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Modern business and public health: A value co-creation perspective

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Modern business and public health: A value co-creation perspective

Topic editors

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Has COVID-19 Changed China's Digital Trade?—Implications for Health Economics

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Digital technologies have played a significant role in the defense against the COVID-19 pandemic. This development raises the question of whether digital technologies have helped Chinese exports recover quickly and even grow. To answer this question, we study monthly data on Chinese exports to 40 countries/regions from January 2019 to June 2020 and covering 97 product categories. The study takes the COVID-19 outbreak as a natural experiment and treats digital trade products as the treatment group. Using a generalized difference-in-differences (DID) approach, we empirically investigate how this major global public health crisis and digital trade have influenced Chinese exports. Our empirical analysis reveals that the COVID-19 pandemic has inhibited China's export trade overall, digital trade has significantly promoted trade, and the supply mechanism has played a significant role in promoting the recovery of exports. Heterogeneity tests on destination countries/regions reveal that digital trade has significantly promoted exports to countries/regions with different income levels, with a more significant effect on low-risk destinations than on high-risk destinations. The sector heterogeneity test demonstrates that digital trade has enhanced the export recovery of sectors dealing in necessities for pandemic prevention. Other robustness tests, including parallel trend and placebo tests, support the above conclusions. Finally, we extend the research conclusions and discuss their implication for health economics and the practice of fighting COVID-19.

Keywords: COVID-19, digital trade, Chinese exports, natural experiments, generalized difference-in-differences

INTRODUCTION

COVID-19 has become one of the most severe global public health crises and has led to a serious economic crisis. It has slowed economic growth and worsened employment prospects (1), and it may continue to impact the world (2). In almost all major countries around the world, 2020 saw a downturn in GDP, although China still achieved GDP growth of 2.3%, which is lower than before the outbreak of the pandemic. Notably, once the pandemic broke out in Wuhan, China, in early 2020, the Chinese government ordered an immediate lockdown in Hubei Province and

restricted industrial activities after the Chinese New Year holiday. Although the lockdown measure is thought to have devastated the national economy and international trade, the loosening of the regulation may have risked a recurrence of the pandemic (3). According to the National Bureau of Statistics of China, China's GDP growth rate changed from negative to positive in Q2 2020, as did the growth rate of cargo imports and exports in Q3 2020, despite the shocks caused by the pandemic. These outcomes prove that the impact of a general lockdown on the economy is temporary and controllable and does not alter megatrends of economic development (4).

Given the economic recession caused by the general lockdown, the capacity for economic recovery capacity after the lifting of the lockdown is particularly important. We may recall that the lockdown implemented in the early stage of the pandemic forced people to isolate themselves at home and to work from home, and the combination of proactive prevention measures and smart technical solutions minimized the transmission of COVID-19 in some countries, e.g., China and South Korea (5). Examples of popular smartphone applications include the Health QR Code and Journey QR Code, which the Chinese government rolled out to identify potential transmission routes and to safeguard economic recovery based on big data on population movement, although certain countries have been concerned about consumer privacy and legal rights issues arising from the collection of positioning information. After the lockdown was lifted, the Chinese government implemented information technology (IT)-based initiatives to stimulate consumption and thus drive economic recovery. For example, local governments issued electronic consumption coupons in cooperation with China's prevailing e-pay platforms, such as UnionPay Quickpass, Alipay, and WeChat. However, it has been pointed out that the digital divide further expanded during the pandemic (6). It is undeniable that digital technologies have become one of the safeguard measures for fighting the pandemic and restoring economic activity.

On the world market, the pandemic has forced consumers to move from offline to online consumption. The demand for e-commerce, which is based on Internet platforms, has grown abruptly all over the world (7, 8). One major reason is that digital trade, which operates on cross-border platforms, can help a company quickly identify new partners once its supply chain is interrupted. In particular, the quick matching of pandemic prevention materials between suppliers and buyers across the world has helped alleviate the impact of the pandemic on world trade and accelerate the recovery of global trade chains.

This paper aims to examine the role of digital technology in promoting China's export recovery and growth as COVID-19 has severely suppressed international trade. in particular, this paper takes the pandemic as a natural experiment under a seminatural experimental approach to policy effect assessment. The pandemic has severely affected all forms of trade, but different forms of trade may suffer different degrees of damage, and the feedback may also differ. We assume that some digital trade performs have been better than others during and after the pandemic, and we treat them as the treatment group. Conventional forms of trade are treated as the control group. To review how the treatment and control groups influence Chinese exports in the pandemic, we establish a generalized difference-in-differences (DID) model through the interaction of grouping and month dummy variables to assess the unique impact of digital trade during the pandemic. The studied data are the gross values of 97 product categories falling under the China Customs Sections and Divisions that China exports to 40 major countries/regions 1 year ahead of the pandemic and half a year thereafter.

This study is potentially significant in three ways. First, taking the pandemic as a natural experiment can reveal the unique impact of digital trade on Chinese exports, thereby providing empirical evidence to facilitate Chinese exports for self-initiated transformation and to respond to emergencies. Second, this study empirically tests the influence of digital trade on Chinese exports. The experience gathered from Chinese practices may provide a reference for the recovery of the global economy and trade. Third, the pandemic has seriously endangered public health and caused an enormous impact on economic growth. This article further proposes implications for health economics to promote the long-term healthy development of the world economy.

The subsequent contents are organized as follows. Section Theoretical Basis and Research Hypotheses proposes the hypotheses of this paper based on a review of the theoretical background and the performance of digital technologies in foreign trade and the defense against the COVID-19 pandemic. Section Research Methods introduces the empirical models and data. Section Regression Analysis performs empirical analysis and tests of the models. Finally, section Conclusion and Discussion discusses conclusions, implications, and limitations of this study and suggestions for future research.

THEORETICAL BASIS AND RESEARCH HYPOTHESES

Digital Trade and China's Practices

The development of conventional international trade benefits from large-capacity transport vehicles emerging from three industrial revolutions. The easy availability and wide use of computer networks have led to Internet-based platforms, including cross-border e-commerce (CBEC) platforms. In the 4th industrial revolution, highly digital technologies such as big data and blockchain have promoted the rapid digital transformation of traditional international trade. Therefore, digital trade will become the leading pattern of international and domestic trade in the coming years (9). Digital trade was initially defined as the trade of digital products and services, excluding physical products (even products with digital features) (10, 11). Later, the definition was expanded to stress that digital trade is the trade realized by digital means and that it includes conventional international trade that involves the use of Internet technologies, i.e., Internet transactions of physical and digital products and services in physical or digital forms (1, 12). In general, digital trade is characterized by modern information networks as carriers, online dealing supported by knowledge and information digitalization technologies, and the transfer of physical and digital products and services.

China's digital transformation of trade originates from the application of the "Internet plus" in the fields of both conventional trade and e-commerce[1], giving birth to the new pattern of Internet-based CBEC, which has developed quickly and been acclaimed as the "new engine of China's foreign trade" (13, 14). Internet-based CBEC significantly reduces the intermediate trading steps (1), effectively decreases matching costs, and improves trading efficiency (15, 16). At the same time, digital transformation has altered the process of consumer value creation and cocreation (17). Furthermore, as digital technologies are applied and developed, CBEC is endowed with more features in more dimensions, and China's CBEC will ultimately iterate into digital trade (18). China's leading Internet companies are seeking breakthrough innovations by launching digital innovative strategies such as the "Digitalize Global Trade" strategy of Alibaba.com. Furthermore, China's national strategies are oriented toward digital transformation in the Industry 4.0 era through the implementation of strategies such as intelligent manufacturing and Made in China 2025.

COVID-19 Pandemic, Foreign Trade, and the Application of Digital Technologies

The outbreak of the COVID-19 pandemic has brought exponential growth in the use of information and communication technologies (ICTs) (19) to mitigate the unfavorable impact of the physical distance resulting from the lockdown and isolation. In some countries, advanced digital technologies have been applied for pandemic surveillance, control and analysis, thus feeding decision makers with more precise information more quickly and ultimately driving the recovery of economic activity (20, 21). The COVID-19 crisis has accelerated technological innovation and integration, promoting the digitalization-based strategic transformation of the global economy (22). This development highlights that digital transformation is crucial for mitigating the economic recession, maintaining well-being, and accelerating economic recovery (1).

Digital trade is a new form of trade established based on the new generation of ITs such as big data, cloud computing, the Internet of Things, and artificial intelligence, and it has new features that are different from those of conventional forms of trade. Digital trade utilizes ICTs to realize the efficient exchange of physical goods, digital products and services, and digital knowledge and information. It overcomes the damage to the global economic ecosystem caused by pandemic containment measures implemented in various countries. In particular, it alleviates the spatial limitation of labor flow. For this reason, digital trade could account for as much as 62.8% of the total trade volume worldwide as global trade suffered tough shocks in 2020. Digital trade is promoting a profound revolution of global value and innovation chains and has become a key driving force for global trade recovery in the post-pandemic period.

[1]Guidance by General Office of the State Council on the Promotion of Cross-Border E-Commerce in a Healthy and Rapid Way. Available online at: http://www.gov.cn/zhengce/content/2015-06/20/content_9955.htm (accessed on 20 June 2016). (In Chinese).

Based on the above analysis, we believe that digital technologies enable digital trade to substitute for face-to-face trade in the pandemic context. Digital trade, including CBEC, digital media and communication services, grew quickly and promoted the development of innovative forms of global trade and stable growth in the global trade volume. Therefore, we propose the following hypothesis:

Hypothesis 1. Digital trade is positively related to exports.

How have digital technologies played an important role in the fight against the pandemic and helped boost the recovery and development of global trade? The collapse of global trade triggered by the COVID-19 pandemic occurred due to mandatory preventive measures. Baldwin and Tomiura (23) pointed out that COVID-19 has impacted global trade from both the demand and supply sides and has been accompanied by increased supply chain contagion in the trade of intermediate goods. This paper attempts to explore how digital technologies drive global trade recovery from the demand and supply perspectives.

From the supply (exporter) perspective, the physical distance maintained by measures such as social distancing has effectively curbed the spread of the pandemic but simultaneously shrunk the labor market. The suspension of production, e.g., the shutdown of factories and the interruption of supply chains, has reduced the scale of production, thereby decreasing the supply of exports. On the supply side, digital technologies can smooth the way for export trade through the short-term use of Internet channels. Products and services supplied through the use of digital technologies are included within the scope of digital trade. First, online interviews and employment are revitalizing the labor market. Second, working from home and online conferences arising in response to pandemic prevention are sustaining business operations. Third, digital trade platforms are offering cost-effective and efficient trade solutions. For instance, online exhibitions reduce matching costs and time compared to physical exhibitions. Additionally, through CBEC service platforms, manufacturers that have stopped production due to supply chain disruptions can quickly identify new suppliers and establish possible partnerships. On the basis of the above analysis, we propose the following hypothesis:

Hypothesis 2. Digital trade utilizes digital services to reduce trading costs and accelerate export recovery.

From the demand (importer) perspective, demand countries suffering seriously from the pandemic may implement lockdowns, causing high unemployment and a loss of labor income, which directly affects total demand (24). In addition, fear of the pandemic has prevented members of the general public from leaving their homes, and the shrinkage of retail shops has also reduced total demand. During the pandemic, digital trade has substantially promoted trade recovery by activating non-contact demand, and Internet-based retailing has substituted for shrinking physical shops. Meanwhile, insufficient domestic supply has caused a significant increase in cross-border online orders, which in turn has stimulated export enterprises on the supply side to maintain business operations. The transition

of demand from offline to online will continue and may have profound effects on future global trade. Based on the above analysis, we propose the following hypothesis:

Hypothesis 3. Digital trade provokes partner countries' demand potential and thus promotes a quick recovery of exports.

RESEARCH METHODS

Empirical Models

DID models have been widely applied in studies on policy effects, and they are believed to be an effective approach to differentiating time trends and policy effects and an effective empirical method to solve endogeneity problems in economic and financial research (25). In general, the design of a DID model is based on identifying a treatment group, which is subject to government policy interference, and a control group, which is free from such interference. However, in the real world, some policies apply to all individuals, such as the abolition of the elite recruitment system (26), making it hard to identify a control group that is completely free from undesired interference. Nevertheless, by identifying the systematic difference that a policy change impact may have on a certain dimension, it is possible to construct treatment and control groups by dividing the samples by the degree of systematic influence (27–29).

We attempt to apply this idea to our study on the impact of the COVID-19 pandemic on Chinese exports. First, nobody could forecast the COVID-19 pandemic until it broke out. Therefore, it can be regarded as a pure exogenous shock, avoiding the endogenous problem of the shock itself. Second, the pandemic had an impact on all countries worldwide in a short period of time, and Chinese exports of goods were also affected. Considering that digital trade has played a significant role in fighting the pandemic (1), we divide Chinese exports based on the degree of digitalization of products to acquire the control and treatment groups, thereby observing how digital products have influenced Chinese exports before and after the pandemic.

After the pandemic broke out, the change in the volume of Chinese exports to major destination countries may result from (1) the time-dependent effect and (2) the pandemic-dependent effect. Through this approach, we established a DID model that is based on the universal application of pandemic prevention measures.

$$\begin{aligned} LnEXP_{itc} &= \alpha_0 + \alpha_1 CBEC_i + \alpha_2 Covid19_t \\ &\quad + \alpha_3 CBEC_i * Covid19_t + \alpha_4 X_{tc} + \varepsilon_{itc} \end{aligned} \quad (1)$$

where i stands for Harmonized Commodity Description and Coding System (HS) 2-digit products; t stands for the month; and c stands for the major destination countries/regions of exports. The explained variable $LnEXP_{itc}$ stands for the logarithmic value of the trade volume of product i exported from China to country c in month t. The explanatory variables include the individual differential variable $CBEC_i$, which indicates whether product i is a digitalized product, and the time differential variable $Covid19_t$, which indicates whether month t is subject to the impact of COVID-19. The coefficient of the interaction term $CBEC_i * Covid19_t$ measures the impact of the pandemic on product exports and is the core coefficient that our study focuses on. X_{tc} is the control variable of country c in month t. ε_{itc} stands for other random disturbance terms that affect product exports.

We further use a two-way fixed effects model, which is a standard panel data model, to separately control for individual and time fixed effects and mitigate omitted variable bias. We add month, product, and sector fixed effects to Model (1) and eliminate the individual and time differential variables to avoid strict multicollinearity. The model is thus modified as follows:

$$\begin{aligned} LnEXP_{itc} &= \alpha_0 + \alpha_1 CBEC_i * Covid19_t + \alpha_2 X_{tc} + \nu_t \\ &\quad + u_i + \omega_{it} + \varepsilon_{itc} \end{aligned} \quad (2)$$

where $i = 1, 2, \ldots 76, 78, \ldots 98$ and $t = 2019 - 01 \sim 2020 - 06$.

Lastly, to analyze the mechanism through which digital trade promotes export recovery, we add country/region-characteristic variable H, which separately characterizes the action mechanism of demand and supply. The mechanism testing model is as follows:

$$\begin{aligned} LnEXP_{itc} &= \alpha_0 + \alpha_1 CBEC_i * Covid19_t * H \\ &\quad + \alpha_2 CBEC_i * Covid19_t + \alpha_3 X_{tc} + \nu_t + u_i \\ &\quad + \omega_{it} + \varepsilon_{itc} \end{aligned} \quad (3)$$

Variables and Sources

Explained Variable

The explained variable $\mathbf{LnEXP_{itc}}$ stands for the logarithmic value of the trade volume of HS 2-digit products exported from China to major countries/regions. It measures the level of export trade. The 43 export destination countries/regions are sourced from the Monthly Statistics Bulletin of the General Administration of Customs of the People's Republic of China. The export trade volume covers 97 product categories included in the China Customs Sections and Divisions[2]. Considering that China Customs increased Division 99 (*articles of B2B cross-border e-commerce in simplified customs procedures*) in July 2020, we selected a time range of 18 months from January 2019 to June 2020 to avoid a data shortage due to the change in statistical coverage. The data are sourced from the China Stock Market and Accounting Research (CSMAR) database. Exports from China to major countries/regions in December 2019 are corrected based on the China Customs database. In the empirical analysis, the export volume data are transformed into natural logarithms after adding 1 so that zero trade flows are not eliminated.

Core Explanatory Variables

Individual differential variable $CBEC_i$. As analyzed above, products sold based on CBEC platforms have digital characteristics. Following the method of Ma et al. (18) for identifying products traded on CBEC platforms, we identified

[2]China Customs' Sections and Divisions of export products are in accordance with the hierarchy and coding order under the *Commodity Classification for China Customs Statistics*, which is compiled on basis of the Harmonized Commodity Description and Coding System (HS).

1,413 HS 8-digit[3] CBEC products. Notably, natural shock experiments are subject to the impact of objective conditions and data acquisition. When monthly data were considered to increase the time series, we could only obtain the monthly export data published by China Customs on products under the HS 2-digit Section and Division system. To align the product category levels, we first convert the HS 8-digit products into international standard-compliant HS 6-digit products and thus identify 1,013 product varieties, although such practice involves information omission due to the reduction in the number of individual products. Then, we count the number of HS 6-digit products under the HS 2-digit system to calculate the percentage of products traded through CBEC channels. Using this percentage, we rate the trade into five levels of digitalization, namely, "fully digitalized," "highly digitalized," "moderately digitalized," "minimally digitalized," and "not at all digitalized." Furthermore, with reference to Moser and Voena (30), a product category is included in the treatment group as long as one product of that category is sold on CBEC platforms. Moreover, we will examine the dosage effect later in this paper by reconstructing the control and treatment groups through different combinations of digitization levels (e.g., by regarding full and high digitization levels as the treatment group and the other two levels as the control group) to help determine the robustness of the identification strategy.

Time dummy variable Covid19_t. The time of the outbreak of the COVID-19 pandemic in Wuhan, China, i.e., January 2020, is held as the shock point of the natural experiment. A value of $Covid19_t = 0$ is assigned for the period before the outbreak of the pandemic, and a value of $Covid19_t = 1$ is assigned for the period thereafter.

Interaction term $\text{CBEC}_\text{i}*\text{Covid19}_\text{t}$. The coefficient of the interaction term is meaningful only after the outbreak of the pandemic and only for the experimental group. In other words, it measures the impact of digital trade on exports after the outbreak of the pandemic.

Control Variables

The trade gravity model is among the most popular models in global trade research. We incorporate the common assumption of the gravity model into our control variables. The classical gravity model assumes that the trade volume positively correlates with the economic scale of trading countries and negatively correlates with the distance between them (31).

$relat\_gdp_{tc}$. GDP is typically used to measure the market economy scale of a country. This measure can reflect the fluctuation in demand in the global market during the COVID-19 pandemic. This study uses the ratio of the GDP of export destination countries/regions to China's GDP in the same period. Considering that most countries/regions publish quarterly and yearly GDP data, we perform quadratic linear interpolation on quarterly GDP data to obtain monthly estimates following Kisman (32). The data are sourced from the CEIC database.

$lndis\_cap_c$. The logarithm of the geographical distance between the capital of China and that of an export destination country/region is used to measure the distance between China and that country/region. The data are sourced from the GeoDist database of the French Institute for Research in the Field of International Economics (CEPII).

The trade gravity model has been continuously expanded in subsequent studies by introducing exogenous variables. Frankel et al. (33) considered the effects of cultural and geographical factors, assuming that the trade volume positively correlates with linguistic commonality but negatively correlates with the land area of the destination country/region.

$language_c$. Whether the export destination country/region shares the same language is used to measure cultural factors. The data are sourced from CEPII-GeoDist.

$relat\_land_c$. The ratio of the land area of an export destination country/region to that of China is used to measure geographical factors. The data are sourced from CEPII-GeoDist.

$contig_c$. We additionally incorporate the geographical contiguity between China and the destination country (region) as a geographical factor. The data are sourced from CEPII-GeoDist.

$relat\_rank_{tc}$. The geographical distance between countries/regions measures the variable trade costs (34). We introduce the economic freedom index of the destination country/region into the model as a measure of fixed trade costs. Assuming that fixed trade costs have a negative impact on trade, countries/regions with higher economic freedom have lower fixed trade costs. Therefore, economic freedom is positively correlated with the export trade volume. We use the ratio of the economic freedom index of the export destination country/region to that of China in each period to measure fixed trade costs. The data are sourced from the Heritage Foundation[4].

fta_c. We include a dummy variable for whether a destination country/region has signed a free trade agreement (FTA) with China. The data are sourced from the Ministry of Commerce of the People's Republic of China.

Descriptive Statistics

This paper studies the impact of the COVID-19 pandemic on Chinese exports based on the export volume of 97 categories of products exported from China to 43 major countries/regions from January 2019 to June 2020. The treatment and control groups are established by discriminating the degree of digitalization. As data on the GDP control variable of Pakistan and Burma are not available[5], the export destinations are reduced

[3]In 1992, the commodity coding system was changed to an 8-digit system based on the Harmonized Commodity Description and Coding System (HS). The first 6 digits form the HS code, and the last 2 digits form a subcatalog to serve the needs of China's customs duty, statistics and trade administration.

[4]The economic freedom index is a total score of 12 components, such as government expenditure, the tax burden, business freedom, labor freedom, trade freedom, and financial freedom. It is divided into five levels: complete freedom, relative freedom, limited freedom, relatively suppressed, and suppressed.

[5]The CEIC database https://info.ceicdata.com does not provide the monthly nominal GDP data of Pakistan and Burma. We also tried to obtain such data from the International Monetary Fund (IMF), the statistics of the Association of Southeast Asian Nations (ASEAN), and the Central Statistical Organization of Burma but failed.

TABLE 1 | Descriptive statistics of the variables.

	Variable	Obs	Description	Expected impact direction	Min	Mean	Max	Std. Dev.
Explained variables	LnExp	71,586	China's export volume		0.00	7.26	16.55	3.40
Core explanatory Variables	CBEC	71,586	Whether it is a digital product	+	0.00	0.74	1.00	0.44
	Covid19	71,586	Whether it is after the COVID-19 outbreak	−	0.00	0.33	1.00	0.47
	CBECxCovid19	71,586	Interaction term	+	0.00	0.25	1.00	0.43
Control variables	relat_gdp	71,586	Relative economic scale of the destination country/region	+	0.00	0.11	1.81	0.24
	lndis_cap	71,586	Variable trade costs	−	6.86	8.68	9.87	0.65
	Language	71,586	Whether the same language is spoken	+	0.00	0.12	1.00	0.33
	relat_land	71,586	Relative land area of the destination country/region	−	0.00	0.19	1.78	0.37
	contig	71,586	Whether contiguous	−	0.00	0.15	1.00	0.35
	relat_rank	71,586	Fixed trade costs	+	0.83	1.18	1.54	0.17
	fta	71,586	Whether an FTA has been signed	+	0.00	0.32	1.00	0.47

to 40 countries/regions. The descriptive statistics of each variable are presented in **Table 1**.

REGRESSION ANALYSIS

Baseline Regression Analysis

Table 2 presents the DID estimates of the impact of the COVID-19 pandemic on Chinese exports. On the basis of Model (1), control variables are introduced one by one in Columns (1)–(4). On the basis of Model (2), Columns (5)–(8) introduce 3 types of fixed effects. Overall, the estimated coefficient of the interaction term of the DID variables indicates a significant increase in the export of digital products despite the impact of the COVID-19 pandemic. This result is in line with the assumption.

Core Explanatory Variables

The estimated coefficients of *CBECxCovid*19 are all positive and significant at the 1% level, demonstrating that digital products still play a significant role in promoting Chinese exports under the pandemic impact when various factors are controlled for, leading to an increase of 18.8–22%. The estimated coefficients of *Covid*19 are all negative and significant at the 1% level, indicating that compared with the years before the pandemic, China's export of various products decreased by ∼45% on average after the pandemic. The estimated coefficients of *CBEC* are all positive and significant at the 1% level, indicating that the export of digital products is higher than that of conventional products.

Control Variables

The baseline regression results of *relat_gdp* and *lndis_cap* are consistent with the classical gravity model assumption that trade flows are positively correlated with economic scale and negatively correlated with distance. The estimated coefficient of *language* in Column (3) is significantly positive. However, after introducing the dummy variables for economic freedom and FTAs, the coefficient is no longer significant and is very small. Speaking the same language is not significantly related to trade flows. The estimated coefficient of *contig* is still significantly negative after controlling for various factors, indicating that China's export products are more welcome in non-contiguous countries than in contiguous countries. The estimated coefficient of *relat_land* is significantly positive, meaning that the larger the land area of a trading partner country/region is compared to that of China or, in a sense, the better its resource endowments are compared to those of China, the higher the volume of exports from China to the country/region. Lastly, the estimated coefficient of *relat_rank*, namely, the trade freedom level representing variable costs, is significantly positive, indicating that the higher economic freedom of an export destination country/region compared with China means lower variable trade costs and, therefore, higher trade flows. The estimated coefficient of the binary variable, which indicates whether an export destination country/region has signed an FTA with China, is significantly positive, suggesting that the existence of an FTA reduces the market entry costs and therefore promotes the trade in imports and exports. This supports the expected direction of influence.

Parallel Trend Test

The use of the DID approach must satisfy the parallel trend assumption (35), i.e., the exports of all products to major destination countries/regions showed the same trend before the COVID-19 pandemic. In the time series plot on the left of **Figure 1**, the blue continuous line and red dotted line represent the average logarithm of the monthly export volumes of the treatment group and control group, respectively. In the period before the outbreak of the pandemic, which is represented by the section to the left of the vertical dotted line for January 2020, the two groups showed largely identical trends. This finding can be preliminarily considered to be in line with the parallel trend assumption. Similar trends of the two groups are also observed in the first 3 months after the outbreak of the pandemic, meaning that both groups suffered almost the same shocks from the pandemic. However, the two groups showed different trends after the first 3 months.

TABLE 2 | Baseline regression results.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	LnExp	**LnExp**	**LnExp**	**LnExp**	**LnExp**	**LnExp**	**LnExp**	**LnExp**
CBECxCovid19	0.220***	0.220***	0.220***	0.220***	0.220***	0.220***	0.220***	0.188***
	(0.061)	(0.058)	(0.058)	(0.057)	(0.057)	(0.042)	(0.042)	(0.047)
Covid19	−0.453***	−0.459***	−0.458***	−0.455***		−0.455***		
	(0.053)	(0.051)	(0.051)	(0.051)		(0.039)		
CBEC	2.650***	2.650***	2.650***	2.650***	2.650***			
	(0.035)	(0.033)	(0.033)	(0.033)	(0.033)			
relat_gdp		3.169***	2.684***	2.775***	2.808***	2.775***	2.808***	2.808***
		(0.043)	(0.047)	(0.050)	(0.050)	(0.032)	(0.032)	(0.032)
lndis_cap		−0.931***	−1.102***	−1.009***	−1.008***	−1.009***	−1.008***	−1.008***
		(0.017)	(0.020)	(0.020)	(0.020)	(0.012)	(0.012)	(0.012)
Language			0.354***	0.007	0.009	0.007	0.009	0.009
			(0.038)	(0.042)	(0.042)	(0.029)	(0.029)	(0.029)
relat_land			0.927***	0.967***	0.957***	0.967***	0.957***	0.957***
			(0.036)	(0.036)	(0.036)	(0.023)	(0.023)	(0.023)
contig			−0.561***	−0.516***	−0.513***	−0.516***	−0.513***	−0.513***
			(0.041)	(0.041)	(0.041)	(0.029)	(0.029)	(0.029)
relat_rank				0.426***	0.414***	0.426***	0.414***	0.414***
				(0.084)	(0.084)	(0.056)	(0.056)	(0.056)
fta				0.630***	0.633***	0.630***	0.633***	0.633***
				(0.028)	(0.028)	(0.018)	(0.018)	(0.018)
Month FE	No	No	No	No	Yes	No	Yes	Yes
Id FE	No	No	No	No	No	Yes	Yes	Yes
Sector*Month_FE	No	No	No	No	No	No	No	Yes
N	71,586	71,586	71,586	71,586	71,586	71,586	71,586	71,586
R^2	0.1242826	0.1951522	0.2021798	0.2093159	0.21702	0.649811	0.657515	0.6592744

****p < 0.01.*

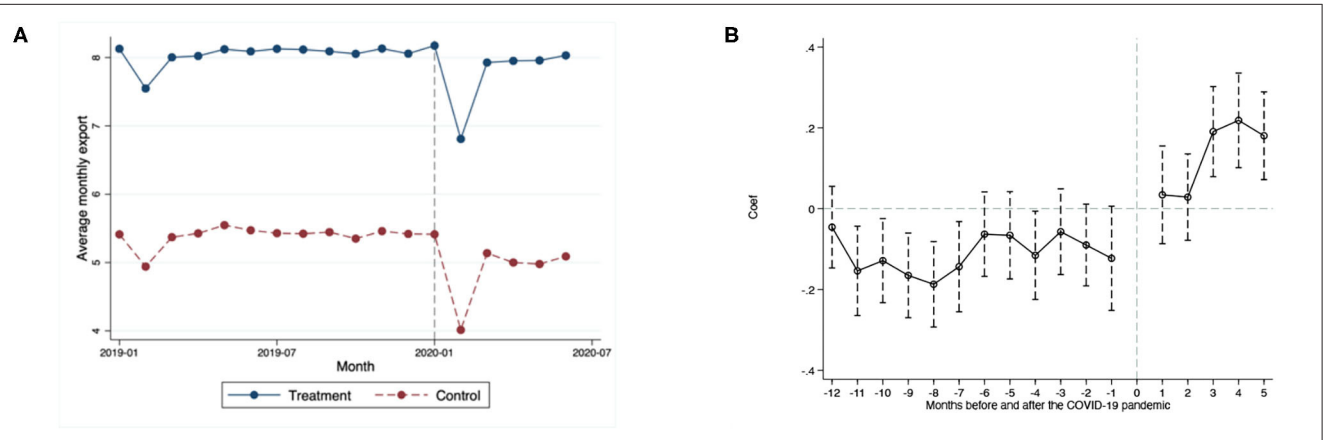

FIGURE 1 | Parallel trend test. **(A)** Time series plot. **(B)** Regression coefficients of the pandemic effect.

The diagram on the right uses the event study method to test the parallel trends and the dynamic effects of digital trade on Chinese exports in the aftermath of COVID-19. The 0 point on the horizontal axis represents the base period of the pandemic. Each circle represents the regression coefficient of the interaction term. The vertical dotted line crossing each circle represents the 95% confidence interval of the coefficient. For the purpose of testing the parallel trends of the samples, the dummy

TABLE 3 | Placebo test regression results of virtual time points.

	(1)	(2)	(3)
	LnExp	**LnExp**	**LnExp**
CBECxCovid19_fake1	−0.066		
	(0.109)		
CBECxCovid19_fake2		−0.053	
		(0.076)	
CBECxCovid19_fake3			−0.025
			(0.064)
Month FE	Yes	Yes	Yes
Id FE	Yes	Yes	Yes
Sector*Month_FE	Yes	Yes	Yes
N	47,724	47,724	47,724
R^2	0.6554991	0.6554998	0.6554964

variables for the years before the treatment are multiplied with the interaction term of the treatment variables. If the dummy variables are not significant, the parallel trend assumption is satisfied. In other words, if the regression coefficients before the pandemic are not significant, there is no significant difference between the base period and the period before the pandemic, thus supporting the parallel trend assumption. As the diagram on the right depicts, all regression coefficients of the three periods (indicated by negative figures on the horizontal axis) before the pandemic are not significant at the 5% level. Even at a relaxed significance level, no significant difference between the base period and the 6 months before the pandemic is observed, thus supporting the parallel trend assumption. When viewed dynamically, the regression coefficients of the first 2 months after the pandemic broke out are positive but not significant, which is almost in line with the time series plot. From the third month after the pandemic broke out, digital products played a significant role in promoting Chinese exports.

Placebo Tests

Based on Virtual Pandemic Time Points

The influence of other unobservable factors on the explained variables may impact the conclusions of this paper. Based on the parallel trend assumption, there should be no significant difference between the export trends of the treatment group and control group before the pandemic. Therefore, if a virtual pandemic is set before January 2010, the estimated coefficients of the core variables should not be significant. Following the practices of Topalova (36), we reduce the sample to a 12-month period before the pandemic, i.e., the entire year of 2019, and set the virtual pandemic to October, November, and December 2019. **Table 3** reports the regression results of the three virtual pandemic time points. As the interaction term coefficients are not significant, the direct impact of certain unobservable factors on the export trade can be ruled out.

Based on Virtual Grouping

It can also be questioned whether the statistical significance of the explained variables may be the result of certain random factors. The estimation bias may come from variables at the product-timing level. Therefore, we perform placebo tests by randomly grouping digital trade products (37, 38). The model consists of 97 product categories at the HS-2 level, 72 of which are included in the treatment group of digital products. We establish a virtual treatment group by randomly drawing 72 product categories and generate a virtual interaction term and add it to Model (2) for the placebo test. As the virtual treatment group is generated randomly, the interaction term in the placebo test should not have a significant influence on the dependent variable. In other words, the regression coefficient should not deviate significantly from the zero point. Meanwhile, to avoid interference by less probable events, we repeat the above process 500 times, record the interaction term coefficient and *p*-value of each regression result, and display them as kernel density plots. As shown in **Figure 2**, most regression coefficients are around the zero point, and the *p*-values of most estimates are over 0.1 (see the horizontal dotted line, not significant at the 10% level). The estimates of the true regression coefficients (see the vertical dotted line) are abnormal values in the placebo test. This finding indicates that our estimation results are unlikely to be obtained by chance and are therefore unlikely to be affected by other policies or random factors.

Robustness Tests

Robustness Test Based on the Construction of the Control and Treatment Groups

As noted above, a product category is included in the treatment group as long as one product of that category is sold on CBEC platforms. With reference to Campello and Larrain (29), changing the methods of constructing the control and treatment groups and rerunning the Model (2) regression can help guarantee the robustness of the empirical results. Put simply, we reconstruct the groups by trichotomy to calculate the proportion of products falling under the HS-6 code segmented from each HS-2 code that are sold through CBEC channels. Then, we construct two groups of dummy CBEC variables. The first is the CBEC_low treatment group, in which over 33.3% are CBEC products, and the second is the CBEC_high treatment group, in which over 67.7% are CBEC products. In essence, we raise the criteria for discriminating digital trade products, thus reducing the number of samples in the treatment groups. Lastly, we add the two treatment groups to Model (2) for regression and obtain the results shown in **Table 4**.

We find that when the difference in the proportion of CBEC products between the treatment and control groups dwindles, the core regression coefficients decrease accordingly and are all significant at the 1% level. These results mean that the effect of the digitalization level decreases during the pandemic, which is in line with the dosage effects. Hence, the identification strategy can be considered robust.

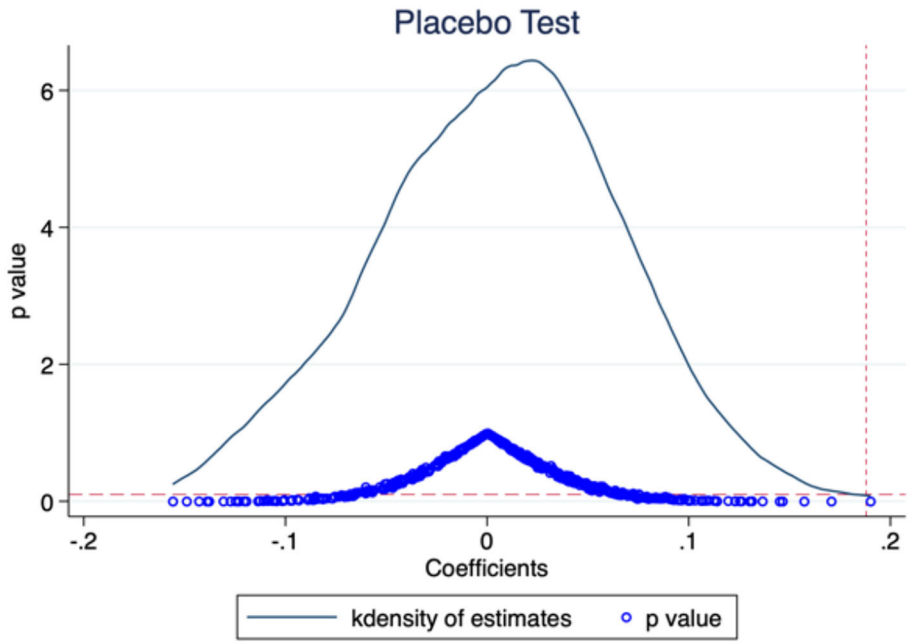

FIGURE 2 | Placebo test based on virtual grouping.

TABLE 4 | Regression results of the robustness test based on grouping.

	(1)	(2)	(3)
	LnExp	**LnExp**	**LnExp**
CBECxCovid19	0.188***		
	(0.047)		
CBECxCovid19_low		0.146***	
		(0.054)	
CBECxCovid19_high			0.122***
			(0.042)
Month FE	Yes	Yes	Yes
Id FE	Yes	Yes	Yes
Sector*Month_FE	Yes	Yes	Yes
N	71,586	71,586	71,586
R^2	0.6592744	0.6592137	0.6592174

****p < 0.01.*

Robustness Test Based on Subsamples

Considering that Chinese exports are not equally distributed among destination countries/regions, the USA, Hong Kong, and Singapore should be ruled out to avoid the effects of excessive trade volume and entrepot trade. The subsample regression results presented in **Table 5** indicate a significant positive correlation, although the estimated coefficients of the core explanatory variables decrease. Interestingly, linguistic commonality is significantly positive in the subsample robustness test, whereas economic freedom shows a significant negative correlation. Clearly, the three countries/regions excluded herein have higher economic freedom than China.

Mechanism and Heterogeneity Tests

Mechanism Test

In the demand-side mechanism analysis, we assume that digital trade accelerates export recovery by reducing trade costs. With reference to the explanations of trade costs in the control variable analysis, we take $relat\_rank_{tc}$, which stands for fixed trade costs, and $lndis\_cap_c$, which stands for variable trade costs, and make them interact with $CBEC_i{*}Covid19_t$, which is the original core interaction variable, to construct a new core interaction variable. For the purpose of supply-side mechanism analysis, we assume that digital trade accelerates export recovery by increasing the demand of partner countries/regions. With reference to the explanations of the economic scale of destination countries/regions in the control variable analysis, we make $relat\_gdp_{tc}$ interact with $CBEC_i{*}Covid19_t$, which is the original core interaction variable, to construct a new core interaction variable. The mechanism test focuses on the significance of the coefficient of the new core interaction terms, thus indirectly identifying the potential mechanisms through which digital trade promotes exports in the aftermath of the pandemic. The regression results of Model (3) are shown in **Table 6**.

The supply-side mechanism regression results demonstrate that the coefficients of the new core explanatory variables are positive and significant at the 1% level. Digital technologies break through the limitation of geographical distance and increase exports mainly by reducing fixed trading costs through increased economic freedom. This means

TABLE 5 | Regression results of the robustness test based on subsamples.

	(1)	(2)
	LnExp	LnExp
CBECxCovid19	0.188***	0.175***
	(0.047)	(0.047)
relat_gdp	2.808***	10.920***
	(0.032)	(0.090)
lndis_cap	−1.008***	−0.700***
	(0.012)	(0.013)
Language	0.009	0.158***
	(0.029)	(0.035)
relat_land	0.957***	0.834***
	(0.023)	(0.023)
contig	−0.513***	−0.777***
	(0.029)	(0.031)
relat_rank	0.414***	−0.832***
	(0.056)	(0.055)
fta	0.633***	1.018***
	(0.018)	(0.018)
Month FE	Yes	Yes
Id FE	Yes	Yes
Sector*Month_FE	Yes	Yes
N	71,586	66,348
R^2	0.6592744	0.6919224

****p < 0.01.*

TABLE 6 | Regression results of the mechanism test.

	Baseline regression	Demand-side mechanism		Supply-side mechanism
	LnExp	LnExp	LnExp	LnExp
CBECxCovid19	0.188***			
	(0.047)			
CBECxCovid19xlndis_cap		0.025***		
		(0.005)		
CBECxCovid19xrelat_rank			0.181***	
			(0.037)	
CBECxCovid19xrelat_gdp				−0.155***
				(0.058)
lndis_cap	−1.008***	−1.014***	−1.008***	−1.007***
	(0.012)	(0.012)	(0.012)	(0.012)
relat_rank	0.414***	0.414***	0.374***	0.413***
	(0.056)	(0.056)	(0.056)	(0.056)
relat_gdp	2.808***	2.808***	2.807***	2.850***
	(0.032)	(0.032)	(0.032)	(0.036)
Month FE	Yes	Yes	Yes	Yes
Id FE	Yes	Yes	Yes	Yes
Sector*Month_FE	Yes	Yes	Yes	Yes
N	71,586	71,586	71,586	71,586
R^2	0.6592744	0.6593145	0.6593166	0.6592024

****p < 0.01.*

that during the pandemic period, digital trade has indeed promoted Chinese exports by reducing the trade costs on the supply side.

The demand-side mechanism regression results demonstrate that the coefficients of the new core explanatory variables are negative and significant at the 1% level. In other words, Chinese exports are negatively correlated with the economic scale of the destination country/region. This means that digital trade plays a role in promoting Chinese exports but not through economies of scale in the export destination countries/regions. This finding does not agree with our hypothetical mechanism. In the following destination country/region heterogeneity test, we will further investigate what has limited the influence of digital trade on the demand side.

Export Destination Country/Region Heterogeneity Tests

The heterogeneity test considers the differences in pandemic severity and economic development levels among destination countries/regions.

In terms of pandemic severity, we collect the number of confirmed COVID-19 cases in China's major destination countries/regions in the period from February to April 2020. Countries/regions with an above average number of confirmed cases are rated as high-risk areas, and the rest are rated as low-risk areas[6]. In terms of the economic development level, we divide China's major export destination countries/regions into three groups, namely, low-middle-income, middle-high-income, and high-income countries/regions, based on the World Bank's latest 2020 national income classification. **Table 7** presents the results of the heterogeneity tests. In the pandemic severity heterogeneity test, the interaction regression coefficient for high-risk areas is not significant, while that for low-risk areas is positive and significant. In the income heterogeneity test, the interaction regression coefficients for all income levels are positive and significant. It can be directly observed that as the income level of a country/region decreases, the role of digital trade in promoting exports actually increases in the aftermath of the pandemic. Thus, we speculate that in the mechanism test, the demand mechanism of destination countries/regions is affected by the relatively low levels of demand of these high-income countries/regions. One possible reason is that high-income countries/regions suffer serious pandemic shocks. Therefore, we perform a pandemic risk heterogeneity test on the high-income countries/regions. The results also demonstrate that the interaction regression coefficient for high-income countries/regions in high-risk areas is not significant; however, that for high-income countries/regions in low-risk areas is significantly positive.

[6]In accordance with the COVID-19 Data Repository of the Center for Systems Science and Engineering (CSSE) at Johns Hopkins University, among the major export destination countries/regions studied in this paper, the USA, Spain, Italy, the UK, Germany, France, Turkey, Iran, and Brazil (ranked from high to low by the number of infections) are classified as high-risk areas.

TABLE 7 | Regression results of the country/region heterogeneity tests.

	Risk		Income			Risk*High_income	
	Risk_high	Risk_low	High_income	Upper_middle	Lower_middle	HH	HL
CBECxCovid19	0.107	0.210***	0.174***	0.177**	0.262***	0.119	0.191***
	(0.082)	(0.052)	(0.059)	(0.079)	(0.099)	(0.079)	(0.066)
Month FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Id FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sector*Month_FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	15,714	55,872	45,396	15,714	10,476	10,476	34,920
R^2	0.8081507	0.6753944	0.6509717	0.7979662	0.8094717	0.8790593	0.6703296
Empirical *p*	0.000***			-		0.030**	

***$p < 1\%$.
**$p < 5\%$.

When the model settings are identical among grouped samples, the regression coefficients can be compared between groups. Following Cleary (39), we test the significance of the differences in the interaction coefficients between groups after grouping regression. We obtain an empirical *p*-value based on 100 bootstrap replicates. Pandemic severity heterogeneity is significant at the 1% level. The high-income country/region heterogeneity in areas of different risk levels is significant at the 5% level. This result means that the two sets of interaction coefficients can be compared.

By further analyzing the interaction coefficients for high-risk and low-risk areas, we find that the estimated coefficients of low-risk areas are larger and more significant, implying that in the aftermath of the pandemic, digital trade has a stronger positive effect on exports to low-risk areas than on exports to high-risk areas. Higher-income countries/regions enjoy higher economic development and have higher levels of demand. In particular, we find that exports to high-income and high-risk countries/regions account for a considerable proportion of Chinese exports[7]. The non-significant estimated coefficient of high-income countries/regions severely suffering from the pandemic implies the reason why the demand mechanism fails to work.

Sector Heterogeneity Test

To study the sector heterogeneity of export products, we categorize the 98 product categories of the China Customs Sections and Divisions into 7 sectors and perform subsample regression on these 7 sectors. **Table 8** reports the test results. The interaction regression coefficients of three sectors, namely, agricultural and food products, electromechanical instruments and vehicles, and garments, shoes and hats, are positive and significant at the 1% level, while those of other sectors are not significant. This result means that digital trade has mainly promoted the growth in exports of these 3 sectors after the outbreak of the COVID-19 pandemic.

We further explain sector heterogeneity from the demand perspective. The COVID-19 shocks to demand evidently differ between goods that are necessary and unnecessary for pandemic prevention. Digital trade further enhances this difference. For example, "panic buying" resulting from physical distance has dramatically increased the demand for agricultural and food products, face masks, and other pandemic prevention necessities. As COVID-19 spreads quickly around the world, the demand for medical instruments such as ventilators and medical textiles such as protective garments increases sharply. While helping recover the supply, digital trade accelerates the export recovery of these three sectors. In contrast, digital trade has no significant effect on mitigating the negative COVID-19 shocks to the demand for goods that are unnecessary for pandemic prevention, such as chemicals, minerals and metals, rubber and leather, clocks, watches and toy, and woods, paper and non-metals.

CONCLUSION AND DISCUSSION

Conclusion

We base our study on monthly export data on 97 product categories under the China Customs Section and Division system that China exports to 40 major countries/regions in the period from January 2019 to June 2020. Using the DID method, we empirically study how digital trade has influenced Chinese exports under the natural shocks of COVID-19 and discuss the effects of digital trade on China's exports in the aftermath of the pandemic and the potential mechanisms.

Through empirical analyses, we obtain a number of findings.

First, the overall regression demonstrates that digital trade is significantly and positively correlated with Chinese exports in the pandemic context, suggesting that digital trade has positively promoted Chinese exports. There might be two reasons for this result. The first is the technical advantages of China. China ranks among the top countries worldwide in the use of the Internet, wireless broadband, and mobile terminals, and it has submitted nearly 20% of the world's

[7]The percentage of exports to high-income and high-risk countries/regions total 31.28% of China's export volume, including 19.98% to the USA, 3.83% to Germany, 3.10% to the UK, 1.60% to France, 1.52% to Italy and 1.25% to Spain, based on the sample calculation.

TABLE 8 | Regression results of the sector heterogeneity test.

	Full sample	Agricultural and food products	Electromechanical instruments and vehicles	Chemicals, minerals and metals	Garments, shoes and hats	Rubber and leather	Clocks, watches and toys	Woods, paper and non-metals
CBECxCovid19	0.188***	0.448***	0.386***	0.079	0.316***	−0.314	0.000	−0.096
	(0.047)	(0.123)	(0.148)	(0.076)	(0.085)	(0.240)	(.)	(0.138)
Month FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Id FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sector*Month_FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	71,586	17,712	7,380	18,450	13,284	3,690	3,690	6,642
R^2	0.6592744	0.5005582	0.7587776	0.6696178	0.5428716	0.731179	0.7764769	0.7709698

****p < 1%.*

patent applications in the fields of big data, cloud computing and artificial intelligence. Meanwhile, China ranks first in blockchain-related patent applications, filing ∼33,000 such patent applications. Social media and search engines are also in high demand overseas. The global service capability of China's BeiDou Navigation Satellite System is evidently enhanced. The second reason is the institutional advantages represented by the number of digital trade demonstration zones, 12 digital service export bases, 29 cultural export bases, 28 service trade innovation and development pilot areas, and 31 service outsourcing demonstration cities. Additionally, we found two control variables of interest. The first one *language* is not significantly related to trade flows. One possible reason may be that the use of machine translation mitigates the negative impact of language barriers on trade. Brynjolfsson et al. (40) found that the machine translation provided on CBEC platforms can boost growth in trade. The second one *relat_land* in the estimated coefficient of is significantly positive and the result differs from our expectations. One possible reason is that these countries/regions are facing more serious shocks under the pandemic and are therefore resorting to more imports.

Second, the sudden outbreak of COVID-19 has significantly inhibited Chinese exports overall. The dynamic parallel trend test demonstrates that digital trade started to significantly promote exports from the third month after the outbreak of the pandemic, implying that the lockdown had a negative effect on export trade but that digital trade quickly recovered after the lockdown was lifted.

Third, the mechanism test indicates that in the case of China, digital trade accelerates export recovery and growth mainly through the supply mechanism rather than the demand mechanism. One potential reason may be that the samples are taken from a relatively short time series after the pandemic. At least as viewed from the situation with a short period after the pandemic, digital trade did not play a role in increasing the demand of partner countries/regions.

Fourth, the country/region heterogeneity test shows that digital trade positively promotes exports to low-risk areas more strongly than it promotes those to high-risk areas, even in high-income countries/regions, implying that the pandemic control effect in destination countries/regions can impact the promoting effect of digital trade and that high-income and high-risk countries/regions may have potentially affected the effect of the demand mechanism.

Fifth, the sector heterogeneity test indicates that digital trade has significantly promoted the export of goods that are necessary for pandemic prevention.

Finally, a series of robustness tests, including the parallel trend test and placebo test, prove that our conclusions are robust.

Implications for Health Economics

The impact of COVID-19 will foreseeably continue for a period of time, and digital trade will play a more important role in global trade in the post-pandemic era. More importantly, reflecting on events such as COVID-19 that have had an enormous impact on economic growth is conducive to promoting sustained and healthy economic development. Taking into account digital technology in response to major health emergencies, through the storage, matching, analysis and visualization of large data on population movements, this study reveals the relevance of human behavior and processes, and it provides development opportunities for health economics. We propose the following implications for health economics from the perspective of digital technology:

1. Global health management cooperation. At present, countries around the world have not yet reached a consensus on health management measures such as epidemic control and vaccination. Our heterogeneity test results point out that differences in health management have led to an imbalance between demand and supply; as a result, digital technology has been unable to maximize trade and economic recovery. Therefore, we suggest that global health organizations must unite, pay attention to the impact of the pandemic on interpersonal relations and economic recovery, increase investment in human resources such as health, and accelerate the integration of digital technology and the healthcare industry.
2. Establishing an early warning and emergency response mechanism for public health crises. It is believed that COVID-19 will continue to exist for a period of time in the future. Therefore, the post-COVID-19 period is particularly important for retrospective data in epidemic-related or health

fields. From the perspective of this article, it is necessary to focus on and address the labor factor in the supply chain (demand and supply). The digitalization of the relationship between supply and demand is an important factor in the supply chain construction (41). Health is a human resource, and early warning and emergency mechanisms need to be verified. Therefore, we call for establishing a national-level health strategy and social care system, flexibly implementing social distancing and epidemic investigations, giving full play to the role of the government as an information intermediary (42, 43), and providing sufficient resources to support economic recovery.

3. Establishing medical and health big data. Health economics research also uses the DID model to analyze the sample data and to analyze and explain the value of health. Pandemic-related data showed an exponential growth trend during COVID-19. These open health and medical data make the data collection and analysis of health economics possible. We suggest using health big data to pay attention to the impact of personal ideas and social norms as well as other cultural factors on health behaviors. Personal health behaviors include the willingness to receive the COVID-19 vaccine, the willingness to wear masks, the behavior of people gathering together, and potential challenges to the fairness and accessibility of the national medical security system.

Limitations and Future Research

First, this paper focuses only on China, where an enormous number of confirmed cases of COVID-19 occurred in the early stage of the pandemic, to study the effect of digital trade on Chinese exports, but research can go further to cover more objects of study. China resolutely enforced a series of strict control measures such as stopping production and work soon after the outbreak of the pandemic to curb its spread despite the sacrifice of economic effects. In this respect, globally, China represents a rare case. The objects of future research may expand to include high-risk countries in the post-pandemic era and countries where digital trade is well developed. By incorporating the contribution of digital trade in those countries after the outbreak of the pandemic, the conclusions of this paper can be more solid and robust.

Second, the time series of the study cover only the 6 months after the outbreak of the pandemic. This decision was made to focus on how digital technologies have promoted Chinese exports in the short term. Furthermore, it is due to data limitations caused by the changes in China Customs' statistical coverage in July 2020. Short-term time series actually pose challenges for variables selection. Many indicators that reflect national capabilities, such as digital capabilities, and some lagging variables, such as FDI (44), are not exhaustively listed in the empirical regression, but are controlled with fixed effects. Similarly, we did not find appropriate short-term instrumental variables to control for endogeneity problems caused by potential reverse causality. Based on the regular pandemic situation of COVID-19, it is particularly important to investigate the mechanism through which digital technologies have a lasting effect on global trade. In future research, it is necessary to obtain data from a longer time series and thus explore the action mechanism of digital trade in more detail.

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

All authors undertook research, writing, review tasks throughout this study, read, and agreed to the published version of the manuscript.

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Service Innovation, Inter-organizational Trust, and Performance in Hospital Platforms: Social Network and Agency Perspectives

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Service industries contribute significantly to the economic, social, and even life aspect of the world. However, service innovation has been rarely discussed in healthcare context, especially in the digital healthcare context Service innovation needs to be organized in the premise of mutual trust to be efficient, thereby improving service performance. The trust and efficiency here demands a good online platform service to both virtualize the interaction processes and maintain trust and agency. This research uses social network theory and agency theory to emphasize the importance of trust in cooperation in hospitals, and the relationship between organizational trust and organizational performance. Furthermore, we analyzed the role of agents in enhancing the relationship between service innovation and trust. Based on the analyses, five propositions and future research directions are proposed.

Keywords: service innovation, inter-organizational trust, service performance, organizational agency, social network, hospital

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INTRODUCTION

Service innovation has become an important key and means for hospitals to compete with each other and succeed. However, service innovation has less been discussed in the context of digital platform in healthcare organizations, especially in hospitals' extended inter-organizational relationships. Nowadays, digital platforms serve as a non-human bridging and bonding mechanism for large-scope, cross-boundary operations and collaborations. A hospital can be treated as one open, interconnected platform-based organization because the service delivery for value creation depends largely on the intense interactions between the personnel of a hospital, the patients and families, government, community, etc. In such context, a digital platform can assist in virtualizing such interactions and value co-creation. Thus, it is critical to discuss the inter-organizational relationships in the context of hospital service innovation.

In the case of competition between various platforms, network service innovation has promoted transactions and controlled the hospital's connection due to network strategies. This is also true in a healthcare organization, which simultaneously contains non-for-profit service spirits and public service agency, as well as money transactions at the same time. The transaction competition between two or more different users connected through indirect networks has attracted attention

from all walks of life. The bilateral market of the network has evolved into the current multilateral platform, which is dependent on sales, execution, and knowledge sharing (1). How organizations create new network service value has received less attention in service innovation research in the early stage, and focused on the results and process of service innovation (2). The research on service innovation allows us to understand the types and strategies of service innovation and so on. Most innovation research focuses on products rather than services. (3). The strategic plans established for the development of new products mostly focus on profitability. Innovation is a necessary choice for the industry, not just a strategy (4). Product development is the basic process for the success and survival of organizational innovation. Service innovation is an important link for organizational structure and hospital progress. Service innovation is divided into tangible and intangible. The development of intangible products for new services is an activity for the benefit of customers, while tangible products are the concept of product manufacturing innovation (5).

The process of service innovation development is different from the process of product development in some respects. Past studies have regarded the service innovation process as the service process of product technology innovation. Service innovation is not a new concept, but in innovation research, most scholars focus on the research of technological innovation in manufacturing organizations (6). After decades of continuous research by many scholars, different views on current service innovation have gradually formed, such as assimilation, differentiation, and integration. So far, most studies on service innovation have been discussing product-related logic (7). According to Schumpeter's economic growth theory. It is divided into different types of innovation, such as: product, process and organizational innovation. The value of innovation is not defined by the output of the hospital, but by how the hospital provides better services.

In addition, the past research seldom discussed network service innovation from the perspective of agency theory. The service innovation of close interaction with customers highlights the importance of external relationships, and involves the exchange of knowledge between hospital interactions. Early research on service innovation focused more on the innovation within the hospital, while ignoring the key service innovation in the external partnership structure. In recent years, some scholars have explored the research of open innovation, and have been focusing on the resources obtained by the internal development of the organization and external partnerships. External development is especially important for the acquisition of knowledge. The combination of stakeholder relations is the result of all the combination stakeholder relations of the organization, showing that the allocation and management of the investment portfolio affects service innovation (8). Enterprise Services stakeholder relations with external parties to achieve innovation goals. This is usually because they do not have the resources they need, and lack the ability to develop the resources they need internally. Or through the relationship between partners to achieve complementary goals for external resource cooperation.

Therefore, the purpose of this article is to analyze how agency relationships regulate the impact of network service innovation on organizational performance, and explore from the perspective of agency theory, whether inconsistencies in agency relationships will have a negative impact on organizational performance. The research question explores how the agency relationship regulates the impact of network service innovation on organizational performance. The difference of the inconsistency scale of agency theory relationship represents the inconsistency of goals. Will it affect the service performance of the hospital?

THEORETICAL BASIS, LITERATURE REVIEW AND DISCUSSION

Theoretical Basis: Organizational Trust, Agency Theory, Social Capital

Organizational Trust and Social Capital

Inter-organizational trust is the antecedent of establishing exchange relationships between organizations. Since the organization is not an individual, and its thinking direction prioritizes interests, previous studies believe that this mode of thinking is a consideration of (calculative trust). In the (inter-organizational context), the degree to which computational trust will become the core of the exchange relationship will affect the actions taken by both parties in this relationship. When computational trust accounts for a greater degree, "writing a contract" is a way to ensure that both parties to the exchange perform their responsibilities and obligations, and avoid possible risks through "prevention". Previous research called it "bounded rationality" (9). Therefore, the establishment of a contractual relationship is based on the position of "dis-trust carefully" (10). Through the contract, the two parties in the exchange relationship are expected to exchange their expectations Keep under the same cognitive framework to maintain the cognitive consistency of the exchange relationship between the two parties. When the exchange relationship does not develop as expected (i.e., the consistency of cognition is broken), since the contract has established a default range acceptable to both exchange parties, both parties only need to make corresponding adjustments to respond to the default (11).

Another type of trust is presumptive trust. Presumptive trust refers to the organization's characteristics, identities, roles, rules and other information, which can help exchange parties to establish positive social expectation (12), and then promote trust. In other words, presumptive trust builds trust on "social identification." Since the presumed trust between the organization and the organization must be impersonal, the social identification information of the organization is aggregated from the main characteristics of the members of the organization. When the social identification information between the organization and the organization is more similar, the presumed trust between the two parties is stronger (11). At the same time, the leader of the organization can determine the appearance of the organization, and the display of the leader's leadership will also be presented in the organization's social information. For example, leaders are very particular

about product quality, and the organization's social identification information may be reflected in the organization's good reputation for products. This kind of trust relationship is established on the fact that both organizations can clearly recognize the position, responsibilities and obligations of their work roles, and take actions that match the roles, so as to maintain the consistency of social identification of each organization, so that they can exchange relationships. Establish a presumptive trust relationship.

In addition, the trust relationship between the leader and the leader can also be inferred to the relationship between the organization and the organization. When the leader of an organization has a good relationship with other leaders, the leader can identify opportunities through personal social networks (13), obtain resources (14), and mobilize Resources (15) and establish legitimacy for its organization (16). From the perspective of Social Capital, an excellent social network can help organizations achieve better performance. There are several key points in the transformation of social networks into social capital: one is structural hole, the second is the strength of ties, and the third is network diversity. The former focuses on whether the organization occupies the main node of the network, the two discuss the strength of connection with other organizations, and the last is the degree of tightness of the network structure. The three can determine the advantages and disadvantages of the organization in the entire social network, and then enable the organization to use the network to occupy a part of the industrial chain.

In an online healthcare communication context, there is a partnership between hospitals, or cooperation between projects, which needs to be shared or authorized among multiple hospitals. In the environment of multiple networks, it may be necessary to exchange and share resources between different domains. Therefore, the exchange between multiple domains involves each hospital performing its duties and building bridges, so the trust and connection between hospitals is very important. At the same time, through the exchange of resources between hospitals, the online environment is promoted to be effective. Therefore, this research analyzes from the perspective of social capital and organizational trust.

Agency Theory

Agency relationship is a kind of contract. According to the contract, one or more people (principal) hire another (agent) to provide certain services on their behalf, including entrusting certain decision-making powers to the agent, according to the scholar (17) proposed agency theory. This theory later evolved into the theory of signing a contract as a transaction behavior. The hospital is composed of a series of contracts. The supplier holding capital and the management department of the operation, the hospital and the supplier (customer), and the hospital and the employee are a series of contractual relationships. The agency's operating power is mainly the contractual relationship between the organization's resources given to specific suppliers. The relationship between the organization's shareholders and managers conforms to the agency relationship. According to the agency theory, the hospital entrusts the management right to the manager's agent, and then delivers it to the manager in the form of a contract. Including capital providers and capital operators.

Agency theory is mainly the relationship between the two parties' commitment to the contract. The contractual relationship between the provider and user of corporate capital. When the manager himself is the holder of corporate capital, the manager is working hard for his own hospital. Under this circumstance, there is no so-called agency problem. If the hospital obtains capital through debt, not through the hospital's issuance of stocks, there is also the agency problem, but the method of obtaining it is different (17).

