective study among 780 older patients using STOPP/START criteria in Taiwan showed that 39% from the patients had at least one PIM. Multivariate analysis revealed that PIM risk was associated with the number of medications prescribed ($P < 0.001$) and the presence of cardiovascular ($P < 0.001$) or gastrointestinal disease ($P = 0.003$) (33). We found that the PIPs in the observed Bulgarian population are similar than that in Latvia. Unfortunately, in Bulgaria there is no system on place for their evaluation like STOPP/START criteria.

Previous study performed a meta-analysis of the reported risks for PIPs and related risk for Bulgaria (34). It calculated that 244,227 people are exposed to risk for PIP in the population above 65 years of age. Our study shows that the real risk is with 167,697 people more than calculated based on literature data. These results must raise concern for health care professionals, both pharmacy and physicians.

A recent study in Serbia applied Beers criteria for detecting PIMs among 1,500 older patients with CVDs. The results showed that the PIM frequency in the older population was 70.3%, more frequent in female elders. Several risk factors were pointed out as polypharmacy, gender, nicotine use, cognitive status, nutrition state, as well as the number of diseases in the study sample (35). Ubeda et al. conducted a review of the medication and clinical records of 81 residents in nursing home in Spain, using Beers and STOPP/START criteria, v01. The Beers criteria identified potentially inappropriate medication use in 25% of patients and 48% of patients used at least 1 inappropriate medication according to STOPP criteria. START detected 58 potential prescribing omissions in 44% of patients. Calcium-vitamin D supplementation in osteoporosis was the most frequent rule (15%), but omissions corresponding to the cardiovascular system implied 23% of patients (36). Our research also confirmed that one of the most common PPO is exactly associated with Calcium Vitamin D supplements. Our study is in accordance with those results.

A cross-sectional retrospective study (PIM-CCVAE) was performed at a secondary healthcare level in Brazil to identify the use of PIMs focusing on cardiovascular and cerebrovascular Adverse Events. The study showed that 74.2% of older patients used at least one PIM-CCVAE and were taking daily 1.3 (±1) PIM per older. The most significant factors associated with intake of PIM-CCVAE were found to be the presence of comorbidities, cardiovascular diseases, polypharmacy, and low to moderate morbidity and mortality scores (37).

Several studies, focused on the detection of PIMs, identified PPIs above maintenance dosage for >8 weeks as most frequent PIM (38–40). It's worth mentioning that our study did not support these results most likely because our patients are primarily with CVD. Hence, further studies need to be done to identify if this is a common PIM in Bulgaria as well.

Analysis of the European project EUROAGEISM H2020, FIP7 program was performed aiming evaluation of approval

rates and marketing of EU (7)-PIM criteria compared to AGS Beers 2015 criteria in six EU countries. The research showed that the lack of evidence on PIM prescribing in older patients in different level of settings of healthcare, especially in Central and Eastern Europe, contributes to probably still higher rates of inappropriate prescribing of PIMs in many countries. High specificity of these criteria was determined for the pharmaceutical market of a country that contributed to the development of the EU (7)-PIM list (ES). Authors also pointed out that the criteria are with a low specificity in Eastern and Central EU countries, and that more research effort should be devoted in this area (41).

Applying STOPP/START criteria is admittedly valuable for the practice of HCPs and pharmacists; however, when it is paper-based, it is time-consuming. After developing STOPP/START criteria, more effort was put into the electronic deployment, which is highly desirable for use in routine practice. Two clinical trials (SENATOR and OPERAM) involve the fully electronic deployment of STOPP/START criteria. They used diagnostic and medication coding systems, supplemented by other patient data that quantify functional and cognitive status and laboratory test results. However, considering that currently, the number of criteria in version 2 is 114, experts supposed that there is a need to train health professional to be able critically to interpret the results of the STOPP/START criteria, related to any particular case (22).