The agent has more information about the business operation than the principal. In the case of two principals, these principals may have different risk preferences. If the interests are inconsistent and the goals are inconsistent, then the information may be hidden, resulting in information asymmetry. The relationship between principal and agent operates most efficiently. It can be used to view the explicit (legal) and implicit (social) aspects of the contract. This kind of information asymmetry will affect the principal's effective supervision of the agent manager. It is possible that some of these actions will damage the rights and interests of the principal (business owner) and cannot be monitored in time. For example, under the guise of any name, increase one's wealth. In order to protect the respective interests of both parties and the cooperative relationship, the owner of the hospital and the agent manager will sign a contract. In order to reduce the risk of the agent and protect the interests of the agent, the two parties will sign a contract to protect the rights of both parties. For example, the financial report will be reviewed externally, and the agent managers will perform their duties carefully in order to prove their efforts to the corporate clients.

Agent managers will also ask for the right to exercise internal audits for their own interests, so that the principal can understand the efforts of the agent managers (17). When one (agent) represents another (principal), there is a principal-agent relationship. These relationships are usually because the agent has some professional knowledge. however. Because there is an asymmetric information behavior pattern, it can satisfy the agent's own interests, not the interests of the principal. Agency theory believes that the corporate governance mechanism helps to align the interests of the principal with the interests of the agent. For example: clear instructions, provision of audit standards, some incentive measures, such as variable compensation or bonuses, can indicate that the interests of the agent are aligned with the interests of the principal. In terms of employment, employers (principals) can use piece rate/commissions, profit sharing, efficiency wages, performance measurement (including financial statements), agents to post security deposits or threats of termination of employment, so that the interests of workers are in line with their own interests be consistent. If the interests of the principals often diverge, in addition to the moral hazard that the agents still face, they will also face incentives that promote their personal interests rather

than the common interests of all clients. Problems can also arise when organizations increasingly respect powerful management. Since shareholders are deprived of the power of supervision, management problems may also arise.

In the case of two principals, these principals may have different risk appetites. Information is regarded as a commodity that can be exchanged. If the interests are inconsistent and the goals are inconsistent, then the information may be hidden, resulting in information asymmetry. The relationship between principal and agent operates most efficiently. It can be used to view the explicit (legal) and implicit (social) aspects of the contract. It involves solving the measurement and incentive problems that occur when the principal and the agent have different goals and desires, and the principal verifies that the agent's performance is economically.

The Evolution of Service Innovation

The process of service innovation development is different from the process of product development in some respects. Past studies have regarded the service innovation process as the service process of product technology innovation. Service innovation is not a new concept, but in innovation research, most scholars focus on the research on technological innovation of manufacturing organizations (6). After decades of continuous research by many scholars, different views on current service innovation have gradually formed, such as assimilation, differentiation, and integration. The definition of service innovation has crossed different fields. The current service innovation mainly elaborates on four aspects: First, the result of service innovation is separated from the development process. Second, innovation must be put into action. Third, innovation must be a new concept. Fourth, innovation must create value (18). Service innovation In the manufacturing industry, the innovation process is a common service process for manufacturing and production, and service is a behavior or process rather than a product. In the past ten years, the innovation trend has been to require supplier networks to provide products and services, and to connect with suppliers and customers through technology. This is the concept of application and reorganization innovation.

Since the development of service innovation research, scholars have developed another open innovation research. Most of this research focuses on internal development and externally obtained resources. External partnerships are essential for stakeholder relation integration. Partners are the most critical operating procedures for service innovation. In order to acquire knowledge, hospitals combine with various stakeholder relations, including customers, suppliers, and competitors, to achieve the goal of promoting service innovation. And organizations form stakeholder relations with external parties to achieve the goal of innovative services. This is usually because they do not have the resources they need each other, or they lack the ability to develop the required resources internally. force. Or want to obtain external resources through the relationship between partners to achieve complementary goals.

Team Network Service Innovation

The innovation of network organization is the products and services provided by the supplier network. In order to take full advantage of this relationship, the product is expanded and developed into a combination of services and products provided by an organization's network. According to Powell (1990), the network of organizations is regarded as a relationship of mutually beneficial and interdependent organizational forms. In a network organization, suppliers or partners provide resources to jointly design or jointly produce innovative services and products.

The network platform refers to the products and services that connect the two groups of users in the bilateral network. The business operation model of the platform has the phenomenon of increasing returns to scale. Under each platform is a layered platform after another. The network The platform is divided into four layers: infrastructure support, reading support, content selection and content, allowing us to better understand the structure of the platform. The emergence of Internet platforms and various emerging technologies has changed the relationship between hospitals and changed the traditional linear structure business model to a diversified and connected market structure, resulting in innovative services. The knowledge sharing provided by the Internet platform and the essential aspects of the innovative services included in the market economy have been transformed from the old thinking and extended, and the participation in the activity planning mechanism highlights the innovation of its differentiated services. In the online platform market, although the innovation driven by product recognition innovation and differentiated services is felt, in the evolution and development of Taiwan's online platform, the innovative services of the online platform have gradually gained the trust of consumers, but still There are many aspects that still need to be overcome one by one. From the perspective of knowledge sharing and innovative services, there is still considerable room for development in providing a consumer-oriented service innovation model. However, for the legal issues that must be paid attention to in the commercial activities of the online platform, such as consumer protection, protection of intellectual property rights, maintenance of transaction security, protection of privacy rights, etc., existing laws must be regulated to provide industry players. There is a good system to follow for the development of online platforms. The Internet platform connects platform operators, hospitals, and consumers to continuously innovate services, and through the experience of mutual cooperation and connection, provides innovative and differentiated services to meet the needs of consumers, and to share and create value. The connection of innovative service models all come from the mutual trust relationship between consumers and hospitals, which is the product of the sharing of knowledge. The emergence of online platforms has brought different thinking directions for business owners and consumers, and found that business owners and consumers produce value together, and develop and pursue value creation together, and rely on mutual trust and reasonable and even distribution. The act of creating added value. The Internet platform is to provide more information services to meet the needs of consumers, and to provide more value through

the information management system. The network platform provides a brand new service in the cloud, which makes it more convenient and stable for consumers to use, and overcomes the limitations of mobile devices. The network platform cloud service enables suppliers to expand and support various online services. Enhance many competitive advantages.

The interaction of partners or stakeholder relations is through the mutual exchange of knowledge and complementation, and the management of mutual cooperative relations. The mutual exchange of knowledge among partners is related to the degree to which new knowledge is created through mutual influence. The relationship between partners and stakeholder relations and mutual management is an important key role in service innovation, and mutual trust, learning and sharing of professional knowledge to achieve common goals, and active participation in activities and execution are very important. While the combination of stakeholder relations becomes partners, they also learn from each other, rely on and enjoy various resources. And by sharing knowledge and co-creating and sharing new product development and services with partners.

An hospital is a system in which there are various important resources, processes and behaviors, and suppliers and partners are important in this role. The network combines the competitiveness of different suppliers with tangible and intangible technologies. The results of this combination of different suppliers are different.

In the stakeholder relation of hospitals, suppliers play an important role in the key to service innovation. In order to obtain the source of knowledge, the hospital forms stakeholder relations with various hospitals to share resources and share risks. It is also because of this stakeholder relation to learn more about new technological developments. And often competitors may also become partners of technology and knowledge sharing, and develop toward a common goal.

In the past 10 years, many suppliers have been carrying out their innovative services. With the rapid development of network technology, the demand for the network is increasing. The rapid growth of the network has caused the continuous development of innovative services. And the innovation of service innovation through network stakeholder relations has created a new situation in the industry, whether it is technology. The growth, the different types of services and the value created cannot be ignored.

Suppliers through stakeholder relations are considered a powerful source of knowledge, because they often learn more about new technological developments, and because of these cooperative stakeholder relations and cooperation to develop new services, they also share investment and risks. On another level, it also has a considerable impact on hospital performance. Past studies have shown that innovation is to treat stakeholder relations as a learning tool for insights generated when managing stakeholder relation relationships. The extent to which customers participate in stakeholder relation cooperation has a differentiated impact on service innovation. Customers provide diversified experience sharing, and organizations can use the shared experiences of customers to use it to improve innovative ideas for future products and services. Differences in the degree of customer participation have different impacts on service innovation. Customer partnership is to learn from each other, have common goals, common responsibilities, mutual trust, and participation to promote service innovation.

Performance

The network between organizations is a kind of exchange or transaction relationship between organizations. The stakeholder relation between organizations and external suppliers is usually because both parties take what they need and supplement the resources they need, and complement each other through the relationship between the two partners their common goal. Hospitals form stakeholder relations because of their strategies, and the formation of strategic stakeholder relations regards service innovation as a tool for mutual learning between hospitals, focusing on the expansion of product innovation and the development of new services. The network hospital formed through the hospital's external network will improve the existing service process and develop together through the network relationship. If the hospital members have a benign dynamic relationship and tacit understanding, they can help the hospital members to complete their tasks more effectively. The ability to direct the relationship to the goal of the organization, so that the transaction cost between the organization and the manufacturer is greatly reduced, and the organization can produce high results (19).

Trust

In social sciences, trust is considered a dependency. Trustworthy individuals or groups mean that they abide by ethics, laws, and previous commitments to implement policies. However, trust is to simplify the cooperative relationship between people, whether it is at the interpersonal, inter-team, and inter-organizational levels, there is interdependence. Interdependence means that there is an exchange relationship between the two parties. Regardless of the content of the exchange, it means that the two parties have at least a certain degree of interest. Inter-organizational communication in organizational management is one of the necessary conditions for maintaining the relationship between internal personnel of the organization, and its purpose is to promote mutual trust as objective trust through the interconnection of internal members of the organization.

According to (20), the definition of trust is when one party is willing to be affected by the actions of the other party because it expects that the other party will work hard to implement the tasks assigned by the client without supervision. Or doubt the ability of the other party. Trust itself does not take risks, but the willingness to take risks. The willingness to take risks is one of the few characteristics that all trust funds share. This definition of trust applies to a relationship that is identifiable to another party, and the other identifiable party is considered to respond to and respond to actions taken by the principal. This definition is the same as (21). The definition is similar (22) means that there are some important things to be lost, making yourself vulnerable. This has blurred the nature of trust. These include cooperation, confidence and predictability (23).

Organization Agent

Ross (24) paid great attention to the development of agency theory. In principle, the agency literature proposes the recommendations of the contract agent between the parties: (1) the preferred structure of the contract parties, (2) the uncertainty of nature, and (3) the information structure in the environment. And usually it is more focused on risk sharing, and the relationship between the principal and the agent in the form of contract (25).

The agency relationship is defined as a contract. According to the mutual agreement of the contract, the connection between one or more (principals) and another (agent) represents that they are implementing certain service agreements, which involves some decision-making powers that will be granted to the agent. If this kind of mutual relationship, both parties are the greatest utility, then there are good reasons to believe that the agent does not always act in the interests of the principal.

The deposit or cost is to ensure the principal to ensure that the agent will not take certain actions that will harm the principal. And get compensation when taking such actions. However, it is usually impossible for the principal or agent to ensure that the agent makes the best decision from the principal's perspective at zero cost (17).

ANALYSIS AND DEVELOPMENT OF THE RELEVANCE BETWEEN THE VARIOUS CONSTRUCTS

Team Network Service Innovation and Team Performance

The performance of modern network distribution depends to a large extent on the network services used for information between computers, and the development speed of these services is much lower than the environment established by computer computing systems. The slow evolution is neither due to a lack of demand nor a lack of innovative ideas, but because of the changes in various computer network connections that do not support multimedia applications and accommodate more potential mobile hosts, although the requirements for these changes were reached a long time ago. They agree, but they have not yet fully deployed. The main problem is that the current process of changing network protocols is lengthy and difficult. Therefore, the requirements for standardization should be based on network protocols and interactive operability, which means that there must be a clear time and consensus on requirements. Once the new agreement is accepted, it can be completed in a compatible and renewed manner. Therefore, through the innovative method of network service, it can be a standardized communication model instead of a separate communication protocol. The potential resources provided by the network platform are difficult for the industry to access through their own marketing methods. For example: OTA can help hotels protect and Process reservations, communicate with guests and manage reviews. OTA can quickly respond to government policies, integrate resources, and create service value together. OTA can protect the profit of the hotel and not become a price war. Therefore, the strength of ties can improve work performance under the efficient use and execution of the network (26).

Proposition 1

The strength of the network connection will enhance the team's work performance under the efficient use of network services.

Team Network Service Innovation and Team Trust

Service has become a key value driver for each hospital. Currently, there is a lack of understanding of the science on which the design and operation of service systems depend. New conceptual understanding and theoretical foundation are needed to systematically describe the nature and behavior of the service system. Therefore, the mobile network theory can be used as a theoretical perspective to study the development and adoption of service innovation. The development and adoption of service innovation requires the integration of multiple elements across hospitals, including people, technology, and networks. In order to succeed in service innovation, it is necessary to coordinate and coordinate the technologies and interests of actors. Therefore, as an understanding of the relationship between actors, and to show the development and adoption of service innovation of these actors in various organizations to meet their needs through network formation, it will definitely show the expected goal of service innovation and development, and be able to win the trust Service object (27). When the leader of an hospital has a good relationship with other leaders, the leader can obtain resources through the personal social network (14), and the trust relationship between the leader and the leader can also be inferred to the hospital and the relationship between the hospital. Presumptive trust (presumptive trust) is through the hospital's characteristics, identities, roles, rules and other information, this information can help exchange parties to establish a positive social expectation (12), and then promote trust. From the perspective of Social Capital, an excellent social network can help hospitals achieve better performance.

Proposition 2

The better the relationship between social network service innovation and the team, the trust of the team will also increase.

Team Trust and Team Performance

The development of online platforms has triggered a new e-commerce model called social commerce. Use online platforms for social interaction to promote online purchases and sales of various products and services. In recent years, this development has involved many transaction-related issues. Trust is built on "social identification". When the social identification information between an hospital and an hospital is similar, the presumptive trust between the two parties is stronger (11). Reputation, scale, information quality, transaction security, communication, and word of mouth are the key factors that determine the quality of an online platform. Therefore, the social identification information of the hospital is aggregated from the main characteristics of the members of the hospital. At the same time, the display of the leader's leadership can determine the

appearance of the hospital, and it will also be presented in the hospital's social information. Consumers' trust has become a key factor in the success of commercial organizations. Leaders are very particular about product quality, which is reflected in the hospital's social recognition. Information may be on the excellent reputation of the hospital's products. For example, a trust relationship is established when both hospitals can clearly recognize their work role (work role) and take actions that match the role, so as to establish a presumed trust relationship in the exchange relationship (11). Therefore, the following proposition can be derived.

Proposition 3

The better the trust relationship between teams, the better the team's work performance.

The Through Mechanism of Team Trust on Team Network Services and Team Performance

The emergence of the Internet platform brings different thinking directions for hospitals and consumers, and the added value created by mutual trust and reasonable and even distribution. The development of trust is crucial to task performance, and performance becomes an indicator of the degree of trust development. In the online platform market, although the innovation driven by product recognition innovation and differentiated services is felt, in the evolution and development of Taiwan's online platform, the innovative services of the online platform are gradually gaining the trust of consumers. The network platform provides more information services to meet the needs of consumers, and provides new services in the cloud through the information management system, which makes the convenience and stability of consumers' use relatively improved, and overcomes mobile devices. However, the network platform cloud service allows suppliers to expand to support a variety of online services and enhance many competitive advantages. For example: Internet platform and international SiteMinder link Online Travel Agent. From the current order operation mode, the original inventory adjustment, price adjustment, and switch room adjustment must be operated from the OTA, and the order creation method must be established manually. The order creation cycle must be established at any time, and the cancellation of the order to supplement the room must also be manually supplemented, and the new cloud service is provided through the information management system. The future operation mode of inventory adjustment, price adjustment, and switch room adjustment will be unified by the SiteMinder system. The order construction method is automatically transferred in. The order creation cycle is once every 3 min. The cancellation of the order and the replacement of the room are automatically replaced by the system operation. Therefore, the suppliers through the stakeholder relation are considered to be a powerful source of knowledge, because they often learn more Technology development, and because of these cooperative stakeholder relations and cooperation to develop new services, they also share investment and risks. On another level, it also has a considerable impact on hospital performance. In the network environment,

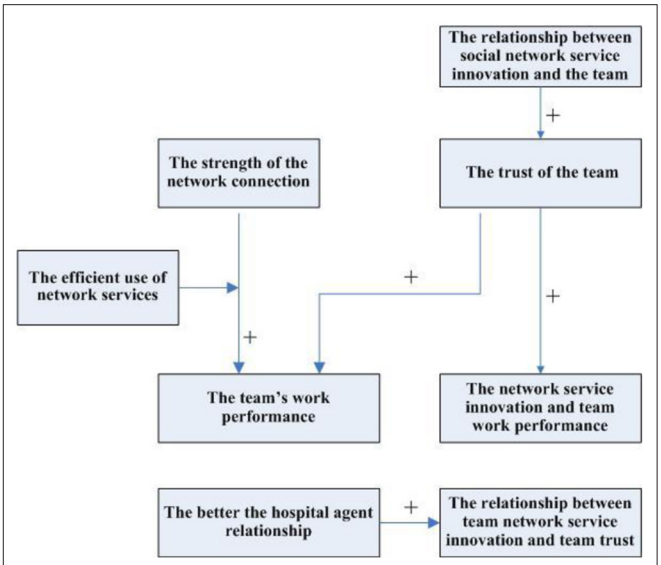

FIGURE 1 | Relationship model between main factors.

when there is a partnership between hospitals, or cooperation between projects, which need to be shared or authorized among multiple hospitals, trust relationship can be used to establish trust between hospitals. Under the environment, it may be necessary to exchange and share resources between different domains. At this time, a role is required to serve as the information exchange role in the network environment of different hospitals. Therefore, an intermediary is established between multiple domains. The role of is to trust the hospital and share information. Therefore, the following proposition can be derived.

Proposition 4

The higher the trust between teams, the better the quality of network service innovation and team work performance.

Moderating Relationship Between Hospitalal Agency Relationship and Team Network Service Innovation and Team Trust

People are increasingly realizing that value creation occurs in any hospital that produces something, and it becomes an input to the process in the business network. Innovation, network, and service are the key themes related to the processes related to service innovation in the supply network from a multidisciplinary perspective. Each topic provides the basic principles of interrelationship. From Schumpeter (1939, 1943) believes that innovation provides opportunities for prosperity. The network plays a key role in innovation and knowledge transfer. In addition, the significant growth of the global service industry, the innovation process in the supply network, is the internal interaction of the service sector An important part of our business network, which contributes to innovation in the supply chain (28).

The network of European regulators in industries such as telecommunications, securities, energy and transportation in Europe is considered to be an important example of European network governance law. From the point of view of principal-agent, coordination issues are the main factor that promotes the establishment of a network of regulatory agencies. The network is given a wide range of tasks and membership, but it has almost no formal powers or resources. Therefore, in terms of institutions, the spread of network governance is actually limited (29). According to (30), raise the question of social theory. That is, the question of structured agency, to what extent can it reflect the mutual penetration of agency and structure in social life. In an environment where the hospital is fully authorized to act as an agent, team network service innovation can be supported by various measures that enable the network hospital to progress, resulting in the promotion of high-impact team trust. Therefore, the following proposition is derived.

Proposition 5

The better the hospital agent relationship is, the better the relationship between team network service innovation and team trust will be enhanced.

When the agency relationship is lower, the relationship between team network service innovation and team trust will be lower.

According to the above propositions 1–5, the relationship between service innovation, inter-organizational trust, social network, agency and performance in hospital platforms can be obtained, as shown in **Figure 1**.

DISCUSSION AND CONCLUSION

Cooperation and innovation are the keys to the survival of an organization. Firstly, trust between organizations is a necessary condition for organizational cooperation, and it is also the basis for establishing social networks between organizations. Secondly, because organizations trust each other, the innovative activities of organizations can be developed. Through the social network to exchange resources and opportunities, so that each organization in the network can obtain performance improvements. Finally, agency is a further demonstration of inter-organizational trust, which can be used to supplement the organization's own deficiencies and discover opportunities. Through the above discussion, this research discusses the important role of trust in organizational performance through two viewpoints: (Social Network) and (Agency Theory).

This study puts forward the above five propositions and proposes three future research directions based on the propositions: First, whether the relationship between the agent and the agent will affect the strength of the network connection, the willingness to cooperate and the willingness of the agent, and the efficiency of the entire network. Secondly, whether the reputation of the agent's past performance represents that his future performance will be good for the hospital, and whether the reputation can represent future performance, this point can be further explored in the future. Finally, if the trust relationship between the teams is not good, the relationship between the two hospitals is not good, whether it will affect the efficiency of the entire network. This is something that future research can explore.

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

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

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Education, Income, and Happiness: Evidence From China

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Happiness is the continuous joy that people experience when they are satisfied with their lives long term, and is the ultimate goal pursued by all citizens. In this study, we investigate the relationship between education, income, and happiness in the migrant population in China. Using 1,31,186 individuals in the 2012 China Migrants Dynamic Survey (CMDS) as research samples, the estimated results of ordinal logistic regression show that education, including secondary education and higher education, has a significant and direct impact on individual happiness, and that the impact of education on happiness can also be mediated by income as an intermediary mechanism. In addition, factors such as gender, flow distance, flow time, employment status, type of housing, number of children, degree of preference for the city, and degree of discrimination by locals have obvious effects on happiness. This work provides important insights for countries seeking to implement an active education policy in order to increase economic income and thus achieve the development goal of universal happiness among their citizens.

Keywords: happiness, education, income, migrant population, China

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INTRODUCTION

Happiness is the most direct response of people to life satisfaction and a positive psychological state of happiness. As an important indicator of public health, it is increasingly becoming the focus of health and economic policies. In 2010, the National Bureau of Statistics of the United Kingdom designed the index of happiness and studied national citizen's happiness. In 2011, the German government established the Economic Growth, Happiness and Quality of Life Research Committee to research the German Happiness. In 2021, United Nations evaluated the impact of the COVID-19 pandemic and the response measures of various countries, and published the "2021 World Happiness Index Report" based on factors such as health, work pressure, social support, freedom, and income. Among the 149 countries surveyed in the world, China ranked 84th with a score of 5.339 (1). However, compared with the ranking of China's economy in the world, China's happiness index ranked relatively low.

Happiness is a complex concept involving multiple disciplines such as neurophysiology, psychology, and economics. Happiness is a neurophysiological process produced by comprehensive coordination of the prefrontal cortex, cingulate cortex, and amygdale (2). It is composed of mental activity that consists of two basic levels of cognition and emotion, which in turn involve three stages: emotional response, emotional experience, and cognitive evaluation (3, 4). Emotional response and emotional experience are the individual real-time reaction to the objective circumstances and state of life (5, 6). Cognitive evaluation emphasizes the rational or intellectual evaluation of the individual

expectations of happiness and real-life satisfaction, which is a positive psychological experience based on life satisfaction (7). Happiness is the continuous happy mood that people have when they are in a state of life satisfaction long term. Whether they are happy depends on their balance between happiness and painful emotional experiences (8). From the economic perspective, happiness is closer to the concept of utility, wherein, as proposed by Jevons, the satisfying effects of consumer goods are applied to determine the level of welfare from the perspective of utility (9).

Happiness is closely related to education, which is often portrayed as one of the key (direct or indirect) aims of education (10, 11). Previous studies have shown that education can change an individual's cognitive abilities, and the higher the level of education, the happier the individual (12, 13). Being educated gives individuals have increased control over their work and life, which helps to alleviate psychological worries of being controlled and deprived: this is also conducive to dealing with problems more actively and optimistically and thus to achieve self-realization and independence in work (14, 15). Meanwhile, the empirical research on education and happiness indicates that after controlling for the influence of variables such as health, income, and occupation, education has a significantly positive impact on happiness. Moussa and Ali (16) measured the level of happiness of higher education students and their relationship to academic success during the COVID-19, and data analysis showed that there was a positive correlation between happiness and academic achievement levels for students in higher education in the UAE. A recent study by Nikolaev (17) used the 2001–2013 Household Income and Labour Dynamics in Australia (HILDA) survey data to examine the relationship between higher education and three different measures of happiness; the results showed that the higher the level of education of individuals, the more satisfied they were with most areas of life (finance, employment opportunities, neighborhood, local community, children at home) and the higher their level of happiness. From a long-term development perspective, people with a higher education level can achieve their expectations and goals more effectively, and therefore experience more control over their lives and undoubtedly be happier (18–20).

Through education, not only can individuals' cognitive abilities be improved, but also their knowledge and skills, thus enabling more economic value and a higher level of consumer utility to be obtained. The accumulation of knowledge through education is the main way for individuals to improve their human capital; this human capital enables them to increase their income by improving their individual cognitive ability and work efficiency, that is, "education-human capital-income" (21). Under the free competitive market conditions, educational qualifications are viewed as indicators of highly skilled labor (22). Higher education diplomas signify that the individual has higher skills, which translate into higher remuneration (23). Generally, individuals with higher educational backgrounds earn higher wages (24, 25). Furthermore, high income can expand the set of feasible choices available to consumers, allow consumers to meet their individual preferences and needs better to improve the level of utility, thus, providing them a higher level of happiness as individuals (26). After Samuelson proposed the consumption revealed preference theory (27), the Marshall's demand function and the indirect utility function were used to correlate utility with income through Roy's Identity, thus achieving the "income-consumption-utility-happiness" conversion. Examining the relationship between education and happiness, Tran et al. (28) explored the mechanism underlying the impact of education on women's happiness in Australia when income is introduced as a mediating variable into the regression of education on happiness; the findings showed the coefficient of education's influence on happiness dropped significantly and the mediating effect of income on happiness was still statistically significant, indicating that income is one of the important mediators for education to have a positive impact on happiness. Even within families, education disparities can affect couples' happiness, and income remains a channel for couples to achieve happiness (29). Therefore, education may increase the individual perception of happiness by increasing the individual's economic income.

However, there is a complex relationship between education and happiness, wherein happiness is mainly determined by the gap between actual income and expected life satisfaction; people with higher education levels also have higher expected goals (30). Although individuals with higher education receive higher income, they are also more likely to find that their income expectations are not met, and the frustration of such individual expectations will have a negative impact on happiness (31, 32). Jongbloed (33) focused on the impact of higher education on the happiness of Europeans and found that education has little effect on satisfaction indicators such as personal optimism and self-esteem; people with higher levels of education are less likely to perceive a sense of accomplishment from their work, indicating that, higher education may not fulfill the role of improving happiness in Europe.

Furthermore, Easterlin et al. (34) found that in a given country, rich people are happier than the poor: happiness does not increase as a country's income rises over the long term, and analysis of the relationship between income and happiness revealed the level of national happiness in poor and rich countries to be almost the same, which is defined as "Easterlin paradox," that is, there is no obvious positive correlation between income and happiness. FitzRoy and Nolan (35) studied the relationship between education, income, and happiness based on the 1996–2009 British Household Panel Survey (BHPS) and found that individuals with lower levels of education, as their income levels increase, their sense of happiness in life declines, which was consistent with the "Easterlin Paradox." This showed that the pursuit of economic income may not bring happiness, and the pursuit of a sense of mission was the main channel for education to improve happiness (36, 37). Using internationally comparable data on more than 48,000 individuals in 24 countries, Araki (38) found a positive link between educational attainment and happiness, a relationship that was no longer substantiated once a fairer distribution of pay in the labor market was taken into account. Therefore, as discussed above, most of

the evidence for this relationship to date has been limited to developed countries.

In contrast, for developing countries like China, the evidence for the link between education and happiness is still scant due to a lack of reliable data. Yang et al. (39) research believes that the happiness level of Chinese residents has doubled from 2003 to 2015, and the main factor for the improvement of happiness is the increase of income or education level. Zhang and Liu (40) used the cross-sectional data of the 2010 China Comprehensive Social Survey (CGSS) to find that the level of happiness of Chinese people with high education is higher than that of people with low education. In addition, individuals will try to compare living standards with their peers, and higher income and wealth means more material happiness (41). However, while China's economy is growing rapidly, income inequality has also increased significantly, and happiness increases with the increase in income inequality (42). At present, China is in an emerging economy transitioning to a market economy and has huge research space. By clarifying the relationship between education, income and happiness of Chinese residents, it provides a detailed reference for promoting the happiness development of Chinese residents and the development of people's livelihood and happiness in other developing countries.

In this context, personal happiness may not be related only to education itself, but also to the increase in economic income brought by education. Empirical testing of the relationship between happiness and education in the Chinese population is an important way to judge the happiness level of the Chinese population. This paper makes contributions to several aspects. First, we establish the mechanism of happiness affected by education. There is a logical relationship between education and happiness, which appears as "Education-Human capital-Income-Consumption-Utility- Happiness" transformed in turn. We use a mediation model to verify the transmission mechanism through which education affects happiness via economic income. Second, we analyze overall performance of happiness of Chinese residents, and use ordered logistic regression to test the causal effect of education on individual happiness, which provided support for the positive relationship between education and happiness. Third, there are some interesting findings of other influence factors on happiness of Chinese residents, such as individual characteristics, psychological characteristics and job characteristics have a significant impact on happiness.

Using data from the 2012 China Migrants Dynamic Survey, we find that individuals' education level is positively correlated with happiness. Education can affect individual happiness both directly and via the intermediary mechanism of income factors. That is to say, the higher the education level of an individual, the higher his/her income level and the stronger his/her sense of happiness.

The rest of the paper is organized into five sections. Section Data and Variables describe the data source and variable definitions. Section Models and Methodology describes the models and methods for the assessment of education, income, and happiness. Section Results describes the results. Section Discussion describes robustness check and Section Conclusion presents the findings.

DATA AND VARIABLES

Data

In this study, we use data from the China Migrants Dynamic Survey (CMDS) conducted by the China Population and Family Planning Commission in 2012. The CMDS collects information on the migrant population, including information on basic demographic characteristics, family, employment, income, medical and health services, public services, health, and life experience from a representative sample of the floating population aged 15–59 years old in 31 provinces (autonomous regions and municipalities directly under the Central Government) and the Xinjiang Production and Construction Corps.

Variable Definitions

The dependent variable in this study is self-evaluated happiness. The CMDS contains the question "do you feel happy now compared with how you felt in your hometown (place of outflow)" and provides five responses, where 1 means "very happy," 2 means "happy," 3 means "so-so," 4 means "unhappy," and 5 means "very unhappy." We grouped these responses into an ordered scale of happiness by coding responses in reverse order. This variable is measured by 5 levels, where 1 is very unhappy and 5 is very happy.

The independent variable is education level. Considering that China's nine-year compulsory education policy covers all regions of the country, we divided education levels into elementary education, secondary education, and higher education by coding respondents who have attended elementary school, junior high school, or have not attended school as elementary education or 0; those who have attended high school or technical secondary education as secondary education or 1; and those who have attended college, undergraduate, or postgraduate education as higher education or 2.

The intermediary variable is income. Wage income includes personal wages, bonuses, overtime pay, allowances, and funds equivalent to the food and housing of work. If the surveyed person had not received their salary for the current month, the most recent salary was recorded.

Based on the review of the literature on happiness research by Easterlin and other scholars, the control variables mainly include personal characteristics, flow characteristics, social characteristics, and psychological characteristics. Personal characteristics include gender, age, household registration. There are two main variables to represent flow characteristics: flow distance and flow time. Flow distance includes inter-province flow, intra-province flow, intra-city flow. The flow time refers to the most recent date on which the respondent arrived in the city, district, or county to commence work and residence. Social characteristics include employment status and the type of housing. Employment status includes whether the individuals are employees, employers, or self-employed workers. Respondents' housing includes low-rent housing, self-rented housing, free

beds in the factory, and self-owned housing. Low-rent housing refers to the respondents' housing as rented units or employer's housing; low-rent housing to that provided by the government; self-leased housing includes rented private houses and other informal residences; free beds in the factory include free housing and employment places provided by the unit or employer; self-owned houses include self-purchased houses, self-built houses, and borrowed houses. In terms of reflecting psychological factors, indicators of the adaptation and identification of the floating population to the city, such as the degree to which individuals like the city and the evaluation of whether they accept or discriminate against the locals, were selected.

The factors affecting personal income mainly include personal characteristics and job characteristics. Personal characteristics include education level, gender, age, household registration, flow distance, and flow time. Job characteristics include occupational type, industry, nature of the work, employment status, and work intensity. To classify occupations, we categorized the heads of state agencies, parties, and mass organizations, enterprises and institutions, professional and technical personnel, civil servants and related personnel, and business as the leading technical class; vendors or those employed in catering, cleaning, security, decoration, transportation, other commercial service personnel, no fixed occupations, and others were classified under the service class; workers in agriculture, forestry, animal husbandry, fishery, and water conservancy production, production, construction, and other transportation equipment operators and related personnel were classified as the production class. Categories based on the nature of the unit were as follows: public-owned units, private-owned units and foreign-funded units. The division of industries is as follows: manufacturing, electricity, coal and water production and supply, mining, construction, agriculture, forestry, animal husbandry and fishery in the statistical survey as manufacturing; wholesale and retail, accommodation and catering, and others as the sale of food and accommodation services; social services, financial and insurance real estate, transportation, warehousing and communications are classified as housing money transportation services; health, sports and social welfare, education and culture, radio, film and television, scientific research and technical services, party and government agencies and social organizations are classified as science, education, culture, and health. In terms of employment status, domestic helpers were categorized into self-employed workers, and there were three categories with self-employed workers, employees and employers. Work intensity includes daily working hours and weekly working days.

Descriptive Statistics

Table 1 shows descriptive statistics. After excluding outliers and missing values, the sample included 1,31,186 individuals. The average happiness score is 3.74. The percentages of individuals

TABLE 1 | Descriptive statistics.

Variables	Definitions	Mean	Std. Dev.	Min	Max
Happiness	1 = very unhappy, 2 = unhappy, 3 = so-so, 4 = happy, 5 = very happy	3.740	0.720	1	5
Education level	0 = elementary, 1 = secondary, 2 = higher	0.411	0.662	0	2
Income	Monthly income (yuan)	3128.048	3201.859	100	98000
Gender	1 = female, 0 = male	0.408	0.491	0	1
Age	Respondent's age	33.869	9.052	15	60
Household registration	1 = non-agricultural, 0 = agricultural	0.158	0.365	0	1
Flow distance	0 = Inter-province, 1 = Intra-province, 2 = Intra-city	0.575	0.739	0	2
Flow time	The length of the last visit to this city/district/county	4.399	4.636	0	51
Employment status	0 = employees, 1 = employers, 2 = self-employed workers	0.721	0.904	0	2
Type of housing	0 = Self-rented housing, 1 = Low-rent housing, 2 = Free beds in the factory, 3 = Owned housing	0.816	1.151	0	3
Number of children	Number of children owned by the respondent	1.380	0.716	0	7
Like the city	0 = completely disagree, 1 = disagree, 2 = basically agree, 3 = completely agree	2.438	0.558	0	3
Feelings of discrimination	0 = completely disagree, 1 = disagree, 2 = basically agree, 3 = completely agree	1.003	0.787	0	3
Industry	0 = science, education, culture and health, 1 = industry, 2 = sale, food and accommodation service, 3 = housing money transportation service	1.731	0.773	0	3
Occupational type	0 = production class, 1 = leadership class, 2 = service class	1.194	0.836	0	2
Nature of work	0 = private ownership unit, 1 = public ownership unit, 2 = foreign ownership unit	0.226	0.538	0	2
Working hours per day	The number of hours the respondent worked in a day	9.446	1.902	1	16
Working days per week	The number of days the respondent worked in a week	6.256	0.959	0.5	7

FIGURE 1 | Direct effect of education on happiness.

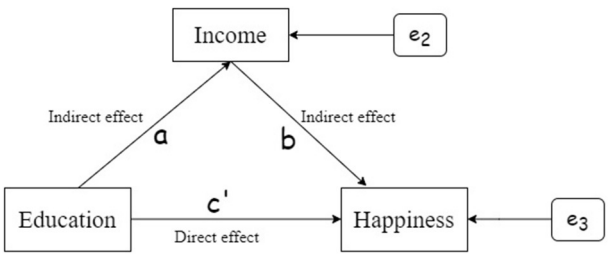

FIGURE 2 | Intermediate effect of education on happiness.

whose answers were "very happy, happy, so-so, unhappy, and very unhappy" were 18,666 (14.23%), 62,222 (47.43%), 48,083 (36.65), 1,967 (1.50%) and 248 (0.19%), respectively. The average education level is 0.411. The numbers of individuals with elementary, secondary, and higher levels of education were 90,118, 28,186, and 12,882, respectively. The average income level is 3,128 yuan.

MODELS AND METHODS

Mediating effect analysis is an important step to test whether a variable is a mediating variable and to what extent it plays a mediating role. **Figure 1** can be used to describe the relationship between education and happiness, and the path coefficient is *c*. Because the third variable is not involved, the coefficient *c* represents the total effect of education acts on happiness.

Figure 2 shows the relationship between education and happiness after controlling the intermediate variable income. The coefficient *a* represents the effect of education acting on the income, and the coefficient *b* represents the effect of the intermediate variable income acting on happiness. The two constitute the indirect effect of the relationship between education and happiness. The coefficient c' represents the effect of education acting on happiness after controlling the income variable, that is, the direct effect between education and happiness. Then, the total effect between variables should be equal to the direct effect plus the indirect effect: that is, the total effect equals $ab + c'$. Combining **Figures 1**, **2**, we get $c = ab + c'$, where *c* is total effect, c' is the direct effect, and *ab* is the intermediate effect, also called the indirect effect. The analysis of the mediation effect is to test whether the *ab* effect exists and what its proportion of the total effect is, and reflect the degree of the mediation effect.

The corresponding structural equation is:

$$\boldsymbol{Y} = \boldsymbol{cX} + \lambda \boldsymbol{P} + \boldsymbol{e_1} \quad (1)$$

where Y is the dependent variable happiness; X is the independent variable education level; and P is the control variable that affects happiness, including personal characteristics, mobility characteristics, social characteristics, and psychological characteristics. The coefficient to be estimated *c* is the total effect of education on happiness, and λ is the influence of control variables on happiness.

$$\boldsymbol{M} = \boldsymbol{aX} + \lambda \boldsymbol{P}' + \gamma \boldsymbol{W} + \boldsymbol{e_2} \quad (2)$$

M is an intermediary variable, that is, the logarithm of individual income; P' is a control variable that affects income, including personal characteristics and mobility characteristics; and W is a control variable reflecting work characteristics that affect individual income, including occupational type, industry, nature of work, employment status, daily working hours, and weekly working days; b the coefficient *a* to be estimated is the impact of education on income.

$$\boldsymbol{Y} = \boldsymbol{c}'\boldsymbol{X} + \boldsymbol{bM} + \lambda \boldsymbol{P} + \boldsymbol{e_3} \quad (3)$$

The coefficient c' to be estimated is the direct effect of education on happiness, and the coefficient *b* to be estimated is the effect of income on happiness.

Considering that the dependent variable is a group of ordinal categorical variables and the number of response variables is >2, ordinal logistic regression is suitable for the analysis of Equations (1), (3) (43). The income is a set of continuous variables, and the ordinary least square method is used for estimation. Therefore, we check the regression coefficients in three steps (44–46).

RESULTS

The models 1.1–1.3 in **Table 2** are the estimated results for the model of the mediating effect of education on happiness. Model 1.1 is the estimated result of Equation (1) by using the ordinal logistic regression method, Pseudo R^2 is displayed as 0.087, the LR statistic is 18795.77, and the corresponding *p* value is 0.000; therefore, the joint significance of all coefficients (except the constant term) of the entire equation is very high. Studies have found that after controlling the gender, age, flow, and psychological characteristics of the migrant population, education significantly affects happiness. Compared with elementary education, the impact of secondary education on happiness for the floating population was found to be 4.8%, passing the 1% significance test; the effect of higher education on happiness was 14.3%, which is significant at a significance level of 1%. It shows that the higher the education level of the individual, the higher their happiness.

Model 1.2 is the estimation result of Equation (2) obtained by using the ordinary least square method. In addition to controlling the basic personal characteristics and psychological characteristics of floating individuals, the work characteristics of individuals, such as their occupation, industry, nature of work, working hours, and other variables, are included. The results of the study show that, compared with migrant individuals in elementary education, the impact of secondary education on

TABLE 2 | The mediating effect model estimation results of education on happiness.

Variables	1.1 Happiness	1.2 Income	1.3 Happiness
Secondary education	0.048***	0.092***	0.030*
	(0.017)	(0.004)	(0.017)
Higher education	0.143***	0.297***	0.082***
	(0.027)	(0.006)	(0.028)
Income			0.176***
			(0.011)
Gender	0.065***	−0.210***	0.111***
	(0.013)	(0.003)	(0.013)
Age	−0.001	0.001***	0.001
	(0.001)	(0.000)	(0.001)
Household registration	−0.001	0.092***	−0.015
	(0.020)	(0.005)	(0.020)
Intra-province	0.185***	−0.130***	0.209***
	(0.014)	(0.003)	(0.015)
Intra-city	0.176***	−0.173***	0.208***
	(0.018)	(0.004)	(0.018)
Flow time	0.026***	0.001**	0.026***
	(0.001)	(0.001)	(0.001)
Employers	0.182***	0.409***	0.106***
	(0.019)	(0.005)	(0.020)
Self-employed workers	0.081***	0.133***	0.056***
	(0.014)	(0.004)	(0.014)
Type of housing	0.100***		0.098***
	(0.005)		(0.005)
Number of children	−0.019**		−0.017*
	(0.010)		(0.010)
Like the city: disagree	−1.350***		−1.345***
	(0.116)		(0.116)
Like the city: basically agree	0.275***		0.277***
	(0.100)		(0.100)
Like the city: completely agree	1.462***		1.469***
	(0.100)		(0.100)
Discriminate: disagree	−0.586***		−0.588***
	(0.015)		(0.015)
Discriminate: agree to some extent	−1.018***		−1.019***
	(0.020)		(0.020)
Discriminate: completely agree	−0.814***		−0.813***
	(0.033)		(0.033)
Manufacturing		0.049***	
		(0.009)	
Sale, food, and accommodation service		−0.061***	
		(0.008)	
Housing, money, transportation service		−0.001	
		(0.009)	
Leadership class		0.152***	
		(0.005)	
Service class		−0.002	
		(0.005)	
Public ownership unit		−0.080***	
		(0.005)	
Foreign ownership unit		0.096***	
		(0.007)	
Working hours per day		0.015***	
		(0.002)	
Working days per week		0.016***	
		(0.001)	
/cut1	−6.229***		−4.804***
	(0.132)		(0.160)
/cut2	−3.913***		−2.487***
	(0.108)		(0.141)
/cut3	−0.066		1.363***
	(0.105)		(0.139)
/cut4	2.607***		4.041***
	(0.106)		(0.140)
Constant		7.543***	
		(0.016)	
Observations	101527	131186	101527
Pseudo R^2	0.087		0.088
LR chi^2	18795.77		19043.98
Adjust R-squared		0.166	

*Robust standard errors in parentheses; *p < 0.10, **p < 0.05, ***p < 0.01.*

income is 9.2%, which is significant at the level of 1%; the impact of higher education on income is as high as 29.7%, and it is also significant at the level of 1%. It indicates an increasing trend with the level of education. Whether education is the accumulation of human capital or an indicator of high-skilled labor, individuals with higher education levels have higher income levels than those with lower levels, that is, increasing the number of years of education is still an efficient human capital investment (47).

Model 1.3 is the estimated result of Equation (3) obtained by using the ordinal logistic regression method. Pseudo R^2 is displayed as 0.088, the LR statistic is 19043.98, and the *p* value is 0.000; therefore, the joint significance of all coefficients (except the constant term) of the entire equation is very high. After controlling the personal characteristics, flow characteristics, social characteristics, and psychological characteristics of the floating population, the individual economic income variables are introduced. It is found that the impact of income on happiness passes the 1% significance test, and the impact degree is 17.6%. It can be calculated that the mediating effects of secondary education and higher education on happiness are 1.62% (17.6% * 9.2%) and 5.23% (17.6% * 29.7%), respectively. The mediating effect among the total effect is 33.72% (17.6% * 9.2%/4.8%) and 36.55% (17.6% * 29.7%/14.3%), respectively. The results show that compared with elementary education, the direct effect of secondary education on happiness in the floating population is 3.0%, which is significant at a level

TABLE 3 | Regression results of restricted working time range.

Variables	2.1 Happiness	2.1 Income	2.3 Happiness
Secondary education	0.046*	0.102***	0.025
	(0.026)	(0.005)	(0.026)
Higher education	0.105***	0.314***	0.037
	(0.036)	(0.007)	(0.036)
Income			0.172***
			(0.020)
Gender	0.062***	−0.225***	0.115***
	(0.020)	(0.004)	(0.021)
Age	−0.001	0.003***	0.001
	(0.001)	(0.001)	(0.001)
Household registration	−0.008	0.103***	−0.025
	(0.029)	(0.006)	(0.029)
Intra-province	0.192***	−0.149***	0.221***
	(0.024)	(0.005)	(0.024)
Intra-city	0.162***	−0.208***	0.200***
	(0.029)	(0.006)	(0.029)
Flow time	0.023***	0.005***	0.022***
	(0.002)	(0.001)	(0.002)
Employers	0.309***	0.443***	0.231***
	(0.042)	(0.010)	(0.043)
Self-employed workers	0.107***	0.071***	0.095***
	(0.027)	(0.006)	(0.027)
Type of Housing	0.121***		0.118***
	(0.008)		(0.008)
Number of children	−0.015		−0.014
	(0.016)		(0.016)
Like the city: disagree	−1.277***		−1.281***
	(0.183)		(0.183)
Like the city: agree to some extent	0.233		0.234
	(0.158)		(0.158)
Like the city: completely agree	1.430***		1.435***
	(0.158)		(0.158)
Discriminate: disagree	−0.550***		−0.555***
	(0.025)		(0.025)
Discriminate: agree to some extent	−0.980***		−0.986***
	(0.032)		(0.032)
Discriminate: completely agree	−0.820***		−0.828***
	(0.053)		(0.054)
Manufacturing		0.030***	
		(0.009)	
Sale, food, and accommodation service		−0.057***	
		(0.009)	
Housing, money, transportation service		0.017*	
		(0.009)	
Leadership class		0.159***	
		(0.007)	
Service class		−0.010	
		(0.006)	
Public ownership unit		−0.078***	
		(0.006)	
Foreign ownership unit		0.091***	
		(0.007)	
Working hours per day		0.012***	
		(0.004)	
Working days per week		0.018***	
		(0.001)	
/cut1	−6.184***		−4.796***
	(0.207)		(0.264)
/cut2	−3.944***		−2.557***
	(0.171)		(0.237)
/cut3	−0.087		1.304***
	(0.167)		(0.234)
/cut4	2.566***		3.961***
	(0.167)		(0.235)
Constant		7.502***	
		(0.027)	
Observations	39351	57258	39351
Pseudo R^2	0.0855		0.0864
LR chi^2	7206.42		7278.78
Adjust R-squared		0.236	

*Robust standard errors in parentheses; *p < 0.10, ***p < 0.01.*

of 10%. Higher education significantly effects happiness; the direct effect of 8.2% is significant at the 1% significance level. It shows that the mechanism of education on happiness is a partial mediating effect. Furthermore, education also influences happiness via the mediating factor of income, consistent with the conclusions of Ross and Willigen (48) and Chen (49).

In addition to education and income as factors that affect the happiness of migrants, the estimation results of models 1.1 and 1.3 in **Table 2** show that the number of children, the distance of migrated, employment status, the degree of preference for the city, and the indicators of local discrimination significantly affect their level of happiness. For example, the larger number of children that need to be raised, the weaker their sense of happiness. Childbirth and upbringing requires personal time and money, consumes the individual's passion and energy to cope with life, affects the individual's happiness in work and life, and causes the individual's perception of happiness to decline. The influence of flow distance on happiness is significantly negative. The happiness of the intra-city and intra-province floating population is higher than that of the inter-province population. The happiness of employers and self-employed workers is significantly higher than that of the employees. Psychological factors significantly impact happiness. Happiness itself is a psychological feeling, which is inevitably closely related to other psychological states. Happiness comes from inner positive and joyful emotions. A positive attitude toward the city can obviously improve the happiness of

TABLE 4 | Marginal effect table of explanatory variables.

Variables	3.1 Very unhappy	3.2 Unhappy	3.3 So-so	3.4 Happy	3.5 Very happy
Secondary education	−0.0001	−0.0004	−0.0054	0.0023	0.0035
Higher education	−0.0001**	−0.0011**	−0.0148**	0.0061**	0.0099**
income	−0.0003***	−0.0023***	−0.0319***	0.0136***	0.0208***
Gender	−0.0002***	−0.0015***	−0.0202***	0.0086***	0.0132***
Age	−0.0001	−0.0001	−0.0001	0.0001	0.0001
Household registration	0.0001	0.0002	0.0027	−0.0012	−0.0018
Intra-province	−0.0003***	−0.0027***	−0.0379***	0.0160***	0.0249***
Intra-city	−0.0003***	−0.0027***	−0.0378***	0.0160***	0.0248***
Flow time	−0.0001***	−0.0003***	−0.0048***	0.0021***	0.0031***
Employers	−0.0002***	−0.0013***	−0.0192***	0.0081***	0.0127***
Self-employed workers	−0.0001***	−0.0007***	−0.0102***	0.0044***	0.0066***
Type of Housing	−0.0002***	−0.0013***	−0.0178***	0.0076***	0.0116***
Number of children	0.0001	0.0002	0.0031	−0.0013	−0.0021
Like the city: disagree	0.0072***	0.0574***	0.2101***	−0.2291***	−0.0455***
Like the city: agree to some extent	−0.0006*	−0.0054*	−0.0599**	0.0478**	0.0181**
Like the city: completely agree	−0.0020***	−0.0174***	−0.2941***	0.1572***	0.1571***
Discriminate: disagree	0.0006***	0.0057***	0.1051***	−0.0335***	−0.0782***
Discriminate: agree to some extent	0.0014***	0.0123***	0.1901***	−0.0847***	−0.1191***
Discriminate: completely agree	0.0011***	0.0091***	0.1492***	−0.0583***	−0.1011***

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

migrants, and the evaluation of discriminatory feelings against locals is also an important reflection of such a positive attitude (50).

DISCUSSION

To check robustness of our results, we changed the sample range. Working hours are often an important factor that affects physical and mental health. Researchers from World Health Organization (WHO) and International Labour Organization (ILO) have conducted a global analysis of the loss of life and health caused by long working hours based on relevant data from 194 countries or regions around the world, and found that people who work 55 h or more a week compared with the standard working hours (35–40 h per week)are at higher risk of ischemic heart disease and stroke. The burden of disease caused by long hours of work accounts for about one-third of the total disease burden, and working long hours has been determined as the risk factor with the greatest burden among all occupational diseases (51). Furthermore, extended working hours will take up the free time of individuals, reduce the amount of things they like to do, and thus reduce their sense of happiness. In order to avoid the decrease in happiness caused by long working hours, we limit the number of working days to 4–6 days a week, and the daily working time is 4–12 h. According to the parameter estimation results (see **Table 3**) of Model 2.1, obtained by re-estimation with 57,258 individuals, compared with that of elementary education, the total effect of secondary education on happiness is 4.6% and the total effect of higher education on happiness is 10.5%. However, in Model 2.3, the direct effect of education on happiness becomes insignificant, while the impact of income on happiness is 17.2%, which is significant at a level of 1%. It can be thus inferred that secondary education and higher education have an effect on happiness, and the mediating effects were 1.75% (17.2% * 10.2%) and 5.40% (17.2% * 31.4%), respectively. The mediating effect accounted for approximately 38.14% (17.2% * 10.2%/4.6%) of the total effect, 51.44% (17.2% * 31.4%/10.5%). This finding shows that after considering the influence of working hours, the impact of education on happiness is completely mediated by the income mechanism, and education does not directly affect happiness.

In order to more intuitively show the marginal effect of each explanatory variable on happiness, we calculated the mean marginal effect of each explanatory variable to show that the change of the explanatory variable affects the probability of happiness taking each value. The results are shown in **Table 4**. When all explanatory variables are at the mean value, compared with elementary education, each level of higher education increases, the probability of an individual being very unhappy, unhappy, so-so, happy, and very happy will change at the 1% significance level by −0.0001, −0.0011, −0.0148, 0.0061, and 0.0099, respectively. The probability of an individual feeling very happy is 0.0038 higher than the probability of being happy for each level of higher education. It shows that the higher the education level of individuals, the higher the probability of obtaining happiness. This reflects that education improves people's sense of happiness and satisfaction, which is conducive to promoting people to form a good level of mental health and to participate more actively in future life.

From the perspective of other explanatory variables, for each additional unit of income, the probability of an individual feeling very happy is 0.0072 higher than the probability of being happy. Therefore, the higher the income, the stronger the individual's happiness. The happiness level of women is significantly higher than that of men. Individuals who choose to move outside the province and outside the city have a higher sense of happiness than those who move within the city. The longer the flow time, the higher the individual's happiness. The stronger the love of the city, the higher the individual's sense of happiness, on the contrary, the stronger the discrimination, the weaker the sense of happiness.

CONCLUSION

In this study, we examined the relationship between education, income, and happiness among migrants in China. We found that education had a positive effect on income and happiness, and that it can directly affect individual happiness. Furthermore, it can also influence happiness via the mediating effect of income.

The results of this study provide some practical implications. First, the findings are different from those of empirical research by scholars on the contradictory relationship between education and happiness in the UK and European countries: the higher the level of education that China's individuals receive, the stronger their happiness level, indicating that in China, higher education can fulfill the role of enhancing happiness. Second, research has found that the income level can increase with the education level. This means that increasing investment in education can not only bring higher economic income to individuals, but also increase the per capita national income of the country. Third, there is an obvious positive correlation between income and happiness, and the happiness that education brings to individuals via the income mechanism is significant. This conclusion strongly refutes "Easterlin Paradox." Therefore, individuals are encouraged to accumulate human capital by obtaining higher-level education, improving their academic qualifications and thus their salary earned, and therefore enhancing their direct happiness. Meanwhile, government should also seek to strengthen resource input into higher education, reduce the cost of education investment, improve the price mechanism of human capital and labor market, increase the rate of return from education, and achieve a simultaneous increase in income and happiness.

DATA AVAILABILITY STATEMENT

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

AUTHOR CONTRIBUTIONS

DY conceived and designed the research, provided guidance throughout the entire research process, and responsible for all R&R works. GZ and ML participated in data analysis and wrote and supplemented the English paper. HW reviewed and edited the article. All authors contributed to the article and approved the submitted version.

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Exploring the Relationship Between ESG Performance and Green Bond Issuance

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As an important part of green financial instruments, green bonds have become increasingly popular in recent years. This study employs green bond issuance as a proxy to measure investors' recognition of a firm's sustainable activities by linking literature on ESG and financial performance and those on green bond issuance. This study innovatively creates the datasets by combining the ESG performance of Chinese listed companies with their green bond issuance from 2016 to 2020 based on the Wind and CSMAR databases and examines the relationship between the performance of ESG dimensions and green bond issuance from the perspective of listed firms in the emerging market. The results indicate that decent ESG practices not only increase the propensity in green bond issuance by listed firms but also help them issue more green bonds. More specifically, we found evidence to support this finding from every dimension of these sustainable practices. However, this study identified the negative effect of financial performance in issuing green bonds when combining the effect of ESG performance.

Keywords: green bond issuance, ESG, financial performance, environment, sustainability

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INTRODUCTION

Past several decades have witnessed a profound trend that emerges in corporate sustainability, from voluntarily involving in sustainable activities to actual requirements because of both social expectations and regulatory pressure (1). In recent years, global issues such as climate warming, environmental pollution, and carbon emissions have become increasingly prominent. A great deal of firms have adapted sustainability strategies and disclosed environmental, social, and governance (ESG) information, which results in fundamental changes in business models and management theory. These changes have shifted from conventional shareholder-oriented management (2) with aims of financial performance enhancement and the shareholders' welfare maximization to stakeholder-oriented management (3), which considers all the stakeholders, including shareholders, consumers, customers, communities, and other related groups, and eliminating externalities and maximizing social value regarding ESG issues (4).

Environmental, social, and governance has obtained great attention in academia and business management in recent years (5, 6). Firms have a burden not only to maximize productivity and profitability but also to experience constant demand concerning the social and environmental impacts of their activities (7). A successful firm should implement good corporate governance practices and maintain strong relationships with society and the environment (8). As the measure of sustainable strategies, ESG performance has been widely studied in its relationship with the financial performance (FP) of firms (9–11). While some researchers found a positive effect of ESG on FP (12–14), certain researchers found negative effects (15, 16). Others concluded that there is no relationship between the ESG score and FP (17–19).

To overcome the lack of funds for the development of a green economy, sustainable financing provides a driving force for companies to seek ESG investment. As one of the important carriers of green finance, green bonds play a positive role in financing the transition to a low carbon economy (20). A green bond refers to a plain fixed income tool that can be used to finance or refinance new or existing projects accelerating the progress of economically sustainable activities (21). Green bonds build an extremely effective link between corporate finance and corporate sustainability considering their standard financial characteristics bundled with the dedication to environmental issues (22).

It is suggested that the issuance of green bonds symbolizes the attention of firms to environmental protection and green innovation, which improves the development of a low-carbon economy and green finance and builds a good social image (23). Thus, when some investors consider the contribution of firms to a green economy, they will link the financing function of green bonds with individual stocks, associating the growth of firm performance and stock price with the positive external effect of ESG practices (20). In recent years, academic researchers study green bonds in different aspects. Reboredo (24) assesses the link between the green bond market and the financial market, while Febi et al. (25) investigated the effects of the liquidity premium on the green bond yield spreads. Furthermore, Chiesa and Barua (26) examined the factors affecting green bond issuance and pricing (27).

All these studies have been focused on firms in developed countries, while the impact of this relationship on emerging country firms in China remains far from clear (28–30). The empirical evidence shown in these studies cannot be generalized to emerging markets in terms of the relevance of the value of ESG activities. It is important to emphasize that firms are significantly and systematically different from those in developed countries in terms of their social, cultural, and managerial practices (31), such as weak or dysfunctional institutions (32–34), limited state control (35), less favorable business climates, a lack of corporate governance (36, 37), higher levels of uncertainty, specifically higher corruption levels (38), and greater political risks (39). In sum, China provides an ideal research environment and unique context for us to understand the development of green bonds, and specifically for identifying the effect of ESG practices on the issuance of green bonds.

According to the World Bank's WDI database, China is the largest carbon emitter and developing economy. Cheap labor and heavy investment contributed to China's past economic growth, but a huge environmental price was also paid for this development. The financial market is adjusted by the Chinese government to relieve the contradiction between economic growth and environmental protection (40). China's SRI investment market is currently in the early stages of rapid development (41). The green bond market is one of the major financial innovations promoted by the central government. As shown in **Figure 1**, the issuance of green bonds in China has been booming in recent years (20). It achieves the highest amount ever in 2019, although the issuance retreats in 2020 and 2021 due to the effect of the pandemic.

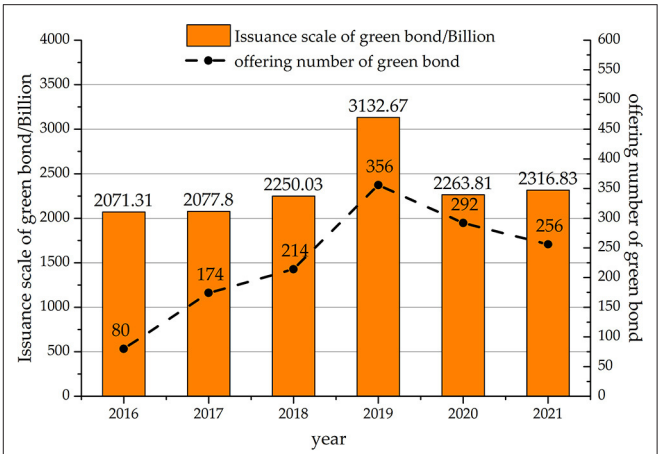

FIGURE 1 | Issuance scale of green bonds in China.

This research aimed to explore the relationship between ESG performance and green bond issuance. It is achieved by two stages of analysis in this study, which are to investigate whether a listed firm with good ESG performance issues green bonds and to examine the volumes of green bonds issuance by the listed firms who provide better ESG practices. Our result confirms that good ESG performance and practices lead to more green bond issuance, even when considering their sub-factors from the environment, society, and governance dimensions. These factors enable investors to identify a responsible and sustainable firm.

Based on the Wind and CSMAR databases, this research builds a dataset combining the ESG performance of Chinese listed companies with green bond issuance between 2016 and 2020 to examine the relationship between green bond issuance and ESG dimensions. In addition, probit models are used to identify variables that impact the issuance of green bonds.

This study makes several key contributions. First, only a few studies directly established the relationship between ESG practices and investment recognition, and there is no research on the impact of ESG practices on green bond issuance. This study innovatively constructs the relationship between ESG practices of Chinese listed companies and investment recognition and discusses in detail how ESG practices affect green bond issuance. This study does not treat the green bond as a simple debt but as a recognition of the sustainable and responsible firm by investors. It employs the issuance of the green bond as a proxy of such recognition, which innovatively builds a link between the green bond and ESG practices. This study neither observed green bond from the perspective of pure debt nor examined the ESG from the perspective of its impact on financial performance. It combines both aspects and extends the literature on green bonds and ESG study. In doing so, this study incorporates the ESG scores and financial performance into the model of impact on the issuance of green bonds by creating an unprecedented dataset, which probes the roles of ESG practices in green investment.

Second, although the investment philosophy of ESG is gradually accepted, most of the related products are based on ESG

overall scores and indexes related to the environment (E), but study on indexes related to society (S) and corporate governance (G) are relatively scarce. At present, there is a lack of research on specific indicators in the ESG evaluation system and green bond issuance. This article not only illustrates the effect of ESG scores on green investment as a whole indicator but also examines environmental (E), social (S), and governance (G) separately to determine accurately the relationship of each sub-factor to green investment in China. In terms of the three dimensions, we used specific practices to be proxies of the three sub-factors, which makes the indicators more detailed and more inclined. Different institutions have different scoring frameworks and evaluation criteria for companies' ESG practices. The use of processed "indirect data" evaluated by institutions cannot fully reflect the company's real situation to a certain extent, and it is impossible to explore the specific paths through which different practices affect investment decisions, and affect the richness of research results. This study uses the "direct data" on ESG practices disclosed in the annual reports of listed companies to more truly and accurately establish the relationship between them and investment recognition. By applying resource-based views, the analysis of the influence of ESG scores and individualized effects of each sub-factor (E–S–G) on green investment contributes to the literature on multinational firms (42).

Third, there is a great deal of controversy on the practice of socially responsible investment in investment management, including financial performance, and no consensus has yet been reached. This article explores the moderating effect of financial performance in green investment. It reveals the contradictive relationship between ESG performance and financial performance, especially its effect on influencing the issuance of green bonds. This creatively echoes the argument about the ESG investment's negative effect on financial performance.

Fourth, previous studies have mainly focused on the effect of ESG in developed countries. Most of the existing ESG studies use developed markets as samples, and there is a lack of research on emerging markets such as China (9). This study focuses on firms in the emerging market. Although studies about emerging economies are in very recent literature (30, 38), few empirical ones have been performed on ESG dimensions in green investment. The research on China's ESG evaluation system is still in the theoretical stage, and the concept of ESG investment has not been widely popularized and applied. Since this relationship has not been directly explored in the context of China, these findings fill an important gap in the field.

The remainder of this article is organized as follows. First, this article summarizes relevant literature on the relationship between ESG with financial performance and green bond issuance activities. On the basis of previous studies, this article proposes hypotheses from both ESG and its sub-factor (E–S–G) dimensions. Then, in the data and methods section, this article describes the sample, the variables, and models used in this study, including the probit model and other regression models. Furthermore, this article explains the empirical results and discusses the result from both theoretical and managerial views. Finally, the last section concludes and points out the limitations.

LITERATURE REVIEW AND HYPOTHESES

ESG and Green Bond Issuance

It is argued that if a firm uses its resources more sustainably, it will generate some clear positive outcomes from a view of economic efficiency. Some studies identified that, for firms involving well-developed environmental management systems, the debt financing cost is lower compared with their rivals (43). In particular, recent literature revealed that firms with corporate social responsibility (CSR) policies and high CSR performances can issue bonds at a lower cost, and thus investors have a large investment pool deduced by such a higher market evaluation (44). ESG has evolved from CSR as the development of firm sustainable strategies. Therefore, a higher sustainability performance can lead to a lower-cost equity capital (45). This results in a high chance of green bond issuance in good ESG practices, which is shown in the below hypothesis.

Hypothesis 1a: The firms with good ESG practices are more likely to issue the green bond.

It is shown that firm solvency and their ratings are positively related to environmental practices, consequently, implying their low risk in potential legal, regulatory, and reputational costs (46). Firms without effective sustainable practices will potentially experience expensive fines and strong resistance from stakeholders, which can increase their default risk and liabilities (47). Polbennikov et al. (48) corroborated that bonds with higher ESG scores have higher returns. Furthermore, the issuer of the green bond with green certification and sufficient information disclosure will decrease the screening costs of investors and improve the confidence of investors in green bonds. Thus, the high bond premium and low company financing costs resulting from sustainable practices stimulate the issuance of green bond (20). This is shown in the hypothesis 1b.

Hypothesis 1b: The good ESG practices will facilitate firms to issue more green bonds.

The Moderation of Financial Performance

To date, a great deal of empirical literature has examined the relationship between corporate financial performance (CFP) and corporate sustainability to explore the implications of stakeholder-oriented management for CFP (14, 19, 49). According to the Porter hypotheses (50), corporate social responsibility (CSR) activities, especially environmental activities, create excess turnover which can cover the additional costs, thus an appropriate sustainable strategy can improve CFP. Most of the empirical studies display a positive relationship between CFP and CSR (19, 51, 52). However, agency problems and inefficient resource allocation could generate additional costs in sustainable activities, which results in a disadvantage for firms in the free and competitive market (2, 53). Some empirical studies with negative relationships were documented (54). For instance, Lee and Faff (55) found that ESG investment worsens CFP.

In addition to positive and negative relationships, a neutral relationship has also been found between CFP and CSR (56). However, according to Barnett and Salomon (57), the relationship between CFP and CSR is neither strictly positive nor

strictly negative. They found an inverted U-shaped relationship between CFP and corporate environmental performance, which exhibits evidence for the nonlinear relationship (58, 59).

According to the traditional neoclassical approach, investing in ESG activities brings additional costs for a firm (60), which impacts CFP. For instance, investments in reducing emissions or improving the use of natural resources are excessive (61, 62). In a production process, the cost of considering its effect on the environment, clear emissions reduction, noise control, or waste management policies is high. When these firms decide not to invest in environmental initiatives, they could avoid economic resources being compromised, and their performance increases in the case that environmental goals are not priorities for them. Thus, even if good ESG practices encourage green bond issuance, this trend will be compromised by the moderating effect of potentially good financial performance. This deduces hypothesis 2.

Hypothesis 2: When considering the firm's financial performance, it will negatively interfere with the positive effect of ESG practices on green bond issuance.

The Practices in Three Dimensions of ESG

Since the ESG score is weighted on a company's performance in the environmental (E), social (S), and governance (G) sub-factors, a company possibly involves in individual E, S and G activities at different levels (63). The practices developed from individual one of these three dimensions could improve the financial value for some firms but undermine it for other firms (64). There is no consensus on the actual effect of individual ESG on green investment. Therefore, to obtain a better understanding the impact of ESG activities on green investment, a more detailed analysis of the sub-factors may be necessary.

Environmental Dimension

In terms of the environmental dimension of ESG activities, it is argued that environmental regulations result in an additional cost for the company that decreases profitability and efficiency. In contrast, according to the Porter hypothesis, the strict but flexible environmental regulation may provide companies with incentives to innovate technologically or managerially. This improves efficiency that neutralizes the additional costs and grows more revenue eventually (4). However, it is still questioned whether environmental regulations can generate additional revenue and higher corporate efficiency by offsetting the excess cost (65). Additionally, firms often show inconsistent words and actions in conforming to environmental policies (66). Empirically, the strict environmental standards will stimulate higher market value than that of less strict regulations (67). In a high-growth industry, profitability is positively linked with environmental performance (68). Such profitability impacts the recognition of these firms by investors. Thus, a firm's environmental performance positively affects the issuance of green bonds issued by the firm (21). Unfriendly environmental activities will negatively impact the issuance of green bonds. According to the previous studies discussed above, we propose hypothesis 3a.

Hypothesis 3a: Unfriendly environmental activities are negatively related to the issuance of green bonds.

Social Dimension

In terms of the social dimension of ESG activities, social activities show controversial relationships with financial performance. On the one hand, Brammer and Millington (69) supported a positive relationship between good corporate social performance, such as charitable giving, and financial performance in the long term. Besides, reputation, brands, and large quantities of natural resources could strengthen these benefits in some sectors (70). However, social activities share the same concerns regarding additional costs with environmental activities. Costs come along with practicing social activities, for example, having a health and safety policy. It is also argued that providing employees with CSR training cannot contribute to the financial performance. These controversial arguments support that if the additional costs can be addressed by the benefits, social activities, including corporate reputation enhancement and able employees' attraction, will improve profits and efficiency (4). These firms' social practices will be further positively related to the issuance of green bonds (21).

Hypothesis 3b: Social activities that attract capable employees are positively related to the issuance of green bonds.

Governance Dimension

In terms of the governance dimension of ESG activities, a board structure is focused on several aspects to explore the firm's performance. Zhu et al. (71) found that a firm's value tends to be improved if the firm sets up the structure of independent directors. In certain industries, such as the banking industry, good corporate governance has a positive effect on financial performance (72). The reputation and status in society of independent directors ensure that a firm's attention is paid more to environmental opportunities and development in corporate innovations (73). The existence of independent executive directors on the board is beneficial to the control over the quality of information disclosure (74). Therefore, an audit and/or supervisory committee composed of independent directors will ensure such practices and make the image of a responsible company to investors (75). Polbennikov et al. (48) identified the positive relationship between ESG bond scores, including individual governance score and bond performances.

From another aspect, shareholders have less control over management (76) and less communication with executives (77) in firms with relatively dispersed ownership. The less diversified stakes may provide more assurance in engaging sustainable practices (78). Thus, the shareholding of the large shareholders could force management to disclose more information related to environmental responsibility and increase the success of green bond issuance (75).

According to the discussion above, several activities regarding global sustainable strategies and board composition are positively associated with firm performance and efficiency (4). Following the previous studies, we further added global sustainable governance principles as a factor in our analytical model to

investigate how governance activities are linked with green bond issuance. We propose the following hypothesis.

Hypothesis 3c: Governance activities that involve an independent and diversified board of directors are positively related to green bond issuance.

DATA AND METHODS

Data Collection

The article employs the green bonds issued by companies listed in the Chinese stock market between 2016 and 2020 in the Wind database. We creatively combined the information on green bond issuance and financial data from the CSMAR database. Previous studies (20, 75) examined issues on ESG performance or green bond issuance using the Wind and CSMAR databases, which provide a theoretical basis for this research. In addition, Wind and CSMAR databases are vital in terms of their comprehensive data. The selected period comes primarily for two reasons. First, China began issuing green bonds in 2015, but data are available from 2016. Second, green bond issuance before 2021 is essentially unaffected by the COVID-19 pandemic. As a result, this research selected data from 2016 to 2020.

In the remainder of the analysis, we limit the sample to the green bonds of these listed companies. After excluding unlisted companies that issue green bonds and companies listed on the Hong Kong Stock Exchange and other overseas stock exchanges, a total of 94 samples of listed companies remain. In addition, this study considers industry factors, and we divided them into 19 industries according to the China Securities Regulatory Commission (SEC)'s industry classification.

Variables and Model

Dependent Variable

As shown in **Table 1**, the dependent variable is green bond issuance. In the first stage of analysis, whether a listed firm issues a green bond is introduced as a dummy to construct a probit model. Furthermore, the second stage of analysis investigates the volume of green bond issuance in these listed firms to identify the factors of investors recognizing a responsible and sustainable firm.

Independent Variables

In the third-party independent rating in the Wind database, compared with several other ESG rating scores, Huazheng's ESG rating score[1] covers more comprehensive data. Therefore, this study used the ESG rating scores retrieved from the Wind database as independent variables. The total ESG score, which is called the Huazheng ESG rating score, can be classified as an added value of CSR performance for the three subgroups (E, S, and G). Values range from 0 to 9, with 9 as the highest score.

This study next investigated the effect of a firm's financial performance (FP). Return on Assets (ROA) is used in this article as a proxy for the firm's FP. ROA is widely utilized in the literature as a proxy to assess the impacts of ESG on FP (79–81). ROA is defined as the net income's ratio to total assets and focuses on how a company's earnings respond to different managerial policies and the relative efficiency of asset utilization (55). In the second stage, the interaction term between financial performance and ESG scores is used to assess the moderating role of FP in green bond issuance.

This article also analyses the impacts of the three E, S, and G score components separately: the environmental dimension is measured by water usage and greenhouse gas emission; the social dimension is measured by the number of employees; and the governance dimension is measured by the shareholding stake of top 10 shareholders and whether there is a chairman of the supervisory committee.

Control Variables

To exclude the impact of other factors on the issuance of green bonds, several control variables were introduced into the regression models.

- Firm ownership: Since the state-owned economy is the dominant part of the Chinese economy, state-owned firms bear greater social responsibilities and will also bear more environmental responsibilities (82). Hence, we used firm ownership as a control variable and measured it as a dummy variable (1 for state-owned enterprises and 0 otherwise) (75).
- Firm IPO age: Firms with longer listing time have a better reporting structure (83) and have a higher awareness of great environmental pressure (84). Therefore, the longer the firms' listing time, the higher the degree of corporate environmental responsibility disclosure. Consequently, we used firm IPO age as a control variable and measured it with the number of years since its first IPO (75).
- Firm size: Larger firms obtain more public attention and subjected to greater political and regulatory pressures from external stakeholders (85), so large firms tend to disclose more information to illustrate that their actions are legitimate and consistent with good corporate citizenship (76, 78, 86). Consequently, we used the firm size as a control variable and measured it with the logarithm of total assets (75).
- Leverage: Firms with low financial leverage have more resources and the intention to disclose environmental responsibility information (78, 86) to ensure that the market participants properly evaluate their financial risks (87). Hence, we estimated that there is an inverse relationship between corporate financial leverage and green bond issuance. Consequently, we used firm leverage as a control variable and measured it with the ratio of total debt divided by total assets (75).

[1]According to the company announcements, the Huazheng ESG evaluation system is based on the core connotation and development experience of ESG, combined with the actual situation of China's domestic market, to build a three-tier indicator system from top to bottom. Specifically, it includes 3 primary indicators, 14 secondary indicators, 26 tertiary indicators and over 130 underlying data indicators. The rating scope covers all A-share listed companies, and the rating is presented in the form of a total score of 100, with a corresponding rating of "AAA-C" in nine grades.

TABLE 1 | Variable description.

Type	Variable name	Variable symbol	Variable description
Dependent variable	Green bond dummy	D_greenbond	The likelihood of green bond issuance
	Green loan volume	Greenloan3	The volume of green bond issuance
	ESG scores	esg_huazheng	ESG rating of Shanghai Huazheng index information service Co., Ltd
	Environmental dimension	ln_water	Total water consumption
		ln_greenhouse_gas	Total greenhouse gas emissions
	Social dimension	ln_employee	Total number of employees
Independent variable	Governance dimension	Supervisory_chair	Is there a chairman of the supervisory board
		top10_shareholder	Stocks held by the top 10 major stockholders/all stocks
	Financial performance	roa	Return on Assets, which is net margin/total assets
	Leverage	gearingrate	Asset-liability ratio, which is liabilities/total assets
	Firm size	ln_total_asset	Natural logarithm of total assets (ln)
	Firm IPO age	ipo_age	The number of years since its first IPO
Control variable	Firm ownership	soe	Dummy variable, 1 for state-owned listed companies, or 0
	Firm growth	Sales_growth	Increase rate of business revenue, which is amount of operating income for the current year-amount of operating income for the same period of the previous year

Model Setting

This study first used a probit model to explore what factors impact the likelihood of green bond issuance. Probit models can be used for modeling the relationship between one or more numerical or categorical predictor variables and a categorical outcome. For the probit model, the following relationship is assumed:

$$\mathbf{P(Y = 1|x_1, \ldots, x_k) = \Phi(\beta_0 + \beta_1 x_1 + \ldots + \beta_n x_n)} \quad (1)$$

where Φ denotes the distribution function of the standard normal distribution, and it also transforms the regression into the interval (0, 1). The regression coefficients of the probit model are effects on a cumulative normal function of the probabilities that $Y = 1$ (i.e., the probability that a firm issues a green bond). As such, its metric can easily be understood as a standard normal score. Using this, the coefficients can be interpreted directly.

The parameters of the probit model need to be computed *via* a non-linear method such as maximum likelihood estimates (MLE) or nonlinear optimization techniques. These parameters cannot be solved *via* ordinary least squares (OLS). The probability of the event y being observed is then computed from the inverse of the normal distribution. This is:

$$\mathbf{prob(y) = F^{-1}(z)} \quad (2)$$

Our first stage model is expressed as follows:

$$\mathbf{D\_greenbond_{it}} = \alpha_0 + \alpha_1^* \mathbf{esg\_huazheng_{it}} + \alpha_2^* \mathbf{roa_{it}} + \alpha_3^* \mathbf{X_{it}} + \varepsilon_{it} \quad (3)$$

Where X_{it} denotes the vector of control variables, including Leverage, Firm size, Firm IPO age, Firm ownership, and Firm growth. ε_{it} is the error term.

In the second stage, our models are run in the OLS regressions. They are expressed as follows:

$$\mathbf{greenloan3_{it}} = \beta_0 + \beta_1^* \mathbf{esg\_huazheng_{it}} + \beta_2^* \mathbf{roa_{it}} + \beta_3 * \mathbf{esg\_roa} + \beta_4^* \mathbf{X_{it}} + \mu_{it} \quad (4)$$

$$\mathbf{greenloan3_{it}} = \delta_0 + \delta_1^* \mathbf{E_{it}} + \delta_2^* \mathbf{S_{it}} + \delta_3^* \mathbf{G_{it}} + \delta_4^* \mathbf{roa_{it}} + \delta_5^* \mathbf{X_{it}} + \sigma_{it} \quad (5)$$

Where X_{it} denotes the vector of control variables, and μ_{it} and σ_{it} are the error terms. esg_roa is the interaction term between ESG score and financial performance. E_{it}, S_{it}, and G_{it} are environmental, social, and governance dimensions of ESG practices, which are measured by ln_water, ln_greenhouse_gas, ln_employee, top10_shareholder, and supervisory_chair, respectively. We have attempted all combinations of variables within these dimensions and reported the representative models in the Results section.

Ordinary least squares (OLS) regression is a useful, easily interpretable statistical method. However, in regression analysis, the presence of outliers in the dataset can strongly distort the classical least-squares estimator and lead to unreliable results. For instance, when running an OLS regression, it can at times be highly affected by a few records in the dataset and can then yield results that do not accurately reflect the relationship between the explained variable and the explanatory variables seen in the rest of the records. To address this, several robust-to-outliers methods have been proposed in the statistical literature. Robust regression offers an alternative to OLS regression that is less sensitive to outliers and still defines a linear relationship between

the outcome and the predictors. As such, we adopted the robust regression in the second-stage analysis.

ANALYSIS AND RESULTS

Descriptive Statistics

Descriptive statistics are provided in **Tables 2**, **3** along with correlation coefficients. The sample size of greenloan 3 is 300 with a mean of 42.147 and a standard deviation of 130.173. The minimum and maximum of greenloan 3 are 0 and 1,000, respectively. The mean of greenloan 3 is rather high, indicating that it has a large issuance, and the high standard deviation means that it has high issuance dispersion, that is, the issuance of greenloan 3 is uneven, presenting a very changing curve.

The sample size of esg_huazheng is 264 with a mean of 7.273 and a standard deviation of 1.141. The minimum and maximum of esg_huazheng are 4 and 9, respectively. The mean of esg_huazheng is relatively high, indicating that firms perform better sustainable practices generally, and the low standard deviation means that it has even score distribution and low dispersion. Furthermore, according to its minimum and maximum, it fluctuates within small ranges from 4 to 9.

Probit Model and Marginal Effects

Table 4 illustrates the marked differences between green bond issuance and ESG rating score between listed public firms with issuing green bonds and those without issuing green bonds. Notably, the ESG activities appear important in explaining the performance of green bonds. However, we seek to move the debate on the role of Huazheng ESG rating score in explaining the likelihood of green bond issuance within listed companies by controlling for other financial information. The significant and positive sign of Huazheng ESG rating score shows that public firms with good sustainable practices are more likely to successfully issue green bonds, which confirms hypothesis 1. It shows that the probability of green bond issuance will increase 0.073% if the listed firm improves its Huazheng ESG score by 1 grade.

Table 5 lists the impact of ESG practices on green bond issuance and particularly the roles of individual dimensions of ESG. Model 1 is the baseline model in which we explored the impact of Huazheng ESG rating score on green bond issuance. The significant and positive sign of the coefficient represents that the higher the ESG score, the larger the volume of green bond that is successfully issued. This confirms hypothesis 1b. In this model, ROA shows negative and significant sign, which implies that a firm's good FP will negatively affect the green bond issuance. This can be explained that less input into ESG practices is often associated with cost saving, which results in good FP in the short term. Thus, it reduces the green bond issuance. The negative and significant sign of the gearing ratio indicates that financially vulnerable firm usually issues fewer green bonds because investors would be concerned about its high proportion of debt and operational risk. In terms of firm size, the positive and significant sign of total asset elaborates that a large firm can issue more green bonds.

Model 2 adds the interaction term between ESG score and ROA based on model 1 to probe the moderating role of financial performance. In model 2, this interaction term shows a negative and significant sign while ROA's sign becomes positive and significant. It suggests that FP includes two elements in affecting green bond issuance which are the roles of itself and its moderating effect. Good FP, *per se*, increases green bond issuance, but it shows a negative effect on issuance when it moderates ESG practices. Furthermore, the interaction term distinguishes the roles of these two elements, so ROA displays its positive effect on its own and the interaction term represents the negative role of its moderating effect on ESG activities in model 2. This confirms hypothesis 2 and not only supports the previous literature on the negative effect of financial performance but also creatively

TABLE 2 | Descriptive statistics.

Variable	Obs	Mean	Std. Dev.	Min	Max
Greenloan 3	300	42.147	130.173	0	1,000
esg_huazheng	264	7.273	1.141	4	9
ln_water	54	13.749	3.707	9.572	23.706
ln_greenhouse_gas	29	12.345	3.673	8.387	19.633
top10_shareholder	300	63.534	16.596	20.580	99.828
supervisory_chair	300	0.573	0.495	0	1
ln_employee	199	9.135	1.555	3.989	13.116
roa	210	5.407	3.407	−13.115	15.078
gearingrate	300	70.846	17.387	18.697	95.020
ln_total_asset	300	25.401	2.091	21.284	30.934
ipo_age	300	11.567	8.359	−4	28
soe	300	0.650	0.478	0	1
sales_growth	300	13.981	21.577	−47.461	119.763

Greenloan 3, Green loan volume; esg_huazheng, ESG scores; ln_water, Environmental dimension; ln_greenhouse_gas, Environmental dimension; top10_shareholder, Governance dimension; supervisory_chair, Governance dimension; ln_employee, Social dimension; roa, Financial performance; gearingrate, Leverage; ln_total_asset, Firm size; ipo_age, Firm IPO age; soe, Firm ownership; sales_growth, Firm growth.

decomposes this negative effect. Except for these two variables, model 2 reports the same sign and significance as model 1 in terms of ESG score and other control variables. This confirms the baseline model.

Models 3, 4, and 5 examine the individual dimensions of ESG activities separately. In model 3, water usage shows a negative and significant sign, which indicates that the bad environmental practice will hinder the green bond issuance. This supports hypothesis 3a. The shareholding of the top 10 shareholders reports a positive and significant sign. It implies that the good governance structure increases the successful issuance of green bonds because concentrated shareholding entitles investors more power to make management comply with the ESG requirement. This supports hypothesis 3b. In terms of the social dimension, the positive and significant sign of employee number exhibits that more employment will increase green bond issuance because employment encouragement convinces investors that the company is responsible. This supports hypothesis 3c.

Particularly, model 3 reports negative and significant signs of IPO age and state-owned firm. Although firms with a long history since IPO or state-owned status often show better practices from the perspective of information disclosure and ESG activities, they have more channels to obtain finance other than green bonds. Therefore, green bond issuance constitutes a small proportion of their debt finance. In addition, the longer firm is listed, the less it issues green bond, and particularly when it is state-owned. The gearing ratio is consistent with models 1 and 2.

Model 4 generally confirms model 3 in terms of environmental and social dimensions of ESG, gearing ratio, and IPO age. Model 5 replaces water usage and shareholding of top 10 shareholders with greenhouse gas emission and chair of the supervisory committee based on environmental and governance dimensions of ESG, respectively. It shows that good governance structure and social responsibility will obtain more recognition of sustainable firms from investors, and thus issue successfully more green bonds. However, there is no evidence of increased green bond issuance from the environmental consideration. When considering individual dimensions of ESG, a firm's financial performance expresses a negative effect, which is consistent with model 1.

DISCUSSION

To date, research on the relationship between the performance of ESG and green bond issuance remains a less-explored area in emerging markets. In particular, less attention has been paid to the context of China. Van Duuren et al. (88) found that institutional investors focus on corporate governance aspects of ESG, while individual investors focus more on environmental aspects. Compared with most empirical studies in Chinese literature, which are based on a single perspective among environmental responsibility, social responsibility, or corporate governance, this study analyzed these three factors as a whole based on the perspective of ESG rating by selecting the representative practices of the three dimensions. We addressed this gap in the research by studying the relationship between

TABLE 3 | Correlation between variables.

		1	2	3	4	5	6	7	8	9	10	11	12	13
1	Greenloan 3	1												
2	esg_huazheng	−0.010	1											
3	ln_water	−0.215	0.331**	1										
4	ln_greenhouse_gas	−0.131	0.285	0.935***	1									
5	top10_shareholder	−0.080	0.256***	0.352***	0.376**	1								
6	supervisory_chair	0.048	−0.016	0.284**	0.235	−0.063	1							
7	ln_employee	0.261***	0.175**	0.326**	0.317*	0.221***	−0.137*	1						
8	roa	−0.082	0.149**	−0.296	−0.363	0.153**	0.033	−0.260***	1					
9	gearingrate	0.266***	−0.118*	−0.539***	−0.509***	−0.068	−0.082	0.446***	−0.441***	1				
10	ln_total_asset	0.400***	0.145**	−0.296**	−0.265	0.157***	−0.011	0.686***	−0.273***	0.772***	1			
11	ipo_age	0.015	0.218***	0.384***	0.616***	0.101*	0.159***	0.081	0.013	−0.421***	−0.072	1		
12	soe	0.139**	0.162***	0.126	0.176	0.207***	0.116**	0.078	0.158**	−0.095	0.179***	0.284***	1	
13	sales_growth	−0.067	0.034	−0.073	−0.057	−0.059	0.098*	−0.090	0.243***	−0.039	−0.127**	−0.163***	−0.152***	1

Greenloan 3, Green loan volume; esg_huazheng, ESG scores; ln_water, Environmental dimension; ln_greenhouse_gas, Environmental dimension; top10_shareholder, Governance dimension; supervisory_chair, Governance dimension; ln_employee, Social dimension; roa, Financial performance; gearingrate, Leverage; ln_total_asset, Firm size; ipo_age, Firm IPO age; soe, Firm ownership; sales_growth, Firm growth.
**** = statistically significant at 1%, ** = 5%, and * = 10%.*

TABLE 4 | The likelihood of green bond issuance within listed companies.

	Probit model	**Marginal effects**
	D_greenbond	D_greenbond
D_greenbond		
esg_huazheng	0.042**	0.001**
	(0.021)	(0.000)
roa	0.001	0.000
	(0.000)	(0.000)
gearingrate	0.000**	0.000**
	(0.000)	(0.000)
ln_total_asset	0.313***	0.005***
	(0.016)	(0.000)
ipo_age	−0.014***	−0.000***
	(0.003)	(0.000)
soe	0.213***	0.004***
	(0.050)	(0.001)
sales_growth	−0.000	−0.000
	(0.000)	(0.000)
Pseudo R2	0.162	
No. of observations	29,241	29,241

D_greenbond, Green bond dummy; esg_huazheng, ESG scores; roa, Financial performance; gearingrate, Leverage; ln_total_asset, Firm size; ipo_age, Firm IPO age; soe, Firm ownership; sales_growth, Firm growth.
*** = statistically significant at 1%, ** = 5%, and * = 10%.*

the performance of ESG dimensions and green bond issuance from the perspective of listed firms in the emerging market. Our empirical results indicate that ESG scores are positively associated with the likelihood of green bond issuance according to a probit model regression. The good ESG performance also helps listed firms achieve large issuance of green bonds. More specifically, we found the evidence to support this finding from every dimension of these sustainable practices.

Some investors doubt that ESG performance factors can help companies manage risk, provide profits or avoid minefields. They believe that ESG investment will increase the cost of enterprises, which will lead to lower profits, but ignore the hidden value of the ESG investment concept to help enterprises avoid risks and accumulate reputation to attract talents. The ESG system can avoid risks by guiding and regulating the microscopic behavior of enterprises and reducing negative events in the enterprise environment and social perspectives. This research demonstrates the relationship between ESG performance and green bond issuance through empirical evidence, helps investors to correctly understand ESG investment, and changes the previous concept that "ESG investment is just a sentimental investment," so that it can actively incorporate ESG performance into the investment and decision-making process (89).

Furthermore, our study differs from previous literature whose findings focus on the negative relevance of relations between ESG and financial performance, that is, firms with the best ESG scores tend to be less profitable. When considering the effect of financial performance on green bond issuance, it shows two aspects of its role. On the one hand, the good financial performance, *per se*, which indicates creditworthiness, promotes green bond issuance. On the other hand, its destructive effect will display by combining with ESG. This occurs because costs related to the implementation of ESG initiatives influence a firm's financial performance in short term. Investments in ESG may nibble a firm's cash flow and divert resources required for its operation. Thus, the interactive effect will reduce the volume of successful green bond issuance. Through the analysis above, this study makes companies fundamentally aware of the importance of ESG investing. From the perspective of long-term development, investors will gradually prefer to invest in companies with good ESG ratings and use ESG ratings to screen and avoid negative companies (90). That is, companies with better ESG performance will gain greater support in the market, which will force companies to increase their emphasis on the environment, society, and corporate governance, and ultimately have a positive impact on the sustainability of China's economic green transformation.

Our study has significant implications for managers and policy makers. From a managerial point of view, the results suggest that managers and executives should pay attention to issues in the societies and environment during their operation because a firm's strategy integrating ESG considerations allows them to have greater reputation, accountability, and credibility. This encourages managers to deploy efforts and resources toward long-lasting ESG practices to achieve the company's legitimacy in local markets. Meanwhile, managers should convert their cognition of ESG to be an investment rather than an expense. Such commitments as addressing the different social and environmental needs, institutional requirements and expectations of stakeholders in the different markets will enhance their competitive power and consequently improve their long-term financial performance. Additionally, governmental and regulatory powers at the national and international levels should encourage firms to apply best ESG practices, which attracts more firms to formulate and implement advanced and responsible environmental, social, and governance initiatives.

As the development of socially responsible investing in emerging markets lags behind developed economies, emerging market investors' awareness of ESG is also relatively backward. The investment management practice of long-term funds in China still adopts the performance evaluation methods of short-term investment. Investors value short-term interests so that the investment advantages of long-term funds cannot be effectively utilized. The purpose and practical significance of this research is to comprehensively study the practice of ESG-responsible investment in China, change the operating goals of listed companies, and guide them to the long-term goal of emphasizing social value and sustainable development. This will help value-oriented institutional investors establish and develop a practical approach to ESG-responsible investment (91).

CONCLUSIONS

This study examined the green bond market in China, which has attracted increasing attention in recent years. Data for

TABLE 5 | The volume of green bond issuance within listed companies.

	(1) Greenloan 3	(2) Greenloan 3	(3) Greenloan 3	(4) Greenloan 3	(5) Greenloan 3
esg_huazheng	1.792**	4.142***			
	(0.766)	(1.468)			
roa	−0.488*	2.742**	−0.209	−0.082	−2.588*
	(0.291)	(1.290)	(0.720)	(0.971)	(1.092)
gearingrate	−0.206*	−0.317**	−1.127***	−1.350***	−1.102**
	(0.121)	(0.134)	(0.365)	(0.442)	(0.384)
ln_total_asset	3.172*	3.278**	5.206	10.200	−33.570
	(1.638)	(1.636)	(6.174)	(7.452)	(24.490)
ipo_age	0.238	0.191	−1.459*	−1.699*	−1.947
	(0.226)	(0.231)	(0.767)	(0.894)	(1.866)
soe	−1.700	−2.035	−10.920*	−8.008	−38.740**
	(2.961)	(3.030)	(5.245)	(6.183)	(11.960)
sales_growth	0.015	−0.005	−0.008	−0.029	0.095
	(0.044)	(0.046)	(0.095)	(0.113)	(0.091)
esg_roa		−0.500** (0.217)			
ln_water			−3.486*** (0.496)	−3.514*** (0.584)	
top10_shareholder			0.229** (0.088)		
ln_employee			17.180*** (2.791)	16.410*** (3.496)	14.740** (4.855)
supervisory_chair				−4.535 (5.102)	9.630* (4.380)
ln_greenhouse_gas					6.896 (3.507)
cons	−62.650**	−71.820**	−140.900	−223.700*	753.500
	(30.440)	(30.700)	(100.300)	(118.400)	(484.500)
R^2	0.117	0.133	0.972	0.962	0.999
N	199	199	25	25	14

Greenloan 3, Green loan volume; esg_huazheng, ESG scores; ln_water, Environmental dimension; ln_greenhouse_gas, Environmental dimension; top10_shareholder, Governance dimension; supervisory_chair, Governance dimension; ln_employee, Social dimension; roa, Financial performance; gearingrate, Leverage; ln_total_asset, Firm size; ipo_age, Firm IPO age; soe, Firm ownership; sales_growth, Firm growth.

**** = statistically significant at 1%, ** = 5%, and * = 10%.*

Chinese listed companies, which have been issuing green bonds since 2016, are analyzed to determine the impact of the issuing companies' ESG practices on green bond issuance. The relationship between ESG and a firm's financial performance has been widely discussed, but we sought to examine investors' recognition of the firm's ESG activities, that is, responsible and sustainable companies. To reveal this veil, we employed green bond issuance as a proxy to measure investors' recognition of the firm's sustainable activities by linking literature on ESG and financial performance and those on green bond issuance. In doing so, we innovatively created the datasets by combining the ESG performance of Chinese listed companies with their green bond issuance from 2016 to 2020. The results indicated that decent ESG practices not only increase the propensity in green bond issuance by listed firms but also help them issue more green bonds. Given that ESG scores are determined by many factors, each of which may have a different impact on green bond issuance, we analyzed the individual effects of the E, S, and G dimensions, respectively. They all confirm the previous hypotheses. However, this study identified the negative effect of financial performance in issuing green bonds when combining the effect of ESG performance. This reveals that some listed firms do not place social or environmental goals as priorities in their corporate strategies in the short term, which are consistent with the findings of prior studies. The research results provide experience and reference for the continuous progress of Chinese listed companies and enhance the attention of listed companies on ESG practices. Implementing ESG practices promotes corporate growth and achieves a win–win situation, thereby promoting the sustainable growth of Chinese listed companies and the green transformation of the national economy.

Our study has several limitations. First, the ESG performance and its three dimensions data considered in our sample originate from only listed companies in mainland China due to the availability of data. In future research, it would be interesting to include other firms from China and other listed firms from other stock exchange markets for comparison. Second, the data used for the ESG performance have a global score based on secondary data. Although the variable has been widely used in the recent International Business literature and is treated to facilitate statistical analyses, the score assigned to each variable is not

free of subjective influences, which may decrease the validity of our results. For comparison, we used objective secondary data for E, S, and G dimensions, respectively, to address this subjectivity issue. Future studies could choose other alternative and innovative measures of ESG performance (i.e., information derived from other secondary databases such as Sustainalytics and KLD, and information obtained through questionnaires and interviews). Third, it can be seen that the green bond market in China emerged in recent years, thus our study could only use data starting from 2016 to 2020. The short period and relatively small sample size could affect the accuracy of some results. The study of green finance and ESG is an interesting and novel topic in China. Therefore, when there is more perfect data for the green bond in the future, further study in this area will be worthy of being developed.

Our results imply that green bond issuance is not merely virtue signaling in relation to environmental protection and sustainable development but can produce significant economic and environmental benefits. As the quantity of maturing green bonds increases, the importance of green bonds in improving companies' profitability, operational performance, and innovation capacity will be expected to emerge. To cater to this trend, China's green bond market requires continuous improvement, and green bond standards should be strictly implemented to accelerate the alignment of China's market with international community expectations. In terms of information disclosure, external supervision should involve in the theoretical design of green bonds and related trading systems to maintain the health of green projects. It is worthy of further research on information disclosure in ESG investment.

DATA AVAILABILITY STATEMENT

Publicly available datasets were analyzed in this study. This data can be found here: https://www.wind.com.cn.

AUTHOR CONTRIBUTIONS

SW: conceptualization, formal analysis, investigation, and writing-original draft. SW and DW: writing-review and editing. DW: funding acquisition. All authors have read and agreed to the published version of the manuscript.

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Exploring the Effect of Team-Environment Fit in the Relationship Between Team Personality, Job Satisfaction, and Performance

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This study explores whether team-organization fit (T-O fit) and team-job fit (T-J fit) play a mediating role between team personality, team job satisfaction, and team performance. Conscientiousness and openness to experience are common antecedents of team personality. Additionally, T-O fit and T-J fit are derived from person-environment fit theory, which is used to discuss the interaction between team members and the environment that affects behavior. The research purpose is to understand the factors that affect job satisfaction and performance from a team perspective. This is different from previous studies based on an individual perspective. The research object of this study has 365 respondents from 81 teams in different industries, and the structural equation modeling is applied to the empirical analysis. The research results show that T-J fit has a significant mediating effect on team personality and team job satisfaction. The team job satisfaction has also a significant mediating effect on team personality and team performance. Therefore, when team members recognize their work, they work harder to achieve team job satisfaction and performance. This study suggests that companies not only pay attention to the work abilities of employees, but also understand the fit between them and their jobs.

Keywords: team personality, team-organization fit (T-O fit), team-job fit (T-J fit), team job satisfaction, team performance

INTRODUCTION

With the advent of economic globalization and knowledge-based economy, many new topics have been put forward for the research about organizational behavior. Furthermore, as the change of politics, economy, and international situation, organizations encounter many internal changes, such as strategy, structure adjustment, system innovation. The complexity of organizational functions and tasks is increasing. It is only by replacing individuals with teams as the basic unit of organization, bringing together the capabilities and characteristics of individuals, leveraging the

power of the team, and providing better responsiveness, task-oriented effort, and organizational productivity, that the key to achieving corporate vision and goals are achieved (1).

In the past, traditional recruitment often focused on finding a person according to job responsibilities and qualifications required by job functions (e.g., person-job fit). It was usually assumed that as long as people had sufficient professional knowledge, skills and abilities, they would be able to perform the tasks, duties, and responsibilities of the job. This kind of recruitment based on person-job fit does not consider whether personality traits and values of employees are compatible with organizational culture and philosophy. Employees may resign because they feel that they are not suitable for the company. If turnover occurs frequently, not only will the organization take more time and cost to recruit, but the morale of employees will also be low. This phenomenon is not conducive to organizational development. Therefore, when the organization recruits new employees or selects members of the team, in addition to considering the professional skills of the candidates, it should also consider whether their personality traits are consistent with the organizational culture or team personality. Obviously, the traditional human resource management system built based on person-job fit cannot meet the needs of organizational development (2).

The issue about the compatibility of personality traits with various occupations have been emphasized, as is the issue regarding person-environment fit [e.g., (3, 4)]. This study argues that individual factors (e.g., technology and values) and organizational factors (e.g., working conditions, organizational culture, and organizational climate) can be considered simultaneously, the research results are more objective and accurate. Moreover, the research field of personal and organizational fit is most often discussed (e.g., person-organization fit), for example the interaction between individual behavior and organizational behavior, person-organization fit in the employment process (e.g., selection, employment decision, and career choice decision). The person-environment fit (especially, person-organization fit) has been continuously discussed [e.g., (2, 5–8)]. Thus, the research on person-organization fit has broaden new horizons for the development of organization behavior and human resource management. On the other hand, personality is also an important factor that affects team functioning and performance (9). However, most research has discussed the individual-level personality. Subsequently, scholars have applied the Big Five personality traits to explore the impact of team-level (group-level) personality on performance. They have argued that the Big Five personality traits can indeed be used to deal with team-level personality, and to verify that team personality (especially conscientiousness and openness to experience) can affect team performance [e.g., (9–11)].

In the past literature, the consistency and fit between the individual and the environment have attracted the attention of researchers (12). As a result, the person-environment fit (P-E fit) theory has been developed, which emphasizes the state of individual and environmental fit. Since the late 1980s, scholars have discussed P-E fit. Subsequently, there was much research on the relationship between P-E fit and behavior and outcomes of work. For example, Kristof-Brown et al. (4) indicate that P-E fit can predict and explain multiple behaviors and attitudes, such as organizational commitment, organizational citizenship behavior, turnover intention. The relationship between job satisfaction and performance has been paid attention to by researchers [e.g., (13–15)]. However, there are relatively few researches on team-job fit (T-J fit) and team-organization fit (T-O fit). A few researches have tested multiple types of fit simultaneously (16). There is no large number of empirical results showing how T-O fit and T-J fit affect team job satisfaction and team performance.

According to the above perspective, this study explores the extension of P-E fit theory from the team-level. Thus, this research purpose is to empirically demonstrate the mediating effect of T-O fit and T-J fit between team personality, team job satisfaction and team performance. Structural equation modeling was used as the analytical method. The next sections include compiling relevant literature and research findings, proposing research hypotheses and models, and then conducting empirical analysis and discussing the findings. It is hoped that the research findings will fill the gaps in the relevant research fields and serve as a reference for companies to develop strategies to recruit and select team members and to promote team job satisfaction and team performance.

BACKGROUND AND LITERATURE REVIEW

Team Personality

This study mainly takes the team as the research and analysis unit. Scholars have defined the team [e.g., (17–20)]. This study refers to the views of scholars and defines a team as a group of people with sufficient skills who are willing to commit to each other to achieve a common goal and be responsible to each other in the process.

In the field of human resource management, personality traits have been discussed. Some scholars are also concerned about the team-level personality [e.g., (9, 10, 21)]. "Personality traits" are considered to be an individual's stable and unchanging psychological characteristics, and are often used to explain or predict a person's behavior. "Team personality" is considered to be a collection of personality traits of members that influence the process and results of team development. Hoch and Dülleborn (21) proposed that team personality is a deep-level aspect, because it is the integration of team members' psychological characteristics and affects team process and results.

Neuman et al. (9) advocated that team personality refers to the average of personality traits of team members and the differences among them. In addition, team personality can be described as the aggregation and configuration of personality traits in a team, and they affect the development and outcome of the team (10). A few researches on team personality have mainly been conducted adopting Big Five personality traits [e.g., (11, 22)]. Therefore, this study also applies Big Five personality traits to measure the team personality.

Individual-Level and Team-Level Personality Traits

The Big Five personality traits are some stable and long-term specific responses of individuals. Compared with emotion or state, personality traits are relatively unchanged. The Big Five

personality includes neuroticism, agreeableness, extroversion, conscientiousness, and openness to experience. It is used to explain the differences in individual personality traits (23). It is one of the important measurements in modern psychology. The five personality traits of the individual remain stable over time. Each personality trait makes an individual inclined to certain behaviors. In a team, the personality traits (such as conscientiousness) possessed by team members are gathered to form team personality in each dimension (24). In addition, in terms of team development, some researches have suggested that personality traits (e.g., conscientiousness and openness to experience) have a positive impact on team operations. Their research found that team personality is the main predictor of team performance (21, 25).

Reasons for Conscientiousness and Openness to Experience as the Research Focus

LePine et al. (26) advocate that openness to experience is a good predictor of individual innovativeness. On the other hand, Peeters et al. (22) had comprehensively analyzed the team personality and proposed that conscientiousness positively affects team performance. They also verified that the personality trait "conscientiousness" can predict both individual performance and group performance. In addition, conscientiousness and openness to experience are mostly valued in organizational change literature. However, there is a significant difference between individual-level and team-level personality traits on teams (27). Thus, referring the viewpoints of previous research, conscientiousness and openness to experience were the focus of this study.

Team-Environment Fit

Which one of individual or environmental characteristics has a greater impact on behavior and job outcomes is an important issue for the human resources department. Lewin (28) proposed "fit" based on interactionist theory and emphasized that the interaction between the individual and the environment influences behavior. Then the personal-environmental fit (P-E fit) theory was developed. Jansen and Kristof-Brown (29) classified P-E fit into five categories, including person-vocation fit (P-V fit), person-organization fit (P-O fit), person-job fit (P-J fit), person-group fit (P-G fit), and person-person fit (P-P fit). Among them, P-O fit, and P-J fit were most discussed. Many scholars have adopted P-O fit and P-J fit as the main independent variables to explore the impact on behaviors, attitudes, and work results such as job satisfaction and job performance [e.g., (30, 31)]. Until now, the P-E fit has continued to be discussed. This is because scholars are convinced of the existence of the P-E fit. Furthermore, some scholars have further pointed out that P-E fit does not only static "exist" but also changes with time. Therefore, they advocate that when discussing issues regarding the P-E fit theory, in addition to integrating other theories or factors, "time" should also be considered (32). Moreover, some researchers are interested in team-level issues. Team-environment fit (T-E fit), including team-organization fit (T-O fit) and team-job fit (T-J fit), has also been considered [e.g., (3, 33–35)]. Compared to the P-E fit, there are very few papers on the T-E fit. Hence, this study attempts to empirically demonstrate the impacts of T-O fit and T-J fit on team job satisfaction and team performance at the team level.

Team-Organization Fit

More and more people realize that employees are an important resource, which makes researchers continue to be interested in the impact of P-O fit on personal work attitude and satisfaction (36). According to the opinions of many scholars, P-O fit is defined as the similarity of values between individuals and organizations and should be used as an important evaluation when the organization recruits and selects employees [e.g., (2, 5–8)]. Lam et al. (37) suggested that a person may be attracted by organizations with similar characteristics. For example, a gregarious person may look forward to working in an organization that emphasizes teamwork. If employees perceive to fit into the organization, they feel that they are part of the organization (38). Therefore, P-O fit is an important condition for the team to select members (39). On the other hand, scholars have different interpretations of T-O fit. Researches have defined T-O fit as a fit between team and organizational values (3, 35). Sekiguchi (33) pointed out that the concept of T-O fit is derived from the Attraction-Selection-Attrition (ASA) model. The ASA model emphasizes that individual and organizational characteristics should be similar. In other words, the team and organizational characteristics should also be similar.

Team-Job Fit

Caldwell and O'Reilly (40) defined P-J fit as the consistency of personality traits with the workplace, or the compatibility of an individual with a specific job. In other words, the skills of employees must meet job requirements. That is, it emphasizes the fit of the individual's personality traits and abilities with the job or task. Scholars have found that P-J fit affects work behavior and outcome (e.g., job satisfaction, job performance, turnover intention, and organizational identification) (41, 42). Later, some scholars also paid attention to T-J fit. Ellis et al. (34) suggested that T-J fit can be measured by the correlation between team personality and job requirements.

Team Job Satisfaction

In addition to individual job satisfaction, team job satisfaction has also received attention from researchers [e.g., (43)]. Team job satisfaction refers to the feelings or emotions of team members about job and the workplace (44). Team members with higher job satisfaction may have a positive attitude toward his job (45). On the other hand, Downes et al. (46) found that team personality is positively correlated with P-O fit, and indirectly affects goal achievement and job satisfaction. Researches have also shown that T-O fit is an important factor affecting job satisfaction (1, 31). Each individual's feelings of satisfaction are different. However, the mainstream value of the individual may be consistent with the value of the organization. The more an individual's values fit the organization's value, the higher the individual's satisfaction with the organization.

TABLE 1 | Operational definitions.

Dimensions	Variables	Descriptions	References
Team personality (TP)	Conscientiousness	It means that the behavior of conscientious team members involved in achieving goals and solving problems.	(25, 53)
	Openness to experience	It means that the adaptability and responsiveness of team members in a dynamic team environment.	
T-O fit (TO)		It means that the individual and the organization have the same values.	(54, 55)
T-J fit (TJ)		It means that the supply of jobs meets the needs of the employees or that the employees' abilities meet the requirements of the job.	(56, 57)
Team job satisfaction (SA)		It means that workers' feelings, attitudes, and affective responses to work, experiences, and the workplace.	(44, 58)
Team performance (PER)		It means that the results and goals that team members achieve after mutual dependence and interaction.	(25, 47)

Team Performance

Team performance not only reflects the overall strength of a team and the group's contribution to its enterprise but also reflects the efforts of each member of the team. Some scholars have proposed that team performance refers to the extension that team members jointly achieve mission and goals (25). Team members must participate in the team process/teamwork to achieve organizational tasks and goals through interrelated attitudes, cognitions, and behaviors (25, 47). Teamwork is a dynamic process. Team performance is one of the most important methods of evaluating teamwork (48). Since team performance is the result of interactions among members or between them and the environment, many researches have discussed the factors that influence team performance, such as team personality, P-E fits, and job satisfaction (10, 25, 49–52).

According to the above literature reviews, this study summarizes and defines each variable (see **Table 1**).

RESEARCH METHODS

Hypothesis and Model

Based on the research purpose and through the literature review, this subsection explores the relationship between team personality, T-O fit, T-J fit, team job satisfaction and team performance, proposes hypotheses, and constructs a research model.

Team Personality and T-O Fit, T-J Fit

The current environment is changing rapidly, and organizations must adapt to such an environment in order to develop sustainably. Kim et al. (59) believe that employee enthusiasm can moderate the relationship between the organization's socialization strategy and P-O fit. Members with openness to experience are committed to fit the team (60), and team execution and responsiveness are enhanced (61). Thus, when a team has openness to experience, it fit the environment more actively. On the other hand, research has confirmed that a high degree of conscientiousness is the most effective predictor of team performance, which helps members focus on completing team tasks, team development and performance improvement (62). Generally speaking, in a team, a member with conscientiousness is more likely to become the task leader. A responsible team should create an environment that encourages and rewards members' responsibility, so as to motivate responsible members to show greater enthusiasm (21). In addition, a high degree of team responsibility leads to team members willing to cooperate and participate in team tasks. A high level of team responsibility also helps improve team performance. Based on the above literature review, this study infers that team personality is related to both T-O fit and T-J fit, so the following hypothesis is proposed.

H1a: Team personality has a positive relationship with T-O fit.
H1b: Team personality has a positive relationship with T-J fit.

T-O Fit, T-J Fit, Team Job Satisfaction, and Team Performance

Generally speaking, job satisfaction is considered a psychological characteristic of a person, and this psychological characteristic is reflected in his work. In addition, when employees' skills and abilities are in line with their job content, their performance and satisfaction will be improved. This indicates that the perception of job satisfaction is the result of the interaction between the person and the work environment (63, 64). Brkich et al. (42) proposed that employees feel more organizational identity when they believe that their values are consistent with the values of the organization and verified a significant relationship between individual and job fit and employees' job satisfaction. Moreover, Xiao et al. (65) explored the impact of P-E fit on the job satisfaction of medical workers. They found that P-E fit (including P-J fit and P-G fit) has a significant positive impact on job satisfaction. There is a research examining the relationship between police officers and their work environment. The results show that when police officers have highly aligned with the overall goals and direction of the organization, they also have high job satisfaction (66). This study extends the above-mentioned arguments and research findings, and inferences that both T-O fit and T-J fit have an impact on team work satisfaction.

On the other hand, performance reflects the degree of an individual's job responsibilities and organizational goals completed in a period. It is an important behavioral outcome variable of the fit between individuals and organizations. When

there is a certain degree of fit between the characteristics of individuals and organizations, the performance is higher. Amarneh and Muthuveloo (52) confirmed that there was a positive correlation between individual fit to job and behavior outcome variables, such as job satisfaction, low work stress, performance, attendance rate, and retention rate. In addition, in temporary organizations, P-E fit (including P-O fit, P-G fit, and P-J fit) has a significant impact on task performance and innovation performance (67). Lim et al. (2) and Dhir and Dutta (6) demonstrated that both P-O fit and P-J fit are positively and significantly related to job satisfaction. Some scholars have proposed that the relationship between leaders can be regarded as the relationship between the team and the organization in a hospital. They also argued that the better the relationship between the teams or the higher the trust between the teams and the organization, the better the team performance (68). Most researches on fit tend to have positive effects, but some researches point out that high fit has some negative effects, which affect the adaptability and innovation ability of the organization (34). However, most of the researches on P-O fit focuses on individual performance. This study argues the higher fit brings more benefits from the team level.

In general, organizational performance is achieved when employees are satisfied with their work. A large number of researches indicated that job satisfaction has a positive impact on performance [e.g., (49–51, 69)]. Furthermore, Khadivi et al. (70) emphasized that job satisfaction is related to organizational performance. Thus, this study infers that team job satisfaction is also related to team performance. According to the previous research, this study establishes the following hypotheses.

H2a: T-O fit has a positive relationship with team job satisfaction.
H2b: T-J fit has a positive relationship with team job satisfaction.
H3a: T-O fit has a positive relationship with team performance.
H3b: T-J fit has a positive relationship with team performance.
H4a: Team job satisfaction has a positive relationship with team performance.

The Mediating Effect of Team-Environment Fit

As mentioned above, team personality is the average of the personality traits of team members (9). O'Neill and Allen (11) found team personality significantly affect team performance. In addition, Sortheix et al. (71) advocate T-E fit refers to the compatibility and consistency of team characteristics and workplace perceived by team members. Most employees expect that the team they will participate in has the characteristics of T-E fit. T-E fit is a psychological resource (72). In addition, the team can adapt to the environment, which helps members integrate into their work, thereby increasing personal professional satisfaction (73). In addition, Ellis et al. (34) suggested that T-J fit can be measured by the correlation between team personality and job requirements. However, the T-E fit needs further discussion and verification (74, 75). As a result, research has explored individual-environment (organizational and job) fit and found that individual-environment fit is related to job satisfaction and job performance (42, 63, 64). Finally, job satisfaction is positively related to organizational performance; job satisfaction is also affected by some factors (such as supervisor, team, and organization) (70). Based on the literature reviews, this study infers that T-O fit and T-J fit have a mediating effect between team personality, team job satisfaction, and team performance; team job satisfaction has a mediating effect between T-J fit and team performance. Then, the following hypotheses are proposed.

H5a: T-O fit has a mediating effect between team personality and team job satisfaction.
H5b: T-O fit has a mediating effect between team personality and team performance.
H6a: T-J fit has a mediating effect between team personality and team job satisfaction.
H6b: T-J fit has a mediating effect between team personality and team performance.
H7a: Team job satisfaction has a mediating effect between T-J fit and team performance.

According to the above discussion and hypotheses, the following research framework is proposed in **Figure 1**.

Research Process and Method

Among the relevant measurement tools, many researchers have developed five personality traits, for example, Goldberg (76) and Saucier (77). This study adopts the International English version of Big Five Mini markers (International English Big Five Mini markers), which developed by Thompson (78). Next, this study refers to the research of Cable and DeRue (57) to develop the scale about T-O fit and T-J fit and adopts the scale regarding job satisfaction developed by Brayfield and Rothe (79). Finally, the Barrick and Stewart's (80) scale was adopted to measure team performance. This study used the Likert scale.

This study selects the teams within some enterprise as the research object. Mainly for the team of 3–5 people, a total of 100 sets of 500 questionnaires were sent out. Through the questionnaire survey, the team members were directly measured, and 395 were recovered, with a recovery rate of 79%. After the index screening, 365 sets were obtained, 30 of which were eliminated in this survey, and the effective questionnaire recovery rate was 73%. The reasons for elimination are incomplete answers and multiple answers to one question. At the team level, 85 team data were collected, 4 teams have <60% effective samples that are not included, so there are 81 effective samples.

SPSS 21 and AMOS 24 are adopted as the analysis tools. Scholars have suggested that the Structural Equation Model (SEM) is suitable for investigating the effects between the various structures and verifying the suitability of the research model (81, 82). Additionally, the two-stage SEM validation procedure is to examine the suitability of the measured modes before the structural modes are examined (83, 84). Consequently, this study utilizes SEM to perform inferential statistics. Furthermore, this study followed the suggestion of some scholars to use Bootstrapping for the examination procedure of mediation effects [e.g., (85–87)] and repeated the sampling 5,000 times.

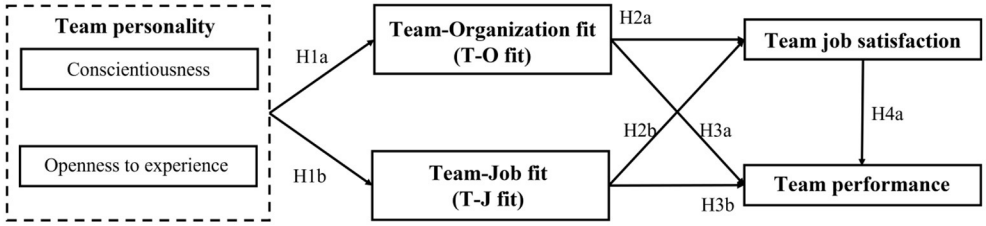

FIGURE 1 | Research model.

RESEARCH RESULTS

Descriptive Statistics Analysis

The descriptive statistics of individual-level data ($n = 365$) are described in **Table 2**. The respondents are more female (60.00%) than male (40.00%), and more single (73.70%) than married (26.30%). The respondents under the age of 25 are the most, accounting for 31.00%. In terms of education level, the majority of respondents are college/university degrees, accounting for 75.34%. Respondents with 1–3 years of working experience are the most (32.60%). Respondents are mainly distributed in private enterprises (89.04%). The respondents in the information department are the most, accounting for 24.93%. At the unit level, 48.77% of the respondents work at the department level. Respondents are the most in the financial services industry, accounting for 23.29%.

Next, this study uses **Table 3** to summarize the team-level data ($N = 81$). The interviewed teams are mainly distributed in private enterprises (88.89%). The team in the information department is the largest, accounting for 25.93%. In terms of unit level, 49.38% of teams belong to departments. The surveyed teams are the largest in the information service industry, accounting for 23.46%.

Since the variables in this study are all at the team level, and the measurement data recovered are at the individual level, it is necessary to integrate individual-level data into the team level before statistical analysis. According to the $r_{wg(j)}$ index proposed by James et al. (88), the data integration of each variable is tested, and the calculation program is compiled under SPSS 21 to calculate the internal consistency of each dimension. When $r_{wg(j)}$ is higher than 0.7, there is a high intragroup consistency, which indicates that it is reasonable to add the data from each team member to the team level. **Table 4** shows that the proportion of $r_{wg(j)}$ index of each variable above 0.7 is above 80%, and the average value of $r_{wg(j)}$ index of each variable is above 0.8 except for team performance 0.795, which is very close to 0.8. The intragroup consistency of all variables was high. Therefore, the data can be integrated at the individual level and converted into team-level data for analysis, that is, the average number of all individuals in each team is used as the score of the team on a certain variable.

Reliability and Validity Analysis

First, this study adopts Cronbach's α to measure the stability of the questionnaire. Peterson (89) thinks that the Cronbach's α of general total scale is better than 0.80, and the Cronbach's α of subscale is better than 0.70, If the Cronbach's α of the total scale is <0.80 and the Cronbach's α of the subscale is <0.60, the items should be revised or deleted. The reliability of each variable shows in **Table 5**. All Cronbach's α are >0.8, indicating that the questionnaire is reliable.

Second, this study used confirmatory factor analysis (CFA) to analyze the construct validity of each scale. Before confirmatory factor analysis (CFA), this study used the item pooling method to reduce the items and used the aggregate score as the observation index to reduce the error and irrelevant variation and to reduce the stability of the observed variables and reduce the possibility of error increase caused by estimation parameter inflation. In addition, T-J fit scale of this study has 18 items in total, which are divided into five items after the projected merger. Scholars have suggested that the internal consistency reliability of each scale should be tested after the merger. This study found that the reliability increased slightly, which exceeded the standard value, indicating that the next step of analysis can be carried out.

In this study, the convergent validity of the study is examined by average variance extracted (AVE). The AVE is the average explanatory variation of each dominant variable of a potential variable to the potential variant. The AVE of each dimension must be >0.5 (90). The composite reliability (CR) of the five dimensions is between 0.850 and 0.947, which shows that the internal consistency of the potential dimension is high. The AVE is between 0.595 and 0.857, indicating that the potential dimension has a high reliability and convergence ability. Then, the factor loadings for all the dimensions are greater than the value of 0.5 suggested by Hair et al. (91), indicating that the questions for these dimensions are consistent with the convergent validity. The results of the tests of convergent validity are presented in **Table 5**.

Torkzadeh et al. (92) proposed that the discriminative validity of the measurement can be used to calculate the confidence interval of the correlation coefficient between the dimensions using Bootstraping. If the confidence interval does not contain 1, it means that it has discriminative validity. **Table 6** shows that the confidence intervals of the correlation coefficients between the dimensions do not contain 1, indicating that the measurement has discriminative validity.

Final, AMOS 24 was used as a statistical tool, and the Bollen-Stine test (93) is employed to test the model fit in this study. The maximum likelihood estimation was used to test the goodness of

TABLE 2 | Distribution of individual-level data ($n = 365$).

Items	Frequency	Percent
Gender		
Female	219	60.00%
Male	146	40.00%
Marital status		
Single	269	73.70%
Married	96	26.30%
Age		
25 or below	113	31.00%
26–30	108	29.59%
31–35	61	16.71%
36–40	44	12.05%
41–45	17	4.66%
46 or above	22	6.03%
Education		
High school or below	22	6.03%
College/University	275	75.34%
Master's degree	61	16.71%
Doctor's degree	7	1.92%
Job tenure		
<1 year	90	24.66%
1–3 years	119	32.60%
4–6 years	65	17.81%
7–9 years	37	10.14%
More than 10 years	54	14.79%
Company nature		
Government agencies	32	8.77%
State-owned enterprises	8	2.19%
Private enterprises	325	89.04%
Department nature		
R&D	30	8.22%
Quality control	14	3.84%
Customer services	45	12.33%
Marketing/sales	55	15.07%
Planning	14	3.84%
Administration	55	15.07%
Information	91	24.93%
Purchasing	5	1.37%
Human resources	5	1.37%
Production/manufacturing	3	0.82%
Accounting/cashier	45	12.33%
Others	3	0.82%
Unit level		
Section	33	9.04%
Subsection	13	3.56%
Division	82	22.47%
Department	178	48.77%
Others	59	16.16%
Industry		
Financial service	85	23.29%
Traditional manufacturing	20	5.48%
Communication services	33	9.04%
High-tech manufacturing	32	8.77%
Information service industry	79	21.64%
Medical services	20	5.48%
Retail	40	10.96%
Real estate	9	2.47%
Others	47	12.88%

TABLE 3 | Distribution of team-level data ($N = 81$).