Although it is beyond the scope of the paper to analyze the reasons behind PIPs, several possible causes for inappropriate prescribing can be speculated. As previously stated, there is a lack of any tool for evaluation of the prescriptions. Reimbursement authorities introduced electronic prescriptions just some months ago, without ways or policies to estimate incorrect prescribing. Furthermore, older patients often visit diverse specialists, and the country does not have mechanisms to control rational prescribing, neither does it offer supplementary education regarding rational drug use or prescribing. This is true on all levels of care – from physicians, to students, to patients. We hope that with this study, we can highlight the dangers this poses and draw the attention of physicians and authorities to the importance of the PIPs and risks for the society, in order to, hopefully, enact measures to improve the situation. According to the report of the National Statistics Institute in Bulgaria the EU's population is aging. The data show an increase in the share of the older (over 65). From 16% in 2001, they reached 21% in 2020—an increase of 5 percentage points. During the period 2001–2020, there was an increase in the proportion of persons aged 65 and over in all Member States (42). The study population included in the current analysis show that all patients have a CVDs and the majority of PIMs are related to treatment of these diseases, especially in older with polypharmacy. It is essential for all health care professionals to increase awareness and understanding of potential PIM use by cardiovascular patients. Based on that we can expect that the risk will increase in the future.

Limitations of our study are that it was performed only with pharmacy visitors in a relatively independent health condition. We do not include people in nursing homes or hospitals where we can expect higher polypharmacy and multimorbidity. The BEERs and STOPP/START criteria are widely used but not customized for Bulgaria that also might be considered as limitation to the study.

Conclusion

Polypharmacy and associated PIPs are common among older patients. In the past 10 years experts focus on drug related problems and the possibilities for avoiding them. Several tools for identification of potential inappropriate medications have been developed aiming to encourage the geriatrics and other HCPs to review in more detail the prescriptions in older population. Along with the aging population in Bulgaria, economic burden of polypharmacy and the prevalence of CVDs it is especially important address PIMs use in cardiovascular patients. There is a considerable necessity for implementation of measures for early detection of PIMs and PPOs as a part of de-prescribing strategies in older patients.

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 human participants were reviewed and approved by Ethical Commitees at the MUS, MUP, MUV. The patients/participants provided their written informed consent to participate in this study.

Author contributions

TK collected data, calculated variables, and analyze and wrote the first drafts. PM calculated PIPs, validated data, and wrote first draft and final text. KT design the study, calculate risks, analyze information, and wrote final version. KM performed statistical analysis, interpret statistics, and validate data. GP design the study, create methodology, analyze data, and wrote final text. All authors contributed to the article and approved the submitted version.

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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

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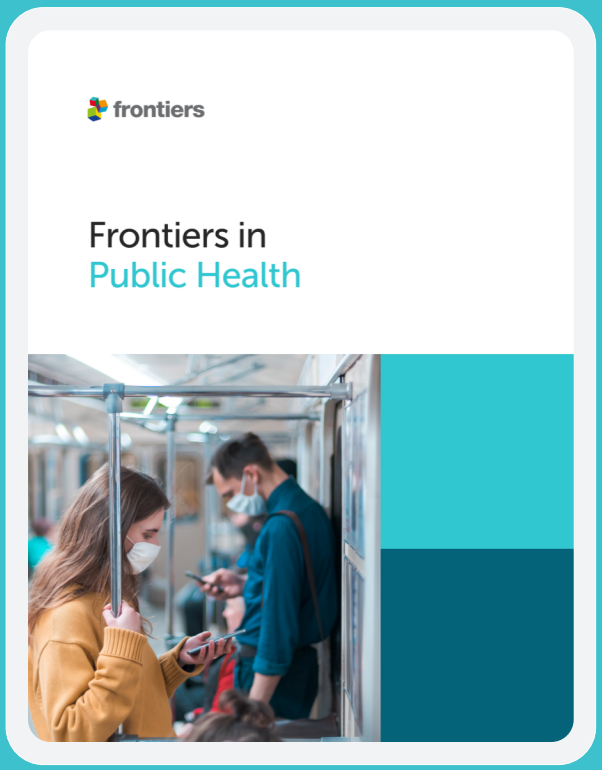

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