Items	Frequency	Percent
Company nature		
Government agencies	7	8.64%
State-owned enterprises	2	2.47%
Private enterprises	72	88.89%
Department nature		
R&D	7	8.64%
Quality control	3	3.70%
Customer services	10	12.35%
Marketing/sales	11	13.58%
Planning	3	3.70%
Administration	12	14.81%
Information	21	25.93%
Purchasing	1	1.23%
Human resources	1	1.23%
Production/manufacturing	1	1.23%
Accounting/cashier	10	12.35%
Others	1	1.23%
Unit level		
Section	7	8.64%
Subsection	2	2.47%
Division	19	23.46%
Department	40	49.38%
Others	13	16.05%
Industry		
Financial service	18	22.22%
Traditional manufacturing	5	6.17%
Communication services	6	7.41%
High-tech manufacturing	7	8.64%
Information service industry	19	23.46%
Medical services	5	6.17%
Retail	8	9.88%
Real estate	2	2.47%
Others	11	13.58%

fit between the data and the model. First, individual-level data ($n = 365$) was analyzed, and the results were described in **Table 7**. The χ^2/df of this analysis was 1.694, which reached the standard Goodness of Fit Index (GFI) that was believed within 2. It refers to the proportion of variation and co-variable that the model could explain the observed data. Generally, it is considered that

a value higher than 0.9 means that the model has good fitness. Because of the large number of samples and the large degree of freedom in this study, GFI is prone to downward bias, Therefore, GFI has only 0.761 roots mean square error of approximation (RMSEA). The smaller the RMSEA, the better the fit between the hypothesis model and the data. In this study, the RMSEA is 0.093, <0.5 (94). The comparative fit index (CFI) in this study is 0.923, and its value is >0.90 and close to 1, indicating good fitness. Second, team-level data ($N = 81$) was examined. However, the number of team-level samples is too small which may lead to the mismatch between the model and the actual observation data or the model is not ideal. The model was examined by Bootstrapping to generate 1,000 samples. It was found that the measurement model with larger sample size resulted in an insignificant p-value of χ^2 and the other model fitness indexes were in accordance with the criteria (see **Table 7**). Therefore, it is indicated that the overall measurement model has a reasonable fit.

Structural Equation Modeling

Path Analysis

The structural equation model is used to examine whether the path between variables is significant, and to verify whether the hypotheses in this study are valid. Based on the above verification results, the measurement model is reasonable, so the following is the result verification of the structural model research hypothesis, the results are shown in **Figure 2**. Next, **Table 8** describes path coefficient and hypothesis testing of theoretical structure model.

First, team personality has a significant positive relationship with T-O fit (t-value = 2.090, $p < 0.05$) and T-J fit (t-value = 2.993, $p < 0.01$). *H1a* and *H1b* are supported, and it indicates that a higher average level of preciseness and openness to experience lead a higher T-O fit and T-J fit. Next, T-O fit and T-J fit have a significant positive relationship with team job satisfaction (t-value = 2.292, $p < 0.05$; t-value = 5.044, $p < 0.001$). *H2a* and *H2b* are supported, and it indicates that a higher level of T-O fit and T-J fit lead to higher team job satisfaction. Then, T-O fit has a

TABLE 4 | Within-group interrater reliability—rwg(j) ($N = 81$).

Variables	$rwg_{(j)}$
Conscientiousness	0.884
Openness to experience	0.869
T-O fit	0.804
T-J fit	0.811
Team job satisfaction	0.817
Team performance	0.795

TABLE 6 | Discriminant validity ($N = 81$).

Dimensions	Correlation coefficients	Confidence intervals (90%)
(TP, TO)	0.172	(−0.014, 0.372)
(TP, TJ)	0.317	(0.107, 0.508)
(TP, SA)	0.266	(0.074, 0.453)
(TP, PER)	0.368	(0.146, 0.536)
(TO, TJ)	0.637	(0.453, 0.756)
(TO, SA)	0.632	(0.461, 0.746)
(TO, PER)	0.676	(0.550, 0.769)
(TJ, SA)	0.839	(0.710, 0.927)
(TJ, PER)	0.779	(0.686, 0.844)
(SA, PER)	0.798	(0.708, 0.861)

TP, team personality; TO, T-O fit; TJ, T-J fit; SA, team job satisfaction; PER, team performance.

TABLE 7 | Model fit.

Model fit index	Criteria	Result 1 ($n = 365$)	Result 2 ($N = 81$)
χ^2	The small the better	299.790	242.71
χ^2/df	$1 < \chi^2/df < 3$	1.694	1.862
GFI	>0.9	0.761	0.870
IFI	>0.9	0.925	0.960
TLI	>0.9	0.909	0.960
CFI	>0.9	0.923	0.960
RMSEA	<0.08	0.093	0.070

TABLE 5 | Reliability and validity.

Dimensions	Variables	Items	Cronbach's α	Factor loadings	CR	AVE
TP	Conscientiousness	8	0.862	0.509–0.826	0.850	0.549
	Openness to experience	8	0.862			
TO	Value	3	0.903	0.872–0.948	0.909	0.593
TJ	Primary demand	3	0.906	0.560–0.858	0.874	0.354
	Self-actualization	3	0.911			
	Self-esteem	4	0.924			
	Capacity	4	0.855			
	Job requirement	4	0.911			
SA		3	0.864	0.955–0.958	0.947	0.734
PER		8	0.947	0.782–0.920	0.939	0.436

TP, team personality; TO, T-O fit; TJ, T-J fit; SA, team job satisfaction; PER, team performance; CR, composite reliability; AVE, average variance extracted.

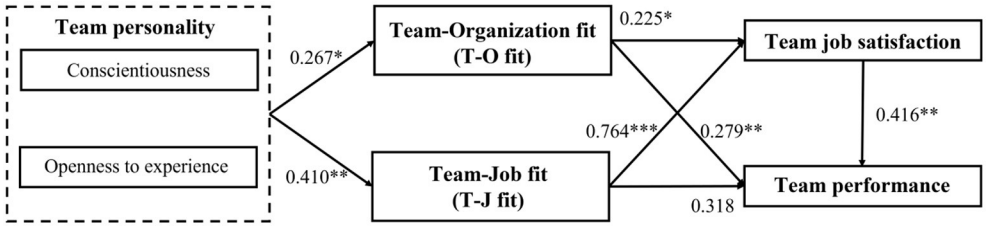

FIGURE 2 | Path analysis of research model ($N = 81$). *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

TABLE 8 | Path analysis—direct effect.

Hypothetical path		Path Coefficient		Standard error	*t*-value	Support
		Unstandardized	Standardized			
H1a	TP → TO	0.278	0.267	0.133	2.090*	Yes
H1b	TP → TJ	0.402	0.410	0.134	2.993**	Yes
H2a	TO → SA	0.422	0.225	0.184	2.292*	Yes
H2b	TJ → SA	1.522	0.764	0.302	5.044***	Yes
H3a	TO → PER	0.296	0.279	0.111	2.669**	Yes
H3b	TJ → PER	0.359	0.318	0.184	1.954	NO
H4a	SA → PER	0.236	0.416	0.088	2.671**	Yes

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.
TP, team personality; TO, T-O fit; TJ, T-J fit; SA, team job satisfaction; PER, team performance.

TABLE 9 | Path analysis—indirect effect.

Hypothetical path	Path coefficient (β)	Bias-corrected percentile bootstrap confidence intervals (90%)	Support
H5a TP → TO → SA	0.117*	(0.020, 0.310)	Yes
H5b TP → TO → PER	0.082	(0.015, 0.209)	No
H6a TP → TJ → SA	0.612**	(0.281, 0.995)	Yes
H6b TP → TJ → PER	0.144	(−0.018, 0.331)	No
H7a TJ → SA → PER	0.359*	(0.134, 0.835)	Yes

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.
TP, team personality; TO, T-O fit; TJ, T-J fit; SA, team job satisfaction; PER, team performance.

significant positive relationship with team performance (t-value $= 2.669$, $p < 0.01$), but T-J fit does not (t-value $= 1.954$, $p > 0.05$). *H3a* is supported, but *H3b* is not. It indicates that higher T-O fit lead to higher team performance. However, the change in T-J fit has no impact on team performance. Final, team job satisfaction has a significant positive relationship with team performance (t-value $= 2.671$, $p < 0.01$). *H4a* is supported, and it indicates that a higher team job satisfaction leads a higher team performance.

Indirect Effect Analysis

This section is used to explain whether T-O fit and T-J fit play a mediating role between team personality, team job satisfaction, and team performance. The result shows that T-O fit and T-J fit have a significant mediating effect on team personality and job satisfaction ($\beta = 0.117$, $p < 0.05$; $\beta = 0.612$, $p < 0.01$). *H5a* and *H6a* are supported. Then, team job satisfaction has a significant mediating effect on T-J fit and team performance ($\beta = 0.359$, $p < 0.05$). *H7a* is supported. However, *H5b* and *H6b* have not significant mediating effect (see **Table 9**).

CONCLUSION

Discussion

There have been much research studying the P-E theory. They have mainly focused on the relationship between employees and the workplace. Then there are more studies to further explore the impact of P-E fit on performance or job satisfaction. However, there are very few research discussions on the issue of T-E fit. In addition, scholars have advocated and confirmed the importance of team personality [e.g., (9)]. Therefore, the purpose of this study is to understand the mediating effect of T-E fit (T-O fit and T-J fit) between team personality, team job satisfaction and team performance from the perspective of team level.

In this section, this study will further discuss the previous empirical results. First, the research result shows that team personalities (i.e., conscientiousness and openness to experience) positively influence on T-O fit and T-J fit. This result is similar to the findings of previous research [e.g., (21, 60)]. In other words, most members of the team have conscientiousness and openness to experience, and the T-O fit and T-J fit will become stronger. This study further deduces two reasons. First, when members have the high conscientiousness, they can reduce the mistakes in their work. It is especially important for the team. If one member

of the team makes a mistake, the work may be affected, and other members need to allocate additional time to solve the problem. Second, when the openness to experience of the team is higher, the team members are willing to brainstorm and think about the problems the team faces, and their acceptance of innovative ideas is also higher.

Second, there are many researches discussing the correlation between P-E fit (organization and job), and job satisfaction and performance. They found that P-E fit (organization and job) significantly and positively affects job satisfaction [e.g., (2, 6, 65, 66)] or performance [e.g., (52)]; satisfaction is also positively related to performance [e.g., (49–51)]. However, few studies have examined the team level [e.g., (71)]. This study empirically demonstrated the relationship between T-O fit, T-J fit, team job satisfaction, and team performance. The results showed that T-O fit significantly and positively influenced team job satisfaction and team performance; T-J fit was significantly and positively related to team job satisfaction, but not team performance; team job satisfaction also positively influenced team performance. Apparently, the results on the relationship between the environment fit, job satisfaction, and performance were similar at the team level and at the individual level. The more consistent the values of team members are with the organization; the more team satisfaction and performance can be achieved. This verified result is similar to the proposition proposed by scholars (68). Teams that have a good relationship or shared values with the organization will also perform well. The more the competencies of most team members can meet the job requirements, the higher the team's job satisfaction will increase. In addition, when team job satisfaction rises, it leads to an increase in performance. However, the effect of T-J fit on team performance was not significant. This result is different from previous researches [e.g., (65)]. The inference may be due to the reason that this study discussed the team-level and multiple industries, whereas previous researches explored the individual-level and single industry. Further, the largest number of respondents and teams interviewed in this study were in the information department and information services industry. Information personnel are in a support role and often have to face and solve complex problems but their performance is difficult to measure.

Third, the results of this study showed that both T-O fit and T-J fit had a significant positive mediating effect between team personality and team job satisfaction; team job satisfaction had a significant positive mediating effect between T-J fit and team performance. Peeters et al. (22) had found the team personality and proposed that conscientiousness positively affects team performance. Furthermore, Lim et al. (95) had pointed out that openness to experience is related to team adaptability. When a team has better personality than other teams in adapting to the changing environment, which improve T-J fit, reduce the sense of incompetence, and greatly improve job satisfaction. The more the employees' professional skills meet the job requirements, the higher the sense of accomplishment they get at work, which generate more satisfaction with the work and ultimately improve team performance. On the other hand, T-O fit has a good predictability for the team members' behaviors. By selecting the employees who fit with the organization, it is conducive to enhance the communication and cooperation among the members of the organization, increase the cohesion and efficiency of the organization, and improve job satisfaction and performance. However, to a certain extent, it may lead to organizational rigidity and conservatism, lack of innovation, and reduce organizational adaptability. As a result, teams and organizations should be flexible in order to contribute to performance growth. Moreover, Khadivi et al. (70) concluded that job satisfaction affects organizational performance and that job satisfaction is influenced by other factors. The results of this study are consistent with their arguments. Apparently, team job satisfaction not only positively affects performance, but it also plays a mediator between T-J fit and team performance. In other words, T-J fit needs to be influenced by team job satisfaction to affect team performance. If team members are competent in team work, team job satisfaction will rise and team performance will be further increased.

In conclusion, the results of this study confirm that team personality is an effective predictor, which can be used to select team members and configure tasks. T-O fit and T-J fit can not only predict team job satisfaction but also contribute to the development of team norms and influence the effectiveness of behavior at the team-level. Since there are a lot of researches on the role of personal characteristics in the context of the collaborative office, there are few researches on the role of T-E fit in a team. Since many current researches focus on the impact of individual-level personality traits and environmental fit on satisfaction and performance. Relatively few researches have explored the team-level personality. However, some scholars have concerned about team-level issues and argued that individual-level and team-level personalities are different (27). Hence, this study promotes an in-depth understanding of the interaction between these team-level phenomena, which is also beneficial to theory and practice.

This study investigates the team members in the enterprise and discusses the mediating effect of team and environment (organization and job) fit on team personality, team job satisfaction and team performance, and provides a certain empirical and theoretical basis on how to improve the fit. The main contributions of this study are as follows. First, discussing team personality. Through the study of the relationship between team personality combination and team performance and team job satisfaction, analyze the influence of different personality combinations on team performance. Taking the team member personality combination as the starting point, explore the team combination that is conducive to team performance and team job satisfaction. Provide powerful help for the company in the construction of the team, so that the recruited object not only meets the needs of the job position, but also considers the complementary relationship between the existing members of the team and the new members, and meets the fit between people, job, and organizations. Second, exploring T-O fit and T-J fit. The research findings on T-O fit and T-J fit have very important theoretical and practical implications. In terms of theory, the P-O fit and P-J fit in the P-E fit theory have been extended to the team level. Additionally, this study not only verified the

predictability of T-O fit and T-J fit on team job satisfaction and team performance, but also explored their mediating roles in team personality, job satisfaction, and team performance. In terms of practice, the findings of this study provide a new recruitment model for enterprises to attract and retain key employees, theoretical support for personnel recruitment research, and a reference for organizational culture research. Moreover, the recruitment, assessment, and cultivation of talents not only consider whether the individual's abilities are consistent with their job (T-J fit) but more importantly, use effective methods to measure the relationship between their individual characteristics and organizational characteristics compatibility. Therefore, the research on T-O fit provides favorable support for human resource management, highlighting a new type of management concept and development strategy.

Management Implications

The purpose of this study is to explore the relationship among team personality, T-O fit and T-J fit, team job satisfaction, and team performance. The mediating effect of T-O fit and T-J fit on the relationship between team personality, team job satisfaction, and team performance was investigated. Then, this study found that T-O fit and T-J fit are enhanced to improve team job satisfaction and team performance. Thus, the management implications are further discussed from the following perspectives. First, personnel recruitment and selection. When recruiting new employees, the organization should strengthen the test of the personal values of job applicants and select employees with a high conformity with the organization's values, which help improve their job satisfaction and increase team performance. Second, organizational socialization. T-O fit and T-J fit are closely related to employees' attitudes and behaviors. Hence, in the socialization process, organizations should arrange training not only on job content and skills, but also on organizational culture to increase the value fit between the organization and employees. Employees can not only improve their work efficiency but also strengthen their sense of identity with the organization. Then, the morale and stability of the team also increase. Third, human resource management. Managers can use various measures such as regular meetings to continuously achieve value recognition with employees. In the performance management indicators, the value compatibility should also be regarded as an important indicator. Final, career development. Employees are able to continuously assess their T-O fit and T-J fit to help plan their careers. Through these assessments, employees can understand whether they are suitable for their current positions and teams. On the other hand, the organization understands T-O fit and T-J fit of employees to adjust and propose appropriate HR strategies. The more flexible an organization is, the more it can respond to changes in the external environment.

Limitations and Future Research

Given the limited capacity, resources and time, there are still some inadequacies in this study. There are some limitations in this study, which can remind us to pay attention to the future research direction. First, the survey results of the scale in this study are self-reports from employees. This method is often criticized for causing common method variance (CMV). Therefore, this study adopts some preventive measures to reduce errors and avoid unnecessary interference to answerers, such as using more rigorous procedures to construct the scale, and carefully consider the text. In addition, this study refers to the suggestions of Podsakoff et al. (96) and uses an anonymous questionnaire. However, whether the respondents fill in the questionnaire truthfully cannot be guaranteed. Future research should focus on more objective behavioral measurements, such as using actual data (e.g., salary increase percentage, team turnover) to evaluate performances [e.g., (97)]. Final, this study selected two factors (conscientiousness and openness to experience) from the Big Five personality traits based on previous literature reviews. However, scholars have different definitions of personality traits. Not all personality traits can be transformed into team personality. Future research can refer to the personality traits and team personality proposed by different scholars to further explain the team personality more clearly and make the research more complete.

DATA AVAILABILITY STATEMENT

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

AUTHOR CONTRIBUTIONS

Conceptualization: Y-TL, Y-CL, and S-CC. Methodology: OS, UR, AR, and S-CC. Validation: T-HC, Y-CL, and AR. Formal analysis: XL, UR, and Y-TL. Investigation: XL and Y-TL. Writing—original draft preparation: XL, Y-TL, Y-CL, and S-CC. Writing—review and editing: OS, T-HC, UR, and AR. Visualization: Y-TL and Y-CL. All authors have read and agreed to the published version of the manuscript.

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Assessing the Antecedents and Consequences of Experience Value in Online Education: A Quantitative Approach

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The experience value of online education is a hot topic in both theoretical and practical circles, but research on its mechanism of action is limited. Therefore, this study systematically investigates the relationship between brand image, experience value, and continuance intention through a theoretical analysis of brand image, and discusses the boundary role of effective commitment in it. In this study, 475 users were used to conduct structural equation modeling analysis. The results of the study found that experience value had a positive and significant effect on user continuance intention under the significant influence of brand image, but affective commitment did not play a positive moderating role in the relationship between experience value and continuance intention. This study examines the mechanism of the antecedents and consequences of experience value, and provides a new direction for the construction of online education and the development of online education and marketing strategies.

Keywords: brand image, experience value, continuance intention, affective commitment, online education, marketing strategies

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INTRODUCTION

In the new round of technological revolution, the trend of digitalization and wisdom of industry is becoming more and more obvious, and online education in the virtual environment is no exception (Xiong et al., 2021). From the promotion and application of offline education to the construction of online education, the experience value plays an increasingly important role in the brand building of online education (Rashid et al., 2021). As an important typical representative of virtual communities, online education is driven by the amplification of market demand and the accelerated breakthrough of technological innovation to upgrade the value of user experience, attracting more and more users and showing a broad market prospect (Liu and Qu, 2020; Wang et al., 2021). The instantaneous, interactive, global sharing, low transmission cost, self-management, and open communication characteristics of online education (Sun, 2020; Wang et al., 2020) have made it one of the most popular learning methods in recent years. With the development of information technology, public awareness of the use of online education platforms has sprung up (Ko, 2016; Li et al., 2022). However, given that the growth of users is much slower than the growth of online education platforms, and that many users are concentrated in a few well-known online education platforms, this makes the development of online education more difficult, and competition for users will become increasingly fierce

(Li et al., 2021, 2022). The concept of experiential marketing was first introduced by Schmitt (1999), who defined experiential marketing as a process in which individual customers feel certain stimuli after observing or participating in an event, thus inducing motivation and generating thoughtful recognition or purchase behavior. In contrast to traditional marketing, which focuses on product features and price, experiential marketing has a broad content framework that emphasizes the inherent good feelings of consumers regardless of the company, product, brand, or service content (Pine and Gilmore, 1998; Same and Larimo, 2012; Trevinal and Stenger, 2014). Obviously, under the influence of experiential marketing, the public can feel the experiential value of feeling, emotion, and thinking, and this experiential value stimulates users to take a series of actions associated with online education, such as approval or continuance intention.

Studies have shown that experiential value is a series of marketing activities carried out by enterprises through the production and operation of high-quality products, with service products as the platform and tangible products as the carrier, with the goal of meeting consumers' experiential needs and generating feelings and gains (Verhoef et al., 2009; Vada et al., 2020; Bu and Yang, 2021; Prentice et al., 2022). In non-online contexts, the basic concept of experiential value is the value gained from a retail experience through interactions involving direct use or remote viewing (indirect observation) of goods or services, with various cues constantly interacting with customers, not individually, but in an integrated way, providing "value" to customers one fashion retailer at a time (Varshneya and Das, 2017). However, unlike traditional marketing in the past, the value of experience in an online education context is to create a special and unique experience, and consumer psychology and behavior are derived from the experience, so good experience value can bring positive usage psychology and behavior to consumers (Kim, 2012; Yang et al., 2021a). It can be seen that for online education, experiential value has become a new marketing model and represents the future direction of marketing. Implementing experiential value is an inevitable choice for online education companies to brand themselves, build brand loyalty, and construct a competitive advantage (Stavrianea and Kamenidou, 2022). Obviously, for online education, experiential value as a means to enhance the user's perception of the experience and a good reinforcement of the user's continuance intention. As Pine and Gilmore's (1998) study predicted, the era of experiential value has arrived, the marketing battlefield will focus on the creation of great experiences, and the economic form driven by experiential value is the key way to make high profits from online education (Liu et al., 2021; Xing and Li, 2021). Therefore, it is clear that the driving force behind the success of online education operations is the establishment of experiential value. Previous literature has focused on the practical and technical aspects of online education (Shukla, 2012; Chen, 2020). However, there are also studies that suggest that online education is like entertainment media (Hultén, 2012), and that everything is entertainment. Therefore, it will be a challenge for online education managers to master the emotional approach to provide unforgettable experience value to their users and generate the magic that drives users to desire to re-experience (Zhou et al., 2012; Varshneya and Das, 2017).

Existing studies point out that as competition in the online education market continues to intensify, product homogenization is increasing and brand image is increasingly valued by companies and consumers (Kautish and Sharma, 2018). From the point of view of online education users, today's consumers continue to be influenced not only by the product, but also by the brand and its experience value, because this image and its value often represent the user's own image and recognition of the brand value, so online education with a very strong symbolic meaning is more attractive to the public to continuance intention (Varshneya, 2021). From the perspective of online education enterprises, in order to avoid fierce competition in the market, differentiation is often the first choice of enterprises. However, the uniqueness of the brand image is the most reflective of the differences between enterprises and their operations, and this difference in image increases the user's willingness to continue to engage with the brand and is also a competitive advantage that cannot be replicated by other enterprises (Roggeveen et al., 2020; Zhang and Su, 2021). Therefore, online education attaches great importance to brand image shaping and management, which is undoubtedly a wise move, but brand image is rich and there are differences in perspectives, so it is necessary to conduct a systematic study of the mechanism of the role of existing online education brand image (Liu, 2021; Feng and Bao, 2022). To sum up, this study takes online education users as the research object and conducts an empirical study on the relationship between experience value, brand image, and users' continuance intention, to deeply explore and verify the antecedents and consequences of experience value, aiming to understand the mechanism of how experience value and brand image affect users' continuous use of online education, and provide a new direction for the construction of online education and the formulation of online education and marketing strategies.

The remainder of the paper is organized as follows. The next section outlines the theoretical foundation and hypothesis development. After this, the research methodology is explained, followed by the data analysis results. Finally, we present our conclusion.

THEORETICAL FOUNDATION AND HYPOTHESIS DEVELOPMENT

Brand Image

Since the 1950s, brand image, as an important concept in marketing, has been a hot topic for academics and businesses (Janonis and Virvilaite, 2007; Hyun-Jung, 2013; Huang et al., 2020), and has become a meaningful topic of discussion, commentary, and theoretical construction in the field of business-consumer relations. Brand image is an important component of measuring a brand and needs to be analyzed from different perspectives. As the personality characteristics of a brand expressed in the market and in the minds of the public, brand image reflects consumers' evaluation and perception of the brand (Li et al., 2016). Studies have been conducted based on various elements, such as brand attributes, name, packaging, and reputation, while considering consumers' perceptions of

brand image, pointing out that brand reputation and brand personality are important elements reflecting brand image (Li et al., 2016). Brand reputation refers to the brand identity presented by the company, the promises made to consumers, and the extent to which consumers experience the branded product or service, which is a signal sent by the company to the market and is an important representation of brand image (Skard and Thorbjornsen, 2014). Brand personality refers to a set of personality traits associated with a brand, which is important for brand image evaluation. After a brand is given personality traits, it is no longer a passive exchange object, but an active relationship partner. Brands possess personality traits as a natural response from consumers, which can be seen as brand perceptions and feelings formed by consumers in their contact with the brand, reflecting consumers' emotions and embodying their psychological, identity, status, and other personalized needs (Su and Tong, 2015). Undoubtedly, brand image not only reflects the overall impression of a particular brand and represents the message and meaning of the brand; but also represents the personification of the brand and reflects the image of the consumers themselves (Cho et al., 2015).

It is clear that brand image is an important concept in marketing, and this has been agreed upon early on (Gardner and Levy, 1955). Marketing scholars and practitioners agree that the success of products and services is due more to the symbolic meaning of brand image than to physical features and functions (Aaker, 1991). Brand image is also important to the study of brand equity (Keller, 2003). In the article "How Brand Image Drives Brand Equity", the relationship between brand image and brand equity and the mechanism by which brand image drives brand equity are also clearly presented. Although there is a lot of research on brand image, and with the boom of brand equity research, it has been rapidly increasing. Gardner and Levy (1955), while introducing the concept of branding, criticized past research for being too superficial, focusing only on consumers' stereotypical purchase reasons, and suggested that subsequent research should leave behind superficial purchase reasons and focus on sustainable purchase motivations, i.e., the meaning and value of the brand. However, the meaning and value of brand image in the online education environment has not been clearly verified, and the sustainable purchase motivation of brand image on consumer purchases has yet to be tested. In order to contribute to the study of consumer behavior and to help online education evaluate the effectiveness of brand marketing efforts, this study proposes to apply brand image theory to these new areas of research and to expand its scope of application.

Brand Image and Experience Value

The earliest research on brand image can be traced back to Gardner and Levy (1955), who argued that brand image is a set of perceptions, feelings, and attitudes that consumers have toward a brand. Subsequently, many scholars from different disciplines (psychology, communication, and management, etc.) have conducted a lot of research on brand image and put forward a series of theories on the concept, model, and essence of brand image. Park et al. (1986) and Biel (1992) have developed different brand concept images (BCM) based on different consumer interests, and measured brand image in terms of functional, symbolic, and experiential markers. The BCM measures the brand image in terms of functional, symbolic and experiential. Biel (1992), believes that brand image is a set of attributes and associations that consumers recall when they see a brand name, including corporate image, product image, and user image. As can be seen, it has become common practice to examine the brand image in users' minds according to three aspects, including functional, symbolic, and experiential markers, in the context of online education usage. In online education, brand image reflects a set of ideas, feelings, and attitudes that the virtual community keeps in users' minds, and the symbolic meaning represented by the brand has a richer connotation and personality (Li et al., 2019). As the emphasis expands from the commodity experience to the brand experience, and with the use of various media to enrich the brand, or to have a connection with the individual's life form, it is the special and memorable consumer experience that is used to differentiate from other brands (Fang et al., 2021). Therefore, a good brand image will increase the value of consumers' experience. Based on this, this article proposes the following hypothesis.

H1: Brand image is positively related to experience value.

Experience Value, Brand Image, and Continuance Intention

Although academic research on experiential value dates back to 1985, it is believed that the perception of experiential value is primarily derived from consumer interactions with products or services in a direct or distant state, and that these interactions provide the basis for consumer preferences (Holbrook and Corfman, 1985). However, the ability of online education to create and deliver good experiential value to users is increasingly one of the criteria for measuring their core competencies. Experience value can provide both internal and external benefits to consumers (Mano and Oliver, 1993; Babin and William, 1995). Holbrook (1994) added the "activity" dimension to the traditional classification of intrinsic and extrinsic benefits of experiential value, while Mathwick et al. (2001) defined experiential value as the perception of and relative preference for product attributes or service performance. Based on the dimensions proposed by Holbrook (1994), he subdivided experience value into four categories, namely, customer return on investment (CROI), service excellence, aesthetics, and playfulness, and used them as the experiential value scale (EVS). Thus, it can be found that Mathwick et al.'s (2001) EVS goes beyond the traditional focus on the value of combining price and quality, and is able to detect the value components based on experience. Therefore, according to the connotation and essence of Mathwick et al.'s (2001) definition of experiential value, the content of experiential value in online education can be evaluated and measured. That is, in online education environment, experience value reflects the value that results from consumers' sensory, emotional, reflective, action, and associative experiences with online education, including user investment reward, service superiority, aesthetics, and fun.

Research suggests that continuance intention is often a more accurate measure when trying to predict a person's behavior (Engel et al., 1995). Yin et al. (2015) argues that positive continuance intention causes customers to develop a preference for a company and increase the number of purchases of the company's products or services. For the consumer experience of online education, when users have positive continuance intention for the virtual community, they will praise online education, and at the same time, they will develop a preference for using online education, increase the number of times they use online education, and even recommend online education to their friends (Fang et al., 2021). Lial et al. (2019) showed that information value and social value positively influenced consumers' community satisfaction and community identity, which could increase their willingness to participate in brand communities in the future, by collecting data from several brand communities. Interestingly, information value had a greater impact on consumer community satisfaction, but social value had a greater impact on consumer community identification; and community identification had a stronger impact on consumers' willingness to participate in brand communities in the future compared to community satisfaction. A study by Lial et al. (2019) found that online education value is a prerequisite that influences consumers' continued engagement and is the key to the success of online education. Therefore, the value of a good experience will have a positive impact on user continuance intention.

In addition, it has been argued that experience value is an important influencing factor in consumers' evaluation of product continuance intention (Woodruff et al., 1993). More and more companies are understanding that analyzing user satisfaction is an important thing to do, and if managers can identify the factors that influence user satisfaction with a product or service, then the company may be able to change the experience of the consumer in using the product or service to maximize consumer satisfaction (Petrick et al., 2001). In other words, creating good experience value brings consumers greater satisfaction, which leads to positive continuance intention. Aaker (1991) and Rory (2000) also concluded that with a good brand image, consumers would be more satisfied with their purchases and would be willing to recommend them to others, i.e., positive continuance intention. Meng's (2018) study concluded that the brand image of online education has become an important way for companies to expand their customer base and enhance their market competitiveness, and is an important antecedent factor influencing consumption behavior. Therefore, in the online education usage context, a good brand image will have a positive impact on user continuance intention. As a result, this article proposes the hypothesis that:

H2: Experience value is positively related to continuance intention.

H3: Brand image is positively related to continuance intention.

Moderating Role of Affective Commitment

Affective commitment is the enduring emotional disposition to maintain a valued relationship, and is an essential element for long-term relationship success. It develops on the basis of personal devotion, that is, the individual's desire to maintain a relationship with a long-term perspective of mutual benefit (Bendapudi and Berry, 1997; Yang et al., 2021b). The underlying principle is that affective commitment reflects one's sense of involvement and belonging in the relationship in question. Thus, it encourages the individual to continue the relationship due to the favorable attitudes, influences, feelings, and perceptions held about his or her experience of the relationship. Affective commitment has been considered the most important dimension of commitment to predict continuance intention (Zhou et al., 2015). It has been shown that affective commitment is an important predictor of individual continuance intention in virtual contexts (Malhotra and Galletta, 2005; Li et al., 2010; Zhou et al., 2012). Zhou et al. (2015) investigated the relationship between perceived value, affective commitment, and continuance intention in a virtual socialized world and found that self-indulgence diminishes the effect of utilitarian value and enhances the effect of hedonic value on affective commitment; individualism reduces the effect of relational assets on commitment and weakens the effect of affective commitment on continuance intention.

Experiential value is a core topic of research in the field of relationship marketing. The literature supports the idea that satisfaction, trust, and commitment are the key substructures of continuance intention (Shin et al., 2013). A good relationship between experience value and continuance intention can only be established when users feel valued and make an affective commitment to the operator. It has been shown that experiential value positively influences affective commitment in virtual environments (Kim and Son, 2009; Zhou et al., 2012). In online education, experiential value enhances users' continuance intention to continue with the online education, and the role of experiential value in predicting users' continuance intention is limited due to the uncertainty and risk of online education. Thus, users with higher levels of affective commitment tend to strengthen the advantages of online education and weaken the risks of using online education, thus enhancing the positive effect of experience value on continuance intention. Based on this, and based on the analysis of previous literature, it can be found that affective commitment has a positive moderating effect on the relationship between experiential value and continuance intention. In view of this, the following hypotheses are proposed in this study:

H4: affective commitment plays a positive moderating role between experiential value and continuance intention.

In summary, this study proposes a research model as shown in **Figure 1**.

METHOD

Participants and Measurement Items

In this study, "Thousand Chat" was chosen to collect relevant survey data. In this study, there are two main reasons for using "Thousand Chat" as the survey respondents. The first reason is that "Thousand Chat" has become a mainstream user product as one of the learning tools that users use on a daily basis. In most cases, most people using "Thousand Chat" care not only about the quality of online education, but also other information

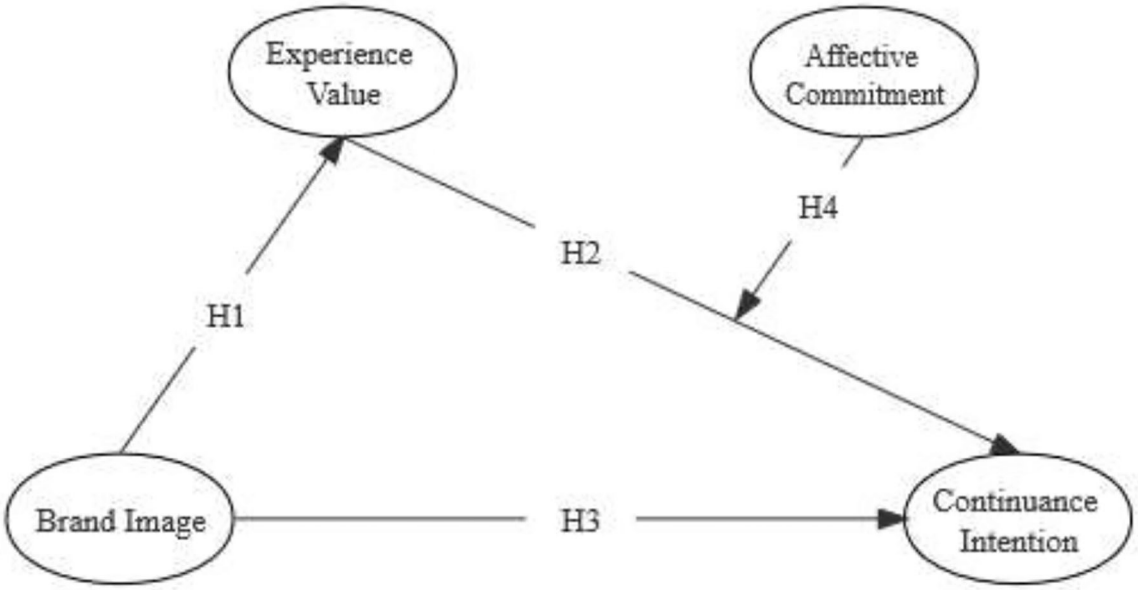

FIGURE 1 | Theoretical model.

about the corporate brand of "online education," and "Thousand Chat" has become an important representative of the brand of online education that users care about. The second reason is that, as one of the largest online education platforms in developing countries, "Thousand Chat" is typical, and if the findings of this study can be supported by data from "Thousand Chat," it can provide management recommendations for companies in online education to conduct experiential activities. Based on the above analysis, "Thousand Chat" was selected for data collection in this study. The measured constructs and their items are shown in **Table 1**.

This paper examines the antecedents and consequences of experiential value in online education. As such, it is a validation study, suitable for data analysis by means of structural equation modeling (SEM). Therefore, it is appropriate for this study to use AMOS 24 to evaluate the empirical data of this paper.

TABLE 1 | Variables and measurement item.

Variables	Items	Sources
Brand image	BI1. The Thousand Chat brand has been established. BI2. The Thousand Chat has a clear image. BI3. The Thousand Chat has a differentiated image in comparison with the other brand.	Sasmita and Mohd, 2015
Experience value	EV1. The Thousand Chat has brought me a lot of joy. EV2. Thousand Chat allows me to find amazing products or special events. EV3. Thousand Chat can make me relax and enjoy myself. EV4. In short, Thousand Chat makes me feel the value.	Sheth et al., 1991
Continuance intention	CI1. I share the experience of using TikTok with my friends. CI2. When I have the need, I use TikTok. CI3. In the future, I will continue to use Tikka. CI4. I recommend TikTok to my friends.	Bhattacherjee, 2001; Thong et al., 2006
Affective commitment	AC1. When I use TikTok, I immerse myself unconsciously. AC2. I have a deep affection for TikTok. AC3. TikTok gives me a strong sense of belonging. AC4. TikTok is very attractive to me.	Zhou et al., 2015; Yang et al., 2021b

DATA ANALYSIS AND RESULTS

Descriptive Statistical Analysis

In this study, the questionnaire survey was conducted over a period of 5 months from August 2021 to January 2022. In this survey, 600 questionnaires were collected, and 475 valid paired questionnaires were obtained after eliminating invalid questionnaires. The gender distribution in this paper is relatively balanced, with a moderate gender ratio of 50.3 and 49.7%, respectively. In terms of age distribution, the majority of the respondents are young people, and the proportion of respondents aged 30–39 years old is 44.8%. In terms of occupation, the majority of respondents were civil servants (44.2%). In terms of personal monthly disposable income, 5.3% of the respondents had a monthly disposable consumption level of less than RMB 2,000, 14.9% of the respondents had RMB

2,000–3,999, 24.0% of the respondents had RMB 4,000–5,999, and 55.8% of the respondents had RMB 6,000 (including) or more. Respondents generally had an undergraduate education, with only 57 (12.0%) educated to college level or below, 375 (78.9%) educated to undergraduate level, and 43 (9.1%) educated to Master's degree level and above. The details are shown in **Table 2**. In summary, the sample group in this study has the characteristics of high education, youthfulness, and low personal disposable monthly consumption level, which may be related to the fact that the main target participants of this questionnaire survey are the internet group. In view of this, this study considers that the collected sample data reflects the basic situation of the sample as a whole and is somewhat representative.

Measurement Model Analysis

The results of the Confirmatory Factor Analysis (CFA) are shown in **Table 3**. This study evaluates and revises the measurement model of CFA according to the approach of Anderson and Sullivan (1993). That is, CFA should primarily report Cronbach's α, Composite Reliability (CR), and Average Variance Extracted (AVE) for all variables, and only after these metrics pass the test can structural model evaluation be performed (Kline, 2011). Fornell and Lacker (1981), Nunnally and Bernstein (1994), and Hair et al. (2017) clearly stated that when the Cronbach's α is >0.70, the CR is >0.60, and the AVE is >0.50, the measurement model has good convergence validity. In this study, the Cronbach's α is between 0.816 and 0.878, the CR is between 0.824 and 0.882, the AVE is between 0.555 and 0.657. Thus, the results of Cronbach's α, CR and AVE meet the criteria of Fornell and Lacker (1981), Nunnally and Bernstein (1994), and Hair et al. (2017). Therefore, the results of the CFA analysis indicate good convergence validity for all the constructs.

There is discriminant validity when the variance among the constructs of a model is lower than the variance that each construct shares with its items. This study uses the Fornell and Lacker (1981) test to examine the discriminant validity. **Table 4** shows that the square root of average variance extracted for each construct is greater than the correlation between the constructs and all other constructs. Therefore, the results of this study support Fornell and Lacker's (1981) recommendation for discriminant validity.

TABLE 2 | Descriptive statistical analysis.

Variables	Item	Frequency	%	Cumulative %
Gender	Male	239	50.3	50.3
	Female	236	49.7	100.0
Age (year)	19 or less	9	1.9	1.9
	20–29	187	39.4	41.3
	30–39	213	44.8	86.1
	40–49	47	9.9	96.0
	50 or above	19	4.0	100.0
Marriage	Married	321	67.6	67.6
	Unmarried	151	31.8	99.4
	Divorce	3	0.6	100.0
Profession	Student	47	9.9	9.9
	Freelance	30	6.3	16.2
	Executive in private enterprise	158	33.3	49.5
	Civil servant	210	44.2	93.7
	Clerk in state owned enterprise	24	5.1	98.7
	Executive in private enterprise	6	1.3	100.0
Education	College and blow	57	12.0	12.0
	Undergraduate	375	78.9	90.9
	Master's degree and above	43	9.1	100.0
Consumption (RMB)	Below 2,000	25	5.3	5.3
	2,000–3,999	71	14.9	20.2
	4,000–5,999	114	24.0	44.2
	6,000 or more	265	55.8	100.0
Continuous use time (year)	less than 1	74	15.6	15.6
	1–2	199	41.9	57.5
	Over 3	202	42.5	100.0

Structural Model Analysis

Model fit was analyzed according to the recommendations of Jackson et al. (2009) in this study. The results found ML $\chi^2 = 48.564$, DF = 41, 1 < Normed Chi-sqr (χ^2/DF) = 1.184 < 3, RMSEA = 0.020 < 0.08, SRMR = 0.021 < 0.08, TLI (NNFI) = 0.996 > 0.9, CFI = 0.997 > 0.9, GFI = 0.982 > 0.9, AGFI = 0.955 > 0.9. This indicates that the structural model of this study has a good fit (Bollen and Stine, 1992). The path coefficients are shown in **Table 5**. Brand image (BI) (β = 0.275, *p*-value < 0.001) is positively associated with experience value (EV). Therefore, H1 is supported. Experience value (EV) (β = 0.397, *p*-value < 0.001) is positively associated with continuance intention (CI). Therefore, H2 is accepted. Brand image (BI) (β = 0.108, *p*-value < 0.01) is

TABLE 3 | Confirmatory factor analysis.

Construct	Item	Cronbach's α	CR	AVE
Brand image (BI)	BI1	0.816	0.824	0.612
	BI2			
	BI3			
Experience value (EV)	EV1	0.832	0.832	0.555
	EV2			
	EV3			
	EV4			
Continuance intention (CI)	CI1	0.878	0.882	0.657
	CI2			
	CI3			
	CI4			
Affective commitment (AC)	AC1	0.848	0.852	0.592
	AC2			
	AC3			
	AC4			

TABLE 4 | Discriminant validity for the measurement model.

Variables	Mean	SD	AVE	1	2	3	4
1. Brand image (BI)	4.654	1.231	0.612	**0.782**			
2. Experience value (EV)	5.012	0.999	0.555	0.436	**0.745**		
3. Continuance intention (CI)	5.756	0.901	0.657	0.354	0.484	**0.811**	
4. Affective commitment (AC)	5.325	1.002	0.592	0.515	0.613	0.619	**0.769**

The diagonal value is the square root of AVE.

TABLE 5 | Regression coefficient.

	Unstd	S.E.	Unstd./S.E.	Std.	*p*-value
H1: BI->EV	0.275	0.037	7.521	0.435	***
H2: EV->CI	0.397	0.059	6.670	0.407	***
H3: BI->CI	0.108	0.033	3.237	0.175	**

BI, Brand Image; EV, Experience Value; AC, Affective Commitment; CI, Continuance Intention.
***p-value < 0.01, ***p-value < 0.001.*

positively associated with continuance intention (CI). Therefore, H3 is also accepted.

The moderating effects are reported in **Table 6**. In the present study, affective commitment (AC) is the moderating variable. The results of structural equation modeling have been shown that the moderator effect of experience value (EV) × affective commitment (AC) on continuance intention (CI) is -0.034 ($z = |-1.015| < 1.96$, p-value > 0.001), implying the presence of a positive moderating effect of affective commitment (AC) on the relationship between experience value (EV) and continuance intention (CI). Specifically, the slope of experience value (EV) on continuance intention (CI) increases negatively by -0.034 units for each 1-unit increase in the moderating variable affective commitment (AC). That is, experience value (EV) has a negative moderating effect. Therefore, hypothesis 4 is not verified.

RESEARCH RESULTS AND DISCUSSION

Conclusions

First, the results of the study indicate that brand image has a positive and significant impact on continuance intention. The findings are consistent with the conclusions drawn from Meng's (2018) study. This is because online education is full of widespread and distorted information, which makes online education users cautious when they experience the fun during online education with their senses, thoughts, and feelings, and they do not know whether the online education is trustworthy or not. But a good experience will leave a good image of that online education provider in the user's mind, and multiple good experiences keep strengthening this positive image, thus making the online education users feel more and more satisfied with the use of that online education provider. Therefore, companies should focus on strengthening the brand image of online education, establishing an honest and reliable image in the virtual world where online education is plagued by viruses and flooded with false information, and should work to replace viral online education methods with high-quality information services and fast response speed.

Second, there is a positive and significant impact of the brand image of online education on the value of the experience. The findings are consistent with the Fang et al. (2021) study, which may be related to the fact that online education security is the main key feature, and the security performance of the online education as well as functional features, product prices, and other functional images will directly affect the brand of the online education, which are elements valued by the users of online education, so the brand image plays an role in online education. When such users are attracted by the practicality and artistry of the online education content, the online education provider will secure users thanks to the terms of information and service performance. In addition, for online education, the role of brand image in influencing user behavior is more pronounced. This is because online education tends to speak from "strength" and use the quality of data to attract online education users. Therefore, brand image plays a relatively important role in influencing users' continuance intention.

Third, the findings suggest that experiential value has a positive and significant effect on continuance intention. The findings are consistent with the conclusions reached by scholars such as Lial et al. (2019) in their previous studies. It is speculated that the reason may be because both the experiential marketing of online education and their brand image positively influence users' continuance intention through the mediator of users' experience value. Therefore, in the management practice of online education, it is not enough to implement experiential marketing and branding strategies, but it is also necessary to introduce more relevant tools through management marketing innovation to enhance users' experience value, so that users of online education will visit again and recommend the website

TABLE 6 | The analysis of moderating effect.

DV	IV	Path coefficient (β)	S.E.	Z-value	*p*-value
Continuance intention (CI)	Experience value (EV)	0.187	0.052	3.569	***
	Affective commitment (AC)	0.464	0.063	7.418	***
	Experience value (EV) × Affective commitment (AC)	−0.034	0.034	−1.015	ns

$^{***}p < 0.001$; ns, non-significant.

to their friends and family. Therefore, when building online education, companies should pay attention to the overall aesthetics of the online education page, and the placement of advertisements should be integrated within the entire online education platform.

Fourth, the results of the study showed that affective commitment did not have a positive moderating effect on the effect of experience value on continuance intention. According to the results of the moderating effect analysis, it is clear that affective commitment does not have a positive moderating effect between experiential value and intention to use. Users with higher affective commitment tend to be more emotionally attached to online education operators based on long-term interaction. Users with higher affective commitment tend to trust service providers more, see the advantages of online education more easily, and tolerate certain inappropriate behavior from online education operators; thus their experience value has a stronger impact on continuance intention. On the contrary, users with lower affective commitment lacked trust in the online education service provider and interacted less with the online education service provider. Therefore, users with a higher experience value may be less willing to use online education than those with higher levels of affective commitment.

Theoretical Contributions

On the one hand, this paper breaks through the limitations of previous studies, which focused on the influence of motivation and behavior on the behavior of users in online education, and starts from the perspective of the online education experience, focusing on the psychological perception of members, while considering the antecedents and consequences of experience value. The theoretical model of the influence of community members' experience on their continuance intention is constructed based on the literature on brand image. This model has contributed to the development of the theory and practice of online education.

On the other, the rise of the internet has diversified the communication channels between companies and users, and the establishment of online education is a new form of interactive communication between companies and users, and therefore has received increasing attention from academics. However, the existing theories on online education mainly focus on the impact on brand loyalty from the way community members participate in communication, but rarely focus on the community experience that plays an important role in users' psychological perception. This paper examines users' experience value and its antecedents and consequences through an empirical study to validate the overall theoretical model, thus broadening the research channel on the experience value of online education and extending the study of experience value to the field of online education.

Practical Implications

First, for online education, the role of experiential value is to gain insight into users' motivations and needs for participation, and to design policies that reinforce users' sense of commitment and participation in the community. This paper shows that experiential value is a key psychological link between users and communities, which provides guidance to community operators on how to strengthen the design of user "identity" display mechanisms in online education. In addition to creating a positive brand image, it is also important to actively encourage users' own perceptions of the community experience. Online education operators need to give users adequate tools for self-expression, such as reputation, ranking, rating systems, signatures, and personal websites, and online education providers need to take full advantage of technology-mediated features to support the construction of users' experience needs and the experiential interactions that occur through identity presentation.

Second, improving the brand image of online education is a management component that community operators need to focus on. Offline connections in online education only occur when a brand image is generated within the community, and offline connections among online education members are increasingly important to the cohesiveness of online education. Of course, increasing interaction is a means to an end, but so is promoting a social identity within online education. This can be seen from two perspectives. One perspective is that, at the technical level, functional modules can be developed and designed to promote brand image management, such as the cross-group, live-streaming function of the online knowledge community represented by the Thousand Chat community; another perspective is that at the management level, operators of online education can set up dedicated interpersonal managers to regularly and purposefully guide mutual communication and sharing among members in the community, such as fan groups, regular offline parties and promotional activities, so that brand image promotion becomes a normal phenomenon in online education.

Third, online education managers can influence users' continuance intention through the policy control of brand image, and enhance the experience to bring value to users through various technical features of online education, real-time communication, interactive content (UGC), and various interactive tools application, etc., in order to promote

the realization of individual consumption psychology and behavior. Therefore, in order to guarantee the effectiveness of experiential marketing, the community can regularly evaluate and monitor both the form and level of experiential marketing as well as the effectiveness of experiential marketing. In addition, different virtual community design policies can be adopted. For example, when developing communities that focus on interpersonal connections the formation of relationships between members of the community must be promoted. This means that it is not enough to have online interactions; offline activities between members should also be encouraged. Accordingly, this requires community policies that encourage more direct sharing of private information between members.

Fourth, it is important to categorize and manage online education users. In online education, empirical results show that users with high levels of affective commitment are more important for brand image, value experience, and continuance intention, which means that community operators should have a very high level of content creation so that they can guide, control, and create new content to retain the group of users who stay in the wider community. Therefore, before developing and implementing marketing initiatives, online education providers first need to segment and target user groups in the market, manage the categories, and focus their efforts on key users. For example, users who use online education more than once a week have higher brand image, experience value, and willingness to use the online education than other frequent users. For this group, online education needs to emphasize the innovative points of online education in the marketing process, and enhance the value of user experience through differentiated marketing activities.

Limitations and Future Research

Although this paper draws some conclusions about the importance of both theory and practice of online education experience marketing, there are still some limitations. Since users of different genders, geographic regions, and consumption levels can have differences in online literacy, this can affect their feelings about the online education experience; however, this paper does not classify the sample by the above characteristics for empirical study. Subsequent research could compare the differences in gender, geography, and consumption inequality characteristics to find out the impact of these characteristics on the relationship chain in this paper.

DATA AVAILABILITY STATEMENT

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

ETHICS STATEMENT

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. Informed consent was obtained from all subjects involved in the study.

AUTHOR CONTRIBUTIONS

HZ: conceptualization and writing original draft. LS: formal analysis and investigation. HZ and LS: writing—review and editing. All authors have read and agreed to the published version of the manuscript.

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Lexical Features of Economic Legal Policy and News in China Since the COVID-19 Outbreak

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Lexical features are influenced by different languages and genres. The study of lexical features in different genres of texts on the same topic is helpful to understand the universalities and peculiarities of languages. This study constructs a research on the lexical feature and word collocations of two self-build corpora (China's economic Legal Policy Corpus and English News Corpus during the COVID-19 pandemic), the methods of Quantitative Linguistics and context interpretation are adopted. It was found that: (1) the word length, word frequency, word cluster and high frequency word distribution in English economic news and Chinese economic legal policies are influenced by language and genre to some extent, and they conform to different functional image distribution; (2) during the COVID-19 pandemic, "development" has been the focus of China's economic legal policies and English news, the two have attached importance to economic recovery and taken a positive attitude toward it in different ways. These findings suggest that: (1) There are some universalities and peculiarities between English economic news and Chinese economic legal policies in the distribution of lexical feature; (2) there is a certain synchronization between laws and news, and both of them maintain a positive and objective attitude toward the economic development during the pandemic. This study carries out a macroscopic investigation on internal structure and external interpretation, which enriches the study on lexical features and cultural features of language and provides some references for relevant studies.

Keywords: lexical feature, corpus studies, news text, economic legal policy, COVID-19

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INTRODUCTION

The study of language can be divided into two fields: the study of language structure and the study of language application [(1), p. 1], corpus plays an important role in language research in both fields. "As one of the branches of Computational Linguistics, Corpus Linguistics deals with the principles and practice of using corpora in language study. A corpus is a collection of linguistic data, either compiled as written texts or as a transcription of recorded speech" [(2), p. 413]. Corpus Linguistics takes corpus as the starting point of language description or uses corpus as the method to verify linguistic hypotheses (3). Halliday (4) believes that Corpus Linguistics links data collection with theoretical construction and promotes people's understanding of language.

Corpus Linguistics is widely used in the field of language teaching (5–7), translation studies (8–12), second language acquisition (13–15), discourse analysis (16–18). Through corpus analysis, effective comparison and data statistics can be made between the two or more corpora to better explain language phenomena.

From the perspective of Quantitative Linguistics, "Quantitative Linguistics concerns itself with the various language phenomena, language structures, structural properties, and their interrelations in real-life communicative activities," through mathematical quantitative methods, "it conducts accurate measurement, observation simulation, modeling and explanation of these phenomena in order to discover the mathematica laws underlying the language phenomena" (19). To investigate the progress of discourse research at home and abroad on the basis of Quantitative Linguistics is an important reference to clarify the research context at home and abroad (20). Through the research method of Quantitative Linguistics, we can better describe the laws of language phenomenon and explain the framework of its internal mechanism.

Sinclair [(21), pp. 131–142] proposed lexical grammar under the influence of different languages and themes, held that word was the starting point of building lexical models, and proposed the framework of lexical semantic meaning relationships, the first of which was lexical collocation relations. Lexical features include word length, word frequency, high frequency word and others. Genre, language style, language and other factors that may affect lexical features and lexical collocation. Word is one of the important elements of text, the analysis of lexical features can better understand the differences between different genres of text. In the field of second language acquisition, there are many research achievements in lexical features (22–24). Lexical features are also the focus in the field of translation (25, 26).

In addition, context interpretation can also be used to interpret lexical features. Malinowski put forward "situational context" and "cultural context" respectively in 1923 and 1935. Up till now, after continuous development, the context theory has been applied in linguistics, the interpretation and restriction effects of context on the meaning of language have been recognized. Context can help us to understand the meaning of language in communication, stimulate the internalized language form, and promote effective and correct expression.

There is also much discussion about the universalities and peculiarities of languages. "What is the relationship between languages, are they fundamentally different from each other or do they have a common law? If they have anything in common, how much? These questions have always been the subject of concern and the focus of linguists" (27). At present, there are few comparative studies of different genres based on Quantitative Linguistics and corpus methods. During the pandemic, the country's legal policies can better reflect the country's response, and the news can also reflect a certain response attitude, so in order to better explore the differences between different genre text and understand the universalities and peculiarities of languages, this paper constructs a research on the lexical feature and word collocations of two self-build corpora (China's economic Legal Policy Corpus and English News Corpus during the COVID-19 pandemic), the methods of Quantitative Linguistics and context interpretation are adopted. It is hoped that this study may provide some tentative answers to the issue above by focusing on the following questions:

(1) What is the distribution characteristics of lexical features of legal language and news language? Do they follow certain laws or models?
(2) Whether the focus of China's economic laws and news during the COVID-19 pandemic are synchronized? What values do they reflect?

Question (1) aims to discuss the different distribution characteristics of the two texts at lexical level, and find out the commonness of the lexical features of the two texts. Question (2) is intended to explore whether there is a social and semantic connection between the two, and find out the values behind it. It is hoped that these questions can give some enlightenment to the comparison of words of texts in different genres with the same theme.

MATERIALS AND METHODS

Detailed information about the study's methods and materials, including data sources, procedures and data analysis are presented in this part.

Data Sources

The construction of Legal Policy Corpus (LPC) and News Corpus (NC) is the foundation of this research, which needs to determine representativeness of corpora and collect data.

Legal policies include not only laws, but also administrative regulations, judicial interpretation, departmental rules, military regulations, party regulations, group provisions, industry regulations and other different types of legal provisions. There are also differences in the writing criteria and style among different types of legal provisions. Laws, administrative regulations, judicial interpretation and departmental rules are important parts of legal policies, which have distinct linguistic features and good representativeness. The outbreak of COVID-19 pandemic is sudden and uncertain, and the legal policies issued by the government during this period are of good reference significance for the study of legal language. The COVID-19 pandemic is having a serious impact on various aspects of the country, especially the economy, which is an area of national priority and urgent need to restore order. Beida Fabao-Laws & Regulations Database developed by Peking University on the basis of its Legal Information Center in 1985, after more than 30 years to improve and perfect, it is one of the domestic advanced mature professional database of laws and regulations. Therefore, in order to objectively reflect the facts of the legal corpus and investigate the linguistic characteristics of the legal text, this study selects the Beida Fabao-Laws & Regulations Database as the data source of the Legal Policy Corpus (LPC).

China Daily is one of the six national key media websites and a comprehensive news media website integrating news information and entertainment services. It serves the domestic and international mainstream medium and high end readers, and is the online bridge between China and the world. As the largest English news portal in China, China Daily is one of

the national key news websites. It presents every process of China's development to the world with objective and accurate reporting, unique news perspective and humanized expression. China Daily has carried a lot of reports on the COVID-19 pandemic, including detailed reports on the economy, politics and culture of countries around the world during the pandemic. It has also tracked China's response policies and their effects in detail. Therefore, in order to objectively reflect the facts of news corpus and investigate the linguistic features of news texts during the COVID-19 pandemic, China Daily was selected as the data source of News Corpus (NC) in this study.

Produce

In this study, economic legal policies issued in 2020 were retrieved through Beida Fabao-Laws & Regulations Database (interview date: November 4, 2020). Laws and regulations that have expired or have no relation to the COVID-19 pandemic and economy are removed. Finally, the current economic legal policies in effect during the pandemic from January 2020 to November 2020 will be retained. A total of 39 pieces were collected, including four laws, three administrative regulations, three judicial interpretations, and 29 departmental rules, with a total word count of 174,904 in Chinese (see **Table 1**).

At the same time, this study searched the economic news after 2020 with "COVID-19" as the keyword on China Daily website, and manually excluded the news irrelevant to domestic economic policies. Finally, 202 English news with a total of 123,333 English words have been published on the international section from April 2020 till now (November 2020) were collected (see **Table 1**).

After collected the data, all of them were faithfully kept in a TXT format. Before data analysis of Chinese corpus, word segmentation is needed, and different word segmentation standards will lead to slight differences in statistical results. This study takes the above two corpora as the main materials, and uses ROST Content Mining System 6.0 word segmentation tool to do the word segmentation to the Chinese corpus and convert it into Unicode encoding.

After automatic processing, this paper manually proofreads and corrects the text to eliminate unnecessary punctuation marks or links, so as to increase the analyzability of the corpus.

AntConc 3.4.4w and Wordsmith Tool 6.0 were used for data analysis when analyzing Chinese and English corpus in this study. At present, there are many retrieval tools of corpus. AntConc 3.4.4W is adopted because it can provide retrieval function for Chinese corpus and can retrieve specific information of corpus to provide detailed data, and Wordsmith Tool 6.0 can supplement with it. AntConc 3.4.4w has functions such as Concordance Tool, Concordance Plot Tool, Clusters/N-Grams, Word List, etc. It can be used together with Wordsmith Tool 6.0 and they can be complementary to each other, enabling more accurate retrieval of Chinese and English corpora and statistics of word frequency and collocation. At the same time, adopt the method of Quantitative Linguistics, correlation analysis of word length and word frequency was carried out by IBM SPSS Statistics 23, and matching analysis of word length and word frequency dispersion point graph and function model was carried out by RStudio V0.99.902.

Data Analysis

Vocabulary is the basic unit of language structure and plays a fundamental role in language performance. In traditional linguistic studies, vocabulary is considered to be lawless [(28), p. 3]. In recent years, vocabulary has gradually become the main object of linguistic research. Sinclair (29) believed that the rise of vocabulary research was mainly due to Halliday's research methods and the development of computers. Halliday (30) proposed the importance of vocabulary in the study of grammar and highlighted the position of corpus. The rise of computers makes it possible to further analyze the vocabulary and sentences of large-scale corpora. As one of the branches of computational linguistics, "corpus linguistics deals with the principles and practice of using corpora in language study," "a corpus is a collection of linguistic data, either compiled as written texts or as a transcription of recorded speech" [(2), p. 413]. With the appearance of corpus linguistics, grammatical relations at the lexical level based on a large number of natural texts can be explored.

This paper compares China's economic legal policies and economic news during the COVID-19 pandemic, and discusses the differences between legal policies and news in terms of word length, high frequency words and their collocations. The basic information of the two corpora in this study is as follows:

As shown in **Table 2**, the Type-Token Ratio (TTR) and the Standard Type-Token Ratio (STTR) of News Corpus were lower than those of the Legal Policy Corpus, while the mean word length and the mean sentence length were higher than those of the Legal Policy Corpus. TTR and STTR are commonly used in corpus linguistics to compare changes in lexical density. The lexical density of News Corpus is lower than that of the Legal Policy Corpus, but the mean sentence length and mean word length are higher than that of the LPC. It can be preliminarily speculated that compared with the legal policy, news tend to use more language units to express meaning with simplified vocabulary and low sentence complexity, which is also influenced by the differences in the types of Chinese and English. For example, in Chinese, verbs can be used together, while in English, there is always only one predicate verb in a sentence. For another example, Chinese predicate verbs have no tenses, person and number changes, but English predicate verbs have abundant changes, etc., which will more or less affect the comparative study of words in this paper. However, this paper mainly compares word length, word frequency, word clusters, high-frequency words and their collocations, rather than grammar and other language areas with great differences. In order to explore the lexical features of legal texts and news texts, the next section will analyze the word length and frequency, word cluster, high frequency words and their collocations in the two corpora.

RESULTS

Word Length

Zipf discovered the relationship between the occurrence frequency of words in the text and their frequency rank (serial number), and proposed a mathematical formula to describe this functional relationship, namely Zipf's law (31). Zipf [(32),

TABLE 1 | Basic information of the two corpora.

Corpus	Type	Language	Words	Timespan	Validity	Source
Legal Policy Corpus (LPC)	Official	Chinese	174,904	Jan.2020—Nov.2020	Currently effective	https://www.pkulaw.com/
News Corpus (NC)	Official	English	123,333	Apr.2020—Nov.2020	International section	http://www.chinadaily.com.cn/

TABLE 2 | Basic features of the two corpora.

	Legal Policy Corpus (LPC)	News Corpus (NC)
Tokens	90,648	122,271
Types	7,116	8,769
Type-token ratio (TTR)	7.85%	7.17%
Standard type-token ratio (STTR)	44.83%	44.06%
STTR standard deviation	52.29	54.83
STTR basis	1,000	1,000
Mean word length	1.87	5.20
Mean word length standard deviation	0.61	2.78
Mean sentence length	22.26	25.70

TABLE 3 | Word length distribution of legal policy corpus (LPC) and news corpus (NC).

	LPC	NC
1-letter words	21,859	2,484
2-letter words	64,514	18,905
3-letter words	5,533	21,371
4-letter words	1,601	18,023
5-letter words	130	12,607
6-letter words	48	11,505
7-letter words	1	12,184
8-letter words	3	9,604
9-letter words	0	6,395
10-letter words	0	4,532
11-letter words	3	2,831
12-letter words	1	1,257
13-letter words	0	1,195
14-letter words	0	291
15-letter words	0	104
16-letter words	0	28
17-letter words	0	9
18-letter words	0	3
19-letter words	0	0
20-letter words	0	5

p. 38] pointed out that the word length is usually inversely proportional to its frequency, and the relationship between the two is not completely proportional, but may conform to the non-linear mathematical function. The word length can reflect the degree of difficulty of the text, so as to reflect the complexity of language units. Human cognitive system and brain information processing mechanism makes speakers tend to choose short and simple words to express specific meaning in order to save energy consumption, which leads to the increase in the frequency of using shorter words in discourse (33). However, there are few studies on the distribution characteristics of word length in legal texts and news texts. Therefore, this section will compare the characteristics of word length in Chinese legal texts and English news texts to get a better idea of their textual complexity.

As shown in **Table 2**, the mean word length of English news corpus is higher than that of Chinese law corpus. **Table 3** shows the basic information of the word length distribution of the two corpora. Chinese corpus calculates the word length with Chinese characters, while English corpus calculates the word length with letters.

As shown in **Table 3**, the relationship between word length and word frequency in the two corpora is in line with the economic principles of the language as a whole. In the Chinese Legal policy corpus (LPC), the proportion of 2-letter words is the highest, followed by the proportion of 1-letter words, which conforms to the main characteristics of the distribution of disyllable word length in Chinese and English (34). Apart from stylistic differences, Chinese and English also have great differences in types, so word length data of English News Corpus (NC) cannot be comprehensively compared with Chinese LPC data in all aspects. In order to understand whether there are similarities between the two corpora in terms of word length and word frequency, this section focuses on the analysis of their relevance. The Kendall's tau-b coefficient of rank correlation test by IBM SPSS Statistics 23 software showed that the word length distribution of LPC and NC was significantly correlated ($p < 0.001$), as **Table 4**.

As shown in **Table 4**, on the whole, the distribution of word length and word frequency of Chinese LPC and English NC is significantly correlated, but there are still differences in the distribution of word length and frequency. LPC has more words with three letters and below, while NC has more words with three letters to ten letters than LPC, as shown in **Figure 1**.

Figure 1 is the word length percentage distribution of LPC and NC, which reflects the Principle of Least Effort. However, there are some differences between them. The percentage of 1-letter words and 2-letter words in LPC is higher than that in NC, and the percentage of 2-letter words occupies the highest proportion in LPC. Starting from 2-letter words, the distribution ratio of word length in LPC showed a downward trend, with no fluctuation, and the percentage of the 3-letter and above words tended to 0. In NC corpus, the proportion of 3-letter words is the highest, which shows an increasing trend before the 3-letter words. Starting from the 3-letter words, the distribution of the word length shows a declining trend with no obvious fluctuation

amplitude, and shows a steady downward trend since the 7-letter words.

There have been many advances in the research on the relationship between word length and word frequency. For example, Zipf (32) proposed that the relationship between word length and word frequency is inversely proportional; (35) discussed the word length of Slovak poetry; (36) conducted a diachronic study on the distribution of Chinese word length; (37) discussed the influence of sentence length on the dependence distance, etc. As for the functional relation between word length and word frequency, (33) pointed out that the power function model could describe the regularity of Chinese words well. This section will discuss the functional relation between word length and word frequency in Chinese LPC and English NC, as shown in **Figure 2**.

Curve fitting was performed by SPSS, and the results were shown in **Figure 2**, the word length distribution of the two corpora can be seen intuitively. Among them, the word length distribution of Chinese LPC is closer to the power function distribution, and that of English NC is closer to the logarithmic function distribution. Compared with English NC, the distribution of word length and frequency in Chinese LPC is relatively discrete.

Tables 5, **6** are the basic information of model summary information and parameter estimation values of the logarithmic function, power function and exponential function of LPC and NC, respectively. Goodness of fit is an important indicator to judge whether a group of data conforms to a model. Through the curve fitting tool of SPSS, R^2 can be used to judge the fitting effect of two groups of data. The value of R^2 is between 0 and 1, when $R^2 > 0.75$, it means that the data is applicable to this model, and the closer the value is to 1, the higher the fitting degree will be. For LPC, R^2 in the power function model is $0.831 > 0.75$, which conforms to the power function distribution. In the logarithmic function model and exponential function model, $R^2 < 0.75$, so it does not conform to the logarithmic and exponential function distribution; For NC, $R^2 > 0.75$ in the exponential function model, but in the logarithmic and power function model, $R^2 < 0.75$, so it conforms to the exponential function distribution, but not to the logarithmic and power function distribution.

In general, the power function model can better explain the distribution characteristics of word length and frequency in Chinese LPC, while the exponential function model can better explain the distribution characteristics of word length and frequency in English NC. This can also be explained that the distribution characteristics of legal language and news do follow certain laws or models.

TABLE 4 | Correlation analysis of word length and frequency distribution between LPC and NC.

			LPC	NC
Kendall's tau-b	**LPC**	Correlation Coefficient	1.000	0.661**
		Sig. (2-ailed)	.	0.000
		N	20	20
	NC	Correlation Coefficient	0.661**	1.000
		Sig. (2-ailed)	0.000	.
		N	20	20

**. *Correlation is significant at the 0.01 level (2-tailed).*

Word Cluster

Lewis (38) believes that traditional grammar and vocabulary are not the basic structure of a language, but word cluster, which is "a kind of language structure with both lexical and

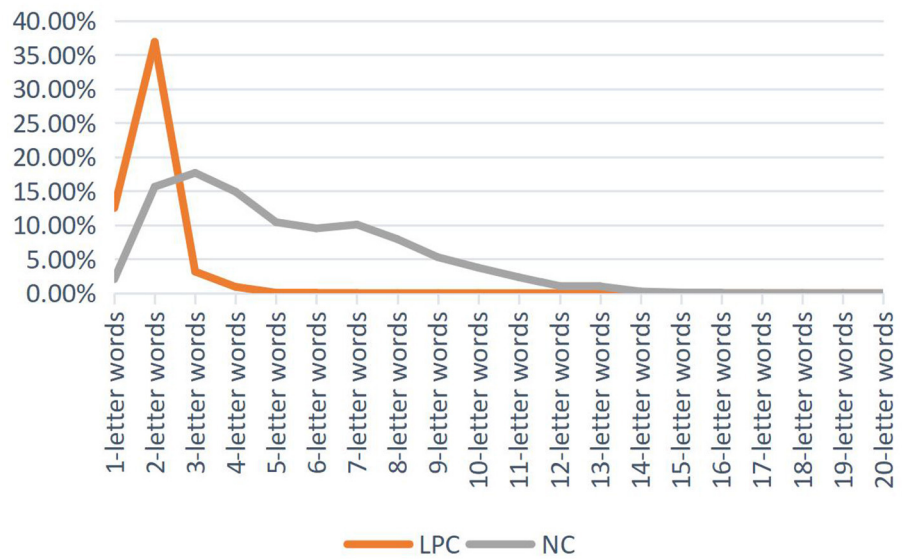

FIGURE 1 | Word length percentage distribution of LPC and NC.

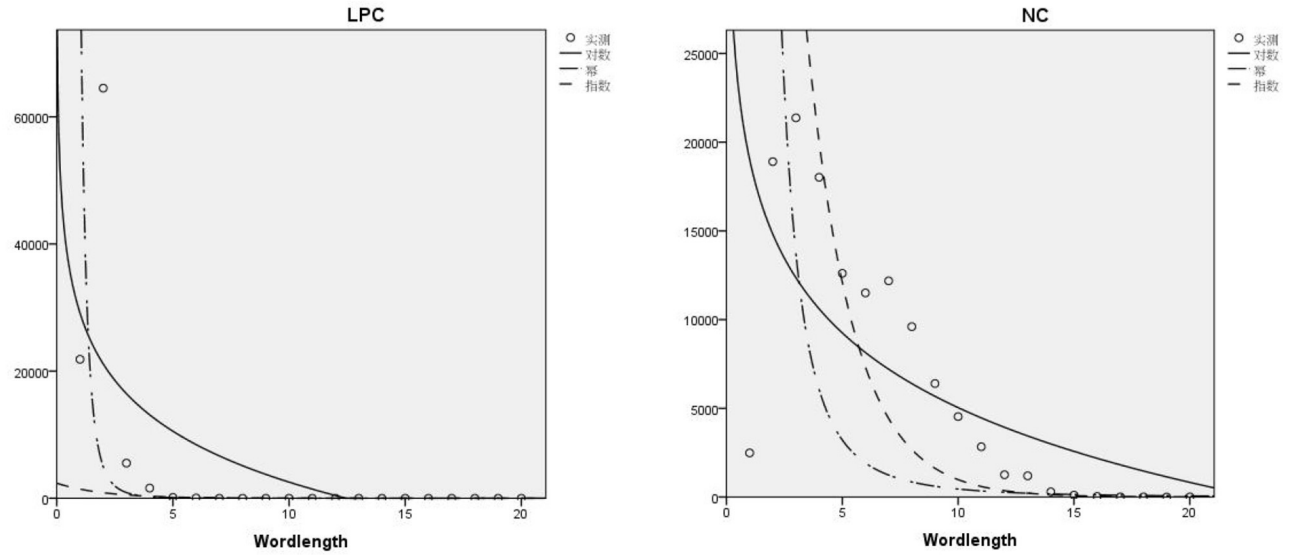

FIGURE 2 | Dispersion diagram of word length and frequency of LPC and NC.

TABLE 5 | Model summaries and parameter estimates of LPC.

Dependent variable: LPC

Equation	Model summaries					Parameter estimates	
	R^2	F	df1	df2	Sig.	Constant	b1
Logarithmic	0.396	11.783	1	18	0.003	29141.417	−11553.425
Power	0.831	88.799	1	18	0.000	91851.245	−4.206
Exponent	0.621	29.542	1	18	0.000	2366.724	−0.500

Independent variable: Wordlength.

TABLE 6 | Model summaries and parameter estimates of NC.

Dependent variable NC

Equation	Model summaries					Parameter estimates	
	R^2	F	df1	df2	Sig.	Constant	b1
logarithmic	0.469	15.880	1	18	0.001	19032.511	−6078.008
power	0.487	17.092	1	18	0.001	309632.055	−2.838
exponent	0.810	76.784	1	18	0.000	149502.906	−0.503

Independent variable: Wordlength.

grammatical features" (39). Word clusters can be composed of multiple words, which are not necessarily complete in structure and meaning. However, they have specific discourse functions and play an important role in language output, which can reflect the characteristics of language repetition. Both the language of law and the language of news are normalized and stylized to some extent. In this section, the word clusters of 2–7 words in the two corpora are taken as the research objects to observe their word cluster characteristics.

As shown in **Figure 3**, there is a certain difference in word clusters of 2 to 7 words which frequency exceeds 20 in the two corpora. Although LPC corpus has more words than NC, the number of word clusters with frequency over 20 in LPC is lower than NC. Next, this paper makes further statistics on the detailed data of word clusters of 2 to 7 words which frequency exceeds 10, as shown in **Table 7**.

As shown in **Table 7**, the number of word clusters of 2–7 words and the total word clusters in Chinese LPC is lower than that in English NC, and the number of word clusters in both of them is concentrated in 2–4 words. The more words in the

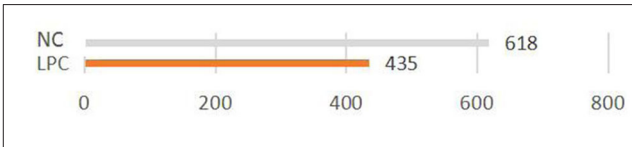

FIGURE 3 | Word clusters of 2 to 7 words with frequencies over 20 in two corpora.

word cluster, the less of the word cluster. According to Xiao [(40), p. 74], standardized word clusters (word clusters/million word times) can be used to measure and compare the distribution of word clusters. Since the size of the two corpora in this study is about 100,000 words, standardized word clusters (word clusters/per 100,000 words) are adopted to measure in this section, as shown in **Figure 4**.

Word cluster is one of the effective means to explore textual features and judge text changes. As shown in **Figure 4**, the overall distribution of the two corpora is consistent, but there are also some changes and overlaps. The distribution proportion of NC word cluster in two words is higher than that in LPC, but the

distribution proportion of other words is lower than that in LPC. In LPC, the number of word clusters of 2–3 words was lower than that of NC, but the number of word clusters of 4–7 words was higher than that of NC, and the gap is increasing. It can be seen that English news texts tend to use shorter word clusters compared with legal policy texts. Compared with news texts, legal policy texts are more likely to have repetitive language fragments or policy names, and **Figure 4** also reflects the high repetition rate of long language fragments containing content words in Legal Policy Corpus. Next, this paper will discuss the distribution information of high frequency words of the two corpora in order to further compare their lexical features.

Distribution Information of High Frequency Words

High frequency word is an important factor to measure language features. It not only reflect text features at the lexical level, but also reflect the areas that a text emphasizes to a certain extent, so as to reflect the focus at the semantic level. Wu (41) conducted a quantitative analysis of high frequency words from the perspective of literature year distribution and high frequency word distribution, and believed that the study of high frequency words was conducive to the integrated analysis of information resources; (42) studied the relationship between recognition of high frequency words from speech and second language (L2) listening comprehension, and believed that high frequency words have important research significance in the field of language acquisition. This section firstly takes Laciosa's definition of high frequency words (the lexical items appear at least 0.10%) as the standard [(43), p. 12], and carries out statistical analysis on the overall characteristics of high frequency words in the two corpora, as shown in **Table 8**.

As shown in **Table 8**, The number of high frequency words in English NC is more than that in Chinese LPC, and in English NC, the proportion of the token of high frequency word in the total token of the corpus is significantly higher than that in Chinese LPC. High frequency words show a high frequency in English corpus. From the perspective of practical application, the language of news is more active and covers a wide range than legal provisions; in terms of language categories, English has more morphological and lexical changes than Chinese. In order to further investigate whether the number of high frequency words affected by genre, on the basis of [(40), p. 67] statistical method to analyze high frequency words, ultra high frequency word (≥0.5% of total corpus), high frequency word (≥0.07% of total corpus),

TABLE 7 | Word clusters information of 2 to 7 words with frequencies over 10 in two corpora.

	LPC	NC
word clusters of two words	854	1,298
word clusters of three words	299	388
word clusters of four words	175	103
word clusters of five words	117	34
word clusters of six words	92	10
word clusters of seven words	72	2
Total	1,609	1,835

TABLE 8 | High frequency word distribution basic information of LPC and NC.

	LPC	NC
Number of high frequency words	61	113
Token Ratio of high frequency words	24.72%	50.38%
Type Ratio of high frequency words	0.86%	1.29%

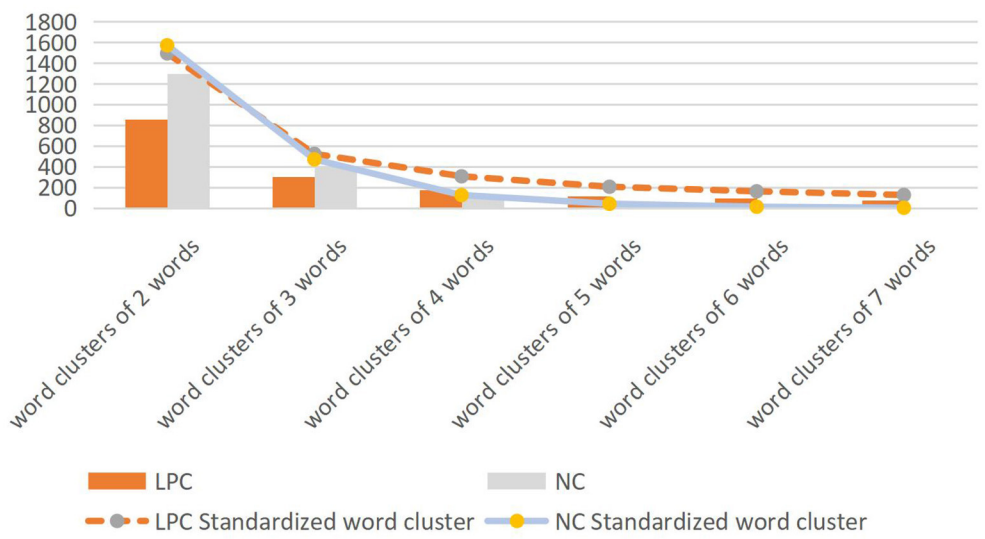

FIGURE 4 | The number of word clusters and the distribution of standardized word clusters.

	≥0.5%	≥0.1%	≥0.07%	≥0.03%	≥0.02%
LPC (number)	2	61	122	381	558
LPC (token ratio)	4.40%	24.72%	34.27%	56.58%	64.76%
NC (number)	20	113	194	471	722
NC (token ratio)	31.14%	50.38%	56.94%	68.77%	74.71%

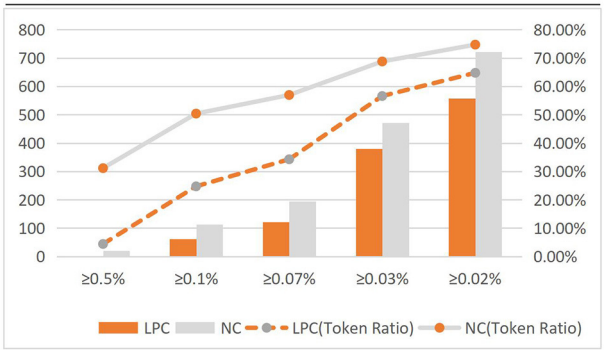

FIGURE 5 | Token ratio distribution of high frequency words of LPC and NC.

	≥0.5%	≥0.1%	≥0.07%	≥0.03%	≥0.02%
LPC (number)	2	61	122	381	558
LPC (type ratio)	0.03%	0.86%	1.71%	5.35%	7.84%
NC (number)	20	113	194	471	722
NC (type ratio)	0.23%	1.29%	2.21%	5.37%	8.23%

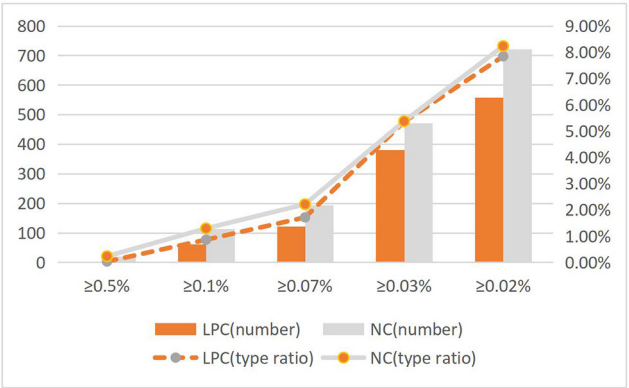

FIGURE 6 | Type ratio distribution of high frequency words of LPC and NC.

high frequency word (≥0.05% of total corpus), secondary high frequency word (≥0.03% of total corpus) and secondary high frequency word (≥0.02% of total corpus) of the two corpora will be further investigated, in order to increase the accuracy of the high frequency word distribution information.

As shown in **Figure 5**, the number of high frequency words in Chinese LPC is lower than that in English NC in all categories, and the token ratio of high frequency words in English NC is higher than that in Chinese LPC, and the token ratio of high frequency words of both LPC and NC is on the rise.

Compared with ultra high frequency words and high frequency words, NC's secondary high frequency words were significantly higher than LPC's. Therefore, the token ratio of ultra high frequency words, high frequency words and secondary high frequency words in the two corpora follows a certain rule, but there are also some differences. Now, the distribution information of type ratio of high frequency words of LPC and NC is analyzed, as shown in **Figure 6**.

As shown in **Figure 6**, the type ratio of high frequency words of English NC is higher than that in Chinese LPC in all categories. But unlike the token ratio, the type ratio curves of the two are basically similar, and even almost identical in secondary high frequency words (≥0.03% of total corpus). There are only slight differences between them in ultra high frequency words and high frequency words, but no significant differences in the whole. The difference in the number of secondary high frequency words (≥0.02% of total corpus) between them is the largest.

The research shows that compared with Chinese LPC, English NC uses more secondary high frequency words with more types, while the Chinese LPC tends to use fewer high frequency words, which further illustrates the influence of different texts on the use of language vocabulary. This study discusses the distribution of high frequency words, and adopts the method of observing the number of high frequency words, token-type ratio and the change of the ratio, which is helpful to understand the influence of the quantitative dimension of language index on the description of different types of text. But, in the legal text and news text, it is the content words that play the main semantic role. The study of the token-type distribution of high frequency words alone is not enough to explore whether the focus and concern of the two corpora are consistent. Therefore, the next section will compare the high frequency content words and their collocations of the two corpora in order to discuss whether the focus and value of the two corpora are consistent.

High Frequency Content Words and Their Collocations

According to AntConc 3.4.4w, the content words ranked top eleven in frequency in the two corpora are shown in **Table 9**.

Table 9 shows that "development" is the most high frequency word in the two corpus (excluding proper nouns and verbs that have no specific meaning). It can be seen that "development" is the focus of economic laws, policies and economic news in China during the COVID-19 pandemic. Due to the COVID-19 pandemic, the world economy has been affected, and economic development has naturally become the focus of the economic field, which is clearly reflected in China's economic laws, policies and news during this period. "Development" is a relatively abstract concept, as a symbol, it has the feature of temporality and spatiality, that is, it has different forms of expression and meaning in different fields and periods. In addition, it can also be found that the word "said" has a high frequency in the news text. In this study, the concordance function of AncConc 3.4.4w was used to investigate the collocations of the word "development" in the two corpora, so as to more comprehensively understand its expression meaning, as shown in **Table 10**.

TABLE 9 | Content words ranked top eleven in frequency in the two corpora.

LPC		NC	
Word	**Frequency**	**Word**	**Frequency**
发展 (development)	801	China	1,614
企业 (enterprise)	756	Said	1,117
服务 (service)	538	Development	501
疫情 (COVID-19)	517	Global	466
建设 (construction)	507	World	444
工作 (job)	487	Economic	440
经济 (economy)	486	Market	420
推进 (improvement)	463	Growth	355
改革 (reform)	414	International	350
政策 (policy)	387	Cooperation	284
管理 (management)	341	Recovery	263

TABLE 10 | Collocations of "development" in the two corpus.

LPC	NC
经济社会发展 (economic and social development)	Stage of development
规划发展 (planning and development)	Development stage
发展战略 (development strategy)	Development area
改革发展 (reform and development)	Investment and development
发展要求 (development requirement)	Global development
企业发展质量 (enterprise development quality)	New technology development
发展定位 (development orientation)	Boosting regional development
发展目标 (goal of development)	Development for recovery
发展的原则 (principles of development)	Development of high-tech
发展理念 (concepts for development)	Development in Shanxi
协调发展 (coordinated development)	Development in China
发展计划 (development planning)	Development and cooperation
高质量发展政策 (high-quality development policies)	Development of foreign trade
发展规范 (development norm)	Sustainable development
发展规划纲要 (outline of development plan)	Development and prosperity
加快发展 (speed up development)	Development of China's film
发展氛围 (atmosphere of development)	Achieving development

Table 10 shows that there are differences in development perspectives between the Legal Policy Corpus and the News Corpus. For example, LPC pays more attention to the development at the macro level, locating and naturalizing the whole development from the direction, plan and other aspects; NC, on the other hand, pays more attention to the development at the micro level, showing the concrete achievements and practices of development from the practical perspective. Even though "development" is mentioned by both, the legal policy plan for development, while the news focuses on the results and effects of development.

DISCUSSION

Word Length Features of LPC and NC

Word length is one of the effective standards to measure the difficulty of text and the complexity of language units. Zipf [(32), p. 38] discovered the relationship between the occurrence frequency of a word in a text and its frequency rank (ordinal number), and proposed Zipf's law. Wang (44), Deng & Feng (33), Chen (45) conducted correlation statistics on word length and word frequency, which contributed evidence to relevant theories. In this study, word length is also used as the research index of lexical text characteristics. The results show that word length and frequency of the two corpora are influenced by language and style to a certain extent, and the relationship between them accords with the economic principle of language on the whole. The more letters in a word, the fewer words there are.

Kendall's tau-b grade correlation coefficient test can also prove that LPC is significantly correlated with NC word length distribution ($p < 0.001$) (**Table 4**). (46) believed that disyllabic words are the most common verbs in modern Chinese, while monosyllabic words are mostly action verbs. There are more 2-letter words in Chinese, followed by 1-letter words, while there are more multi-syllable words in English, which accords with the main characteristics of the distribution of disyllable word length in Chinese and English. As can be seen from **Figure 1**, with the increase of word length, the number of words in the two corpora decreases as a whole, which can reflect that the word length distribution of the two corpora basically conforms to the Principle of Least Effort.

But different data are different in function distribution and matching degree, curve fitting is one of the basic methods in experimental data processing. In this study, curve fitting is used to discuss the distribution of word length and frequency of the two corpora. Gong [(47), p. 73] conducted a functional curve analysis of the distribution of word length and frequency in the study of legal translation visibility, and believed that Chinese texts were more in line with the power function distribution, while English texts were more in line with the logarithmic and exponential function distribution. However, this study shows that English texts do not conform to the logarithmic function distribution, but only to the exponential function distribution, which also reflects that different genres (law and news) have certain influence on the distribution characteristics of word length and frequency.

Word Cluster Characteristics of LPC and NC

Word cluster has both lexical and grammatical features and can reflect the characteristics of language repetition. It can be stored and used as a whole (48), thus virtually reducing the burden of language processing and output and making language communication more efficient, fluent and effective (49). Biber (50), Cortes (51), and other scholars analyzed the high frequency word clusters in discourse. Now, the study of word clusters is

one of the main fields of corpus linguistics, and they regard word clusters as the meaning units in language (52, 53).

In this study, word cluster is used as the index of lexical text repetition rate. The results show that the frequency trend of word clusters in the two corpora is basically the same, the more words in the word cluster, the less of the word cluster.

Compared with English news texts, Chinese legal texts tend to use longer word clusters, and repetitive language fragments are more likely to occur. To a certain extent, legal policies are more standardized and rigorous than news, requiring the approval of state organs at all levels and certain normative requirements for the overall macro situation. Therefore, specific words or phrases, such as specific institutions, policies and regulations, are more often used. News language is relatively free, and the reader is people at all levels. Therefore, the language is more lively and more simple, and short words are used to make it easier for readers to accept it quickly.

Distribution Characteristics of High Frequency Words of LPC and NC

Word frequency refers to the number of occurrences of specific words in a text, which to some extent reflects the stylistic characteristics of a text and is an important reference index for discovering stylistic or stylistic characteristics (54). High frequency words are often used in corpus research, which can reflect the integration of text to information resources and text focus. Johansson (55) compared and analyzed the 50 words with the highest word frequency in the corpus of academic text and fiction text, and found that some words belong to the corpus of academic text, while some specific words belong to the corpus of fiction text, which indicates that the high frequency words are different with different linguistic contexts.

Gong [(47), p. 89] combined with previous studies, discussed the distribution of high frequency words and rare words, adopted the method of mutual evidence of the difference between the proportion changes of token ratio and type ratio, and believed that high frequency words are related to the translation. This paper also discusses the distribution of high frequency words in the two corpora by observing high frequency word type ratio and token ratio, and finds that type ratio and token ratio of high frequency words in English NC are significantly higher than that in Chinese LPC.

In the aspects of ultra high frequency word ($\geq$0.5% of total corpus), high frequency word ($\geq$0.07% of total corpus), high frequency word ($\geq$0.05% of total corpus), secondary high frequency word ($\geq$0.03% of total corpus) and secondary high frequency word ($\geq$0.02% of total corpus), Chinese LPC is lower than English NC. Based on the statistics of the distribution information of token ratio and type ratio of high frequency words of the two corpora, this study finds that, compared with Chinese LPC, English NC tends to use secondary high frequency words with rich types. The legal policy corpus use fewer high frequency words, which further demonstrates that high frequency words are also associated with different text categories or genres.

"From the distribution features of semantic categorization, verbs related to psychology, life activities and social activities are used more frequently" (46). There are few changes of morphology and vocabulary in Chinese, and the language of legal policy is less flexible than that of news. The news language covers a wide range, and there are many changes in English tenses and forms, which have a certain influence on the distribution of high frequency words. "Analysis of word frequency distribution shows that functional words in news headlines are often omitted. No frequent use of first and second person pronouns, the word 'say' is frequently used and the words of news have the characteristics of the times (54). Therefore, high frequency words are not only influenced by translation, but also by different languages, styles or genres.

Interpretation of High Frequency Content Words and Their Collocation in LPC and NC

Since, Firth [(56), p. 12] first put forward the concept of lexical collocation, Halliday, Sinclair and other scholars have carried out a series of pioneering researches on the definition of collocation and related terms: [(57), p. 284–87] put forward the concept of collocation and cohesion in a text, believing that the collocation of words is the function of cohesion in a text. Leech [(58), p. 17] put forward the Collocation Semantic Theory and defined the collocation semantic meaning of words as the relevant meaning obtained from the meaning of context words. Li (59) discussed the collocation characteristics of grammatical words and content words in the report and the address, and found that the two collocation frames are quite different, and the collocation frames with the same form have different semantic trends and pragmatic functions.

The study of high frequency words and their collocation features is also reflected in the field of legal language, Cheng and Pei (60) makes a semiotic explanation of the high frequency words and their collocation in network security law, and believes that legal terms are a kind of symbol with the characteristics of temporality and spatiality. Hu and Qian (61) compared and analyzed the interaction and mutual influence between language and politics in the "Work report of the Chinese Government" and the "State of the Union Address of the United States" based on the collocation features of "develop."

In this study, the high frequency content words in the two corpora are counted, and the data showed that the frequency of "development" was the highest in both corpora. During the COVID-19 period, the economy was affected by the COVID-19 pandemic. "During the Spring Festival alone in 2020, 78% of the catering enterprises lost 100% of their income, 80% of the wholesale and retail industry stagnated, and the entertainment and tourism industry declined by about 85% compared with the same period last year" (62). The outbreak of large-scale pandemic not only seriously threatened public health security, but also had a significant impact on the stable development of the economy. The outbreak has led to a halt in economic activities, leading to economic recession, which can only be alleviated by the resumption of economic activities (i.e., economic development) after the outbreak is under control. Therefore, "the policy of pandemic prevention and control is also the policy of economic recession mitigation" (63). Therefore, economic development

is the focus of economic laws, policies and news during the pandemic.

According to the statistics of high frequency content words, the word "said" appears frequently in news corpus, which is in pursuit of timeliness and authenticity. "Said" can directly reflect the interviewees' original words and attitudes, increase the authenticity and credibility of news, and at the same time give news text the characteristics of simplicity and directness of vocabulary. On the contrary, legal policies need to be checked by governments at all levels or relevant personnel, and the language needs to be highly normative. Personal subjective words are strictly prohibited, so related words such as "said" which are optional will not be used.

In terms of the collocation of high frequency word "development," the two have different standpoint, which reflects their different perspectives of development. The fuzziness, accuracy and normality of legal discourse are its three main characteristics. In legal policies, there are often appears the word "idea," "required" and others which can fully guarantee legal language extension of concept and expand to the scope of the law requires it, and "improve the flexibility and applicability of the law, make up of a series of problems brought by the legal lag, provided judges greater discretion, so as to achieve judicial justice as far as possible" (64). This is also reflected in the results of this study. LPC pays more attention to the development at the macro level, and the words that collocated with "development" are mostly "plan," "positioning," "goal," "requirement," "strategy" and other words for the overall situation. The aim is to provide a framework for economic development that can be referenced and standardized in countries affected by the pandemic, to provide a development framework for relevant economies (such as enterprises and factories), and to make plans for national economic recovery.

Compared with the tedious and formal written language of legal policy, "colloquialism is more and more easy to understand and accept in news" (65). Nowadays, "news reports play an important role of spiritual guidance and cultural guidance, which requires news language to be rational and consistent with national policies, considering the needs of the public, and expressing in the way of public thinking" (66). The results of this study also reflect this. NC pays more attention to the development at the practical level, and starts with the policy implementation effect and the real-time overview of economic recovery to display the domestic economic development. In terms of collocation words, NC uses more vivid words such as "stage," "area," "recovery" and "high-tech," or analogies or extensions, to report the actual economic development results.

Although they have different perspectives, they share a positive attitude toward economic development. In different ways, the two show the importance of national economic recovery and hold a positive attitude toward it. National economic policies have actively set the development direction for the economies of the affected countries during the pandemic period, targeted the development of economies at all levels, formulated development goals and plans, and actively promoted national economic recovery. Economic news reports are objective and fair, keeping pace with national policies and truly showing the domestic economic development under national policies. At the same time, the news also gives full play to its advantages of international communication, actively responds to the requirements of national development strategy and enterprise development positioning, makes use of its own platform, actively appeals for international cooperation and investment, and objectively presents the real economic situation of China on the international level.

CONCLUSION AND IMPLICATION

By means of corpus analysis, this paper finds that English economic news texts and Chinese economic legal policy texts share certain commonalities and also have some differences in the distribution of word length, word frequency, word cluster and the collocation of high frequency words, which reflects certain synchronicity between legal policy and news.

First of all, the distribution of word length, word frequency, word clusters and high frequency words are influenced by language and style to a certain extent. The word length and frequency of Chinese words is more in line with the power function distribution, while the word length and frequency of English words is more in line with the exponential function distribution. Due to the difference in genre characteristics between news and law, compared with news texts, legal texts tend to use longer word clusters, and the frequency trend of word clusters is basically the same between them. The feature of word length, word frequency and word cluster of legal policy texts and English texts accord with the economic principle and Principle of Least Effort of language as a whole. The distribution characteristics of high frequency words are also different depending on the genre and language. The type ratio and token ratio of high frequency words in English news texts are significantly higher than those in Chinese legal policy texts, and English news tends to use secondary frequency words with rich types and strong activity.

Secondly, through the analysis of the high frequency content words and their collocations, it can also be found that during the pandemic period, "development" is the focus of China's economic legal policies and economic English news. During the pandemic, the economy was affected by the COVID-19 pandemic. To mitigate the economic recession are an important issue of concern for economic legal policies, and the news provides live coverage of the benefits and results of economic policies. In different ways, the two show the importance of national economic recovery and hold a positive attitude toward it. The state has formulated reasonable policies and economic laws for the recovery of affected economies and actively promoted their economic recovery. The news media platform plays its role of international publicity through its advantages of wide dissemination and reader, and actively appeals for international cooperation and investment to show the reality of China's economy. This fully reflects the synchronization of China's economic news and economic legal policies in the field of concern, and maintains a positive and objective attitude toward the economic development during the COVID-19 pandemic.

This study combines the study of lexical features with the study of high frequency word collocation to conduct a macroscopic investigation of internal structure and external environment, thus enriching the study of linguistic lexical features and linguistic sociocultural features, and provide some references for relevant research. Although some differences and commonalities between Chinese legal texts and English news texts can be understood through the comparison of lexical features and collocations, more problems of linguistic complexity and relevance between them need to be further explored.

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

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

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Consumers' decoy effect when purchasing pork with traceability technologies

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Despite government investment, policy guidance, and publicity, it has been difficult to establish a traceable food market in China over the past 2 decades. Once a food safety problem occurs, it is difficult to implement effective traceability, recall, and accountability along the food supply chain. How to use the decoy effect to promote the development of China traceable food market? As bounded rationality, a decoy effect exists when adding an alternative to a choice set increases the chance an existing alternative to be chosen. However, few studies have examined the decoy effect in food purchases. Based on consumers in Wuxi, Jiangsu Province, China, we show the decoy effect in traceable pork hindquarter purchases and that the effects differ across product quality and price attributes. The effects are heterogeneous across consumers and are less likely to occur among those who had a personal annual income of more than 50,000 yuan (USD $7,000), were married, and had minor children in the family. These findings have implications on leveraging the influence of the decoy effect on consumer behavior and facilitating the construction of food traceability systems.

KEYWORDS

traceable pork, decoy effect, individual characteristics, negative binomial count regression, food safety

Introduction

Studies on consumer preferences are often based on the assumption of rational behavior, that is, consumer preferences that satisfy completeness, transitivity, and independence of irrelevant alternatives (1). However, many studies have shown that consumer behavior does not always satisfy all the three characteristics. For example, a decoy effect that violates the independence of irrelevant alternatives is commonly found in consumer preferences, as initially defined by Heath and Chatterjee (2). A decoy effect occurs when the addition of a decoy product or product profile to a core set of products makes the target product or target product profile in the core set more attractive and thus more likely to be chosen by a consumer (3, 4). Gonzalez et al. (5) suggested that the addition of an asymmetrically dominant decoy product or product profile shifts consumer preferences to favor the target product or product profile, indicating bounded rationality. This suggests that the decoy effect results from bounded rational consumption. Consumer behavior and the decoy effect are further associated, whereby the more easily a consumer group is decoyed by a decoy product, the stronger the decoy effect may be on their consumption.

A number of studies have examined the decoy effect. Lin et al. (6) found that limited decision time increased the decoy effect, that is, consumers having insufficient time to evaluate the utility of each product make choices by simply comparing the products on the most salient attribute. Malkoc et al. (7) further argued that negative attributes of a product can reduce the decoy effect because consumers demonstrate low attention to negative attributes. Similarly, Malkoc et al. (8) believed that when consumers make decisions about disliked product options, the decoy effect is weakened due to low product utility and psychological resistance. Frederick et al. (9) found that the use of perceptual stimuli can impair consumer comparison of product utility, thus reducing the decoy effect.

Although the decoy effect and the background under which it occurs have been shown by many studies on household consumer products [e.g., (10)], little is known about those on food products. At the same time, the traceable food market has not really been established effectively in China in terms of the current situation in China. Chinese domestic academic circles have also carried out some research on this issue, but those are mainly based on the rational consumption behavior of consumers and seldom have focused on how to use the decoy effect to promote the development of China traceable food market from the perspective of irrational consumption. In the current study, we investigated the decoy effect in food purchase behavior in the case of traceable pork hindquarters and determined the relationship between individual characteristics and the decoy effect in China, which should provide a theoretical basis for promoting traceable food in China and providing consumers with more traceability information. However, although food has the general attributes of ordinary commodities, such as use value, it also has special attributes that differ from those of ordinary commodities because food safety is closely related to individual and public health (11). Therefore, this study does not encourage the abuse of the decoy effect in food purchase, especially its use to market foods that do not comply with laws and regulations. The primary purpose of studying the decoy effect in food market behavior is to protect the normal operation of the food market under relevant laws and to protect the legitimate rights and interests of consumers in the consumption of food, which is closely related to personal health and welfare.

It should be pointed out that there are also other types of irrational behaviors of consumers, such as compromise and anchoring effects, which are sometimes confused. The compromise effect states that a consumer is more likely to choose the middle or compromise option of a choice set, rather than the extremes, thus leading to a larger share of that option in the choice set. The compromise effect is most likely to occur in the choice decision-making process of consumers (12). Anchoring is a bias in which judgments, estimates, or decisions made by consumers in uncertain situations are affected by the initial reference information (initial anchor), making their subsequent estimates biased toward the initial anchor (13). It can be seen that the decoy, compromise, and anchoring effects can be easily distinguished by comparing their concepts.

Literature review and hypotheses

It is generally believed that the decoy effect is caused by two main factors, namely, decision simplification and utility evaluation of product attributes. (1) Decision simplification: According to Ratneshwar et al. (14), consumers may have difficulty comparing various options in a core set of products if they are unfamiliar with the products and their attributes. The introduction of decoy products can facilitate the pairwise comparison between products (15). The decoy products may highlight the relative advantages and disadvantages of various options in the core set of products, thereby reducing the search costs for product information, simplifying product attribute trade-offs, and altering consumer purchase decisions. (2) Utility evaluation of product attributes: Kahneman and Tversky (16) found that consumers evaluate utility gains or losses of products or product attributes based on differences from a reference point. Wedell and Jonathan (17) also reported that for the same amount of utility gains or losses, consumers often have a higher weight on utility losses than on gains, that is, expression of loss aversion. The introduction of a decoy product may provide a reference point for consumers.

As shown in Figure 1, when a decoy product z is added to a core set containing products x and y with y being the target product to change consumer preferences on, compared with the decoy product z, product x has a utility gain in attribute 1 and a loss in attribute 2, whereas the target product y has a utility gain in both attributes 1 and 2. Therefore, consumers may choose target product y to avoid the utility loss associated

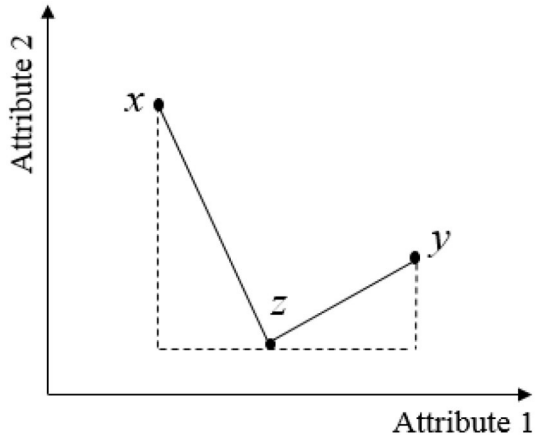

FIGURE 1
Decoy effect from the perspective of loss aversion.

with product x in attribute 1 due to loss aversion. In this case, loss aversion affects consumer choices and can lead to a decoy effect. Ariely and Wallsten (18) suggested that the introduction of a decoy product may also change the weight consumers assign to product attributes, thereby making the target product with a higher weighted attribute more attractive. Again, as shown in Figure 1, after the decoy product z is introduced, if consumers give attribute 1 a higher weight, the utility gain, in other words, the attractiveness of target product y will increase as target product y is superior to product x in terms of attribute 1.

Chernev (19) argued that consumers give attributes that have a strong correlation with their purpose of purchase a higher weight. Müller et al. (20) also demonstrated that decoy products prompt consumer interest and that an attribute may be given a higher utility or weight by consumers if it arouses consumer interest. For example, as Chinese consumers are generally concerned about food (pork) safety, they pay greater attention to attributes reflecting pork safety information on the market, thus assign a higher utility or weight to these attributes (21). In this study, we consider quality attributes of two products: traceability and appearance, in addition to product price. Past studies have rarely considered multiple product attributes.

Research on the correlation between consumer characteristics and the decoy effect shows that consumer characteristics can affect the attribute they would like to know more about and the intensity of the decoy effect on these attributes. For example, Dhar and Glazer (22) found that consumers who have better understanding of a product are less influenced by the decoy effect. Similarly, Ratneshwar et al. (14) pointed out that consumers are prone to the decoy effect if they are unfamiliar with the product attributes. Mourali et al. (23) suggested that the decoy effect is influenced to varying degrees by consumer familiarity with the product and whether they have the intention to seek a gain or avoid a loss. Tentoria et al. (24) and Chang (25) reported that the elderly may have richer purchasing experience. However, only older consumers with expertise in the product of concern make truly rational decisions (26). Consistently, Putrevu and Lord (27) believed that experience and expertise can help consumers make decisions and that consumers more familiar with the product and more experienced in purchase and use are more rational in purchase decision-making. The aforementioned conclusions are also supported by Rao et al. (28) and Li and Zhou (29).

However, Shafir et al. (30) found that the ability of a consumer to make rational purchase decisions declines with age, and older consumers are likely to be more irrational in purchasing. Furthermore, Zhen and Yu (31) reported that consumers of all age-groups are likely to experience the decoy effect to varying degrees, except for subjects younger than 5 years as this age-group is not fully capable of identifying and evaluating products. In addition, Dholakia (32) found that the probability of irrational purchase behavior is significantly lower in men than in women. Dittmar et al. (33) confirmed that female consumers are more prone to irrational purchases, thus more likely to experience the decoy effect. Wood (34) showed that low-income consumers are also more likely to experience contextual effects. Moreover, related studies suggest that family size (35), income (36), occupation (37), marital status, and presence of minor children in a family (28) can have different degrees of impact on irrational consumer behavior.

The aforementioned studies on the correlation between consumer characteristics and the decoy effect have only investigated the relationship between one or very few individual characteristics and the decoy effect. Various individual characteristics have rarely been included in a single framework to examine the correlations between them and the decoy effect. Moreover, most existing literature in this field has focused on the purchase of general goods, with limited research conducted on food purchase. Food has the common attributes of general goods. However, given the importance of food safety to health, food has attributes that are of greater concern to consumer health. Thus, in the current study, we analyze the impact of consumer characteristics on decoy effect in food purchase. We conduct a survey of consumers in Wuxi, Jiangsu Province, China, taking traceable pork hindquarter purchase as an example. We establish the following hypotheses:

H1: There is no decoy effect in the purchase of traceable pork hindquarters.
H1-1: Assume there is a decoy effect; the effect does not change across difference product attributes.
H2: Decoy effect in the purchase of traceable pork hindquarters does not vary with demographic characteristics, which can be tested by specific hypotheses:
H2-1: Decoy effect does not vary with age.
H2-2: Decoy effect does not vary with gender.
H2-3: Decoy effect does not vary with marital status.
H2-4: Decoy effect does not vary with annual income.
H2-5: Decoy effect does not vary with family size.
H2-6: Decoy effect does not vary with the presence or absence of minors in household.
H2-7: Decoy effect does not vary with occupation.

Survey design, implementation, and sample analysis

China is the world's largest producer and consumer of pork. China's pork production and consumption in 2018 accounted for 47.82 and 48.55% of global pork production and consumption, respectively.[1] As pork is the most popular meat in China, consumers are very familiar with it, which allows us to avoid

1 Data source: National Bureau of Statistics of China (ed.): China Statistical Yearbook 2018, China Statistics Press, 2018.

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the possible additional decoy effect caused by unfamiliarity with the basic characteristics of the product itself (14). However, pork is also one of the food categories facing the most food safety concerns in China (38). The Chinese government has committed to developing a traceable pork market for many years. Therefore, traceable pork (specifically, traceable pork hindquarters) was selected as the target product in this study. Limiting to pork hindquarters helps reduce the need to consider the price–product dynamics of various types of pork cuts.

It should be noted that traceable pork hindquarters are not yet widely available on the Chinese market, and the various types of traceable pork hindquarters the policymakers are interested in exploring do not exist in the market. Thus, we used hypothetical pork profiles (for simplicity, traceable pork hindquarter profiles are also interchangeably referred to as traceable pork hereafter) and established the attributes of traceable pork in our design. As noted previously, consumer familiarity with a product can influence the decoy effect. As traceable pork is not yet popular on the market, we assume consumer familiarity with this product is generally identical across individuals. Therefore, using traceable pork as the target product could exclude the influence of factors other than consumer characteristics on the decoy effect.

Traceability information reflects different characteristics of different types of traceable pork. In total, three levels of traceability information were defined according to the characteristics of Chinese hog suppliers: (1) farming alone; (2) farming, slaughtering, and processing; and (3) farming, slaughtering, processing, and distribution (39). For example, if a consumer chooses pork with traceability information covering farming alone, they can only obtain information about the farming process. More traceability information makes identification of possible food safety risks more conveniently. A second pork attribute considered in this study is pork appearance. Numerous studies have shown appearance being an important factor affecting the consumer evaluation of product quality (40–43). Based on discussion with food scientists, we define pork appearance in three levels: fresh, moderate, and unappealing but palatable. Table 1 presents two types of pork products. Type 1 traceable pork contains only traceability and price information; four such products are designed and denoted by *a*, *b*, *c*, and *d*, respectively. Type 2 traceable pork considers traceability, price, and appearance; five products are created under type 2, and are denoted by e, *f*, *g*, *h*, and *i*, respectively.

Compared to non-traceable pork, the production of traceable pork with attributable information involves additional costs, which may, in turn, increase the market price of pork. As mentioned earlier, the traceable pork in this study with different traceability attributes does not currently exist on the market. Therefore, their associated prices were determined based on previous research. Specifically, as the present study was conducted in the same location (i.e., Jiangsu Province) and at a similar time as Wu et al. (44), the same price levels were chosen. Table 1 also present the prices.

TABLE 1 Attributes and levels of pork.

Type 1 traceable pork

Traceable pork	***a***	***b***	***C***	***d***
Traceable information	With traceability information on farming	With traceability information on farming, slaughtering, and wholesale	With traceability information on farming, slaughtering, and wholesale	With traceability information on farming and slaughtering
Price (yuan/500 g; 1 yuan≈0.15 USD)	14	16	18	16

Type 2 traceable pork

Traceable pork	***e***	***f***	***G***	***H***	***i***
Traceable information	With traceability information on farming	With traceability information on farming, slaughtering, and wholesale	With traceability information on farming and slaughtering	With traceability information on farming and slaughtering	With traceability information on farming
Appearance	Moderate	Unappealing but palatable	Fresh	Moderate	Fresh
Price (yuan/500 g; 1 yuan≈0.15 USD)	13.5	14.5	15	15	15

Based on the aforementioned settings of traceable pork, a total of six contexts (scenarios) were designed. Contexts 1–3 were designed for type 1 traceable pork, where option *b* was the target traceable pork, and contexts 4–6 were created for type 2 traceable pork, where option *f* was the target traceable pork. The six contexts are as follows:

Context 1: With no decoy pork, survey participants were asked to choose between two subtypes of type 1 traceable pork, namely, *a* and *b* in Table 1, expressed as $\{a, b\}$.

Context 2: With the introduction of decoy pork *c*, participants were asked to choose among three subtypes of type 1 traceable pork, namely, *a*, *b*, and *c* in Table 1, expressed as $\{a, b, c\}$.

Context 3: With the introduction of decoy pork *d*, participants were asked to choose among three subtypes of type 1 traceable pork, namely, *a*, *b*, and *d* in Table 1, expressed as $\{a, b, d\}$.

Context 4: With no decoy pork, participants were asked to choose among three subtypes of type 2 traceable pork, namely, *e*, *f*, and *g* in Table 1, expressed as $\{e, f, g\}$.

Context 5: With the introduction of decoy pork *h*, participants were asked to choose among four subtypes of type 2 traceable pork, namely, *e*, *f*, *g*, and *h* in Table 1, expressed as $\{e, f, g, h\}$.

Context 6: With the introduction of decoy pork *i*, participants were asked to choose among four subtypes of type 2 traceable pork, namely, *e*, *f*, *g*, and *i* in Table 1, expressed as $\{e, f, g, i\}$.

H1 can be tested by calculating the purchase share of option *b* in contexts 1 and 2, with *P1 (b, a)* defined as the share of *b* in context 1, $\{a, b\}$, and $P2_c$ *(b, a)* defined as the share of the target option *b* in context 2 after the addition of option *c*. If *P1 (b, a)* $\geq$ $P2_c$ *(b, a)* is rejected, H1 is subsequently rejected. In other words, the "decoy effect in purchases of traceable pork" is supported [i.e., *P1 (b, a)* $<$ $P2_c$ *(b, a)*]. Similarly, H1 can also be tested by calculating the purchase share of option *b* in contexts 1 and 3, purchase share of option *f* in contexts 4 and 5, and purchase share of option *f* in contexts 4 and 6. If the null hypothesis H1 is rejected, the existence of the decoy effect is supported, that is, *P1 (b, a)* $<$ $P3_d$ *(b, a)*, *P4 (g, e, f)* $<$ $P5_h$ *(g, e, f)*, and *P4 (g, e, f)* $<$ $P6_i$ *(g, e, f)*, respectively. Hypothesis H1-1 can be checked by testing the equality between $P2_c$ *(b, a)* and $P3_d$ *(b, a)* since they differ by the attribute the decoy effect is intended to operate on. Similarly, hypothesis H1-1 can be tested by examining whether $P5_h$ *(g, e, f)* and $P6_i$ *(g, e, f)* are equivalent. We further constructed a negative binomial count regression model based on the changes in purchases of types 1 and 2 traceable pork after the addition of decoy traceable pork *c*, *d*, *h*, and *i* in order to investigate the correlation between individual characteristics and the decoy effect, thereby testing hypotheses H2 (H2-1 to H2-7).

This study implemented a consumer survey in Wuxi, one of the first Chinese pilot cities to introduce limited traceable pork in 2010 as a joint effort by the Ministry of Commerce and the Ministry of Finance. As such, consumers in Wuxi have some basic, but not intensive, understanding of traceable pork attributes, which helps reduce consumer bias due to product unfamiliarity. Based on this, we investigated whether the decoy effect exists in the purchase of traceable pork hindquarters among consumers in Wuxi. Moreover, Wuxi is one of the largest cities in eastern China, with a high level of economic development, dense population, and wide distribution of individuals with different demographic characteristics, which contribute to the diversity and representativeness of the samples. In addition, to improve representativeness of the samples, this study was conducted in all five administrative districts of Wuxi in large- and medium-sized supermarkets, farmers' markets, and pork shops. For the sake of simplicity, 50 participants aged 18–65 years were recruited in each district, for a total of 250 participants. Every third consumer coming into view was recruited by the research team. The questionnaire was completed by local graduate students *via* face-to-face communication with the participants. The entire study was performed from 10 to 14 August 2021. In total, 241 valid questionnaires were obtained.

The participants were not required to make actual purchases, but actual pork products were on display at each survey site with varying levels of appearance corresponding the levels considered in this study. Each participant was asked to evaluate both types of pork, but the two types of pork were presented in random orders (either contexts 1–3 appeared first or contexts 4–6 appeared first). To resemble a real market, QR codes, as an example shown in Figure 2, were designed for each type of traceable pork. The participants could obtain information on quality and safety of the corresponding traceable pork by scanning the QR code. To remove the order effect, for type 1 traceable pork, the participants were first shown context 1, and then contexts 2 and 3 were presented in a random order. Similarly, for type 2 traceable pork, the participants were first shown context 4, and then contexts 5 and 6 were presented randomly. Each participant was paid 20 yuan (one CNY$\approx$ 0.15 USD at the time of the study) to compensate for their time.

Participant demographic characteristics are shown in Table 2. Women accounted for 52.70% of the sample, which coincides with the fact that women are the major food shoppers in most urban families of China. In addition, 79.26% of participants were aged between 18 and 48 years, 59.75% were married, 67.64% had a junior college or college education, and 36.52% had a family size of three. The participants with an annual personal income before tax of $<$100,000 yuan accounted for 88.38% of the sample. Other demographics, such as the presence or absence of minor children in the family, self-reported health status, and occupation, are also listed in Table 2. It should be noted that there are certain differences between the sample and overall demographics of Wuxi. The main reason is that participants were recruited during specific hours of the day, that is, 08:00–10:00 and 16:00–18:00, two periods when most family food shopping is done. Thus, it is not surprising that the demographics of the participants randomly recruited during these time periods are not consistent with those of the urban population of Wuxi. However, this does not compromise

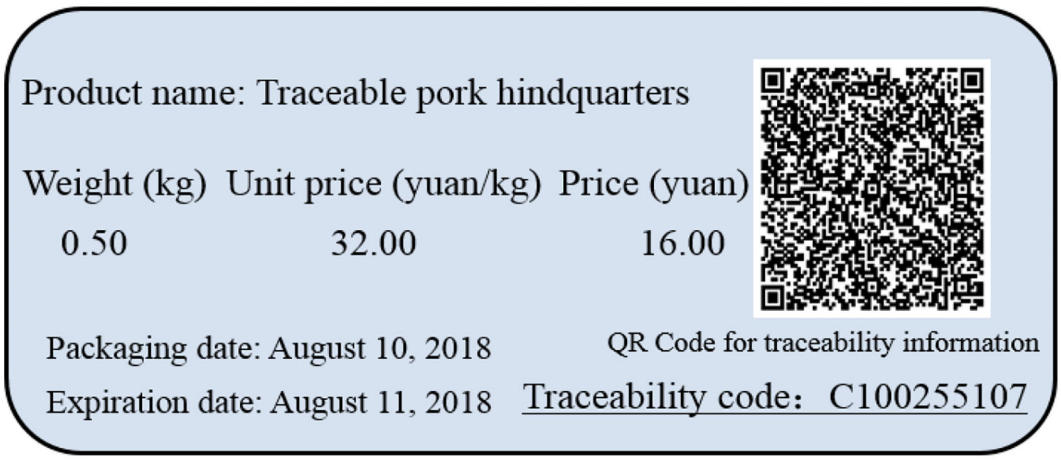

FIGURE 2
QR code for traceable pork hindquarters.

the representativeness of the survey sample. In fact, the sample demographics of this study are generally consistent with those reported by Wu et al. (21) conducted in the same area.

Measures of the decoy effect and result

The decoy effect is measured according to Mourali et al. (23):

$$\Delta P = P_z\left(y; x\right) - P\left(y; x\right) \quad (1)$$

where ΔP is the decoy effect, is the purchase share of option y relative to option x in the choice set $\{x, y\}$, and is the purchase share of target option y relative to option x in the choice set $\{x, y, z\}$, and is calculated as follows:

$$P_z(y; x) = \frac{P(y; x, z)}{[P(y; x, z) + P(x; y, z)]} \quad (2)$$

where is the purchase share of the target option y relative to options x and z in the choice set $\{x, y, z\}$ and is the purchase share of option x relative to options y and z in the choice set $\{x, y, z\}$.

In context 1, that is, choice set $\{a, b\}$, the purchase shares of a and b were 28.63 and 71.37%, respectively. In contexts 2 and 3$\{a, b, d\}$, the purchase shares of target option b were 64.73 and 74.27%, respectively. As shown in Figure 3, the purchase share of option b relative to option a increased from 71.37% in the choice set $\{a, b\}$ of context 1 to 76.85% in the choice set $\{a, b, c\}$ of context 2 and to 79.91% in the choice set $\{a, b, d\}$of context 3, respectively. Hence, ΔP = 5.48% [= 42.95, $p <$ 0.001] and 8.54% [χ^2 (2)= 47.11, $p <$ 0.001], respectively, when comparing context 2 and 3 to context 1. Therefore, H1 is rejected, supporting *P1 (b, a)* <$P2_c$ *(b, a)*, and *P1 (b, a)* < $P3_d$ *(b, a)*, that is, a decoy effect exists. In contexts 4, 5, and 6, decoy effects observed after the addition of decoy traceable pork h and i on to the choice set $\{e, f, g\}$were ΔP = 17.7% [χ^2 (2) = 23.48, $p <$ 0.001] and ΔP = 20.60% [χ^2 (2) = 31.28, $p<$ 0.001], respectively. Similarly, H1 is rejected, supporting *P4 (g, e, f)*<$P5_h$ *(g, e, f)*, and *P4 (g, e, f)* <$P6_i$ *(g, e, f)*. Therefore, a decoy effect appears to exist in purchases of traceable pork.

As shown in Figure 3, $P3_d$ *(b, a)* > $P2_c$ *(b, a)* [χ^2 (2) = 25.62, $p<$ 0.001] and $P6_i$ *(g, e, f)* > $P5_h$ *(g, e, f)* [χ^2 (2) = 13.63, $p<$ 0.05]. This shows that different decoy traceable pork provided different reference points for the participants, thus inducing different levels of decoy effects. Comparing products b and c, product c had identical traceability information as b but was more expensive by two yuan. Comparing products b and d, product d was offered at the same price as b but could not reveal traceable information on the wholesale process. As a result, in this application, the decoy effect generated by a two-yuan difference is less than the traceable information on the wholesale process, providing evidence to reject H1-1. For type 2 traceable pork, both decoy products h and i had the same price as the target product g. Product h offered the same traceability information as product g but was less appealing in appearance (moderate vs. fresh). Product i was at the same level of appearance as target product g but did not offer traceability information regarding the slaughtering process. The result indicated that product i generated a stronger decoy effect than product h, thus also rejecting H1-1.

Regression analysis

We further adopted a negative binomial count regression model to investigate the correlations between individual

TABLE 2 Participant demographics.

Demographic	Category	Sample size (*n*)	Proportion (%)
Gender	Male	114	47.30
	Female	127	52.70
Age	18–28 years	98	40.67
	29–48 years	93	38.59
	49–65 years	50	20.74
Marital status	Married	144	59.75
	Unmarried	97	40.25
Family size (*n*)	1	11	4.56
	2	39	16.18
	3	88	36.52
	4	45	18.67
	5 or more	58	24.07
Education	Primary school or below	7	2.90
	Junior high school and high school (including vocational high school)	65	26.97
	Junior college	62	25.73
	College	101	41.91
	Graduate and above	6	2.49
Personal income before tax	<50,000 yuan	135	56.02
	50,000–100,000 yuan	78	32.36
	More than 100,000 yuan	28	11.62
Presence or absence of minor children in family	Absent	139	57.68
	Present	102	42.32
Health (self-assessed)	Very poor and poor	2	0.83
	Moderate	25	10.37
	Healthy and very healthy	214	88.80
Occupation	Government employee	2	0.83
	Employee of public and private enterprises	125	51.87
	Farming	14	5.81
	Student	28	11.62
	Other	72	29.88

characteristics and the decoy effect, thereby testing hypotheses H2 and $H2_1$ to $H2_7$. In the current study, under the decoy effect, the participants changed their purchase decision due to the presence of decoy products. We define y_i as the number of times consumers changed their decision from a competitive traceable pork to the target traceable pork after the addition of decoy traceable pork *c*, *d*, *h*, and *i*. Therefore, y_i can take a value of 0, 1, 2, 3, or 4. As the dependent variable is a non-negative integer and to allow over-dispersion, we used a negative binomial count regression model with a probability of y_i defined as follows:

$$P\{yi\} = \frac{\lambda^{y_i}}{y_i!} e^{-\lambda} \quad y_i = 0, 1, 2, 3, 4 \tag{3}$$

where λ is a parameter taking only positive values. In addition, it is assumed that parameter λ is determined by dependent variables X_i. The negative binomial count model can then be estimated by maximum simulated likelihood over sample N:

$$\sum_{i=1}^{N} Ln\left(\frac{1}{K}\sum_{j=1}^{K}\tilde{f}(y_i \left| X_i, \theta, u^j{}_i\right.)\right) \tag{4}$$

where $\theta > 0$, $\mu_i = e^{X_i'\beta}$, and $\beta > 0$. θ is a shape parameter, β is a scale parameter, K is the number of simulations, and X_i is a group of demographics affecting the decoy effect. Table 3 presents the definition and measurement of each variable. The estimation was performed using Stata 14.0, and the results are shown in Table 4.

As shown in Table 4, variable X_1 (29- to 48-year age-group) and variable X_2 (49- to 65-year age-group) were not significant; thus, H2-1 could not be rejected. Variable X_3 (male participant) was also not significant; thus, H2-2 could not be rejected. The coefficient of the variable representing whether the participant was married (X_4) was negative and significant at the 1% level; thus, H2-3 could be rejected. Compared with unmarried participants, married participants were less likely to experience the decoy effect.

The coefficients of variables X_5 and X_6 (representing the annual income of 50,000–100,000 yuan and more than 100,000 yuan, respectively) were negative and significant at the 1% level, thus rejecting H2-4. Therefore, compared with participants with an annual pre-tax income of <50,000 yuan, those with a higher annual income were less likely to experience the decoy effect. This result is consistent with the conclusions of Wood (34) but differs from that of Lin and Lin (36). Variables X_7 (family size of 3 or 4) and X_8 (family size of 5 or more) were not significant, so H2-5 could not be rejected. The coefficient of the variable X_9 (presence of minor children in the household) was negative and significant at the 1% level; thus, H2-6 could be rejected. This indicated that compared with participants who did not have minor children at home, those who did were

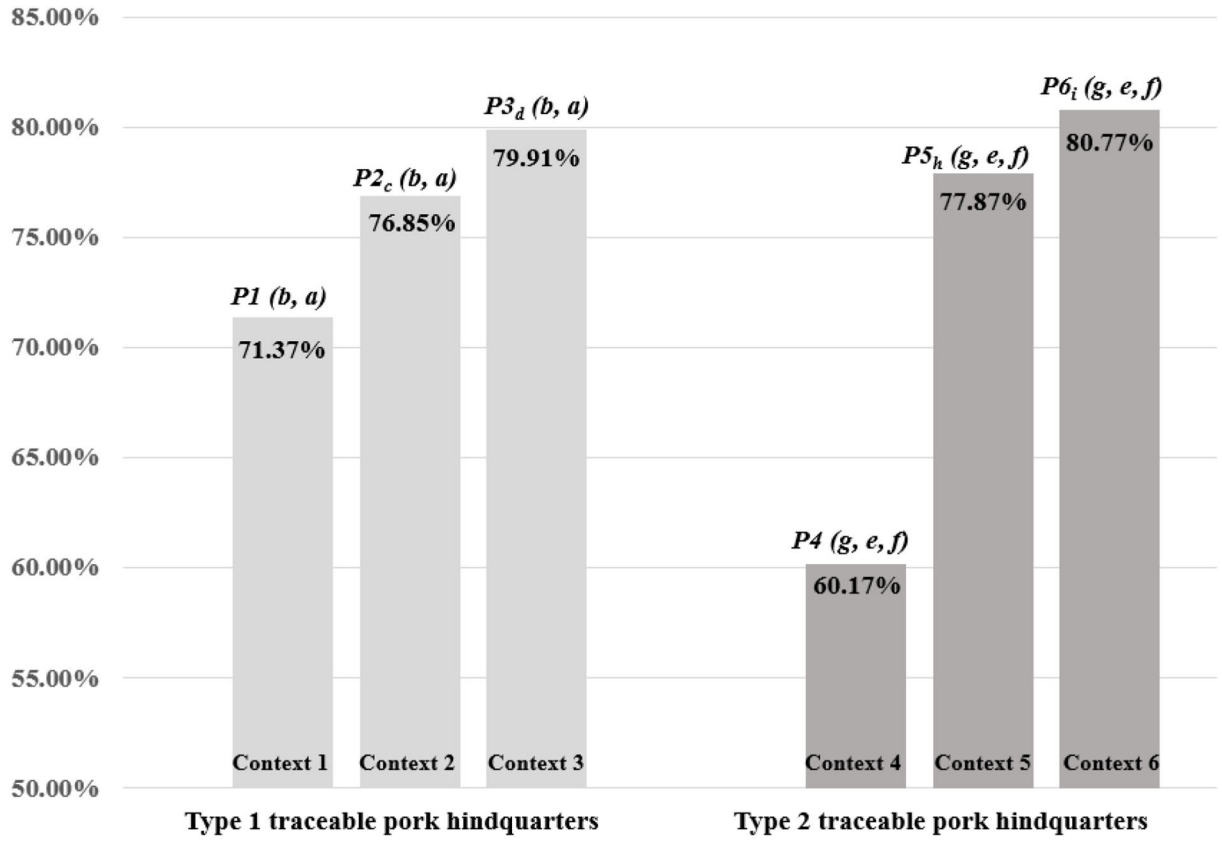

FIGURE 3
Decoy effect in types 1 and 2 traceable pork.

less likely to experience the decoy effect. This differs from the conclusions of Rao et al. (28). Variables X_{10} (government employee), X_{11} (employee of an enterprise), and X_{13} (student) were all insignificant. However, the coefficient of variable X_{12} (farmer) was positive and significant at the 5% level. This indicates that compared with other types of occupation, farmers were more likely to experience the decoy effect. Thus, H2-7 could be rejected. Table 5 reports the marginal effects. When calculating the marginal effect of a single dummy variable, all other variables were measured at the sample median.

Based on Table 5, the marginal effect of variable X_4 (whether the participant was married) was negative (−0.602) and significant at the 1% level. This suggests that married participants made 0.602 less changes in their product choice due to the decoy effect than unmarried participants. As the total possible number of changes was 4, the reduction in the number of changes among married participants was 15.05% relative to those participants who were unmarried. The marginal effects of variables X_5 (annual income between 50,000 and 100,000 yuan) and X_6 (more than 100,000 yuan) were negative (−0.164 and −0.974, respectively) and significant at the 1 and 5% levels, respectively. Specifically, compared with participants with an annual income of <50,000 yuan, the number of changes in purchase decision due to decoy traceable pork was reduced by 0.164 among participants with an income of 50,000–100,000 yuan, or 4%, and by 0.974 among participants with an annual income of more than 100,000 yuan, or 24.35%. Finally, the marginal effect of variable X_9 (minor children in the family) was also negative (−0.645) and significant at the 1% level. Compared with participants without minor children at home, the number of changes in purchase decision due to decoy traceable pork was reduced by 0.645 among participants with minor children. This represented a reduction of 16.12%.

Conclusion and implications

This study investigated whether the decoy effect may exist in the purchases of food, whether the effect may differ across product attributes, and whether there is correlation between the decoy effect and individual consumer characteristics. Based on an in-person consumer survey in Wuxi, China, on traceable pork hindquarters, similar to other types of consumer products, we identified decoy effects in all scenarios we considered.

TABLE 3 Definition and measurement of variables.

Variable	Definition	Mean
18–25 years	"18–25 years" was used as reference group	
29–48 years (X_1)	Dummy variable. Yes = 1; No = 0	0.39
49–65 years (X_2)	Dummy variable. Yes = 1; No = 0	0.21
Male (X_3)	Dummy variable. Yes = 1; No = 0	0.47
Married (X_4)	Dummy variable. Yes = 1; No = 0	0.60
Annual personal income <50,000 yuan (all pre-tax)	"Annual personal income <50,000 yuan" was used as the reference group	
Annual personal income between 50,000 and 100,000 yuan (X_5)	Dummy variable. Yes = 1; No = 0	0.32
Annual personal income more than 100,000 yuan (X_6)	Dummy variable. Yes = 1; No = 0	0.12
Family size of 1 or 2	"Family size of 1 or 2" was used as the reference group	
Family size of 3 or 4 (X_7)	Dummy variable. Yes = 1; No = 0	0.55
Family size of 5 or more (X_8)	Dummy variable. Yes = 1; No = 0	0.24
Presence of minor children in household (X_9)	Dummy variable. Yes = 1; No = 0	0.42
Other occupations	"Other occupations" was used as the reference group	
Government employee (X_{10})	Dummy variable. Yes = 1; No = 0	0.01
Employee of enterprises (X_{11})	Dummy variable. Yes = 1; No = 0	0.52
Farmer (X_{12})	Dummy variable. Yes = 1; No = 0	0.06
Student (X_{13})	Dummy variable. Yes = 1; No = 0	0.12

TABLE 4 Negative binomial count regression model estimation result.

Variable	Coef.	Sta. Err.	*Z*	*P*
29–48 years (X_1)	0.028	0.168	0.16	0.870
49–65 years (X_2)	0.365	0.188	1.94	0.052
Male (X_3)	0.057	0.109	0.52	0.604
Married (X_4)	−0.396**	0.143	−2.77	0.006
Annual personal income between 50,000 and 100,000 yuan (X_5)	−0.510**	0.148	−3.44	0.001
Annual personal income more than 100,000 yuan (X_6)	−0.653**	0.247	−2.65	0.008
Family size of 3 or 4 (X_7)	−0.028	0.144	−0.19	0.847
Family size of 5 or more (X_8)	−0.175	0.165	−1.06	0.291
Presence of minor children in household (X_9)	−0.423**	0.125	−3.38	0.001
Government employee (X_{10})	0.531	0.532	1.00	0.318
Employee of enterprises (X_{11})	0.081	0.145	0.56	0.575
Farmer (X_{12})	0.396*	0.199	1.99	0.047
Student (X_{13})	−0.048	0.210	−0.23	0.817
Constant	0.862	0.221	3.90	0.000

**Significance at the 1% level.
*Significance at the 5% level.
LR chi2 (13) = 63.610; Prob>chi2 = 0.000; Pseudo R^2 = 0.080; log likelihood = −364.517.

Moreover, we show evidence that the decoy effect varied with product attributes, and consumer individual characteristics have strong correlation with how they make product choices given decoy products.

This study can be useful for more accurately assessing patterns of consumer food purchases, product marketing, and developing traceable food markets in China. Consumers are the major actors of traceable food market, and the effective establishment of China traceable food market inherently depends on consumer purchasing behavior. For consumer behavior and marketing, since there is no formalized food traceability system in China, traceable food tends to be marketed with different levels of traceability information. Together with other types of food attributes, this creates room for the decoy effect to influence consumer choices. Our study shows that different consumers react differently to decoy effects on different types of product attributes. With proper consideration of the decoy effect and better knowledge on the consumer profile, marketers will be able to better measure consumer choices and make more precise predictions of the market, particularly when new (traceable) products are introduced to the market. For policymakers, if traceability is deemed to be useful to consumers, after careful cost and benefit assessment, public education and information programs could take advantage of the decoy effect to nudge consumers to make choices supporting a formal and systematic scheme of food traceability. However, the use of the effect to promote the development of China traceable food market discussed here is an auxiliary strategy and is by no means a long-term solution. The key to the development of China traceable food market is that the government should be committed to developing a national unified traceable food standard system, reducing the cost of producers adopting traceable food production standards, and maintaining the stability of traceable food prices to increase the consumption.

TABLE 5 Marginal effect of individual characteristic variables.

Variable	Marginal effect	Sta. Err.	*Z*	*P*
29–48 years (X_1)	0.045	0.260	0.17	0.862
49–65 years (X_2)	0.564	0.294	1.92	0.055
Male (X_3)	0.087	0.168	0.52	0.604
Married (X_4)	−0.602**	0.224	−2.69	0.007
Annual personal income between 50,000 and 100,000 yuan (X_5)	−0.164**	0.232	−3.32	0.001
Annual personal income more than 100,000 yuan (X_6)	−0.974*	0.385	−2.53	0.011
Family size of 3 or 4 (X_7)	−0.041	0.222	−0.18	0.853
Family size of 5 or more (X_8)	−0.264	0.255	−1.04	0.300
Presence of minor children in household (X_9)	−0.645**	0.196	−3.28	0.001
Government employee (X_{10})	0.798	0.824	0.97	0.333
Employee of enterprises (X_{11})	0.128	0.224	0.57	0.568
Farmer (X_{12})	0.602	0.308	1.95	0.051
Student (X_{13})	−0.069	0.325	−0.21	0.833

*Significance at the 5% level. **Significance at the 1% level.

This study has some limitations. First, the analysis is based on data from a single city in China. Due to large regional differences in China and between countries, applicability and generalizability of our results should be verified on a larger scale. Second, despite that the intention of this study is not to obtain an unbiased estimate of consumer willingness to pay for traceable pork *per se*, we hope to offer reliable analysis and add to the related literature. Although we have displayed actual pork products during our survey, consumers made decisions hypothetically and did not involve actual payment. Consumers may have misrepresented their actual purchase intention (41, 45). The discrepancy between hypothetical and actual behavior is known as hypothetical bias, and a number of approaches have been proposed in the literature to reduce such bias (46, 47). A future study like ours can take advantage of these mitigation methods. Furthermore, revealed preference methods such as experimental auction may be used to investigate the decoy effect in food purchases. In particular, this study confirmed that the decoy effect varies according to the attributes of pork hindquarters and that the individual characteristics of consumers are closely related to consumer choices based on decoy pork. However, as the decoy effect is an irrational behavior of consumers, this study does not encourage the abuse of the decoy effect in food purchase, especially the use of the decoy effect to market foods that do not comply with laws and regulations. This is the greatest drawback of this study. Overall, this study aims to promote the construction of traceable food systems in China through marketing strategies employing the decoy effect based on the Chinese situation so that consumers pay more attention to and use traceability information, thereby presenting an auxiliary strategy for promoting traceable food systems in China.

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 Jiangnan University. Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements.

Author contributions

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

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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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The impact of emotion management ability on learning engagement of college students during COVID-19

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During the COVID-19, the wanton spread of novel coronavirus had a huge negative effect on the emotions of college students, resulting in a serious impact on the daily learning behavior of many college students. In this context, college students' emotion management ability is particularly important. Therefore, based on the results of a questionnaire survey of 580 college students, the present study conducts an in-depth analysis of the relationship between current college students' emotion management ability and learning engagement, and explores the mediating role of psychological safety and self-efficacy in the relationship between emotion management ability and learning engagement. The results show that college students' emotion management ability is significantly positive related to learning engagement, psychological safety and self-efficacy; Psychological safety and self-efficacy can play a partial mediating role between emotion management ability and college students' learning engagement. The results reveal the importance of good emotion management ability of college students during the COVID-19, and enlighten colleges and universities to actively pacify students' emotions to promote their normal learning.

KEYWORDS

emotion management ability, psychological safety, self-efficacy, learning engagement, COVID-19

Introduction

At the beginning of 2020, the COVID-19 broke out worldwide, which had a great impact on the daily lives of people all over the world. The COVID-19 has become the largest public health emergency in the world. This sudden disaster has posed a major threat to the lives and health of people around the world, but it is also a severe test for the Chinese nation (Jing and Ge, 2021). Governments of various countries have taken many administrative prevention and control measures to deal with the local COVID-19,

such as maintaining social distance, home isolation, travel restrictions, etc., in order to reduce the speed of the spread of novel coronavirus.

University campus management and control measures are an important part of the prevention and control measures taken by the entire social system in response to the epidemic. In order to prevent and control the epidemic, the Chinese Ministry of Education has put forward the requirement of "stopping classes without stopping teaching, and stopping classes without stopping learning," and adopts a combination of government-led, college-based, and social participation to jointly implement and ensure the online teaching activities of colleges and universities during the epidemic prevention and control period (Zhang, 2021). However, it should be noted that college students are at a special period of physical and mental development, and are at a critical stage of forming their outlook on life, values and worldview. The outbreak of major epidemics (i.e., COVID-19) and other social life stressful events not only have a serious impact on the lives of college students, but also cause great psychological pressure on them and reduce their psychological safety, and thus affecting their learning status. In particular, when the epidemic has not been completely controlled, Chinese college students spend most of their time completing online learning tasks through mobile phones and computers software. At the same time, they are not allowed to enter and exit the school at will. With the passage of time and the extension of online classes time, the engagement of some students in online learning tends to decline significantly, and they are less motivated to answer questions (Yan and Yuan, 2020). Thus, in the context of the rapidly changing social environment and the normalization of epidemic prevention and control, how to maintain and improve college students' learning engagement has become an important element that needs urgent attention in current research.

However, while the epidemic crisis brings a certain amount of psychological stress to college students, it also inevitably has an negative impact on their emotions. On the one hand, college students are bombarded with all kinds of epidemic-related information when browsing traditional news media, Weibo and other we media, which will affect their psychological activities. On the other hand, college students need to adapt to the new online teaching methods and complete various learning tasks arranged by the school. For college students who have been in stressful emotions for a long time, negative emotional states such as loneliness, anxiety, frustration and fear will appear (Fan et al., 2021). If the negative emotions of college students are not paid attention to and adjusted in time, it may bring more problems and obstacles to the psychological condition of college students. The existing literature has analyzed the factors influencing college students' learning engagement from different perspectives, and these factors include cognitive and behavioral elements (Fredricks et al., 2004). In terms of cognition, scholars have examined the influence of learning motivation and learning achievement on learning engagement, showing that the stronger the learning motivation, the higher the learning engagement; achievement goal orientation can directly predict college students' learning engagement (Karimi and Sotoodeh, 2019). At the same time, college students' time insight can also promote college students' learning engagement (Fredricks et al., 2004). In terms of behavior, scholars have examined the effectiveness of individual physiological factors, learning persistence, and environmental factors in promoting learning engagement (Fredricks et al., 2004; Lu et al., 2022). For college students, as mentioned earlier, while paying attention to the epidemic and academics, college students should also take the initiative to improve their emotion management ability and enhance their sense of self-efficacy, so as to relieve greater psychological stress, better engage in learning activities and reduce the emergence of other negative emotions. Existing studies have not focused on the effect of emotion management ability on learning engagement and its influencing mechanism. In view of this, the present study intends to investigate the relationship between college students' emotion management ability and learning engagement, and analyze the mediating role of two psychological states, that is, self-efficacy and psychological security, in the relationship between emotion management ability and learning engagement. Thus, we aim to provide empirical data for the research of college students' learning engagement, and to put forward targeted suggestions for how colleges and universities can alleviate college students' negative emotions and enhance their learning engagement.

Theoretical background

Emotion management ability

Emotion has an important impact on the mental health of college students. Emotion is an important driver of individual behavior and affects the direction of cognitive activity, the choice of behavior, the formation of personality, and the handling of interpersonal relationships. Therefore, it is very important for every individual to manage their emotions well. An individual's emotional state signifies the individual's response to the environment and the biological motivational state in adapting to changes of the environment. The emotion behind the behavior is not only an expression of the results of the behavior, but also represents some kind of adaptive motivational factor (Fredrickson, 2001; Fredrickson and Branigan, 2005). Positive emotions and negative emotions have different psychosocial functions, with positive emotions having a positive effect and negative emotions having a negative effect. Therefore, individuals need to manage their emotions and perform the

positive function of positive emotions. Emotion management ability is a kind of psychological characteristic, which is the ability to recognize, monitor, and drive one's own emotions, as well as the ability to recognize and respond appropriately to surrounding situations (Zhang et al., 2022). College students who are in the transition period from susceptibility to stability in psychological development are characterized by bipolarity in positive and negative emotions, tension and relaxation, excitement and calmness. In the process of promoting the all-round development of college students, the guidance, control and regulation of emotion has become an important part. The psychological and educational communities have clearly understood that the cultivation of emotional management ability of college students is an important issue related to the adaptation to society, survival and development of college students. Emotion management ability refers to the ability to correctly identify one's own emotions and those of others, and to guide, adjust, and control them purposefully, so as to achieve healthy development (Du et al., 2007; Zhang et al., 2022). Research on emotion management has been one of the research hotspots of psychologists at home and abroad, and the theory of emotion management has been exploring the influencing factors between emotion and behavior as the core of its research.

Psychological safety

Psychological safety refers to the anticipation of possible physically and psychologically related dangers or risk factors, and the individual's sense of power/powerlessness to cope with these dangers and risk, mainly manifested in the form of a sense of certainty and controllability. Psychological safety is also a "feeling of confidence, safety, and freedom freed from fear and anxiety, especially with regard to the feeling of the satisfaction of one's present (and future) needs," which is closely related to the objective situation in which an individual or group lives, and is expressed as a sense of psychological safety when the objective situation satisfies the individual's or group's internal needs or experiences. In workplace research, psychological safety is the perception that individuals need to take the consequences of interpersonal risks in the work environment (Edmondson, 1999, 2004). The more psychological safety employees feel about the organization, the more they are willing to communicate and share knowledge (Spreitzer et al., 2012; Liao et al., 2022). With the development of China's economy, the spread of the COVID-19 epidemic, and the intensification of social competition, every Chinese is under tremendous psychological pressure, and one important group is college students. Thus, in recent years, the psychological safety of college students has attracted the attention and focus of all walks of life (Tatiana et al., 2022). According to Maslow, a humanistic psychologist, psychological safety is the most important determinant of mental health. Existing research have pointed out that psychological safety can provide individuals with an organizational atmosphere of mutual trust and respect, which generates incremental psychological resources, so that individuals are more willing to actively engage in work and learning (Yang et al., 2022). For college students, psychological safety is the preconceptions college students have about risk factors related to their bodies or psyches, and the sense of certainty and control they have in dealing with threats. When college students perceive safety, their willingness to engage in self-expression becomes stronger, and they are more willing to share knowledge with others and interact with them frequently, resulting in more work-learning behaviors (Nembhard and Edmondson, 2006; Han et al., 2022).

Self-efficacy

Self-efficacy refers to the degree to which people feel confident that they can use the skills they have to perform a certain job behavior (Bandura, 1977). General self-efficacy refers to an overall relatively stable sense of competence or self-confidence that individuals exhibit when dealing with challenges in a variety of environments (Luszczynska et al., 2005). Self-efficacy is attributed to self-beliefs and is influenced by the individual's own experiences of success or failure in behavior, alternative experiences, verbal persuasion, and emotional arousal. It is an interaction among environment, behavior, and person to interpret human behavior. Self-efficacy is one of the determinants of learning behavior, emphasizing an individual's self-confidence in his or her own abilities and having a broad impact on an individual's cognition, emotions, and behavior (Bandura, 1977; Linnenbrink and Pintrich, 2003). The sense of self-efficacy plays a key role in the generation system of human abilities. The self-efficacy generated by college students in the learning process can help them to build confidence in their academic tasks through a series of organizational and executive measures (Zimmerman, 1995). In the college student population, individuals with high self-efficacy exhibit stronger pressure resistance (Schonfeld et al., 2019; Ye et al., 2021) and higher levels of subjective well-being and mental health. In the study-oriented college student groups, the established research mainly focuses on academic self-efficacy, which is mainly expressed as college students' subjective judgment of learning behavior and achievement ability, referring to a subjective judgment and ability belief of learners about whether they can have the ability, confidence, and strategies to complete learning tasks, including learning ability self-efficacy and learning behavior self-efficacy. Individuals with high academic self-efficacy have strong learning motivation and good learning ability, are able to make positive efforts and

dare to overcome academic difficulties (Chang and Tsai, 2022; Kryshko et al., 2022).

Learning engagement

Learning engagement is an important indicator of the quality of students' learning process (Xie et al., 2020) and is highly correlated with students' learning persistence, academic satisfaction, learning performance, and academic completion (Kuh, 2009). In the past decade, the concept and measurement of learning engagement have been paid more and more attention and focus from researchers and practitioners (Bond, 2020). As a multifaceted structure, learning engagement is defined differently by different researchers according to different research contexts. Schaufeli et al. (2002) first extended job engagement to learning and put forward the concept of "learning engagement," which refers to the positive and fulfilling mental state associated with learning and includes three dimensions: vitality, dedication, and concentration. Vitality means having outstanding energy and resilience, not easily tired in learning and not afraid of hardship; dedication means having a strong sense of meaning, pride, full of enthusiasm for learning and courageous to challenge; concentration means being fully engaged in learning and being able to feel positive and enjoyable experience. From the perspective of learning activities, Fredricks et al. (2004) considered learning engagement as students' commitment or dedication to learning activities and concluded that learning engagement includes three dimensions: behavioral engagement, emotional engagement, and cognitive engagement. Behavioral engagement refers to the academic or non-academic activities that an individual participates in while in school; emotional engagement is the positive emotional response of an individual in the face of learning tasks or teachers, classmates, and a sense of belonging to school; and cognitive engagement refers to the cognitive strategies that students use in learning, i.e., their psychological resources. Fredricks et al. (2016) subsequently added social engagement, which is the social interaction between students and their peers or teachers, to the three-dimensional framework. Bond (2020), in terms of measurement methods and influencing factors, pointed out that learning engagement is the degree of energy and effort students put into the learning process, which can be observed and measured through indicators such as learners' behavior, cognition, and affect, and is influenced by internal and external factors such as teacher-student relationship, student-student relationship, learning activities, and learning environment. It is evident that due to the complexity of learning engagement itself, international researchers have not developed a unified understanding of the concept and framework of learning engagement, which has indirectly led to the diversity of research in this area.

Research hypotheses

Emotional management ability and learning engagement

Emotion management is a flexible response or a delayed response based on a specific situation that is socially acceptable or tolerated by the individual when faced with a range of emotional developments (Bolton, 2004; Lively and Weed, 2014; Polizzi and Lynn, 2021). During the COVID-19 epidemic, Chinese universities responded to the national prevention and control requirements by restricting students from entering and leaving the campus at will, and even implemented complete closure measures in some places where the epidemic was serious (Zhang, 2021). This tends to lead to emotional instability among college students, which reduces college students' engagement in learning. However, learning engagement is a student's commitment or dedication to learning activities and is considered to include behavioral, emotional, and cognitive engagement. Therefore, students with high emotion management ability are able to keep themselves extremely emotionally well in any situation. Emotions affect college students' motivation to learn (Arguel et al., 2019). When a college student is in a positive emotional state, he/she will become willing to learn, good at learning, and will have a strong interest in learning (Finch et al., 2015). It can be said that good academic emotion is the key to improve college students' commitment to learning. In today's world of lifelong learning, it is very important to cultivate good academic emotions in college students so that they can learn actively. At the same time, good emotion makes the function of all the systems and organs of college students more coordinated and sound, which will make them more passionate and creative about learning, and more powerful to overcome the frustration and difficulties in learning (Healey, 2017). Therefore, we hypothesize the following:

> Hypothesis 1. Emotional management ability is positively related to college students' learning engagement.

The mediating role of psychological safety

According to the crisis-growth model, individuals in a supportive environment have access to more resources to cope with stress and reap more security at the same time. In context of the the COVID-19 outbreak changing people's lifestyles, college students face a series of psychological shocks in their studies, and these shocks enhance the negative emotions of the college student population, leading to a decrease in their psychological safety (Yan and Yuan, 2020). According to

emotional intelligence theory, the ability to regulate emotions, i.e., emotion management, is reflected in the adaptive regulation and control of emotions of self and others. For college students during the epidemic, individuals who can regulate and control their emotions well can obtain higher levels of stable feelings and their psychological safety will continue to climb (Mayer et al., 2001). That is, emotion management ability can significantly contribute to college students' psychological safety. First, in the face of the complex social environment and the severe campus epidemic prevention and control policies, college students' emotion fluctuation will aggravate the inner insecurity. And appropriate regulation and management of college students' emotion can enable them to maintain a good state of mind and increase communication with friends and classmates, which is conducive to improving a greater sense of psychological safety. Second, due to the epidemic prevention and control policies, the contact between students and students and students and teachers has been reduced, which will undoubtedly make students feel scared and panic. Faced with this situation, college students with higher emotion management ability will seem more relaxed and even regulate their emotion through exercise and other means. Compared with individuals with poorer emotion management ability, they are more stable inside, i.e., higher level of psychological safety. Finally, the emotion management ability of college students is mainly reflected in the management ability of their own psychological capital, the essence of which is expressed in how to transform psychological capital into the driving force to promote their own adaptation to environmental changes. In other words, when college students perform self-emotion management, it is a special form of regulating their inner insecurity. Accordingly, emotion management is conducive to improving psychological safety. Therefore, we hypothesize the following:

> Hypothesis 2. Emotional management ability is positively related to psychological safety.

From the above analysis, it is easy to find that college students who have higher emotional management ability during the COVID-19 epidemic spread have relatively higher levels of their own psychological safety. However, it should be noted that the sense of psychological safety is a special kind of psychological capital, which is externally expressed as calmness and composure in the face of complex environment. Gong et al. (2012) stated that psychological security represents an environmental state that provides individuals with sufficient certainty and foresight to become more engaged. Edmondson and Lei (2014) stated that psychological security can help individuals overcome anxiety. When individuals have a high sense of psychological security, individuals will spend most of their time on efficiency improvement and goal achievement rather than interpersonal risk prevention, and they will be more inclined to be proactive in presenting themselves and gaining recognition from others. In sum, college students with a higher level of psychological safety are also more likely to devote themselves to their learning and avoid too much disturbance to themselves. In other words, psychological safety is conducive to the daily learning activities of college students. Therefore, based on Hypothesis 2, we hypothesize the following:

> Hypothesis 3. Psychological safety plays a mediating role in the relationship between emotional management ability and college students' learning engagement.

The mediating role of self-efficacy

Social cognitive theory states that self-awareness and self-regulation play a key role in the formation of self-efficacy, while emotion management ability emphasizes the ability of an individual to perceive and regulate self-emotion and self-emotional states (Bandura et al., 1997). Emotion management ability includes the basic and critical things that individuals should have in coping with the environment, solving problems and adaptive survival. This kind of emotion management ability is highly correlated with individual achievement. Thus, emotion management ability can influence the level of self-efficacy of college students. When college students are faced with the problems such as the impact of the COVID-19 epidemic, academic pressure, and career choice after graduation, they need to cope with the pressure of the environment, study and work requirements by combining environmental needs, their own abilities and personality characteristics. At this time, emotion management ability affects the process of how college students seek relevant information and achieve self-development under environmental pressure. College students with high level of emotion management ability are more likely to cope with these issues smoothly, and successfully dealing with these things implies an increase in the individual's perceived level of self-efficacy (Chang and Tsai, 2022). In addition, individuals with better emotion management ability will experience fewer negative emotions and have positive self-evaluations on the completion of expected goals and tasks (Wang et al., 2020). Mayer et al. (2001) took emotion management ability as a dimension of emotional intelligence. According to the emotional intelligence model developed by them, individuals with higher emotion management ability are able to control and express their emotions better, and perceive and understand problems and frustrations encountered well, thus promoting rational problem solving, generating internal satisfaction, and gaining more positive emotional experiences, and finally enhancing their own self-efficacy. Gundlach et al. (2003) proposed that the level of emotion management ability affects the level of individual self-efficacy to some extent from the perspective of emotion management

ability and causal reasoning model. Therefore, we hypothesize the following:

> Hypothesis 4. Emotional management ability is positively related to self-efficacy.

Self-efficacy helps increase college students' motivation to learn, experience positive emotions, and thus devote more time and energy to learning. College students with higher self-efficacy show more interest in learning, are more likely to use various tools (e.g., online tools) for learning, and are more willing to spend more time on learning (Bassi et al., 2007; Bates and Khasawneh, 2007). They are confident that they can handle difficulties, tend to choose challenging learning tasks, persevere in the face of difficulties, and strive to create conditions to achieve their goals even when the behavior fails to reach them. On the contrary, college students with lower self-efficacy tend to set lower learning goals, have a more negative attitude toward academic challenges, are reluctant to invest effort when frustrated, and have difficulty in mobilizing active learning strategies (Linnenbrink and Pintrich, 2003; Fan and Williams, 2010), they think more about their own shortcomings and imagine the learning task as more difficult when they face the learning task, thus creating more stress, all of which can prevent college students from engaging in high-quality learning engagement. Therefore, based on Hypothesis 2, we hypothesize the following:

> Hypothesis 5. Self-efficacy plays a mediating role in the relationship between emotional management ability and college students' learning engagement.

Figure 1 shows our theoretical model.

Materials and methods

Sample and procedure

We aim to explore how emotion management ability affects college students' learning engagement, and the mediating roles of psychological safety and self-efficacy. Therefore, the data were collected by means of online research from four universities in northern China in the current study. We collected a total of 650 surveys, and after removing invalid surveys with missing values above 15%, we obtained a total of 580 valid surveys, with an effective rate of 89.23%. The demographic characteristics of the valid sample show that: In terms of gender, 54.6% of participants were male, and 45.4% of participants were female; In terms of grades, 32.4% were freshman, 25.6% were sophomore, 21.7% were junior, 20.3% were senior; In terms of hometown, 65.8% were rural students, 34.2% were urban students; In terms of family background, 21.3% were from divorced family, 78.7% were from non-divorced family; In terms of personality, 29.4% were extroverted, 46.9% were moderate, 23.7% were introverted; In terms of health condition, 89.3% were in good health, 8.7% were in average health, 2% were in poor health.

Measures

Unless otherwise noted, responses to all items were measured on five-point Likert-type scales, ranging from strongly disagree (1) to strongly agree (5). All variables in this study were measured from well-established scales that are widely used abroad, and all scales have been shown to be valid in Chinese contexts.

Emotion management ability

Emotion management ability (EMA) was assessed using a 22-item scale with five sub-scales based on the research of Du et al. (2007). A sample item is "When I encounter something unpleasant, I will find some reasons to comfort myself to reduce the inner disappointment." In present study, the Cronbach's α score for this scale was 0.913.

Psychological safety

Psychological safety (PS) was assessed using a five-item scale developed by Liang et al. (2012). A sample item is "In my work unit, expressing your true feelings is welcomed." In present study, the Cronbach's α score for this scale was 0.804.

Self-efficacy

Self-efficacy (SE) was based on a scale developed by Schwarzer et al. (1997) and used 10 items. A sample item is "I believe I can solve problems effectively." In present study, the Cronbach's α score for this scale was 0.891.

Learning engagement

Learning engagement (LE) was assessed using Fang et al. (2008)'s 17-item scale. A sample item is "I feel energized when I study." In current study, the Cronbach's α score for this scale was 0.907.

Control variables

In addition, six individual difference variables, including college students' gender, grades, hometown, family background, personality, and health condition in current study. We controlled them to rule out alternative explanations and to carry out a more reliable test. All the controlled variables were dummy coded. Gender was coded as 1 for participants who were male and 2 for participants who were female. Grades were coded as 1 for participants who were freshman, 2 for participants who were sophomore, 3 for participants who were junior, and 4 for participants who were senior. Hometown was coded as 1 for participants who were rural students,

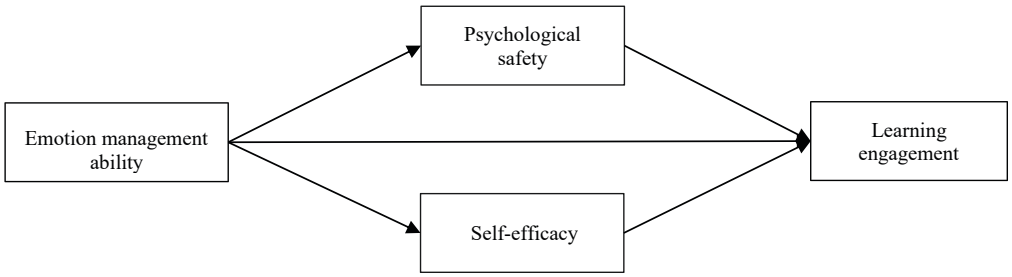

FIGURE 1
Theoretical model.

and 2 for for participants who were urban students. Family background was coded as 1 for participants who were from divorced family, and 2 for participants who were from non-divorced family. Personality was coded as 1 for participants who were extroverted, 2 for participants who were moderate, and 3 for participants who were introverted. Health condition was coded as 1 for participants who were in good health, 2 for participants who were in average health, and 3 for participants who were in poor health.

Data analysis

First, Cronbach's α, composite reliability, and confirmatory factor an analyses (CFAs) were conducted to assess the reliability and validity of the key variables. Common method variance (CMV) was also assessed. Second, we used hierarchical regression analysis to examine the hypothesized relationships. Finally, we used the bootstrapping method to test mediation because of its high power (Preacher and Hayes, 2004, 2008).

Results

Reliability and validity

First, before conducting reliability and validity test, we checked CMV because it is a potential issue in the self-reporting approach research. We used Harmon' one-factor test by including all of the items of the five variables (i.e., emotion management ability, psychological safety, self-efficacy, and college students' learning engagement) to examine CMV in SPSS 25.0. When the first emerging factor accounted for over 50% of the extracted variables' variance, common method bias was suggested and CMV would be a problem. The results demonstrated that the first emerging factor accounted for 27.91% of the explained variance, indicating that CMV was not a significant problem in the present study.

Second, we calculated Cronbach's α of emotion management ability, psychological safety, self-efficacy, and college students' learning engagement to examine the reliability. As mentioned above, the values of Cronbach's α were greater than the threshold value of 0.80, demonstrating acceptable reliability.

Finally, we conducted a series of CFAs using Amos 23.0 on the scales including emotion management ability, psychological safety, self-efficacy, and college students' learning engagement to examine discriminate validity (see Table 1). Results showed that the fit of the five-factor model in which items were loaded on their respective measures was better than any other model (χ^2/df = 2.977, RMSEA = 0.062, CFI = 0.911, TLI = 0.909, IFI = 0.911, SRMR = 0.060). These results of CFA provided full support for the discriminate validity of our study instruments.

Descriptive statistics and correlations

We calculated the correlations among emotion management ability, psychological safety, self-efficacy, and college students' learning engagement using SPSS 25.0. As shown in Table 2, emotion management ability was positively related to psychological safety (r = 0.334, p < 0.01), positively related to self-efficacy (r = 0.285, p < 0.01), and positively related to college students' learning engagement (r = 0.264, p < 0.01). Psychological safety was positively related to college students' learning engagement (r = 0.488, p < 0.01). At the same time, self-efficacy was also positively related to college students' learning engagement (r = 0.591, p < 0.01). These results provided preliminary supports for the hypotheses proposed above. We further used hierarchical regression analysis and bootstrapping method to test the hypotheses.

Hypotheses testing

Research hypotheses were tested using hierarchical regression analysis. The results in Table 3 showed that (1) compared with M5, M6 showed that emotion management ability had a positive impact on college students' learning engagement (β = 0.243, p < 0.001) after the influence of fixed control variables and can additionally explain the

TABLE 1 Results of confirmatory factor analyses.

Models	Variables	χ^2	df	χ^2/df	IFI	RMSEA	CFI	TLI	SRMR
Four-factor model	EMA, PS, SE, LE	1,565.902	526	2.977	0.911	0.062	0.911	0.909	0.060
Three-factor model	EMA, PS, SE + LE	2,065.327	523	3.949	0.873	0.092	0.872	0.856	0.085
Two-factor model	EMA, PS + SE + LE	3,150.954	531	5.934	0.742	0.125	0.751	0.725	0.091
One-factor model	EMA + PS + SE + LE	5,495.122	526	10.447	0.534	0.171	0.531	0.486	0.149

TABLE 2 Results of correlation analysis.

	1	2	3	4	5	6	7	8	9
1. Gender									
2. Grades	0.001								
3. Hometown	0.002	0.037							
4. Family background	0.001	0.023	0.005						
5. Personality	0.005	0.044	0.068	0.101*					
6. Health condition	0.013	0.057	0.004	0.017	0.020				
7. EMA	0.024	0.013	0.037	0.088	0.035	−0.085			
8. PS	0.035	0.057	0.018	0.064	−0.027	0.042	0.334**		
9. SE	0.047	0.001	0.067	0.051	−0.010	0.051	0.285**	0.209**	
10. LE	0.031	0.048	0.029	0.038	0.098*	0.060	0.264**	0.488**	0.591**

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

college students' learning engagement variation of up to 9.2% ($\Delta R^2 = 0.092$). The significant term of emotion management ability offered full support for Hypothesis 1; (2) Compared with M1, M2 showed that the regression coefficient of emotion management ability was significantly positive ($\beta = 0.239$, $p < 0.001$), and an additional 10.5% ($\Delta R^2 = 0.105$) of psychological safety variation was explained. The results offered full support for Hypothesis 2; (3) Compared with M6, after the influence of fixed control variables and emotion management ability, psychological safety was significantly positive ($\beta = 0.417$, $p < 0.001$) and can extra explain 12.8% ($\Delta R^2 = 0.128$) of college students' learning engagement, and regression coefficient between emotion management ability and college students' learning engagement was still significant ($\beta = 0.143$, $p < 0.01$), indicating that psychological safety played a partial mediating role between emotion management ability and college students' learning engagement. These results provided support for Hypothesis 3; (4) Compared with M3, M4 showed that the regression coefficient of emotion management ability was significantly positive ($\beta = 0.158$, $p < 0.001$), and an additional 6.5% ($\Delta R^2 = 0.065$) of self-efficacy variation was explained. The results offered full support for Hypothesis 4; (5) M4, 6, and 8 showed that after the influence of fixed control variables and emotion management ability, self-efficacy was significantly positive ($\beta = 0.574$, $p < 0.001$) and can extra explain 20% ($\Delta R^2 = 0.200$) of college students' learning engagement, and regression coefficient between emotion management ability and college students' learning engagement was still significant ($\beta = 0.151$, $p < 0.001$), indicating that self-efficacy played a partial mediating role between emotion management ability and college students' learning engagement. These results provided support for Hypothesis 5.

To further test the mediation effect of psychological safety and self-efficacy, we used the procedures proposed by Preacher and Hayes (2004) and Preacher and Hayes (2008) and applied bias-corrected bootstrapping method to further examine the mediation effect through the "Process" plugin of SPSS 25.0. This method can produce higher statistical power. The bootstrapping sample size was set to 5,000, the confidence interval was set to 95%, and the results were shown in **Table 4**.

The bootstrapping mediation analysis showed that at the 95% confidence interval level, (1) the indirect effect of psychological safety between emotion management ability and college students' learning engagement was 0.100 and the confidence interval (LLCI = 0.057, ULCI = 0.150) did not included 0, indicating that Hypothesis 3 got full supported. (2) the indirect effect of self-efficacy between emotion management ability and college students' learning engagement was 0.092 and the confidence interval (LLCI = 0.047, ULCI = 0.144) did not include 0, indicating that Hypothesis 5 got full supported.

Discussion

The current study explores the relationship between emotion management ability and learning engagement. The findings show that emotion management ability can affect college students' learning engagement through two indirect

TABLE 3 Results of hierarchical regression analysis.

Variables	Psychological safety		Self-efficacy		Learning engagement			
	M1	M2	M3	M4	M5	M6	M7	M8
Gender	−0.033	−0.095	0.137	0.097	0.347**	0.285**	0.324***	0.236**
Grades	0.023	0.038	−0.056	−0.046	−0.030	−0.014	−0.030	0.020
Hometown	0.103	0.119	0.226***	0.237***	0.135	0.152	0.102	0.035
Family background	0.146	0.153*	0.158*	0.162**	0.154	0.160*	0.097	0.056
Personality	0.099	0.094	0.082	0.079	0.106	0.101	0.093	0.088
Health condition	0.076	0.072	0.063	0.061	0.103	0.099	0.072	0.069
EMA		0.239***		0.158***		0.243***	0.143**	0.151***
PS							0.417***	
SE								0.574***
R^2	0.032	0.137	0.066	0.131	0.057	0.149	0.276	0.349
ΔR^2	0.032	0.105	0.066	0.065	0.057	0.092	0.128	0.200
F	2.596*	9.838***	5.494***	9.306***	4.658**	10.793***	19.610***	27.490***

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

TABLE 4 Results of bootstrapping mediation effect examination.

Paths	Effect	SE	LLCI	ULCI
Emotion management ability→psychological safety→learning engagement	0.100	0.024	0.057	0.150
Emotion management ability→self-efficacy→learning engagement	0.092	0.025	0.047	0.144

paths: emotion management ability affects college students' learning engagement by improving their psychological safety; emotion management ability enhances college students' self-efficacy, which in turn improving their learning engagement. Thus, improving college students' emotion management ability is helpful to enhance their learning engagement, and improving college students' sense of psychological safety and self-efficacy is also helpful to enhance their learning engagement.

Suggestions

Based on the findings of the study, the current study argues that the overall level of college students' learning engagement can be improved by regulating their emotion management ability, enhancing their psychological safety, and promoting their self-efficacy.

First, regulate college students' emotion management ability to improve their learning engagement. College students with higher emotion management ability will actively manage their own emotion and thus proactively and positively adjust their behaviors. This study also found a positive effect of emotion management ability on college students' learning engagement. From the perspective of emotion management ability, the present study proposes suggestions from three aspects: university, family and individual. (1) University aspect. Universities can improve the following two aspects in order to enhance the level of college students' learning engagement. ① The reform of China's education system should integrate the cultivation of emotion management ability into college education and teaching to enhance the level of college students' emotion management ability and promote the improvement of their learning engagement. On the one hand, universities can expand the scope of curriculum selection, enrich the curriculum system, enhance the flexibility of the curriculum, and set the requirements and goals for the cultivation of college students' emotional management ability, so that education on emotion management ability gradually penetrates into daily education and teaching activities, and let college students gradually understand the importance of emotion management ability, and guide them to receive education and cultivation in this regard in the process of curriculum selection. On the other hand, universities can also establish a combination of assessment and counseling mechanisms to reduce the emotional and psychological stress of college students, so as to enhance their enthusiasm and initiative for learning. The establishment of assessment and counseling system can help universities to grasp the problems of college students in emotion management ability, so that they can summarize them in various aspects, and then propose solutions to give more help to college students, such as conducting targeted lectures, quality development training, and training activities about emotional management ability. ② Improve the emotion management ability of university teachers. College students have a lot of contact with lecturers and counselors during their school years, and every word and action of teachers will influence them. Especially for freshmen who have just entered university, their minds are immature and need guidance from university teachers. Therefore, university

teachers need to improve their own emotion management ability and set an example for college students, so that they can learn how to manage their emotion from teachers and better participate in learning activities. In addition, counselors also need to take the initiative to pay attention to college students' study condition and mental health, strengthen communication, and provide timely guidance and education to students who are confused. (2) Family aspect. Parents need to maintain good communication with college students and give them a warm and comfortable environment to grow up. Parents have a significant influence on their children's emotion management ability. Parents should always communicate with their children, pay attention to the things, confusion, and stress they encounter in university, understand children's ideas, and give them support. At the same time, parents also should guide their children to face things positively and optimistically and deal with stress, so as to enhance their active engagement in life and learning. (3) College students aspect. College students need to learn to actively monitor and regulate their own emotion. For example, they can achieve these goals through physical and mental relaxation, strengthening physical exercise, reasonable venting of emotion, and doing things they are interested in to divert their attention and transform their negative emotion. Thus, they can keep a clear head and deal with them calmly when facing stress and difficulties. In addition, college students can also improve their own emotion management ability by building their own interpersonal network and developing the ability to communicate with others.

Second, enhance college students' psychological safety to improve their learning engagement. (1) University aspect. Teachers play a significant role in the growth process of college students, especially in enhancing their sense of psychological safety. A supportive instructional style can effectively control the negative emotion and negative behaviors of college students, which is a basic guarantee for improving their sense of psychological safety. A supportive instructional style can give students effective feedback and resource support in a timely manner, encourage students to make their own judgments, expand their learning scope, and stimulate their interest in learning and their learning initiative. At the same time, teachers also need to pay attention to emotional care and psychological comfort for college students, enhance their sense of psychological safety, increase opportunities for communication and exchange with college students, maintain sensitivity to students' psychological states, take the initiative to understand the problems they encounter and the psychological stressors they face, and take appropriate measures to help students relieve stress and improve their sense of psychological safety, so as to better promote their learning engagement. (2) Family aspect. Parents need to give college students enough care and not make them feel that they need to decide everything by themselves after they leave their parents and enter the college campus, and become alone. Meanwhile, parents also need to respect their children's opinions and give them guidance when they need it, so that their minds are in a more stable state. Parents can use children's summer and winter vacations to strengthen their emotional interaction with their children and put themselves in their shoes to make their children feel secure enough. (3) College students aspect. College students need to face their hearts and analyze the reasons for their psychological insecurity and face them squarely. They also should develop hobbies, expand social circles, and change themselves to live a more fulfilling and happy life.

Finally, promote college students' self-efficacy to enhance their learning engagement. (1) University aspect. Universities should strengthen the professional self-efficacy of college students, pay attention to the construction of school subjects, and let universities have more academic resources and employment learning opportunities, so as to enhance students' subject self-efficacy. Teachers need to guide students to clarify their own learning and development goals, have a good perception of themselves, improve their learning ability, develop good learning habits, and enhance their passion and love for learning. Teachers also need to encourage students and raise college students' expectations of their own abilities; such expectations will motivate them to change their own behaviors and ways of thinking to better engage in their learning. (2) Family aspect. Parents need to help college students learn to cope with setbacks, face failures and learn from their experiences. When college students face setbacks and difficulties and cannot adjust themselves in time, their self-efficacy will become low and their self-confidence will take a serious blow. Parents need to empathize with their children and empathize with them from the heart, so that they can feel the power of comfort. Parents also need to set an example for college students, which means that when parents face failure or setbacks they need to face them with optimism, cope with them strongly, and maintain their self-confidence, thus exerting a subtle influence on their children. (3) College students aspect. College students need to realize that the improvement of self-efficacy needs to start from themselves. They should continuously improve their own quality, study hard to learn professional and cultural knowledge, cultivate hobbies, have an objective evaluation of their abilities, make reasonable plans, learn to face failures and setbacks with a reasonable mindset, learn to attribute correctly, and integrate into the collective and work together with team members to improve the sense of collective efficacy.

Limitations and future research

Our study has several limitations. First, we finally returned 580 valid surveys. The main subjects of the study are college students in universities, while the number of Chinese universities is large and the types are different. The present

study is constrained by the subjective and objective conditions, only 650 students from four universities in northern China were selected for the study, resulting in an inadequate sample size, which leads to some limitations of the research findings. Second, the surveys in our study were mainly self-assessed by new generation employees. Although the Harmon' one-factor test was used to verify that there was no serious common method bias, it was not possible to completely exclude the possibility of its existence. Future research can used a staged data collection approach to weaken common method bias. Third, only six possible control variables were selected in conjunction with previous studies in this study, these are still incomplete. For example, we did not examine whether college students had served as student leaders. Finally, this study was not comprehensive in examining the antecedent variables of college students' learning engagement. We only examined the effects of emotion management ability, psychological safety, and self-efficacy on learning engagement and there could be other variables between emotion management ability and learning engagement, such as social support.

Data availability statement

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

Author contributions

XL made significant contributions to the study concept and design, and was primarily responsible for designing the study, collecting and analyzing data, drafting the manuscript, making several revisions and refinements to the content of the manuscript.

Conflict of interest

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

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Digital finance development and manufacturing emission reduction: An empirical evidence from China

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The implementation of carbon peak and carbon neutral goals cannot be achieved without the effective support of digital finance. This paper studies the inverted N-curve relationship between digital finance and carbon intensity, and identifies the emission reduction effects of digital finance development from the enterprise level. The study found that the development of digital finance has an inverted-N dynamic impact on the carbon intensity of the manufacturing industry. The emission reduction effects of the development of digital finance have typical multi-dimensional heterogeneous characteristics at the regional and enterprise levels. Mechanism analysis shows that the emission reduction effect of digital finance development depends on the combined effect of scale and technology. The initial stage of digital finance development can promote carbon emission reduction through the "scale effect" of reduction, and the digital finance development in the intermediate stage can increase carbon intensity through the "scale effect" of expansion, while long-term emission reductions can be achieved based on technological effect caused by the digital finance development in the mature stage.

KEYWORDS

digital finance, carbon emission, manufacturing, inverted U-shape, scale effect, technological effect

Introduction

China announced at the general debate of the 75th session of the UN General Assembly that "China will increase its independent national contribution, adopt more vigorous policies and measures, strive to peak CO_2 emissions by 2030, and strive to achieve carbon neutrality by 2060." The choice of the manufacturing sector as the breakthrough point is crucial to the effective implementation of the "dual carbon" targets of peak and neutral carbon emissions. In fact, a single end-of-pipe management model is no longer sufficient to meet the needs of the manufacturing sector to promote energy saving and green growth, and digital finance, which is supported by digital technology and integrated with traditional financial industries with more precise matching efficiency, undoubtedly provides a "new answer" for the manufacturing sector to reduce emissions.

Digital finance is defined as the integration of traditional financial business with Internet technology (1), covering such businesses as electronic payment and online investment and financing. Since the introduction of the policy of "encouraging the development of Internet finance" in 2014, China's digital finance has entered the "fast lane" of development, with mobile payment tools such as WeChat and Alipay developing rapidly and growing. The Digital Inclusive Finance Index measured by the Digital Finance Research Center of Peking University shows that in 2019, China's Digital Inclusive Finance Index exceeded that of 2011 by nearly eight times. Although digital finance has impacted traditional financial services to a certain extent, it is able to have many positive impacts on the development of the real economy, such as the manufacturing industry, based on the low threshold nature of financing, the universality of financial services, the accessibility of service scope and the convenience of mobile payments (2, 3). Zhang et al. (4) found that digital financial development can promote inclusive economic growth by stimulating innovation and entrepreneurship, and the economic growth-enhancing effect of inclusive finance is more significant in rural areas. Yu et al. (5) focused on the impact of digital finance on less developed regions, and the results showed that digital finance can help improve the function of financial services to narrow the development gap between urban and rural areas, thus promoting high-quality economic development. Based on the intrinsic connection between digital finance and manufacturing development, it can be inferred that digital finance will inevitably have a profound impact on carbon emissions in manufacturing production activities (6), so it is of great practical significance to build a low-carbon development model for manufacturing supported by digital finance. Based on this, this paper attempts to integrate digital finance and carbon emissions into a unified analytical framework, assess the emission reduction effects of digital finance development at the manufacturing enterprise level, and examine the intrinsic mechanisms.

The possible marginal innovations of this paper are mainly reflected in the following aspects: (1) This paper systematically examines the non-linear association between digital finance and carbon emission reduction in the manufacturing industry from both theoretical analysis and empirical tests. To overcome the potential endogeneity problem, this paper selects natural geographic and historical data such as the spherical distance from each city to Hangzhou and the number of post offices and fixed telephone ownership in 1984 as instrumental variables for endogeneity analysis. (2) The paper analyzes the intrinsic mechanism of digital finance's impact on manufacturing emission reduction through the "scale effect" and "technology effect," and explains it based on the alleviation of financing constraints and digital transformation caused by the development of digital finance. The paper also explains the impact of digital finance on manufacturing emissions reduction through the "scale effect" and "technology effect." At the same time, the dynamic changes in the effect of digital finance on manufacturing emission reduction at different stages of development are examined. (3) This paper examines the heterogeneous impact of digital finance on manufacturing carbon emission reduction from the perspective of regional distribution, resource endowment, enterprise size, enterprise ownership and enterprise age.

Literature review

Literature review on the impact of environmental development on financial pollution

As an important support for economic growth, the impact of financial development on environmental pollution has also received much academic attention. He et al. (7) empirically examined the impact of financial development on environmental pollution using technological innovation as a mediating variable, and the results showed that both the scale of credit of financial institutions and the scale of financing in financial markets could significantly affect environmental pollution. Although the correlation between financial development and environmental pollution has been verified, it is still controversial whether the impact of financial development on environmental pollution is improved or worsened.

Tamazia et al. (8) focused on the financial markets of BRICS countries and found that the reduction of financing costs and the expansion of financing channels provided sufficient financial support for technological research and development, thus significantly reducing carbon emissions in BRICS countries. Hassan and Asall (9) found that financial development can significantly reduce the rate of environmental degradation. Using South Africa as an example, Shahbaz et al. (10) and Salahuddin et al. (11) found that financial development in developing countries can lead to a greater flow of funds to environmentally friendly projects and ultimately reduce pollution. Xu et al. (6) reported that digital finance has the effect of pollution reduction, and the entrepreneurship effect, innovation effect and industrial upgrading effect are important mechanisms. Zhang and Chen (12) found that financial development can coordinate with environmental regulation to promote green economic transformation under the circumstance that environmental regulation fails to play a significant role in policy. Zheng et al. (13) suggested that the digital finance has significant governance effect on environmental pollution. The digital finance can indirectly control environmental pollution by promoting social and economic development, leading industrial transformation and upgrading, and improving the level of green technology innovation.

However, some scholars pointed out that the digital finance can lead to increased pollution.

Sadorsky (14) argued that financial development increases the financing capacity of enterprises, which in turn led to the expansion of production capacity and energy consumption, ultimately leading to increased environmental pollution. Similarly, Tao et al. (15) compared the pollution control effects of financial scale and financial efficiency, and found that the increase in financial efficiency can create incentives for clean product development and hence emission reduction. Sehrawat et al. (16) pointed out that the expansion of consumption in the middle-income group and the resulting increase in carbon emissions are particularly evident in the context of financial development. Zou (17) further suggested that green-oriented financial policies also promote the emission reduction behaviors of enterprises. Song and Bian (18) argued that the direct effect, indirect effect and total effect of financial opening on haze pollution are significantly positive in the short term, that is, the higher the degree of financial openness, the higher the haze pollution level.

Given the uncertain relationship between financial development and environmental pollution, it has become a more common choice to study the intrinsic association between the two from a non-linear perspective. Financial development can promote technological progress and enhance technical support for carbon emission reduction, but it will also lead to an increase in economic growth rate and energy consumption, resulting in an increase in total carbon emissions. Hu and Yi (19) decomposed the environmental effect of financial development into scale effect and technology effect. Ren and Zhu (20) further took into account the structural effect of financial development on environmental pollution, and the results showed that there were differences in the effects of financial development on different pollutants. Wang et al. (21) further distinguished the non-linear relationship between financial scale, financial efficiency and environmental pollution, in which financial scale and environmental pollution showed an inverted N-curve relationship, while financial efficiency has a U-shaped curve relationship with it.

Literature review on the impact of digital finance on economic development

Although the impact of financial development on environmental pollution has been well discussed, it has generally focused on the development of the traditional financial sector, and few studies have addressed the impact of digital finance on carbon emissions reduction, which is the focus of this paper. It is worth noting that most of the studies on digital finance at this stage have focused on the relationship between digital finance and economic growth, which undoubtedly provides an important reference for the argument on how digital finance affects carbon emissions, given the close relationship between economic growth and carbon emissions. As a new type of service industry that integrates traditional finance with digital technology, digital finance can significantly expand the coverage of financial services and thus exert its inclusive effect, while relying on digital technology and the Internet platform can effectively improve the accuracy and efficiency of financial resource matching, enabling financial services to have both fairness and efficiency attributes, thus positively influencing high-quality development. Zhang et al. (4) found that digital financial development can promote inclusive economic growth by stimulating innovation and entrepreneurship, and the economic growth-enhancing effect of inclusive finance is more significant in rural areas.

Through a summary of the existing literature, the incremental effect of digital finance on high-quality economic development comes from three main sources: (1) The digital finance development helps to upgrade the industrial structure. Bai and Zhang (22) suggested that the inclusive nature of financial services can help optimize the allocation of primary capital, which in turn can promote the upgrading of industrial structure. Tang et al. (2) conducted an empirical analysis based on city-level panel data and find that the development of digital inclusive finance has a long-term and significant promotion effect on the upgrading of industrial structure. Second, the development of digital finance helps technological innovation. Li (23) suggested that the process of high-quality development is the transformation from factor-driven to innovation-driven, and innovation-driven cannot be effectively supported by the digital model of financial services. Teng and Ma (24) argued that digital financial development can enhance the innovation level of enterprises and thus provide new momentum for regional high-quality development. Tang et al. (2) find that digital financial development has a "structural" effect on enterprise. Xue and Hu (25) argued that digital finance, with its connotation of financial technology, can play a positive role in channeling capital and other factors and improve the financial industry's ability to serve the traditional economy. Li and Cheng (26) suggested that the application of digital technology has expanded the financing channels of enterprises and promoted capital accumulation and capital utilization efficiency through non-bank credit intermediation.

However, Huang (1) pointed out that there are many antecedents to the impact of digital finance on economic development, and that differences in both economic and institutional variables can lead to differential impacts of digital finance on high-quality development. Cao (27) considered that the integration capacity of China's industrial internet platform system is limited at this stage, and the degree of digitization of enterprises is generally low, thus limiting the development of enterprises and digital financial services which makes it difficult to promote industrial economic growth. Jiang and Sun (28)

similarly found that the development of digital economy based on digital finance has a long-term crowding-out effect on the growth of the real economy, and the impact of digital finance on the real economy has become a non-negligible obstacle affecting the high-quality development of China's economy.

Through the above-mentioned literature, it is easy to find that there is a large research gap to examine the impact of digital finance in the environmental field, and no relevant literature has been found to examine the emission reduction effect of digital finance development in the context of the current "double carbon" targets of carbon peaking and carbon neutrality. In addition, current research often decomposes the impact of financial development on environmental pollution into scale and technology effects, but lacks the examination of specific transmission paths and the analysis of the dynamic change characteristics of the dominant paths. Based on this, this paper constructs a theoretical model of the impact of digital finance on manufacturing industry emission reduction, examines the emission reduction effect of digital finance on manufacturing industry from both theoretical analysis and empirical test.

Mechanistic analysis and research hypotheses

Unlike the traditional financial services sector, the development of digital finance has both a "crowding out" effect and an "incentive effect" on the manufacturing sector, which is typical of the real economy. At the early stage of digital finance development, it tends to channel capital and other factors to the digital economy industry sector, while the traditional real economy such as manufacturing industry is vulnerable to the "crowding out" effect of digital economy industry development due to the generally low degree of digitalization and imperfect digital integration system. At this time, the development of digital finance has limited the technological product development and value creation of the manufacturing technology R&D sector, and the value of the parameter is on the negative side. However, along with the expansion of service capacity and scope, digital finance contributes to the deepening of the integration of the traditional real economy and the digital economy, thus creating an "incentive" impact on the economic growth of the manufacturing sector. The value of the sum parameter tends to change from negative to positive. It is thus inferred that the marginal impact of digital finance development on the economic growth of the manufacturing industry shows a dynamic pattern of "first inhibiting, then promoting." In addition, considering that industry correlation can affect the marginal reduction effect of economic growth, it means that the marginal reduction effect of digital finance development may also be affected by industry correlation. Digital finance development may lead to spillover reduction between industries.

The U-shaped impact of digital finance on economic growth and the inverted U-shaped impact of economic growth on carbon intensity are analyzed together, and the paper suggests that the impact of digital finance on carbon intensity can be summarized in three stages: in the early stage, digital finance tends to crowd out the development of the real economy, such as manufacturing, and achieves carbon emission reduction through the "scale effect" of shrinkage; in the middle stage In the middle stage, digital finance can promote economic growth in the manufacturing sector by easing the financing constraint, which increases carbon intensity based on the "scale effect" of expansion; in the mature stage, the development of digital finance helps drive digital transformation and innovation and research and development of green technologies, driving carbon reduction through the "technology effect In the mature stage, the development of digital finance can help drive digital transformation and green technology innovation and research, and promote carbon reduction through the "technology effect." Accordingly, the theoretical hypotheses of this paper can be formulated.

Hypothesis 1

Digital financial development has an inverted-N type of emission reduction effect on manufacturing.

Hypothesis 2

The emission reduction effect of digital finance development depends on the combined effect of the "technology effect" and the "scale effect," and there are dynamic changes in the dominant effect in different time periods.

Empirical research

Benchmark regression model

Based on the above analysis of the mechanisms by which digital finance affects carbon emission reduction, this paper examines the impact of digital finance development on the carbon intensity of the manufacturing sector at the enterprise level, with the following benchmark model.

$$cc_{ijt} = \alpha_0 + \alpha_2 digital_{ijt} + \alpha_3 digital_{ijt}^2 + \alpha_4 digital_{ijt}^3 + \alpha_5 X_{ijt} + \delta_r \times time + \omega_t \times time + \gamma_t + \sigma_i + \varepsilon_{ijrt} \quad (1)$$

where i, j, r and t denote listed manufacturing enterprises, industry, city and year respectively; denote the explanatory variable carbon intensity of manufacturing enterprises; and denote the digital finance development index. Considering the inverse N-shaped relationship between digital financial

development and carbon intensity proposed in the hypothesis of this paper, this paper introduces both its quadratic and cubic terms into the benchmark model; denotes the random perturbation term, and is used to control for the time trend effect of region and time, respectively, while and denotes the time fixed effect and firm fixed effect, respectively. Meanwhile, other economic characteristics X that may affect the carbon intensity of manufacturing firms are controlled for in this paper, including firm age, firm nature and capital intensity.

Variable description

The carbon emission intensity (cc)

As carbon emission data at the level of listed companies are difficult to obtain directly, this paper refers to Ju (29) and uses the energy consumption data disclosed in the social responsibility reports of listed companies to estimate their total carbon emissions. The resource consumption indicators involved include energy (converted to standard coal), gasoline, diesel, natural gas, piped gas, purchased electricity and purchased heat.

The digital financial development (digital)

This paper mainly adopts the Digital Inclusive Finance Development Index of Peking University's Digital Finance Research Center to characterize the development of digital finance, which measures the level of digital financial development in terms of breadth of coverage, depth of use and degree of digital support services. The index measures the level of digital financial development in terms of breadth of coverage, depth of use and the degree of digital support services, including electronic accounts such as internet payment accounts. The index is based on Ant Financial Services' big data on transaction accounts and is highly reliable (30).

The control variables

Referring to related studies on the productivity of listed manufacturing industries (31–40) this paper introduces a set of control variables: enterprise age (*AGE*) is represented by the difference between 2019 and the year of establishment of the enterprise; enterprise ownership (*ATTR*) is represented by a 0–1 dummy variable. One for state-owned enterprises and zero for non-state-owned enterprises; return on net assets (*ROE*) is represented by the ratio of after-tax profit to net assets of the company; gearing ratio (*LVE*) is expressed as the ratio of total liabilities to tangible assets; operating income growth rate (*REVE*) is expressed as the ratio of current operating income to previous operating income; equity concentration (*CR*) is expressed as the ratio of the largest shareholder's holding; and capital intensity (*CAID*) is expressed as the ratio of fixed assets to the number of employees in the firm.

Data sources

A balanced panel dataset with a study period of 2011–2019 was established through city-firm level data matching. Among them, after eliminating samples with more missing values in the five-year period. Among them, various financial data related to enterprises were obtained from the wind database, enterprise patent data from the CNRDS database, enterprise green technology patent data from the national patent database, and energy consumption data mainly from listed companies' Corporate Social Responsibility Report, etc. In order to overcome the influence of outliers, this paper also carried out the tailing process for continuous variables below 1 and above 99% of the quantile.

Analysis and discussion of empirical results

Baseline regression analysis

The results in Table 1 show that the primary, secondary and tertiary terms of digital financial development pass the test at least at the 10% significance level with negative, positive and negative values, which means that digital financial development has a non-linear effect of "first suppressing, To analyze the possible reasons for this, it is difficult to form an effective interface between digital finance development and the real economy, such as the manufacturing industry, at the initial stage, and its financial services have an obvious bias toward the digital economy industry. Due to the relatively limited integration of the digital economy with the traditional economic development, the real economy tends to be "crowded out," so the initial stage of digital financial development can promote the reduction of emissions in the manufacturing industry based on the "scale effect" of reduced investment, etc.; the medium-term stage of digital financial development The development of digital finance in the middle stage can alleviate the financing constraints of manufacturing enterprises based on its inclusive characteristics, and the integration of the digital economy with the real economy, such as manufacturing, further promotes the in-depth application of digital finance in the manufacturing sector, which will undoubtedly contribute to the expansion of the scale of investment in manufacturing enterprises and the increase in total energy consumption, thus hindering the reduction of emissions in the manufacturing sector based on the "scale effect" of expansion The development of digital finance in the mature stage can not only provide sufficient financial support for green innovation, but also

TABLE 1 Estimated results of the impact of digital finance on the carbon intensity of the manufacturing sector.

	(1)	(2)	(3)	(4)	(5)	(6)
digital	−0.2471***	−0.2503***	−0.0337***	−0.0350***	−0.0619***	−0.0654***
	(−3.53)	(−3.04)	(−2.85)	(−3.01)	(−4.14)	(−4.09)
$digital^2$	−0.1206*	−0.1254*	0.0192**	0.0171**	0.0308***	0.0273**
	(−1.88)	(−1.69)	(2.04)	(2.25)	(2.72)	(2.44)
$digital^3$	−0.0375	0.0366	−0.0041*	−0.0058*	−0.0083**	−0.0100*
	(−1.42)	(1.34)	(−1.75)	(−1.68)	(−1.96)	(−1.78)
Control variables	NO	YES	YES	YES	YES	YES
Firm fixed effects	NO	NO	YES	YES	YES	YES
Year fixed effects	NO	NO	NO	YES	YES	YES
Province x time trend fixed effects	NO	NO	NO	NO	YES	YES
Industry x time–trend fixed effects	NO	NO	NO	NO	NO	YES
Adjusting for R^2	0.4351	0.4647	0.4421	0.4972	0.5013	0.5126

***, ** and * denote tests passed at the 1, 5 and 10% significance levels.

force manufacturing enterprises to actively carry out digital transformation, in which the emission reduction effect of the "technology effect" exceeds that of the expansion of the "scale effect" on The carbon intensity of the expansion will ultimately contribute to the reduction of emissions in the manufacturing sector. Above results partly prove the Hypothesis 1, which states that the development of digital finance has an inverted N-curve relationship with the carbon intensity of manufacturing firms.

Robustness tests

In order to ensure the reliability of the analysis results, this paper uses a series of robustness tests to ensure the reliability of the estimation results, and the results are shown in Table 2. (1) Core explanatory variables are treated with a one-period lag. In order to overcome the potential endogeneity between digital financial development and carbon intensity of manufacturing firms, this paper uses digital financial development with a one-period lag as the core explanatory variable. The results show that the impact of digital financial development on the carbon intensity of manufacturing enterprises is still inverted-N. (2) Replacement of the explanatory variables. Carbon emission reduction includes both the reduction of carbon intensity and the reduction of total carbon emissions. Compared with the carbon intensity indicator, which portrays carbon emissions from the perspective of production efficiency, the total carbon emissions indicator can reflect the carbon emissions level of manufacturing enterprises from the perspective of production scale, so this paper chooses the total carbon emissions indicator as a new explanatory variable. The results show that the development of digital finance has an inverse N-shaped effect on the carbon intensity of manufacturing enterprises. This finding not only fully supports the emission reduction effect of digital finance development, but also reveals that digital finance development has the dual carbon emission reduction effect of "total emission reduction" and "intensity reduction." (3) A sub-dimensional study based on the breadth of coverage, depth of use and degree of digital support services. Specifically, the impact of both the breadth of digital finance coverage and the depth of digital finance use on the carbon intensity of manufacturing enterprises remains consistent in an inverted-N pattern. In contrast, the impact of the extent of digital finance services on the carbon intensity of manufacturing enterprises is only monotonically pro-increasing, thus proving that the inverted-N impact of digital finance development on the carbon intensity of manufacturing enterprises mainly comes from the breadth of digital finance coverage and depth of use. It is easy to understand that the deepening of the application and promotion of digital finance has deepened the reliance of the manufacturing industry on digital finance, and its emission reduction effect has been highlighted, while the convenience of digital financial services mainly affects individual residents, and manufacturing enterprises are relatively weakly affected by it.

There is a possible two-way causal relationship between the development of digital finance and the carbon intensity of the manufacturing sector. On the one hand, as an important support for economic growth, digital finance development can improve the supply of funds and promote the expansion of production capacity by alleviating financing constraints, which in turn has an impact on the carbon emissions of the manufacturing sector; on the other hand, the manufacturing sector needs to base its own emission control and emission reduction on clean technology research and development, and the demand for funds for technology research and development The demand for funds for technological research and development will undoubtedly force manufacturing enterprises to accelerate their digital transformation and deepen the application of

TABLE 2 Results of robustness analysis.

	(1)	(2)	(3)		
	One period lag treatment	Replacement of explanatory variables	Covering the breadth dimension	Depth of use dimension	Level of service dimension
digital	−0.0702***	−0.0527***	−0.0513***	−0.0872***	0.0252*
	(−3.98)	(−3.26)	(−2.62)	(−4.49)	(1.69)
$digital^2$	0.0266**	0.0209***	0.0216*	0.0302**	0.0129
	(2.15)	(2.96)	(1.89)	(2.38)	(1.30)
$digital^3$	−0.0092*	−0.0018*	−0.0047*	−0.0081**	−0.0026
	(−1.85)	(−1.82)	(−1.70)	(−1.97)	(−0.85)
Control variables	YES	YES	YES	YES	YES
Firm fixed effects	YES	YES	YES	YES	YES
Year fixed effects	YES	YES	YES	YES	YES
Province x time trend fixed effects	YES	YES	YES	YES	YES
Industry x time–trend fixed effects	YES	YES	YES	YES	YES
Adjusting for R^2	0.5798	0.7622	0.6214	0.5883	0.3418

***, ** and * indicate passing the test at the 1, 5 and 10% significance levels.

digital finance. Although the previous analysis overcomes the potential endogeneity problem to a certain extent, the variables selected are not specific instrumental variables for digital finance development, so this paper selects specific instrumental variables for endogeneity analysis based on physical geography and historical data. Considering the inverse N-shaped relationship between digital finance development and carbon intensity of manufacturing firms, three instrumental variables are introduced in this paper. (1) The number of post offices per million people (POST) and the number of fixed-line telephones per million people (TEL) in 1984. The history of digital finance is also the history of the development of the digital technology on which it is based, with the Internet and other digital technologies as its core, thus enabling the development of online financial services and the expansion of the scope of services. In fact, the essence of digital technology is the change in the way information is transmitted. In the early days, information transmission was mainly achieved through post offices and fixed telephones, so areas with a dense distribution of post offices and a large number of fixed telephones tended to have more developed information communication, and the rise of digital technology and the development of digital finance was more likely to occur in these places. Considering that data on the number of post offices and fixed telephone ownership at the city level in China can be traced back as far as 1984 in the China Urban Statistical Yearbook, this paper chooses the number of post offices per million people (POST) and fixed telephones per million people (TEL) in 1984 as the specific instrumental variables. This historical data can effectively portray the level of regional communication development and meet the requirement of correlation, while at the same time it is difficult to influence the carbon intensity of the manufacturing industry at this stage due to the long period of time, and satisfies the assumption of exclusivity. (2) The spherical distance from each city to Hangzhou (DIST). The development of digital finance, represented by Alipay, originated in Hangzhou, which is therefore in a leading position, and it can be expected that the closer in geographic distance to Hangzhou, the better the degree of digital finance development should be. At the same time, geographical distance as a typical physical geographical feature is not closely related to economic and social factors, thus satisfying the correlation and exclusivity assumptions as well. In this paper, the spherical distance from each city to Hangzhou is calculated using a Geographic Information System (GIS). To apply the above instrumental variables to the balanced panel data, the interaction terms of the number of post offices/million people in 1984, the number of landline phones/million people and the spherical distance from each city to Hangzhou are constructed in turn as time-series instrumental variables with the digital financial inclusion index.

Table 3 reports the estimation results of the endogeneity analysis. From the first stage regression results, the number of post offices per million people and the number of landline telephones have a significant positive correlation with digital financial development overall, while the spherical distance from each city to Hangzhou has a significant negative correlation with digital financial development, thus demonstrating that all three instrumental variables selected in this paper are closely related to digital financial development. The results of the second stage of estimation show that there is an inverse N-shaped effect between digital financial development and carbon

intensity of manufacturing enterprises, which implies that the effect of digital financial development on carbon intensity of manufacturing enterprises remains robust after overcoming the endogeneity problem.

Heterogeneity analysis

Considering the differences in regional development and enterprises' own attributes, this paper further examines the heterogeneous characteristics of the emission reduction effect of digital finance at the enterprise level and regional level, and the results are shown in Table 4. At the enterprise level, this paper examines the differential emission reduction effects of digital finance development in the enterprise age dimension, the enterprise ownership dimension and the enterprise scale dimension in turn. (1) Firm age dimension. The impact of digital finance development on the carbon intensity of young enterprises is inverted N-shaped, while the impact on the carbon intensity of mature enterprises is U-shaped, indicating that it is difficult for digital finance development to form a long-term emission reduction effect in mature enterprises at this stage. At the same time, comparing the intensity of the impact of digital finance development on both, we can see that the carbon intensity of young enterprises is more deeply affected by digital finance development. The reason for this is that compared to mature enterprises, young enterprises are more receptive to digital financial services and other Internet technology applications, and tend to be more open and forward thinking in their management, while mature enterprises are relatively conservative in their business models and the application of digital financial services within them has lagged. (2) Enterprise ownership dimension. Unlike non-state-owned enterprises, whose carbon intensity is affected by the development of digital finance in an inverted N-shape, the carbon intensity of state-owned enterprises is correlated with the development of digital finance in an inverted U-shape. The carbon intensity of digital finance increases at the early stage of development, while it decreases when the development of digital finance reaches a mature stage. The possible reason for this phenomenon is that SOEs have strong financing guarantees and policy support, and it is difficult to squeeze out manufacturing SOEs from the financing constraints caused by the initial development of digital finance. Thus, compared to non-SOEs, SOEs can move more quickly into the digital emissions reduction phase by actively deepening their use of digital financial services. (3) Enterprise size dimension. The inverse effect of digital finance development on emission reduction in the manufacturing industry is concentrated in large and medium-sized enterprises, while

TABLE 3 Results of the endogeneity analysis.

	Stage 1	Stage 1	Stage 1	Stage 2
digital				−0.0128**
				(−2.15)
$digital^2$				0.0076*
				(1.88)
$digital^3$				−0.0008*
				(−1.74)
TEL	0.0165*	0.0112	0.0205*	
	(1.78)	(1.59)	(1.70)	
POST	0.0202**	0.0246**	0.0175**	
	(2.08)	(1.94)	(2.23)	
DIST	−0.0385***	−0.0186***	−0.0547***	
	(−2.94)	(−2.72)	(−3.13)	
Control variables	YES	YES	YES	YES
Firm fixed effects	YES	YES	YES	YES
Year fixed effects	YES	YES	YES	YES
Province x time trend fixed effects	NO	NO	NO	NO
Industry x time trend fixed effects	YES	YES	YES	YES

***, **, * indicate passing the test at the 1, 5 and 10% significance levels respectively. This paper does not control for area fixed effects given the difficulty of varying geographical distance over time for the geographic data instrument variable.

TABLE 4 Analysis of heterogeneity.

	Young enterprises	Mature enterprises	State-owned enterprises	Non-State-owned enterprises	Small-scale enterprises	Large and medium-sized enterprises
digital	−0.0758***	−0.0545**	0.0492***	−0.0518***	0.0184***	−0.0622***
	(−4.44)	(−2.16)	(2.72)	(−5.28)	(4.09)	(−3.99)
$digital^2$	0.0311***	0.0115*	−0.0170**	0.0263***	0.0066	0.0283***
	(2.87)	(1.87)	(−2.44)	(2.79)	(1.09)	(2.77)
$digital^3$	−0.0093**	−0.0007	−0.0076	−0.0055**	−0.0008	−0.0061**
	(−1.95)	(−1.26)	(−1.23)	(−2.00)	(−0.85)	(−1.98)

***, ** and * indicate passing the test at the 1, 5 and 10% significance levels respectively.

in small-sized enterprises, it is only an increase in carbon intensity. This paper suggests that small-scale enterprises are generally in the initial profit-seeking stage, with weak financing capacity and insufficient emphasis on technological research and development, and therefore the financial factors obtained by small-scale enterprises through digital finance are more inclined to capacity expansion.

Mechanism analysis

In order to examine the intrinsic mechanism of digital financial development affecting carbon emissions, this paper constructs the following panel threshold model (PTM) using digital financial development as the threshold variable to empirically examine the phasing of digital financial development affecting carbon intensity of manufacturing enterprises.

$$cc_{ijt} = \gamma_0 + \gamma_1 digital_{ijt} \times I(digital_{ijt} \leq \lambda) + \gamma_2 digital_{ijt} \times I(digital_{ijt} > \lambda) + \gamma_3 X_{ijt} + \delta_r \times time + \omega_r \times time + \gamma_t + \sigma_i + \varepsilon_{ijrt} \quad (2)$$

where I(·) denotes the indicator function, I(·) = 1 when the function holds and 0 otherwise; and λ denotes the threshold value. The threshold effect model sets the original hypothesis as H0: γ2 = γ3, which means that the original hypothesis is accepted and there is no threshold effect; rejection of the original hypothesis indicates that there is a threshold effect. After passing the single threshold model test, the double threshold model test is continued, and if the double threshold model is significant then the triple threshold model test is carried out by analogy, otherwise the model is a single threshold model. In this paper, the specific F-statistic values of the above equation are estimated under 300 bootstrap self-sampling to determine whether the threshold effect model exists, as well as the number and value of the thresholds, and the results are reported in Table 5. Digital financial development can pass the double threshold test. The impact of digital financial development on the carbon intensity of manufacturing enterprises can be classified into three stages: 'primary', 'intermediate' and 'mature'. The development of digital finance can be classified into three stages: 'primary', 'intermediate' and 'mature'. Meanwhile, in the primary and mature stages, the impact of digital finance development on the carbon intensity of manufacturing enterprises is significantly negative at – 0.0351 and – 0.0102 respectively, while in the intermediate stage, the impact is significantly positive (0.0194), which not only fully supports the conclusion that digital finance development has a "suppressing, then increasing, then suppressing" effect on the carbon intensity of manufacturing enterprises. This finding not only confirms that digital finance development has an inverted N-shaped impact on the carbon intensity of manufacturing enterprises, but also indicates that the impact of digital finance development on the carbon intensity of manufacturing enterprises can be divided into three stages (Table 6).

TABLE 5 Threshold effect test and threshold estimation results.

	Threshold	F–statistic	10%	5%	1%
Part I					
Single threshold	129.54	43.86 [0.02]	23.21	30.01	50.10
Double threshold	280.42	19.52 [0.01]	22.03	25.42	33.25
Triple threshold	340.71	11.67 [0.76]	30.75	35.18	45.19
Part II					
$digital < \lambda_1$		−0.0351**(−1.98)			
$\lambda_1 < digital < \lambda_2$		0.0194**(2.96)			
$digital > \lambda_2$		−0.0102*(−1.85)			

***, ** and * indicate passing the test at the 1, 5 and 10% significance levels respectively.

In the early stages, the development of digital finance can reinforce the financing constraints of manufacturing enterprises and lead to a reduction in their investment scale, and has a potential inhibiting effect on corporate green innovation. This is mainly due to the fact that the financial services provided by digital finance in the early stages of development are more inclined to the digital economy, which is driven by digital technology and digital finance, and the development of the digital economy can create a crowding-out effect on the real economy, such as the manufacturing sector. Moreover, although digital finance can fuel green innovation by forcing the digital transformation of enterprises, this pro-increase effect is not significant in the primary stage. On this basis, only the interaction between digital finance, financing constraints and investment scale (−0.0149) has a significant negative impact on the carbon intensity of manufacturing firms in the primary stage, so the reduced 'scale effect' in the primary stage is the key to the reduction in carbon intensity of manufacturing firms due to the development of digital finance.

In the intermediate stage, thanks to the deepening of the application of digital finance and the effective play of the inclusive feature, digital finance can effectively alleviate the financing constraints of manufacturing enterprises, thus providing sufficient financial support for the expansion of investment scale and enterprise technology research and development. The impact of digital finance development on both investment scale and green innovation is significantly positive, but the effect on investment scale is much stronger than that on green innovation. At the same time, the effect of digital finance development on green innovation based on the digital transformation of enterprises is still not significant, which may be related to the longer period of technology research and development, application and diffusion. At this point, the effect of the interaction term ($digital \times KZ \times invest$)

TABLE 6 Results of the analysis of intrinsic mechanisms.

	Primary stage ($digital<\lambda_1$)			Intermediate stage ($\lambda_1<digital<\lambda_2$)			Mature stage ($digital>\lambda_2$)		
	invest	*gtech*	*cc*	*invest*	*gtech*	*cc*	*invest*	*gtech*	*cc*
digital × *KZ*	−0.5264*	−0.0204		1.2033***	0.0417*		0.8402*	0.0197***	
	(−1.91)	(−0.44)		(2.88)	(1.90)		(1.86)	(2.66)	
digital × *ie*		0.0288			0.0417			0.0202*	
		(0.44)			(1.50)			(1.86)	
digital × *KZ* × *invest*			−0.0149*			0.0228***			0.0127**
			(−1.75)			(3.15)			(2.20)
digital × *KZ* × *gtech*			−0.0112			−0.0076*			−0.0136**
			(−0.85)			(−1.70)			(−1.98)
digital × *ie* × *gtech*			0.0073			−0.0057			−0.0081**
			(0.89)			(−1.53)			(−2.24)
Control variables	YES	YES	YES	YES	YES	YES	YES	YES	YES
Firm fixed effects	YES	YES	YES	YES	YES	YES	YES	YES	YES
Year fixed effects	YES	YES	YES	YES	YES	YES	YES	YES	YES
Province x time trend fixed effects	YES	YES	YES	YES	YES	YES	YES	YES	YES
Industry x time trend fixed effects	YES	YES	YES	YES	YES	YES	YES	YES	YES

***, ** and * denote passing the test at the 1, 5% and 10% levels of significance respectively.

between digital finance, financing constraints and investment scale on the carbon intensity of manufacturing enterprises is significantly positive (0.0228), while the effect of the interaction term (*digital* × *KZ* × *gtech*)between digital finance, financing constraints and investment scale is significantly negative (−0.0076), which indicates that digital finance development in the intermediate stage can induce the "scale effect" and "technology effect" of expansion This indicates that digital finance development in the intermediate stage can induce the "scale effect" and the "technology effect" to jointly affect the carbon intensity of manufacturing enterprises, but since the carbon intensity increase due to the scale effect is significantly greater than the carbon intensity decrease due to the technology effect, digital finance development in the intermediate stage eventually manifests itself as a carbon intensity-enhancing effect.

In the mature stage, digital finance development can still effectively alleviate the financing constraint and expand the scale of corporate investment, but the degree of enhancement decreases compared to the intermediate stage. At the same time, the development of digital finance can also significantly increase the level of green innovation by alleviating the financing constraint and forcing the digital transformation of enterprises. In this stage, digital finance development can also induce the "scale effect" of expansion to increase the carbon intensity of manufacturing enterprises, but the "technology effect" driven by the easing of financing constraints and digital transformation can significantly reduce the carbon intensity of manufacturing enterprises, and the sum of The "technology effect" is significantly stronger than the "scale effect," which ultimately results in a positive carbon reduction effect for manufacturing enterprises.

Conclusions and recommendations

This paper links carbon emissions and digital finance variables. This paper introduces carbon emissions and digital finance variables into the endogenous growth Romer model that includes knowledge output, and theoretically analyzes the inverted-N relationship between digital finance development and carbon intensity; then, by matching city-manufacturing supervisor firm data, we empirically test the impact of digital finance development on the carbon intensity of manufacturing enterprises, and based on the "scale effect" and "scale effect," we also examine the impact of digital finance development on the carbon intensity of manufacturing enterprises. The main conclusions are as follows: The impact of digital finance on the carbon intensity of manufacturing enterprises is based on the "scale effect" and "technology effect." The main findings are as follows:

(1) There is a significant inverse-N relationship between digital finance development and carbon intensity of manufacturing

enterprises. The dynamic impact on carbon intensity of manufacturing industries is "first inhibited, then promoted, then inhibited."

(2) There is typical heterogeneity in the impact of digital financial development on the carbon intensity of the manufacturing sector. On the firm dimension, the emission reduction effect of digital financial development on young manufacturing firms is better than that of mature firms in the long run. Similarly, the emission reduction effect of digital financial development on large and medium-sized enterprises is more prominent compared to small-sized enterprises. State-owned enterprises (SOEs), with their policy support, are better able to benefit from the financing dividend brought by digital finance development, thus showing an inverted U-shaped emission reduction effect, while non-SOEs show an inverted N-shaped emission reduction effect.

(3) The inverse N-shaped impact of digital finance development on manufacturing carbon intensity depends on the combined effect of "scale effect" and "technology effect." In the primary stage, the development of digital finance will aggravate the financing constraints faced by manufacturing enterprises, thus forming a "crowding-out effect" on the development of the manufacturing sector, and this reduced "scale effect" will help reduce carbon emissions; in the intermediate stage, the development of digital finance can On the other hand, it can provide sufficient financial support for technology research and development and force the digital transformation of enterprises, however, due to the long cycle of technology research and development, the "technology However, due to the long cycle of technology development, the "technology effect" is much smaller than the "scale effect" of expansion, so digital finance development can enhance the carbon intensity of the manufacturing industry; although digital finance development in the mature stage can also induce the "scale effect" of expansion, the "technology effect" caused by digital finance development is much smaller than the "scale effect" of expansion. Although digital finance development at a mature stage can also induce the "scale effect" of expansion, the "technology effect" caused by digital finance development is significantly enhanced and exceeds the "scale effect" of expansion.

Based on the above research findings, this paper mainly puts forward the following policy recommendations: The government departments should actively guide enterprises to develop an effective interface with digital financial services, and enterprises themselves should actively seek the optimal path for digital transformation, so as to promote the development of digital finance in the manufacturing sector to break through the "emission reduction inflection point" as soon as possible and build a low-carbon model for long-term emission reduction in the manufacturing sector. Specifically, the development of digital finance needs to clarify the three basic principles of "inclusiveness," "low carbon" and "synergy."

Firstly, digital financial services should avoid an excessive bias toward the digital economy, weaken as much as possible the crowding-out effect of the digital economy on the real economy, and strengthen the deep integration of the digital economy and the real economy. Secondly, digital financial development should be combined with the current development visions of "carbon peaking" and "carbon neutrality," and strengthen the development of digital finance. Finally, the formulation of digital finance development strategies should vary from time to time, from place to place and from enterprise to enterprise. In view of the differential impact of digital finance development on the carbon intensity of the manufacturing industry at the primary, secondary and mature stages, digital finance should develop differentiated development strategies. In order to fully unleash the emission reduction effect of digital finance in the manufacturing sector, it is necessary to strengthen the financial support of digital finance for the research and development of green technology innovation on the one hand, and accelerate the digital transformation of manufacturing enterprises on the other hand, so as to achieve long-term emission reduction by enhancing the effect of technology.

Research outlook

The research deficiencies and improvement plans are mainly as follows: First, this paper only focuses on the impact of digital finance on the manufacturing sector, and future research will be expanded to the entire industrial field. Second, the role of digital finance in affecting the carbon intensity of the manufacturing industry is not clear enough. Therefore, the mechanism analysis needs to be in-depth. Third, the development of digital finance can lead to significant industry spillover effects, while this study ignores this point. The spillover effect between industries needs to be further taken into account in future study.

Data availability statement

The data is available in the wind database, the CNRDS database, the national patent database and the listed companies' Corporate Social Responsibility Report, etc.

Ethics statement

This study was reviewed and approved by the College of Biological and Agricultural Engineering, Jilin University.

Author contributions

YY designed the research, conducted the research, analyzed the data, and wrote the paper.

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Conflict of interest

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

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The effects of environmental tax reform on urban air pollution: A quasi-natural experiment based on the Environmental Protection Tax Law

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Air pollution significantly impacts sustainable development and public health. Taking the implementation of China's Environmental Protection Tax Law in China as a quasi-natural experiment, this paper employs the difference-in-differences (DID) and spatial DID models to evaluate the effects of environmental tax reform on urban air pollution. The findings are as follows. (1) Environmental tax reform can significantly reduce urban air pollution, and a series of robustness tests have also been conducted to provide further evidence. (2) Green technology innovation and industrial structure upgrading from a vital transmission mechanism for environmental tax reform to improve air quality. (3) Environmental tax reform significantly inhibits urban air pollution in cities located north of the Qinling-Huaihe line and big cities. (4) Moreover, environmental tax reform not only promotes the improvement of local air quality but also has a significant negative spatial spillover effect, reducing air pollution in neighboring cities. The research conclusions provide theoretical support and policy suggestions for promoting sustainable economic development, rationally optimizing environmental protection tax policies and improving urban air quality.

KEYWORDS

environmental tax reform, urban environment, air quality, difference-in-differences model, spatial spillover effect

Introduction

Air pollution is the most severe environmental problem faced by countries worldwide, and how to improve air quality has been given high priority by governments. In recent decades, with the rapid development of urbanization and industrialization in China, energy consumption has increased rapidly, leading to increasingly severe air pollution in China (1). According to the 2021 China Eco-Environment Status Bulletin, of the 337 cities at the prefecture level and above in China,

40.1% still have air quality that seriously exceeds the standard. The 2020 Global Environmental Performance Index (EPI) shows that the total score of China is 37.3, and the EPI ranks 120th based on 180 countries and regions. These results severely impact sustainable economic development, public health, and government image. Against this background, the Chinese government has introduced many environmental policies and regulations to reduce environmental pollution. Accordingly, there is no doubt that it is of great theoretical value and policy significance to identify means of improving air quality.

Environmental regulation has been widely used in various countries and regions as an essential tool to alleviate environmental problems. However, due to the different selection of indicators and research samples, there is no unified conclusion on the relationship between environmental regulation and environmental pollution. Related studies have examined the pollution impact effects of different scales, periods, and types of environmental regulations (2–4). Some scholars believe environmental regulation can improve the ecological environment (5). Strict environmental regulation can encourage enterprises to conduct R&D and technological innovation (6), and improve the utilization rate and treatment rate of pollutants, thereby reducing environmental pollution (7). At the same time, environmental regulation can also inhibit the expansion of heavily polluting industries. The number of enterprises emitting large amounts of pollution is sharply reduced, indirectly leading to reducing environmental pollution (8). However, some studies have shown that environmental regulation cannot effectively reduce environmental pollution. Strict environmental regulations may reduce the economic efficiency of enterprises but are not conducive to improving environmental quality (9). Meanwhile, other studies have also concluded that there is uncertainty about the effect of environmental regulations on reducing environmental pollution (10).

As China's first single tax law to promote the construction of ecological civilization, the Environmental Protection Tax Law is an essential part of China's modern environmental governance system (11). It is of great significance to the management of environmental pollution. Before implementing the Environmental Protection Tax Law, China had long implemented the pollutant discharge fee system to replace the environmental protection tax system. The research on the pollution charge system is relatively affluent. The existing studies have verified that the pollutant discharge fee system plays a vital role in pollution control, energy conservation, and emission reduction (12, 13). However, some studies have also pointed out the shortcomings of the pollutant discharge fee system in the implementation process, such as low levy standards, many administrative interventions, non-standard levies, and lack of compulsory and standardized, which affect the effectiveness of its emission reduction (14). Theoretically, as a more compulsory, enforceable and supervisory environmental regulation tool, the environmental protection tax will bring cost pressure and supervisory pressure to force enterprises to undertake environmental treatment.

Environmental tax reform has important practical significance for promoting ecological civilization construction and improving urban air quality. Therefore, it is worth analyzing and discussing whether the Environmental Protection Tax Law implemented on January 1, 2018, can effectively protect and improve the environment and reduce pollutant emissions. This paper regards the implementation of the Environmental Protection Tax Law as a quasi-natural experiment. Based on the panel data of 283 cities in China from 2010 to 2019, the DID and PSM-DID methods are used to explore how the environmental tax reform can improve urban air quality and its transmission mechanism, heterogeneity and spatial spillover effects are empirically analyzed.

The main innovations of this research can be summarized as follows: First, in previous related studies, the measurement of environmental regulation often adopts a qualitative scoring method, single indicator method and comprehensive indicator method. These treatments do not effectively reflect the net effect of environmental regulation. In contrast, this paper adopts the difference-in-differences method, which can more accurately assess the pollution reduction effect of environmental tax reform and ensure the credibility of the estimation results. Second, most previous related studies were based on the pollutant charge system and the two-control zone policy before 2018. As China's first one-line tax law reflects the "green tax system," there are still few studies on the Environmental Protection Tax Law. Based on this, this paper is the first to use the implementation of the Environmental Protection Tax Law as a policy to assess the effect of environmental tax reform on urban air pollution, enriching the literature on environmental governance. Third, based on the "Porter Hypothesis," this paper analyzes that environmental tax reform can reduce urban air pollution by promoting green technology innovation and industrial structure upgrading from theoretical and empirical perspectives.

The rest of the paper is structured as follows. Section two presents the policy background and theoretical analysis. Section three introduces the research design, including model setting and data sources. Section four reports the main results. Section five constructs further analysis, including mechanism, heterogeneity, and spatial spillover effect tests. The last section is the conclusion and some policy recommendations.

Policy background and research hypothesis

Policy background for environmental protection tax law

Environmental protection tax was first proposed by Pigou, mainly through taxation to convert the external problems

caused by environmental pollution into the internal costs of polluters (15). The environmental tax has become one of many countries' accepted macro-control measures (16). For example, the Netherlands pioneered a tax on surface water pollution in 1969; the U.S. Congress proposed a nationwide tax on sulfide emissions in 1971 and a tax on sulfur monoxide and nitric oxide emissions in 1987. The E.U. also has a comprehensive environmental protection tax system.

China's environmental tax system can be traced back to the late 1970s and early 1980s. The Environmental Protection Law (for Trial Implementation) promulgated in 1979 marked the initial establishment of the environmental tax system. In 1993, the Notice on the Collection of Sewage Discharge Fees was issued. Subsequently, in 2003, the State Council promulgated the Regulations on the Administration of the Collection and Use of Pollutant Discharge Fees, which clarified the budget management of pollutant discharge fees and the collection standards for wastewater and exhaust gas emissions (14). Although the pollutant discharge fee system has reduced pollutant emissions to some extent, China's environmental problems are still severe. Based on this, the National People's Congress promulgated the Environmental Protection Tax Law on December 15, 2016, which was officially implemented on January 1, 2018 (11). Meanwhile, the Environmental Protection Tax Law can solve the problems of insufficient law enforcement rigidity and administrative interference in the pollution discharge fee system, which is conducive to improving taxpayers' awareness of the ecological environment and strengthening the responsibility of enterprises for pollution control and emission reduction. In general, the Environmental Protection Tax Law provides a legal safeguard for environmental protection and represents a significant advance for China's environmental governance.

Theoretical analysis and research hypothesis

Environmental regulation is essentially based on the negative externality of pollution. It regulates the activities of various social agents, including enterprises, by formulating corresponding systems and implementing them to achieve the primary goal of environmental protection. Generally speaking, the impact of environmental regulation on environmental quality is mainly transmitted from three dimensions: source, process and end-of-pipe treatment. The environmental protection tax mainly focuses on end-of-pipe treatment, targeting the pollutants already produced to effectively treat them and minimize the total pollutants (17). Environmental protection tax is a specific behavior tax levied by enterprises, producers, and operators that directly discharge taxable pollutants into the environment. Taxable pollutants include air pollutants, water pollutants, solid waste and noise. Enterprises are the main body of pollution discharge and the critical link of environmental governance. The environmental tax reform has increased the cost of enterprises' pollution discharge, which has prompted enterprises to reduce pollution discharge and use more renewable energy in the production process. At the same time, after implementing the Environmental Protection Tax Law, the environmental protection tax all belong to the fiscal revenue of the local government. This makes local governments have a greater willingness and ability to invest in pollution monitoring, thereby improving environmental quality. Based on this, this paper proposes the first hypothesis:

Hypothesis 1: Environmental tax reform can reduce urban air pollution.

As a market-incentivized environmental regulation, the environmental protection tax plays a vital role in green technology innovation. On the one hand, the Environmental Protection Tax Law has raised the levy standards for pollutant emissions, which has brought higher pressure on enterprises to reduce emission reduction costs. According to the theory of enterprise competitiveness, external pressure can help enterprises overcome inertia and stimulate innovative thinking, and promote enterprises to carry out green technology innovation (18). On the other hand, environmental regulation reduces uncertainty about the value of corporate investments in the environmental sector and can affect corporate expectations. The Environmental Protection Tax Law implementation shows the government's determination to protect the environment and the direction of policy development. Therefore, enterprises will carry out green technology innovation for long-term interests (19). At the same time, with the improvement of green technology innovation, enterprises can improve resource utilization efficiency and produce clean and non-polluting products, thereby reducing pollution emissions in the production process (20). Based on this, this paper proposes the first hypothesis:

Hypothesis 2: Environmental tax reform can improve urban air quality by promoting green technology innovation.

The environmental protection tax is not to make enterprises pay more taxes, but according to the tax system design of "more emissions, more payments, fewer emissions, fewer payments, no payments, no payments" and to subsidize enterprises that reduce the concentration of emissions, to improve the innovative power of enterprises. This will optimize low-end industries with high pollution, high energy consumption and high emissions to high-end industries with zero pollution, low energy consumption and zero emissions, and promote the development of strategic emerging industries and high-end service industries, thereby realizing the upgrading of the industrial structure (21). With the upgrading of the industrial structure, new industries will use more non-polluting and clean production factors for production. The sulfur dioxide, smoke, and dust emission in the industrial production process

will be reduced (22). Based on this, this paper proposes the first hypothesis:

Hypothesis 3: Environmental tax reform can reduce urban air pollution by promoting industrial structure upgrading.

Research design

Model setting

DID model

The DID method can efficiently identify the causal effect of the external policy shocks by comparing the net effect between the treatment and control groups. In order to protect the environment and reduce pollutant emissions, the Environmental Protection Tax Law came into effect on January 1, 2018. Hence, taking the Environmental Protection Tax Law as a quasi-natural experiment, this paper applies the DID method to examine environmental tax reform's effects on urban air pollution. The specific model is as follows (23):

$$pollution_{it} = \alpha_0 + \alpha_1 did_{it} + \alpha_c X_{it} + \gamma_t + \mu_i + \varepsilon_{it} \quad (1)$$

$$where\ did_{it} = group_i \times time_t \quad (2)$$

In this formula, i represents the city, t represents the year. $pollution_{it}$ represents the air pollution of the city i in the year t. Urban air pollution includes two indicators in this study: industrial sulfur dioxide emissions per capita ($lnso_2$) and industrial smoke and dust emissions per capita ($lnsmoke$). $group_{it}$ presents city dummies; its value is 1 if city i raises the standard of environmental protection tax, and 0 otherwise[1]. $time_{it}$ presents time dummy variable; its value is 1 if the year is greater than or equal to 2018, and 0 otherwise. X_{it} are the control variables affecting the urban air pollution for city i at year t. $\gamma_t$is the year fixed effect. $\mu_i$is the city fixed effect. ε_{it} is the random error term. At the same time, the robust standard errors are clustered to the city level.

The control variables of this study are as follows: The level of economic development ($lnpgdp$) is expressed in terms of regional GDP per capita. Government regulation (gov) is expressed as the ratio of local fiscal expenditure to GDP. Population density ($lndensity$) is expressed as the ratio of the total population at the end of the year to the land area of the administrative district. The green coverage rate ($greenratio$) is expressed by the ratio of the green area of the built-up area to the built-up area. The foreign direct investment (fdi) is expressed by the actual foreign direct investment ratio to the GDP.

Mechanism test model

A two-stage mechanism analysis model is adopted to analyze the influence mechanism of environmental tax reform on urban air pollution (24). In the first stage, the effects of environmental tax reform on green technology innovation and industrial structure upgrading are examined using Eq. (3). In the second stage, the effects of green technology innovation and industrial structure upgrading on urban air pollution are checked using Eq. (4). The model Settings are as follows:

$$mech_{it} = \beta_0 + \beta_1 did_{it} + \beta_c X_{it} + \gamma_t + \mu_i + \varepsilon_{it} \quad (3)$$

$$pollution_{it} = \vartheta_0 + \vartheta_1 mech_{it} + \vartheta_c X_{it} + \gamma_t + \mu_i + \varepsilon_{it} \quad (4)$$

Where $mech_{it}$is the mediator variable, including green technology innovation and industrial structure upgrading. Green technology innovation (gtp) is measured by the number of green patent applications per 10,000 people (25). Industrial structure upgrading (is) is the added value ratio between the tertiary industry and the second industry (26). The meaning of other variables is the same as formula (1).

Spatial DID model

The implicit assumption of the traditional difference-in-differences model is that any individual will not be affected by whether other individuals are treated or not, so the neglect of spatial correlation between cities will lead to biased estimation results. Hence, it is necessary to employ an SDID model to study the spatial spillover effect of environmental tax reform on urban air pollution (27). The model is set as follows:

$$pollution_{it} = \pi_0 + \rho W pollution_{it} + \pi_1 did_{it} + \theta W did_{it} + \pi_c X_{it} + \delta W X_{it} + \gamma_t + \mu_i + \varepsilon_{it} \quad (5)$$

In Eq. (5), $Wpollution_{it}$ is the spatial lag in urban air pollution, $Wdid_{it}$ is the spatial lag of environmental tax reform, ρ is the spatial autocorrelation coefficient of urban air pollution, π_1 is the coefficient of the effect of environmental tax reform on local air pollution, θ is the coefficient of the impact of environmental tax reform on air pollution in neighboring cities, and W is a 283*283 geographic distance spatial weight matrix. The meaning of other variables is the same as formula (1).

Data sources

Our study sample contains 283 prefecture-level and above cities in China from 2010 to 2019, and these city-level data are driven from China City Statistics Yearbook, China Environmental Statistics Yearbook, and the EPS database.

1 During the implementation of the Environmental Protection Tax Law, each province can independently determine the tax rate according to the local environmental conditions. Some provinces use the original pollution discharge fee collection standard as the environmental protection tax standard, while Hebei, Henan, Jiangsu, Shandong, Hunan, Sichuan, Chongqing, Guizhou, Hainan, Guangxi, Shanxi and Beijing have raised tax rates.

Meanwhile, the number of green patent applications is based on the International Patent Classification (IPC) green list code issued by the World Intellectual Property Organization (WIPO), and is collated according to the patent application information provided by the State Intellectual Property Office of China. The descriptive statistics for the main variables are presented in Table 1.

Empirical results and analysis

Common trend test

The premise of practical estimation of the DID method is to satisfy the parallel trend hypothesis. In other words, if the Environmental Protection Tax Law is not implemented, the variation trend of urban air pollution in the treatment and control groups should be the same. Furthermore, the benchmark regression results reflect the average impact of the environmental tax reform on urban air pollution rather than differences in effect over time. Consequently, this paper uses the event analysis method to construct the following model (28):

$$pollution_{it} = \alpha_0 + \sum_{k=-7,k\neq-1}^{1} \alpha_k did_{it}^k + \alpha_c X_{it} + \gamma_t + \mu_i + \varepsilon_{it}$$

Where did_{it}^k is a dummy variable. Provided that the year when city i is affected by the Environmental Protection Tax Law is s ($s = 2018$), then we set $t - s = k$. When k is negative, if t is smaller than the policy implementation time, then we set $did_{it}^k = 1$; otherwise, we set $did_{it}^k = 0$. When k is no smaller than 0, if t is larger than the policy implementation time, then we set $did_{it}^k = 1$; otherwise, we set $did_{it}^k = 0$.

Figure 1 shows the estimated coefficients of α_k under the 90% confidence intervals. Figure 1A shows the impact of environmental tax reform on industrial sulfur dioxide emissions per capita, and Figure 1B shows the impact of environmental tax reform on industrial smoke and dust emissions per capita. It can be seen that the estimated coefficients of α_k are insignificant before implementing the Environmental Protection Tax Law, which means that there is no significant difference in urban air pollution between the treatment and control groups before policy implementation. At the same time, after the implementation of the Environmental Protection Tax Law, the industrial sulfur dioxide emissions per capita and industrial smoke and dust emissions per capita have been significantly reduced. Therefore, the parallel trend hypothesis was verified.

Main results

The net effect of environmental tax reform on urban air pollution is evaluated, and the empirical results are reported in Table 2, in which the industrial sulfur dioxide emissions per capita ($lnso_2$) and industrial smoke and dust emissions per capita ($lnsmoke$). The estimated coefficient of the interaction term captures the average effect. In each regression, the coefficient of the interaction term is significantly negative at the 1% level.

The benchmark results for the DID model are presented in the first two columns of Table 2. The results show that the coefficients of industrial sulfur dioxide emissions per capita and industrial smoke and dust emissions per capita are all significantly negative. This preliminarily confirms that environmental tax reform can significantly reduce air pollution and improve air quality in cities.

Meanwhile, a potential concern with DID method is that the treatment and control groups may differ in ways that would affect their trends over time, or their compositions may change over time (29). Hence, this paper uses the difference-in-differences propensity score matching (PSM-DID) method to select suitable samples for further comparison and provides unbiased estimation results by effective matching (30). Specifically, we take the urban air pollution as the outcome variables and the control variables in Eq. 1 as covariates and

TABLE 1 Descriptive statistics for the variables.

Variables	Observations	Mean	Standard deviation	Minimum	Maximum
$lnso_2$	2830	−5.027	1.277	−12.59	−1.229
lnsmoke	2830	−8.913	1.297	−13.55	−3.669
did	2830	0.086	0.280	0	1
gtp	2830	0.689	1.492	0.003	22.84
is	2830	1.101	0.682	0.011	6.533
lnpgdp	2830	10.65	0.594	8.576	13.06
gov	2830	0.205	0.186	0.029	3.512
lndensity	2830	5.748	0.917	1.619	7.923
greenratio	2830	0.474	0.470	0.003	11.39
fdi	2830	0.020	0.055	0.001	1.371

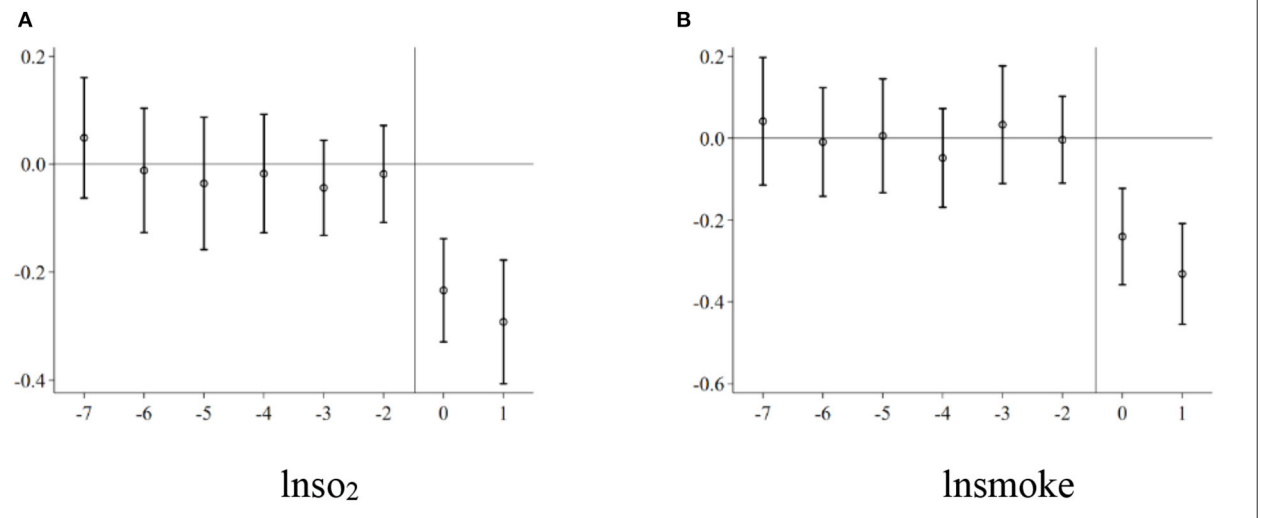

FIGURE 1
Common trend test. **(A)** $lnso_2$. **(B)** lnsmoke.

TABLE 2 Effects of environmental tax reform on urban air pollution.

	DID		PSM-DID	
	$lnso_2$ (1)	*lnsmoke* (2)	$lnso_2$ (3)	*lnsmoke* (4)
did	−0.253***	−0.288***	−0.256***	−0.303***
	(0.073)	(0.075)	(0.075)	(0.076)
Control variables	Yes	Yes	Yes	Yes
City FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Observations	2830	2830	2770	2770
R-squared	0.891	0.840	0.888	0.841

(1) The values in parentheses are robust standard errors for clustering to the city level; (2) ***, **, * represent statistical significance at the 1, 5, and 10% levels, respectively.

carry out corresponding matching according to the one-to-one neighbor matching method with put-back. Columns (3) and (4) in Table 2 show the regression results for the PSM-DID method. It can be seen that the coefficients are both negative at the 1% level, indicating that environmental tax reform has a noticeable lowing effect on urban air pollution.

Taken together, environmental tax reform can significantly improve urban air quality by reducing industrial sulfur dioxide emissions per capita and industrial smoke and dust emissions per capita.

Removing samples that are potentially affected by other policies

During the study period, the Chinese government has also implemented a series of policy tools to reduce environmental pollution, which may lead to overestimating the impact of environmental tax reform on urban air pollution. This paper controls the interference of other policies on the results to solve this problem. It is argued that environmental pollution is affected by the new energy demonstration program and low-carbon city pilot policy (30, 31). On the one hand, the new energy demonstration program could reduce environmental pollution through technological innovation and resource allocation (32). On the other hand, the low-carbon city pilot policy has an important impact on promoting green technology innovation and reducing carbon emissions. Therefore, this paper deletes the cities that implement the new energy demonstration program and the low-carbon city pilot policy in the benchmark regression model to exclude these policies' impact. The regression results are shown in Table 3. When the study samples that are potentially affected by other policies are

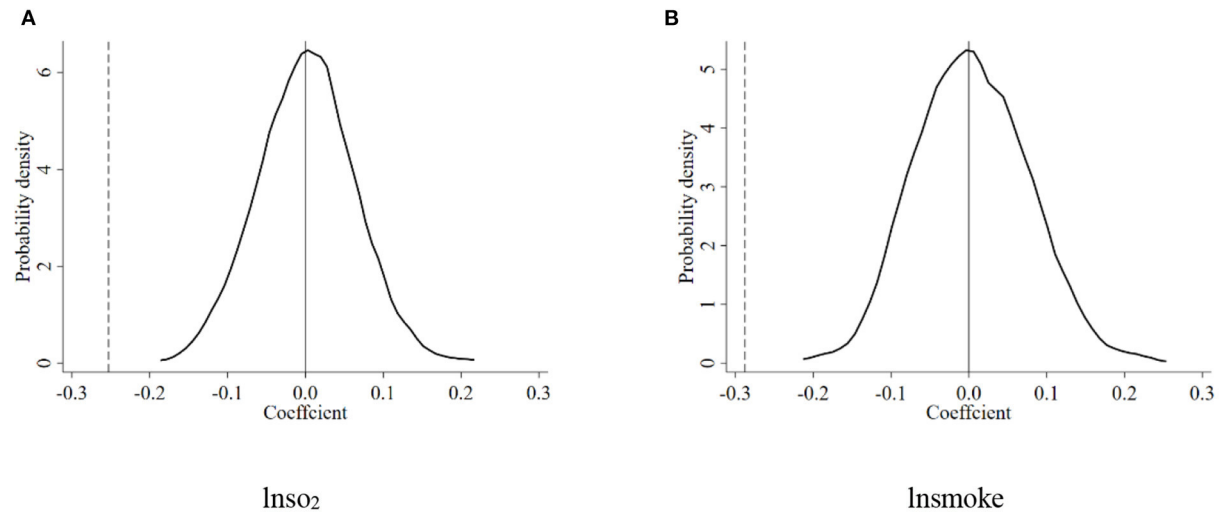

FIGURE 2
Results of the kernel density distribution of the DID of placebo test. **(A)** $lnso_2$. **(B)** lnsmoke.

TABLE 3 Effects of policy uniqueness test.

	Pollution levy standard system		Low carbon city pilot policy	
	lnso$_2$ (1)	*lnsmoke* (2)	*lnso*$_2$ (3)	*lnsmoke* (4)
did	−0.177***	−0.199***	−0.452***	−0.340**
	(0.046)	(0.046)	(0.133)	(0.158)
Control variables	Yes	Yes	Yes	Yes
City FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Observations	1132	1132	1620	1620
R-squared	0.940	0.947	0.881	0.844

(1) The values in parentheses are robust standard errors for clustering to the city level; (2) ***, **, * represent statistical significance at the 1, 5, and 10% levels, respectively.

removed, it can be seen that the regression coefficient remains significantly negative.

Other robustness checks

Placebo test

Another concern about the DID method is other non-observed and omitted variables. Therefore, this paper randomly selected 121 samples as the treatment group from the total sample and a year as the policy implementation time during the study period for counterfactual testing (28). Then, we repeated 1000 estimates based on the benchmark regression results in columns (1) and (2) of Table 2. The probability density distribution of the placebo test regression coefficients is shown in Figure 2. The estimated coefficients are centered around 0, while the benchmark regression result is outside the entire distribution. Hence, it meets the expectations of the Placebo test.

Replace the explained variable

The haze pollution caused by fine particulate matter (PM 2.5) emissions has drawn extensive attention. Therefore, this paper selects PM2.5 as a proxy variable for urban air pollution (33), then re-estimates the impact of environmental tax reform on urban air pollution. The PM 2.5 data were released by NASA Socioeconomic Data and Applications Center (34). Furthermore, we use ArcGIS to parse it into the city's annual average concentration data. The regression results are shown in columns (1) and (2) of Table 4. It can be seen that the regression coefficients are significantly negative regardless of whether control variables

TABLE 4 The results of the robustness test.

	Replace the explained variable		Delete center city		Province clustering	
	PM 2.5 (1)	*PM 2.5* (2)	$lnso_2$ (3)	*lnsmoke* (4)	$lnso_2$ (5)	*lnsmoke* (6)
did	−6.829***	−6.331***	−0.248***	−0.265***	−0.253**	−0.288**
	(1.641)	(1.523)	(0.080)	(0.081)	(0.118)	(0.136)
Control variables	No	Yes	Yes	Yes	Yes	Yes
City FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2480	2480	2830	2830	2830	2830
R-squared	0.887	0.841	0.839	0.840	0.891	0.840

(1) The values in parentheses are robust standard errors for clustering to the city level; (2) ***, **, * represent statistical significance at the 1, 5, and 10% levels, respectively.

are added, which also proves the robustness of the benchmark regression results.

Delete center city

The administrative power of the government in different-level cities may be quite different, and higher-level cities have far more resources than ordinary prefecture-level cities (30). Therefore, this paper deletes the provincial capital cities, sub-provincial cities and municipalities directly in the study sample and only retains the samples of ordinary prefecture-level cities for regression. The results are shown in columns (3) and (4) of Table 4. It can be seen that the environmental tax reform still significantly reduces urban air pollution, further verifying the robustness of the benchmark regression results.

Province clustering

In the above empirical analysis, this paper clusters the robust standard errors to the city level, but different cities in the same province may be affected by policies at the provincial level. At the same time, there is greater independence between provinces. The higher the level of clustering, the weaker the underlying assumptions. Therefore, to ensure the regression results' robustness, this paper clusters the robust standard errors to the provincial level. The results are shown in columns (5) and (6) of Table 4, and it can be seen that the regression results are still significantly negative.

Further analysis

Impact mechanism test results and discussion

The benchmark regression results demonstrate that the environmental tax reform contributes to the improvement of urban air quality according to reducing industrial sulfur dioxide emissions per capita and industrial smoke and dust emissions per capita. Therefore, to further analyze the influence mechanism of environmental tax reform on urban air pollution, green technology innovation and industrial structure upgrading are selected as the mechanism variables in this paper to verify hypotheses 2 and 3. The regression results are shown in Table 5. Specifically, in columns (1) and (4), the coefficients are significantly positive, indicating that environmental tax reform can promote green technology innovation and industrial structure upgrading. The results in columns (2), (3), (5) and (6) show that green technology innovation and industrial structure upgrading effectively reduce urban air pollution. Therefore, the improvement of environmental tax reform on urban air quality by promoting green technology innovation and industrial structure upgrading.

On the one hand, the environmental tax reform brings higher cost pressure for enterprises to reduce emissions and shows the government's determination to control environmental pollution. These external pressures will encourage enterprises to carry out green technology innovation, thereby reducing or even avoiding the additional costs of environmental taxes (35). On the other hand, the reasonable implementation of environmental regulations can optimize and upgrade local low-end industries with high pollution, high energy consumption, and high emissions to high-end industries with zero pollution, low energy consumption, and low emissions. This not only cultivates strategic emerging industries and high-end service industries but also improves urban air quality (36). Therefore, hypothesis 2 and hypothesis 3 of this paper are verified.

Heterogeneity analysis

Impact of city location on environmental tax reform

The Qinling-Huaihe River line is the geographical boundary between the north and the south of China and, to a certain

TABLE 5 Analysis results of influence mechanism.

	Green technology innovation			Industrial structure upgrading		
	gtp (1)	*lnso*$_2$ (2)	*lnsmoke* (3)	*is* (4)	*lnso*$_2$ (5)	*lnsmoke* (6)
did	0.170***			0.080*		
	(0.059)			(0.042)		
gtp		−0.389***	−0.159***			
		(0.046)	(0.037)			
is					−0.715***	−0.380***
					(0.081)	(0.070)
Control variables	No	Yes	Yes	Yes	Yes	Yes
City FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2480	2480	2830	2830	2830	2830
R-squared	0.872	0.745	0.730	0.827	0.755	0.735

(1) The values in parentheses are robust standard errors for clustering to the city level; (2) ***, **, * represent statistical significance at the 1, 5, and 10% levels, respectively.

TABLE 6 Comparison of environmental tax reform effects in different regions.

	North of the Qinling-Huaihe line		South of the Qinling-Huaihe line	
	lnso$_2$ (1)	*lnsmoke* (2)	*lnso*$_2$ (3)	*lnsmoke* (4)
did	−0.517***	−0.533***	−0.063	−0.110
	(0.098)	(0.117)	(0.103)	(0.094)
Control variables	Yes	Yes	Yes	Yes
City FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Observations	1080	1080	1530	1530
R-squared	0.908	0.865	0.869	0.821

(1) The values in parentheses are robust standard errors for clustering to the city level; (2) ***, **, * represent statistical significance at the 1, 5, and 10% levels, respectively.

extent, the boundary of central heating in winter. Heating cities in northern China consume many fossil fuels in winter, which significantly impacts air pollution (37). Hence, this paper examines the impact of environmental tax reform on urban air pollution by dividing cities into two types: north of the Qinling-Huaihe line and south of the Qinling-Huaihe line[2]. Columns (1) to (4) in Table 6 show the results of each sub-sample. The results show that environmental tax reform significantly reduces urban air pollution in the north of the Qinling-Huaihe line. Meanwhile, the impact coefficients on the south of the Qinling-Huaihe line are negative but insignificant. The results indicate that north of the Qinling-Huaihe line performs better in environmental tax reform than south of the Qinling-Huaihe line. The main reason may be that the industrial structure level of northern cities is relatively low, mainly the secondary industry with high pollution and high energy consumption. At the same time, a large number of fossil fuels are consumed for heating in winter, which leads to severe air pollution. Therefore, northern cities' environmental protection tax reform may have more substantial marginal effects.

Impact of city size on environmental tax reform

City size also has a significant impact on air pollution. On the one hand, big cities have an economic agglomeration effect, attracting high-end talents, capital, and technology. Therefore, big cities can better solve environmental pollution by optimizing resource allocation (38). On the other hand, there is a crowding effect in big cities. Big cities have a stronger demand for energy consumption, which leads to the deterioration of the

2 Cities south of the Qinling-Huai River line do not have central heating, while some cities north of the line—Heilongjiang, Jilin, Liaoning, Beijing, Tianjin, Hebei, Shanxi, Inner Mongolia, Shandong, Gansu, Qinghai, Ningxia, Xinjiang, Tibet, Jiangsu Xuzhou, Henan and Shaanxi—use collective heating.

TABLE 7 Heterogeneity analysis of city size.

	Big cities		Small cities	
	$lnso_2$ (1)	*lnsmoke* (2)	$lnso_2$ (3)	*lnsmoke* (4)
did	−0.218**	−0.272***	−0.237	−0.282
	(0.085)	(0.095)	(0.149)	(0.254)
Control variables	Yes	Yes	Yes	Yes
City FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Observations	1560	1560	1270	1270
R-squared	0.893	0.828	0.889	0.841

(1) The values in parentheses are robust standard errors for clustering to the city level; (2) ***, **, * represent statistical significance at the 1, 5, and 10% levels, respectively.

ecological environment (39). Therefore, to further investigate the impact of the city size on the effect of environmental tax reform, this paper divides the sample cities into "big cities" and "small cities." The classification of city size is mainly based on the "Notice on Adjusting the Criteria for Urban Size Division" issued by the State Council in 2014. In our study, cities with a permanent population of more than 3 million are regarded as big cities, and those with less than 3 million are regarded as small cities. The results are shown in Table 7.

For the big cities, environmental tax reform still presents a significant negative correlation with $lnso_2$ and lnsmoke. However, for the small cities, the coefficients are insignificant. One possible explanation is that those big cities have better resource endowments and economic development conditions and shoulder relatively heavy social governance responsibilities and environmental protection responsibilities. Therefore, these cities actively improve air quality, promoting high-quality economic development.

Test of the spatial spillover effect

The premise of using the SDID model is to satisfy the spatial correlation. This paper calculates the global Moran's I index of urban air pollution from 2010 to 2019. Table 8 shows the regression results. The results show that the Moran's I index of urban air pollution is significantly positive at the 1% level, confirming that air pollution among different cities has significant positive spatial dependence. Meanwhile, these results also demonstrate that it is rational to use an SDID model. Hence, this paper adopts a two-way fixed effects model to evaluate the spillover effects of environmental tax reform.

The spatial model differs from the traditional econometric model in that the estimated coefficients of its regression results cannot directly reflect the marginal effects of the explained variables. Therefore, this paper decomposed the regression results to obtain the direct, indirect, and total effects. The regression results are shown in Table 9. The results demonstrate that the direct effect of environmental tax reform on urban air pollution is significantly negative, which further confirms the emissions reduction effect of environmental tax reform. Meanwhile, the results of the indirect effect are also significantly negative, meaning that environmental tax reform has a positive spillover effect on regional air quality. On the one hand, air pollution has a spillover effect, so the pollution reduction effect brought about by the environmental tax reform in neighboring areas may spread to the local area, thereby effectively improving the local air quality. On the other hand, local governments will compete to improve the level of environmental regulation due to NIMBYism and their pursuit of liquidity factors that prefer a high-quality environment (40).

Conclusion and policy implications

Based on the panel data of 283 cities in China from 2010 to 2019, this paper regards implementing the environmental protection tax law as a quasi-natural experiment to empirically test the impact of environmental tax reform on urban air pollution. The findings show that: (1) Environmental tax reform has significantly reduced urban air pollution. This conclusion still holds after a series of robustness tests such as PSM-DID, parallel trend test, and placebo test. (2) The heterogeneity study shows that the environmental tax reform has a more substantial reduction effect on air pollution in cities north of the Qinling-Huaihe line than in cities south of the line; meanwhile, the environmental tax reform has a more significant impact effect on big cities. (3) The mechanism test shows that environmental tax reform improves urban air quality by promoting green technology innovation and industrial structure upgrading. (4) Environmental tax reform not only improves local air quality but also has a reduced effect on air pollution in neighboring cities.

TABLE 8 Moran's I index of $lnso_2$ and lnsmoke.

	$lnso_2$		*lnsmoke*	
	Moran's I	***Z*-value**	**Moran's I**	***Z*-value**
2010	0.192***	8.278	0.184***	7.990
2011	0.221***	9.506	0.183***	7.938
2012	0.208***	8.977	0.200***	8.714
2013	0.216***	9.316	0.228***	9.931
2014	0.197***	8.473	0.227***	9.913
2015	0.199***	8.593	0.245***	10.519
2016	0.180***	7.770	0.230***	9.880
2017	0.145***	6.298	0.202***	8.708
2018	0.109***	4.745	0.217***	9.350
2019	0.117***	5.099	0.221***	9.511

***, **, * represent statistical significance at the 1, 5, and 10% levels, respectively.

TABLE 9 The results of the spatial difference-in-differences model.

	$lnso_2$		*lnsmoke*	
	(1)	**(2)**	**(3)**	**(4)**
Direct effect	−0.135*	−0.105***	−0.052***	−0.083***
	(0.074)	(0.036)	(0.016)	(0.023)
Indirect effect	−1.820***	−1.091***	−1.302***	−1.130***
	(0.300)	(0.252)	(0.198)	(0.228)
Total effect	−1.955***	−1.196***	−1.354***	−1.213***
	(0.275)	(0.228)	(0.159)	(0.192)
Control variables	No	Yes	No	Yes
City FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Spa-rho	0.854***	0.790***	0.702***	0.695***
	(0.015)	(0.019)	(0.023)	(0.024)
Sigma2	0.187***	0.178***	0.274***	0.272***
	(0.005)	(0.004)	(0.007)	(0.007)
Observations	2830	2830	2830	2830
R-squared	0.172	0.250	0.040	0.056

(1) The values in parentheses are robust standard errors for clustering to the city level; (2) ***, **, * represent statistical significance at the 1, 5, and 10% levels, respectively.

Our study adds to a growing body of research exploring the environmental tax reform and provides more definitive evidence from the perspective of prefecture-level cities. This paper proposes policy recommendations based on the findings above. First, actively strengthen the implementation of the Environmental Protection Tax Law and explore more reasonable environmental tax regulations. Collecting environmental tax requires cooperation between the tax department and the environmental protection department. An information-sharing mechanism between the two departments should be established to improve the efficiency of tax collection and management, thereby promoting the improvement of urban air quality. Second, promote green technology innovation and industrial structure upgrading. Promote urban air quality improvement through cleaner production technologies and the development of high-end industries. Third, in the case of significant differences in the endowment conditions of each city, relevant policies should be formulated according to local conditions.

There are still some limitations to be considered to study further. On the one hand, environmental protection taxes have an impact on various pollutants, and this paper only studies air pollution due to data limitations. On the other hand, our results

are more applicable to the Chinese city. However, as the micro-subject of pollution emissions, the research on the impact of an environmental protection tax on corporate pollution is also worthy of attention. We believe that further work will show a useful supplement in these aspects.

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

BG and YW designed the study, performed the research, analyzed data, and wrote the paper. YF and CL collected most of the data. LT and XY checked the spelling of the paper and corrected the mistakes. FH provided fund support and suggestions on revising the paper. 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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How smart senior care can achieve value co-creation: Evidence from China

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With the rapid rise of artificial intelligence, smart senior care has become a new trend for future development. The collection of "Typical Cases of Chinese Elderly Service Industry Development" is selected by the script materials. The main purpose of this article is to investigate how smart senior care can achieve value co-creation by grounded theory. This study explores the phenomenon of value co-creation in the participation of multiple actors in smart senior care services. Findings show that institutional guarantee, technical intake, market empowerment, emotional support, service interaction, and reciprocity norm are identified as the driving factors for value co-creation. In addition, the behavioral processes of value co-creation include multi-actor value consensus, co-creation environment establishment, practical value co-creation, public value sharing, and diffusion of service added value in smart senior care. Finally, this study constructs a practical logic model of achieving value co-creation. It extends and enriches the scope of the value co-creation theory. This study confirms that value co-creation can be effectively achieved in smart senior care by the above-mentioned ways, revealing its driving factors and behavioral processes. The article expands on the application of value co-creation in the field of public healthcare. The results have important theoretical and practical significance for narrowing the public service equalization gap.

KEYWORDS

smart senior care, value co-creation, practical logic, driving factor, grounded theory, digital divide

Introduction

According to the 7th China Census, there are 264 million people aged 60 and above, accounting for 18.7% of the total population in China. Conventional senior care can no longer meet the elderly basic requirements (1). Following the fast growth of new-generation information technology, smart senior care (SSC) is gradually becoming a new development direction to alleviate this dilemma, which is first proposed by the British Life Trust (2). SSC is an expansion of the conventional aged healthcare service that incorporates modern technology to enhance the living circumstances of the elderly (3). Information and communication technologies (ICTs) have promoted the continuous upgrading of medical service modes, making it easier to obtain medical resources on

the Internet, and providing a new method for the public to seek health information and promote healthy communication (4, 5). However, disruptive and fast-expanding ICTs, such as robots, big data, and telehealth, make healthcare services increasingly complex. In this context, the elderly group is generally less receptive to ICTs. This reluctance is a crucial challenge for service innovators in SSC and other technology areas. In order to improve the service acceptability of innovation, service providers may transform technology-based services into value for a wide range of consumers.

Existing research is principally analyzed and presented from a practical level for the design of the SSC platform and its key technological concerns. Studies have developed a home monitoring system for the elderly living alone based on the ZigBee protocol (6). Such a system can collect smart home usage and physiological data like heart rate and skin temperature from the elderly to monitor their health status. Other studies could try to set up internal sensor data cluster systems, environmental monitoring systems, assisted living systems, and remote care detection systems to track tegular life (7). During the period of COVID-19, the importance of such digital health became more prominent (8). Although the range of SSC devices has made geriatric health monitoring more convenient than before, privacy concerns may be tough to overlook. In other words, people's willingness to participate in health care through ICTs is primarily influenced by privacy breaches (9). Previous studies, on the other hand, might provide several clues about how privacy considerations interact with ICTs to impact user participation in value co-creation (10).

In reality, SSC can use modern information technology to fill in the shortcomings of the family senior care function (11). Internet technology connects general hospital professionals with patients in the Web Cloud, enabling them to consult with a doctor from their own homes. Furthermore, SSC may also provide children who are away from home the chance to learn about their parents' health. For example, the elderly use a variety of medical equipment, and then their children may use the Internet to learn about their heart rate, blood pressure, and other physical information of parents. As a part of social support for the elderly, intergenerational support is vital to the physical and mental health of the parents (12). Additionally, SSC may also enhance the quality of life of the elderly by altering the way they are cared for. As interaction is required (13). In other words, it is critical to determine the impact of various interactions between service providers and older adults on the value co-creation process and how to design effective quality care processes.

As an innovative approach to creating value, value co-creation has attracted the academic community's interest (14). Since its inception, the value co-creation theory has been chiefly debated in business services. Vargo and Lusch tried to extend its scope of application to the field of public services (15). Afterward, value co-creation in healthcare services has also received attention (16). According to research, value co-creation is appropriate for exploration in knowledge-intensive service areas (17, 18). Service-Dominant (SD) logic considers the participation of multiple actors are a fundamental part of the value co-creation process (19). Specifically, value co-creation allows multiple actors to create value through interaction. Then such interaction helps customers become effective co-creators to obtain better service outcomes (17). Scholars also attempt to extend the application of SD logic to public services and claim that value co-creation theory could be applied to government-provided public products and services (20). According to previous research, establishing a co-creation environment is essential for achieving government-public interaction and value co-creation (21). Therefore, the participating actors are more diverse, and the co-creation process is more complex. One of the key points is how various social actors participate in the value co-creation of SSC services.

Value co-creation can be achieved directly through interactions between patients and healthcare providers in SSC. Specifically, ICTs are generally used as an intermediary to integrate various resources and achieve indirect interaction in SSC. For example, mobile technology makes it easier for patients to participate in the co-creation process (22). ICTs might enhance collaborative interactions between patients and medical institutions to facilitate the achievement of value co-creation. Medical infrastructure such as the Internet of Things (IoTs), Medical Cloud, Mobile Internet, and Wearable Devices are already integrated into SSC, which supports smart decision-making. The IoTs and wearable technologies might be quite popular and crucial in SSC (23). However, Chinese seniors have a limited understanding of the use of these technologies, resulting in a considerable mismatch between technology use and actual demand (24). This makes the elderly unable to fully enjoy the convenience brought by smart services and eventually become "digital refugees" (25). In response, other countries have adopted several initiatives and policy interventions to promote access and utilization of health care services in older adults (26, 27). Therefore, the importance and urgency of digital divide governance are becoming more and more prominent in China.

Value co-creation has previously been separated into four stages: identifying stakeholders, analyzing the interaction, sharing experience, and providing solutions (28). Other studies implied that value co-creation is divided into three stages, which later evolved into four stages: value consensus, value co-creation, value sharing, and value win-win (29). Interaction and resource integration are two key components of value co-creation. According to SD logic, value co-creation is generated through dialogue and participation with stakeholders in the value network. Service providers and customers play a role in co-creating value through their interactions (30). For example, the elderly are actively participating in high-quality SSC through frequent interaction and information exchange with other participants. This interaction refers to the integration of resources and capabilities by diverse participants to achieve

value co-creation (31). Further, the efficiency of achieving co-creation may be increased when resources are integrated into the service process (32).

Currently, theoretical research lags behind practical innovation. Previous studies have focused more on how to increase the participation of the elderly in conventional care. Besides that, the research on SSC is still in initial stages. Little relevant research has touched on how smart senior care can achieve value co-creation. The theoretical framework for this research is the "Consensus-Co-creation-Sharing-Win-win" process, based on the above literature review. The purpose of this study is to investigate the driving factors and achievement paths for SSC to achieve value co-creation and then to establish a practical logic model for SSC value co-creation.

Materials and methodology

This study utilizes a combination of multiple case studies and grounded theory. Since there is a lack of research on SSC value co-creation, these two research methods are feasible and beneficial when the problem is approached from a unique perspective. Second, this research focuses on the process of value co-creation in which multiple actors are engaged, as well as the construction of a practice logical framework for SSC value co-creation. Data collection and analysis, data coding, and model generation are the three parts of the methodological framework, and the script data is coded and summarized sentence by sentence (33). Continuous comparison, analysis, induction, and generalization were used to investigate the logical connections between the SSC concepts and categories in the literary sources. After theoretical saturation, research obtains a new logical model.

Sampling

This study uses "Typical Cases of Chinese Elderly Service Industry Development" as research materials. These materials are 75 typical cases of senior care services selected by the National Development and Reform Commission, the Ministry of Civil Affairs and the National Office of Aging, after local submission, assessment, review, and online publication in 2017. This collection is produced together by a combination of government departments to highlight and promote the benefits of Chinese elderly service markets in recent years. It has diagnostic, demonstration, and promotional effects on the elderly service industry. Therefore, such materials have the characteristics of authority, authenticity, and reliability and are suitable to be selected as the script materials for this study. In this compilation, all the cases related to the theme of SSC (10 cases in total) are selected in Table 1. Simultaneously, each case content is supplemented by the department's official website and internet news, assembling a total of 53,000 words of analysis script.

Research process

The process of this study included data import, coding, data analysis, and model construction based on grounded theory. Three levels of coding are used to summarize the raw data, including open coding, axial coding, and selective coding. Coding and analysis can be performed simultaneously (34). Theoretical saturation is followed during coding. This means that scripted data have reached theoretical saturation when they can no longer be extended to new ideas or categories. This signifies that sample coding has ceased, and additional analysis and model creation has begun.

Open coding

The SSC content is extracted from the case by sentence-by-sentence analysis. The final coding will include two parts: case number and sentence number. For example, the supplementary material for Tongxiang City's new model of senior care service is numbered "As", and the third sentence in the case is numbered "As-3". Based on understanding the text content, the statements are conceptualized. The initial concepts are then derived by removing duplicate items, combining synonyms, and classifying them. Eventually, in this section, 32 categories are identified. Due to the limitation of space, only representative codes are listed in this paper, as shown in Table 2.

Axial coding

Axial coding serves as a bridge between empirical description and conceptual analysis. In other words, this part refines and separates the categories obtained from open coding, then examines connections and potential logical relationships among the categories, and finally extracts the main categories that govern the others. Five main categories and 17 sub-categories are extracted and defined in this paper (Table 3). Table 4 shows the results of the main coding.

Selective coding

Selective coding entails selecting core categories and relating them to others in a systematic way. The interrelationships are then verified, and the separate concepts are reassembled in the form of a "storyline" (21). The plot of the narrative is as follows: the Chinese SSC model is based on the interaction of multiple actors to achieve value consensus, and the interaction of actors

TABLE 1 Source type and text statistics.

No.	Case	Location	Typical cases (thousand words)	Network information (thousand words)
A	Tongxiang City Wuzhen Internet plus Senior Care Service model	Eastern	3.823	2.327
B	Luoyang City Home Community SSC Innovation Model	Central	4.194	3.606
C	Ningxia Internet plus Senior Care Service Model	Northwestern	3.766	1.763
D	Hangzhou City SSC Service New Model	Eastern	2.764	1.368
E	Maanshan City Internet plus Senior Care Service Model	Eastern	2.45	0.881
F	Wuzhou City "cloud family" Internet plus community home care service	Southern	3.454	0.976
G	Case of senior care services in mountainous areas of Datian County	Eastern	2.871	2.355
H	Changzhou City Healthy Aging Service Industry Cluster Area	Eastern	4.082	2.781
I	Yantai City "Medical, Nursing, and Rehabilitation" Integrated Demonstration Plot	Eastern	3.558	1.978
J	Case of Shanxi Province Ruiquan Senior Care Service Co.	Northwestern	3.483	1.124

TABLE 2 Open coding example.

Concepts	Concept codes	Reference Points	Categories
Insisting on the "combination of medical care, education and health" model to fill the gap in the semi-self-care and non-self-care elderly market (F-24)	Disabled Elderly	11	Service object
The municipal government attaches great importance to the development of elderly services (C-2)	Government Attention	6	Government support
The municipal government provides 150,000 yuan per year for home care service centers and 300,000 to 500,000 yuan from the welfare fund (C-4)	Financial Support	11	Economic support
Installing intelligent care equipment for eligible older people (A-13)	Intelligent Care Equipment	21	Technology application
ECG testing of elderly patients with sudden illness using Internet remote lead technology (Gs-14)	Emergency Assistance	24	Service delivery
The school's Retirement Office, Bureau of Civil Affairs, and service agency have reached a three-way cooperation (Js-4)	Cooperation Intention	39	Multi-actor collaboration
With expanding social influence and growing brand strength, Ruiquan Senior Care has become one of the most successful organizations (J-19)	Brand Influence	11	Demonstration effect
The platform service operating company develops "personalized and precise service" solutions (D-8)	Personalized Services	9	Personalized elements
The service provider offers discounted rates to all seniors at their own expense (E-13)	Low-cost Services	5	Special price
Effective integration of resources by combining medical and nursing care (B-13)	Integrated Services	17	Resource integration
Dozens of older people come to gather every day and live a happy and warm life (Hs-4)	Happy Life	8	Pleasant mood

TABLE 3 Axial coding.

Main categories	Sub-categories	Categories
A1 Multi-actor value consensus	B1 Need Identification	C1 Service Object
		C2 Service Subject
A2 Co-creation environment establishment	B2 Institutional Guarantee	C3 Government Support
	B3 Market Empowerment	C4 Policy Making
	B4 Technical Intake	C5 Economic Support
	B5 Emotional Support	C6 Non-government Investment
	B6 Service Interaction	C7 Industry Development
	B7 Reciprocity Norm	C8 Technology Application
		C9 Intelligent Platform
		C10 Data Operation
		C11 Life Care
		C12 Interactive Exchange
		C13 Service Delivery
		C14 Multi-actor Collaboration
		C15 Demonstration Effect
		C16 Resource Emergence
A3 Practical value co-creation	B8 Functional Value	C17 Personalized Elements
	B9 Economic Value	C18 Inelastic Demand
	B10 Social Value	C19 Social Relationship Building
		C20 Group Identity
		C21 Rewards
		C22 Special Price
A4 Public value sharing	B11 Service Quality	C23 Service Evaluation
	B12 Capacity Excavation	C24 Service Regulation
	B13 Resident Participation	C25 Capacity Enhancement
	B14 Service Supply Innovation	C26 Knowledge Value
		C27 Active Participation
		C28 Conception Renew
		C29 Resource Integration
A5 Diffusion of service added value	B15 Cultural Output	C30 Ecological Culture
	B16 Hedonistic Value	C31 Pleasant Mood
	B17 Technology Collaboration	C32 Technology Empowerment

exists in all aspects of the practice and has an impact on it; "co-creation environment establishment" and "practical value co-creation" are the causal conditions of value co-creation; "public value sharing" is the action strategy that constitutes the behavior and phenomenon of value sharing and finally forms the win-win result of "service added value diffusion". Accordingly, the core scope of selective coding can express as a conceptual model of SSC value co-creation through a four-stage process of "value consensus-value co-creation-value sharing-value win-win" as shown in Figure 1.

Saturation test

The saturation test is conducted to check the theoretical saturation of the coding. The remaining two examples have been coded, conceptualized, and categorized. If no new concepts emerge, so the script materials have been thoroughly explored, and the theory has reached a reasonable saturation level.

Result

Value consensus

SSC services involve a wide range of actors. Specifically, the SSC value co-creation network is formed by different participants, such as government, social organizations, enterprises, institutions, the elderly, and family members, all of whom have different demands and behavioral patterns (2).

> "Ma City Civil Affairs Bureau staff: the city's civil affairs department will encourage all kinds of stakeholders to participate in SSC in order to promote the participation of multiple actors." (Gs, Location 12)

Needs identification is the initial stage in value co-creation (35). That means all stakeholders search for needs and resources and reach a consensus on values (36). The community mainly represents the government position. Communities need to use third-party forces or innovative models to solve problems when faced with insufficient resources to accomplish governance tasks. At the same time, communities expect to help residents to raise awareness of SSC services.

> "... integrate specialized service teams and volunteer organizations to provide three types of services to different elderly customs: public service, low-paid service, and paid service." (D, Location 14)

Social organizations actively cooperate with stakeholders who can provide lower-cost SSC to absorb their service, technology, and talent resources to realize their interests and public interests.

> "The Healthtop company is responsible for the project's operation, specifically customizing the five service packages of life care, community culture, catering, health management, and professional care." (A, Location 12)

Enterprises achieve the integration of community services and heterogeneous resources, both public and commercial services, through intelligent online platforms (37).

TABLE 4 Definition of sub-category.

Sub-category	Definition
Need identification	Stakeholders' various needs for SSC services
Institutional guarantee	The government encourages multi-body participation through document development and policy support
Technical intake	Provide senior care services utilizing intelligent technology
Market empowerment	To meet the needs of the elderly as the primary goal in the market competition, give full play to the role of market mechanisms
Emotional support	The elderly get emotional care through interaction
Service interaction	Formation of collaborative mechanism among multiple actors to jointly promote the development of the SSC industry
Reciprocity norm	Equal trust between participants and gradually form a standardized service order
Functional value	The value that the elder feels about SSC services and product performance
Economic value	Economic benefits from participating in interactions
Social value	Develop social relationships or foster a sense of group belonging by participating in interactions
Service quality	Service satisfaction evaluation and service supervision through feedback
Capacity excavation	Personal improvement through participation in interactions
Resident participation	Enhancing the initiative of the elderly to participate is an essential condition for realizing value co-creation
Service supply innovation	Including concept renewal and technological change
Hedonistic value	The pleasure of participating in interactions
Cultural output	The elderly have a high sense of identification with SSCs, which produces a willingness to co-create value
Technology collaboration	Key technologies and resource introductions are integrated with service capabilities to reconstruct digital resource capabilities

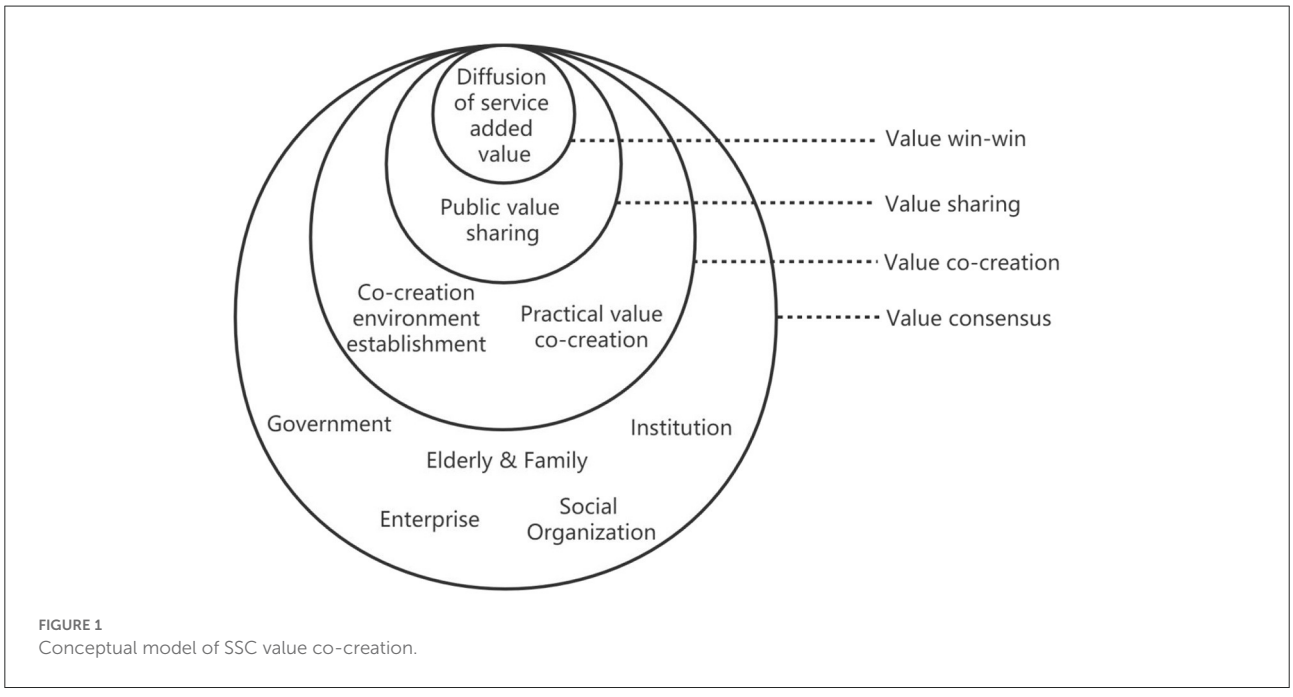

FIGURE 1
Conceptual model of SSC value co-creation.

> "In order to achieve full institutional coverage, SSC service centers are established in county towns, and home-based SSC service stations are established in townships." (H, Location 13)

Medical institutions or care institutions receive support and guidance from the government and social organizations to provide higher-quality services (38). Such services are provided to the elderly with disabilities, living alone, chronic diseases, and poverty.

> "Institutions such as Senior Apartments, Community Care Centers, Senior Activity Centers, and Nursing Homes have actively integrated their resources with the SSC with the support of the county government and the Civil Affairs

> Bureau. To improve the effectiveness of the SSC, multiple actors have fully used existing social resources and organized a group of volunteers." (H, Location 29)

SSC covers the government, institutions, social organizations, enterprises, the elderly, and their families. Adaptability and initiative are two characteristics of such actors. Based on following the value consensus, multiple actors exchange systems, funding, people, and technology through interactions and resource sharing without much prompting. When other components or the environment change, adaptive individuals may adjust their structure and behavior through experience and learning (39). The value consensus stage, where resources are separately identified, constitutes the initial stage of value co-creation.

Value co-creation

The environmental establishment and practical value of SSC are examined in depth in this research. The co-creation environment attracts multiple actors to participate in SSC value co-creation through institutional guarantee, technical intake, market empowerment, emotional support, service interaction, and reciprocity norm. Following that, the practical value represents the physiological, safety, and emotional satisfaction users obtain through SSC online and offline integration, including social value, economic value, and functional value. This study considers practical value as a low level of needs value and the primary extrinsic motivation for the elderly to participate in value co-creation.

Co-creation environment establishment

Institutional guarantee

> "Government Clarifies the leading role of SSC." (I, Location 8)

> "The city government builds an SSC service model with features of Luoyang City." (C, Location 2)

> "The government formulated and introduced Implementation Plan for SSC Activities in Datian County." (H, Location 10)

In SSC, the institutional guarantee is critical. Institutional design and policy formulation by the government are prerequisites for achieving value co-creation. First, the government clarifies the leading position of SSC and assists with service and product optimization. Second, the government regulates the SSC service process and controls service quality by formulating policies to form deep interactions and reciprocal norms among multiple actors eventually (40).

Technical intake

> "Using Big Data, Internet of Things, Artificial Intelligence and other technologies." (E, Location 4)

AI, big data, and other modern technologies have lowered the "barriers" to participation in SSC for the elderly. The interaction between government and members has become more convenient and efficient. As a result, technology intake may provide opportunities and environments for society members to engage in co-creation activities, enrich co-creation content, and optimize co-creation processes.

Market empowerment

> "To support private capital and social forces to enter the field of elderly services." (E, Position 4)

In the SSC value co-creation scenario, the government stimulates local enterprises, social institutions, and other private capital to participate in the design and improvement of the SSC project through a market-based approach. In terms of market empowerment, the market mechanism emphasizes "the survival of the fittest". Enterprises should prioritize satisfying the demands of the elderly, enhance the accessibility of SSC services, and provide high-quality services for the elderly in the market competition.

Emotional support

> "Children of the elderly can remotely check their parents' condition in real-time through a mobile app and book relevant SSC services for their parents." (I, position 27)

Currently, digital literacy among the elderly is relatively insufficient. The elderly are encouraged to engage actively in SSC *via* family intergenerational communication and digital feedback. Meanwhile, intergenerational support is a powerful technique to increase family support for SSC and a social buffer mechanism to alleviate mental isolation (41).

Service interaction

> "The system is used online for the collection and distribution of service requests, and the APP is used offline for the positioning and supervision of services." (Bs, position 15)

Each value co-creator establishes a connection by exchanging interests and requests. Compared with the traditional senior care service, SSC combines online and offline,

which better activates the central position of value co-creation of the elderly (42). Demanders and providers of senior care services might well be efficiently matched utilizing the SSC service information platform in the service interaction. To increase the convenience and timeliness of senior care services, the platform can connect demand information to service providers in real-time.

Reciprocity norm

> "Encourage and support the development of new forms of services, and cultivate several leading enterprises with strong power and high-profile service brands." (E, position 27)

The actors' reciprocity norm efficiently promotes the SSC industry's innovative development and creates public value (43). Meanwhile, the government implements financial incentives, honorary awards, and preferred experiences to increase enthusiasm for enterprise and consumer engagement, encouraging social members to participate and interact in-depth to achieve social value consensus. After that, the social impact of value co-creation forms public value and cultural output and paves the way for the next stage of value co-creation.

Practical value co-creation

> "SSC services are expanded to include personalized service programs that are urgently needed in the lives of seniors." (Ds, position 9)

> "...conducted more than 15,000 times of various services, with 99.5% service satisfaction on return visits." (E, Location 32)

> "Service providers integrate regional service resources, and seniors can enjoy services for free or at low cost." (E, Location 14)

SSC meets the individual needs and rigid demands of senior health through personalized services. The comfort, simplicity of use, and humanization of the service represent its functional value (44). Furthermore, the services may become more convenient and easy to use, which will enhance the functional value acquired by customers. Social value is the development or cultivation of group belonging through participation and interaction. Interaction improves group cohesion and satisfaction with the service, boosting group identification and belonging. Economic value refers to the economic benefits that the elderly obtain by engaging in interaction. Economic benefits include services at favorable prices, gifts, or virtual community rewards to meet their actual needs. Moreover, economic value has a beneficial impact on the appraisal of services and brands, resulting in a greater reliance on and liking for them (45).

Value sharing

> "The SSC Center is a combination of SSC platform, restaurant, club activities, dance, painting and calligraphy, health management and other functions." (As, location 16)

> "The SSC Center provides leisure services for seniors such as swimming, fishing, vegetable gardening, and flower raising, and produces and supplies pollution-free seafood and vegetables." (F, Location 26)

Public value sharing brings positive and extensive impacts, such as capacity excavation, service supply innovation, service quality improvement, and wide resident participation. The whole sharing process is driven by the government, with the involvement of companies, institutions, the elderly, and families to establish a service ecosystem (19). The deep interaction and resource integration of all elements within its system jointly create public values (46). This promotes the innovation and optimization of SSC products or services and ultimately creates a process of public value sharing. SSC innovates service forms, optimizes service experience, and constantly improves service quality in the public value-sharing cycle. Public value sharing may draw the attention and involvement of more people and provide support for the next stage of value co-creation.

Value win-win

> "...meet the diversified needs of the elderly, keep them happy and healthy, and enjoy their senior life happily." (F, Location 16)

> "...create an SSC industrial chain integrating research, training, production, sales and service." (F, Location 27)

In the process of value co-creation of SSC cooperative supply, the service added value is the part that is higher than the value of SSC service itself created by the participation of multiple actors. In the era of big data, digital empowerment has dramatically increased the added value of SSC service value co-creation. The integration of multiple actors makes SSC supply and demand match accurately and improves the

efficiency of service operation, and promotes the technology collaboration among multiple actors (47). SSC services may meet the hedonistic need of the elderly from their heart. Because spiritual value originates from the customer's intrinsic motivation, it is a purely psychological and spiritual need. SSC not only develops intelligent service equipment but also pays attention to the actual needs of the elderly from physical to spiritual levels (48).

Cultural factors are the key to the participation of multiple actors in value co-creation. There are two reasons for this: first, the elderly have a high sense of identification with the culture of senior care. Secondly, the cultural output provided by SSC is the driving force for the elderly to change from "passive consumption" to "active co-creation" (20). In other words, when deep interaction and cultural connotation match, the willingness to participate in value co-creation will be generated (49).

In the stage of value win-win, the government, enterprises, institutions, social organizations, and the elderly have achieved the intersection and integration. The resources of SSC have been effectively utilized, transformed, and fed back, which constitutes the final stage of value co-creation.

Practical logic model of SSC value co-creation

SSC value co-creation is a dynamic evolutionary and continuous optimization process. In this study, institutional guarantee, technical intake, market empowerment, emotional support, service interaction, and reciprocity norm are essential driving factors of SSC value co-creation. The behavioral processes of SSC value co-creation include multi-actor value consensus, co-creation environment establishment, practical value co-creation, public value sharing, and diffusion of service added value.

A practical logic model of multiple actors' co-creation is established in this research. Figure 2 is gradually formed under the role of driving factors and behavior processes. The interaction of its internal elements will influence the behavioral process and results of value co-creation of SSC services. The value co-creation network, which includes government, enterprises, institutions, social organizations, and the elderly, is sociable. In addition, the action result of the Practical logic model is value co-creation, which may be seen as a mediating factor that impacts the whole value co-creation process (50). The internal interaction and resource integration of the Practical logic model drives the elderly and families as service consumers to form a dynamic, balanced, and interactive system with government, enterprises, and other elements. Participants use their knowledge, skills, and experience to contribute to value creation (51).

Discussion

The value co-creation theory under the SD Logic provides guidelines for government public affairs governance and public service supply and encourages social forces to participate in public service value co-creation. While exploring the theoretical aspects of SSC value co-creation, this research also proposes a few points for discussion on the construction and development of public services in SSC.

The critical issues for the government are how to establish a co-creation environment for effective communication, active participation, and continuous interaction among members of society. As a result, it is required to unite social members' awareness and carry out various value co-creation under a unified value consensus dispatch. The government should set up an easy-to-accept method of service delivery for the elderly, as well as a more open and equal co-creation environment. This has the potential to provide hedonistic value and also cultural output. At the same time, it may help SSC service enterprises and institutions enhance their brand image and public service goods (52).

When enterprises and institutions participate in SSC services delivery, they consider things such as upfront construction costs, development profitability, and capital recovery period. This influences their decision to give services to elderly adults in more developed locations. Alternatively, they choose to relocate to locations where the government provides significant incentives, supportive policies, and a favorable investment environment (53). In this research, the vast majority of the instances are in such places. This is due to the fact that in more open markets, the elderly's high economic paying capacity and diverse SSC demands ensure long-term profitability. Market actors are active in the SSC service market and engage in all elements of senior care services because of the market environment under the double guarantee. On the contrary, for regions with lower economic development levels, especially rural areas, low consumption demand and traditional cultural concepts severely restrict the choice of SSC services for the elderly. As a result, the rural SSC market lacks the necessary growth velocity to attract active engagement from social forces, leading to a failure to exploit the function of fundamental public service equalization fully. To improve the positive impact of value co-creation, it is vital to raise visibility *via* social marketing in the face of such issues. This is to encourage more social actors to pay attention to and participate in the design of SSC service products, service quality control, and service optimization. A new round of value co-creation can be formed so that the SSC service level can be continuously improved and enhanced.

The paucity of current senior care resources in China significantly impacts the elderly's perception. With IoTs and big data as the foundational technological support, SSC combines elder care service resources and distributes them logically.

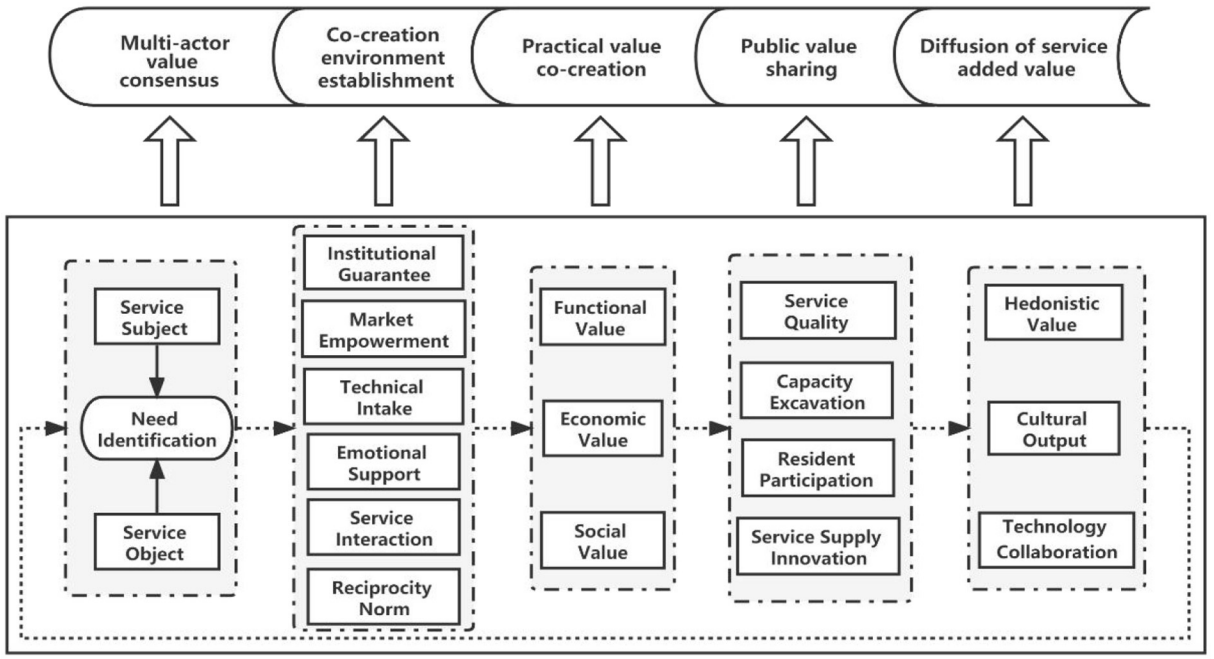

FIGURE 2
Practical logic model of SSC value co-creation.

Using the Internet or new media platforms in value co-creation increases the public awareness of participating in public services (36). Actively building an online interactive platform with a digital service platform as an important carrier can broaden the communication channels with multiple actors. As a result, it achieves the modernization of facilities, as well as the convenience and quality of SSC services, and becomes a new option for addressing the shortfall of total senior care resource supply. China should advocate the SSC model, which applies modern technology to many areas of need for the elderly.

Conclusion

This paper adopts a multi-case study approach and selects the value co-creation process of multiple actors in SSC services as the research object. The study effectively identifies the process of interaction between actors and the process of resource integration by grounded theory. The study constructs a practical logic model of the value co-creation process, which corresponds to the actions and results of value consensus, value co-creation, value sharing, and value win-win. This study confirms that SSC service providers should be oriented to the needs of the elderly and ultimately achieve value co-creation. Different actors participate in SSC and provide differentiated and integrated services for the elderly. Our results provide evidence of how value co-creation is achieved in SSC services, revealing its driving factors and behavioral processes. This way can effectively solve the current problem of insufficient supply capacity and limited resources of senior care services and alleviate the gap of equalization of public services.

The innovation of this paper is mainly reflected in the following three aspects. First, the concept of SSC value co-creation is defined. The driving factors of SSC value co-creation are identified, including institutional guarantee, technical intake, market empowerment, emotional support, service interaction, and reciprocity norm. Second, this study proposes that SSC service value co-creation is a dynamic evolutionary and continuous optimization process and identifies five behavioral processes, including multi-actor value consensus, co-creation environment establishment, practical value co-creation, public value sharing, and diffusion of service added value. Finally, many studies have discussed value co-creation in corporate services. However, there is a lack of in-depth analysis of the mechanism and model behind the phenomenon of SSC value co-creation. This study enriches the theory by combining SSC and value co-creation theory and refines a practical logic model of SSC value co-creation.

This study explores the participation of multiple actors in SSC value co-creation through the grounded theory method, but there are certain shortcomings. First, as a qualitative research method, the grounded theory is analyzed according to the

subjective judgment of the researcher, and there may be a particular bias in the research process. Secondly, the cases analyzed in this study are typical case inferences. In the future, further expansion of the case sample is needed to deepen the study.

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

TP and JH: materials and methodology. TP and JY: coding. TP: validation, resources, and writing—review and editing. LF and TP: result analysis. LF: writing—original draft preparation, visualization, supervision, project administration, and funding acquisition. All authors have read and agreed to the published version of the manuscript.

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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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Ratchet effect in veterinary antibiotic use by contract farmers from the perspective of production risk: Implications for public health

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The current indiscriminate use of antibiotics for veterinary is irresponsible and misguided; it causes antibiotic resistance and adversely affects public health. The terms "habit" and "path dependence" are often used to explain the "excessive" use of agrochemicals. Yet, no research explored where the habit comes from and how it changes. This study investigates how veterinary antibiotic use changed with the production risk based on the multi-period production data set of 1,526 broiler contract farmers. The results show that the production risk has a ratchet effect on farmers' antibiotic use, leading to path dependence of farmers. Specifically, it showed a farmers' habit of steadily increasing antibiotic use and confirmed that the historical broilers' peak mortality was a key determinant to the continuation of this habit. It implies that higher the historical peak mortality, higher the current antibiotic use by farmers. Likewise, the impact of historical peak mortality on antibiotic use gradually increased with the farming experience. The increased historical peak mortality increased farmers' antibiotic use every time. Furthermore, large-scale farmers were more sensitive to historical peak mortality and therefore they increased antibiotic use excessively. The study suggests that improving farmers' production risk management capabilities, especially large-scale farmers, might help prevent extreme events. Moreover, this work contributes to the theoretical and empirical evidence on the ratchet effect, habit formation and farmers' antibiotic use and offers coherent insights for stakeholders to limit antibiotic use.

KEYWORDS

production risk, ratchet effect, agrochemical use reduction, public health, resistance to antibiotics

Introduction

The excessive use of agrochemicals causes resistance, adversely affecting human and animal welfare, and it has been a significant problem in realizing environmental sustainability within Chinese agriculture. Bacteria and pests are resistant to antibiotics and pesticides, respectively (1), and these are transferable to the human body through

living animals, animal products, and contaminated water and soil (2). The bacteriostatic effect of antibiotics for human use becomes weak with the excessive application, and thus health risks are increased. Estimates show that globally, over 700,000 people die of antibiotic resistance yearly (3). Likewise, the similar research project that by 2050 over 10 million people would die yearly from drug-resistant infections, if no serious action is taken to reduce antibiotic resistance.

Agrochemicals are intensively used in China. Ministry of Agriculture and Rural Affairs of the People's Republic of China (MARA-PRC) data reveal that the use of veterinary antibiotics per ton of animal products was 140 and 160 g in 2018 and 2019, respectively, which was much higher than the European Union (4). Trends show that from 1990 to 2018, the total pesticide application in China increased from 730,000 to 1.5 million tons, and pesticides increased from 4.9 to 9.1 kg/ha (5). Hence, a gradual agrochemical increase might threaten human health and sustainable development in the country (1). The Chinese government proposed two action plans to address these issues: (1) zero growth in pesticide use, and (2) reduction of veterinary antibiotic use. While these initiatives have a significant role in reducing antibiotic use, major knowledge gaps remain on whether and how they manifest green development in the agriculture sector.

Farmers' agrochemical use is generally linked to their habitual behavior of "being easy to increase but difficult to decrease." Although extensive agrochemicals have many negative effects, farmers continue to increase their use (6). According to Cowan and Gunby (7), farmers have a low marginal propensity to adopt green alternatives due to the lock-in effect. Moreover, the risk aversion attitude and production risk perception make it difficult for farmers to reduce the use of agrochemicals (8). In a survey among 1,526 broiler farmers in Jiangsu Province, China, we found that the increase in veterinary antibiotic use was consistent with the historical peak mortality of broilers. Through qualitative interviews, we learned that after experiencing extreme mortality events, some farmers would continue heavy use of antibiotics due to fear of loss. Based on this, antibiotic use by farmers shows an obvious ratchet pattern—it seldom decreases and has a substantial chance of increasing. The term "ratchet effect" was proposed by Duesenberry (9). It refers to the impact of previous peak income and consumption experience on the actual consumption of individuals. Once formed, consumption habits are difficult to change, and consumption is easy to increase but difficult to decrease. Later, many researchers supported the habit-forming effects of resident consumption and pointed out that this effect determined the saving tendency of residents. For instance, Carroll et al. (10) demonstrated that the greater the influence of habit formation, the stronger the consumers' awareness of saving. Likewise, Harbaugh (11) pointed out that the memory of the great famine was the main reason for Chinese residents' tendency toward high savings, and that the intensity of the famine was positively correlated with their propensity to save. So far, a substantial literature complies the ratchet effect in labor market contexts and social dilemmas [e.g., (12)]. However, no evidence was found on whether a ratchet effect exists in farmers' antibiotic use, even though antibiotic use seems to have a ratchet pattern.

Inter alia, agricultural production risk is one of the main risks farmers face (13). It usually refers to the uncertainty in the yield and quality of agricultural products due to huge fluctuations in the factors such as temperature, rainfall, diseases, pests, and epidemics (14). Reducing production risk is the primary goal of farmers using agrochemicals. Evidence showed that the larger the mean or variance of historical output, the lower the farmers' enthusiasm to invest in agricultural production and the less willing they are to adopt new agricultural production technologies (15). However, regarding the habit-forming effects of antibiotic use, what should be considered is the impact of the historical peak mortality, rather than the relatively flat mean or variance of historical mortality. Thus, the important questions arise regarding the excessive veterinary antibiotic application and farmers' behavior. First, does there exist a ratchet effect in antibiotic use among Chinese farmers due to production risk? Second, if so, how large is the ratchet effect? Third, does it decrease with the increase in the farming experience? Last, is the rachet effect magnitude have a difference among different groups?

This study takes contract farmers in the broiler breeding industry – company + farmer – model to investigate the habit-forming effects of antibiotic use. The study significantly contributes to the prior literature in many ways. First, this pioneering work cues farmers' habit of using agrochemicals and investigates the causes. Second, it extends the application of the ratchet effect theory to farmers' antibiotic use and provides a new analytical perspective and robust explanation of over-reliance on agrochemicals. Further, this study helps clarify farmers' decision-making mechanism of agrochemicals and coherent policy actions to promote green alternatives and reduce antibiotic resistance risks to human and animal health.

Literature review and hypothesis

Many studies explored the factors of the over-reliance on agrochemicals among Chinese farmers. Representative academic views include risk aversion, insufficient information, and habits. It is widely agreed in the academic community that farmers use agrochemicals in large quantities to avoid production risks. The unanimous conclusion from previous studies indicates that the more risk-averse the farmers, the higher the use of agrochemicals (16). Similarly, farmers' access to information is an important factor affecting agrochemicals' use and vice-versa (17). Most farmers in developing countries cannot obtain timely and accurate technical information and can only decide on pesticide

use from their experience (18). Dasgupta et al. (19) regarded the excessive use of agricultural chemicals as a bad habit and examined whether farmers had bad antibiotic habits based on income and farm ownership. Studies also discussed the habits of pesticide types selection, application frequency, and compliance with the instructions, concluding that farmers tended to use the same types of pesticides for years (20), apply pesticides multiple times in a short period (21), and use pesticides above the recommended doses specified in the instructions (22). These bad habits can cause farmers to overuse pesticides (23). In general, previous studies directly named farmers' behaviors as habits, but did not thoroughly investigate the origin and size of habits.

Habit formation asserts that the utility of current behavior is related to past behavior. In the literature, the term "behavior" usually refers to consumption. Unlike the traditional utility function, the function under habit formation is inseparable in time; hence, the utility of current consumption is related to the weighted average of consumption in previous periods. Thus, ratchet effect explains the origin of consumption habits; previous peak income shape consumption habits, and leads to consistency and continuity between current and previous consumption (9). Therefore, when current income decreases, consumption does not decrease immediately. Individuals would rather reduce savings or borrow money to maintain the original consumption level. However, previous studies usually use consumption in the previous period to represent consumption in various past periods and focus on evaluating the impact of consumption in the previous period on current consumption [e.g., (24)], lacking discussion on the impact of previous peak income. If consumption in the previous period impacts current consumption, the residents have consumption habits. However, where do the consumption habits come from? Consumption in the previous period did not come out of thin air. Therefore, verifying the habit-forming effects of previous peak income is reasonable. A few exceptions, only Corrales and Mejías's (25) work on Latin America incorporated the ratio of current income to previous peak income into the model to examine the ratchet effect of marginal propensity to consume based.

Based on the prior debate on the connection of the ratchet effect with consumption, this study investigates the ratchet effect's influence on farmers' antibiotic use. The farmers' consumption and/or application of agrochemicals has inertia, which may originate from the historical peak mortality. The discussion of the impact of historical peak mortality is similar to that of extreme events. Extreme events often have a long-lasting impact. For example, the experience of hunger in childhood causes great fear in children. Even if they no longer face the real danger of hunger in adulthood, they still cherish food and money exceptionally and tend to increase savings (11). The high loss experience may prompt farmers to form a habit of heavy antibiotic use. The logic is that the memory of loss may cause irrational preventive antibiotic use, and farmers choose to give up part of their profits to avoid losses as much as possible. Individuals tend to imitate past successful behavior patterns, even if the environment has changed (26). Increasing antibiotic use in this state of mind increases their sense of security. Hence, such a loss experience, to a certain extent, further causes sudden and virulent infectious diseases. Given these, the following hypothesis is proposed: The extreme mortality events (i.e., high historical peak mortality), instigate farmers' current excessive antibiotic use. In other words, after an extreme mortality event occurs, farmers' antibiotic use remains relatively high; thereby, the current antibiotic use is consistent with that in the previous period.

Antibiotic use by contract farmers

Data source

The longer-term input and output panel data is considered ideal for studying farmers' behavior of antibiotic use habits. In this study, contract farmers in broiler industry "company + farmer" model were used to acquire sufficient data while maintaining the sample's representativeness.

First, regulations for the broiler industry in China have been raised due to environmental protection policies and technological requirements. As a result, more small and medium-sized farmers have left this industry, and the farming scale and industrialization have continued to increase (27). From 2004 to 2017, the number of farms with an annual output of 2,000–10,000 broilers was reduced by half, while the number of farms with an annual output of more than 50,000 broilers increased by four times (28). Meanwhile, leading companies have increased and are gaining an increasing market share. In 2019, China's total broiler output was 9.3 billion, a quarter of which (2.258 billion) was produced by five listed broiler companies. The sample company in this study is one of the five listed companies. It has 22 fully-owned subsidiaries, mainly located in Jiangsu and Anhui provinces. Contract farmers with this company should represent the fundamentals of broiler farmers in China.

Second, research on production risk requires long-term historical data. In the commissioned farming model, the sample subsidiaries have detailed input and output data at the farmer–chicken house level, enabling the data robustness of this study. According to the contract, the company provides farmers with chicks, feed, medicine, training, and technical guidance, checks the quality, and accepts grown broilers. Farmers build sheds, pay deposits, and carry out broiler farming according to the company standards. The company sets the prices of materials and grown broilers. Farmers receive materials from the company on a credit basis and receive payment of gross profit from the company after the delivery of grown broilers. Farmers have a certain degree of discretion in using antibiotics; they can obtain and use antibiotics by company's recommended

dosage as long as they meet the withdrawal time and residue requirements. Although the company mainly bears the market risk, farmers also bear part of the farming risk. They need to improve farming performance through excessive antibiotics and appropriate management. Therefore, there is a great difference in antibiotic use among farmers. In other words, there is no lack of heterogeneity between contract farmers. The data covers several variables: number of chicks, mortality, cost of antibiotics, cost of vaccines, and cost of disinfectants. The companies provided the individual characteristics of farmers, such as age and years of farming experience.

The sampling period was from January 2016 to June 2018. During this period, 1,526 farmers had farming contracts with the sample subsidiaries and delivered more than 2 batches of broilers. Under normal circumstances, farmers produce 3 batches of broilers per year. Over one-third of the sampled farmers produced 7–10 batches of broilers. A small proportion, less than 10% farmers, produced more than 11 batches of broilers. The costs of antibiotics and other production factors were deflated by the producer price index of agricultural products of live poultry in 2016. The price index data comes from the China Statistical Yearbook 2017–2019.

Antibiotic use by farmers

Figure 1 depicts the overall changes in antibiotic use, one-period lagged mortality, and historical peak mortality by batch during the sample period among the sample farmers. In general, the historical peak mortality showed a increasing trend, and antibiotic use changed consistently with the historical peak mortality. In contrast, one-period lagged mortality was volatile and did not significantly correlate with antibiotic use. In detail, when less than 10 batches were bred, the increase in historical peak mortality was small (probably since extreme events were unprecedented), and antibiotic use fluctuated but remained stable overall. As time passed, the historical peak mortality increased sharply, and so did antibiotic use. Even though one-period lagged mortality sharply decreased, antibiotic use remained high. We can also infer from the changing trend that historical peak mortality had a threshold effect on antibiotic use, as antibiotic use increased only when the historical peak mortality was high enough.

The relationship between mortality and antibiotic use is clearer in individual farmers. As shown in Figure 2, the farmer experienced three increases in historical peak mortality during the sample period. The first increase lasted a long time, from period 3 to 9. During this period, antibiotic use fluctuated slightly, mainly due to many disturbance factors and consequent high uncertainty in agricultural production. The second increase was small, lasted only one period, and is not discussed here. However, the third increase was very large and lasted until the end of the sample period. During this period, antibiotic use and historical peak mortality increased sharply and remained high even when the one-period lagged mortality decreased significantly. After experiencing extreme mortality events, farmers may desire more to avoid losses and maintain low mortality, thus making continued heavy use of antibiotics. It suggests that this phenomenon is common. Therefore, it can be predicted that the production risk has a ratchet effect on antibiotic use by farmers.

Extreme mortality events have randomness (for example, due to an exogenous sudden temperature drop that catches farmers unprepared) and regularity. Generally, farmers with more years of farming experience are more experienced, and those with a larger farming scale have more capital and technology (29). So, is the regularity of extreme mortality events reflected in the lower historical peak mortality for farmers with more years of farming experience or a larger farming scale?

The data suggests, as shown in Figure 3, that this may not be the case. There was no significant difference in peak mortality between farmers with fewer years of farming experience and those with more years of farming experience. Thus, the severity of extreme mortality events was weakly correlated with years of farming experience. This reflects the exogeneity and randomness of extreme mortality events. Extreme mortality events can occur to both beginner and experienced farmers. In contrast, historical peak mortality was associated with the farming scale. Compared with small-scale farmers, large-scale farmers experienced higher peak mortality; they experienced more severe extreme mortality events. Hence, the ratchet effect of antibiotic use may be more pronounced among large-scale farmers. Section Heterogeneity examines the ratchet effect in different groups of farmers.

Sample, model, and variables

Model specification

In analyzing the ratchet effect in consumption, the current marginal propensity to consume depends on the relative values of current income and previous peak income, and the lagged marginal propensity to consume (30). Therefore, the following model is proposed to investigate the ratchet effect in antibiotic use by farmers:

$$Y_{it} = \alpha_0 + \alpha_1 Risk_{it,peak} + \alpha_2 Risk_{it,m} + \alpha_3 Y_{i,t-1} + \alpha_4 X_{it} + \varepsilon_{it} \quad (1)$$

where Y_{it} is the antibiotic use in period t; $Risk_{it,peak}$ is the peak mortality before period t, with the coefficient α_1 representing the strength of the ratchet effect; $Risk_{it,m}$ is the mean mortality before period t; $Y_{i,t-1}$ is the one-period lagged antibiotic use, with the coefficient α_2 representing the strength of the habit-forming effects; X_{it} is other factors that affect antibiotic use in period t, such as the age of household head, years of farming experience, farming scale, current vaccine input, disinfectant input, and rearing density; and ε_{it} is the random error term.

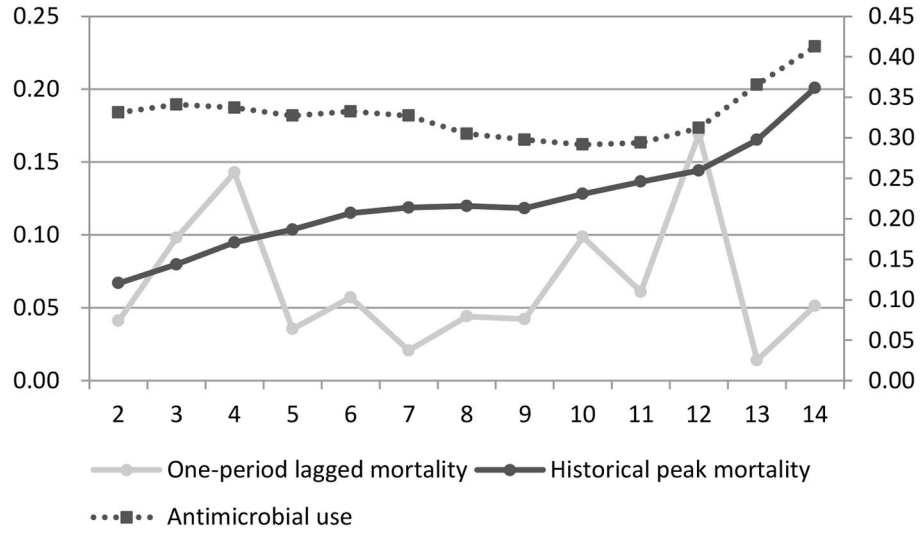

FIGURE 1
Broiler mortality and current antibiotic use among the sample farmers. The horizontal axis represents batches of broilers, the left vertical axis represents the mortality, and the right vertical axis represents the cost of antibiotics per broiler (yuan/broiler).

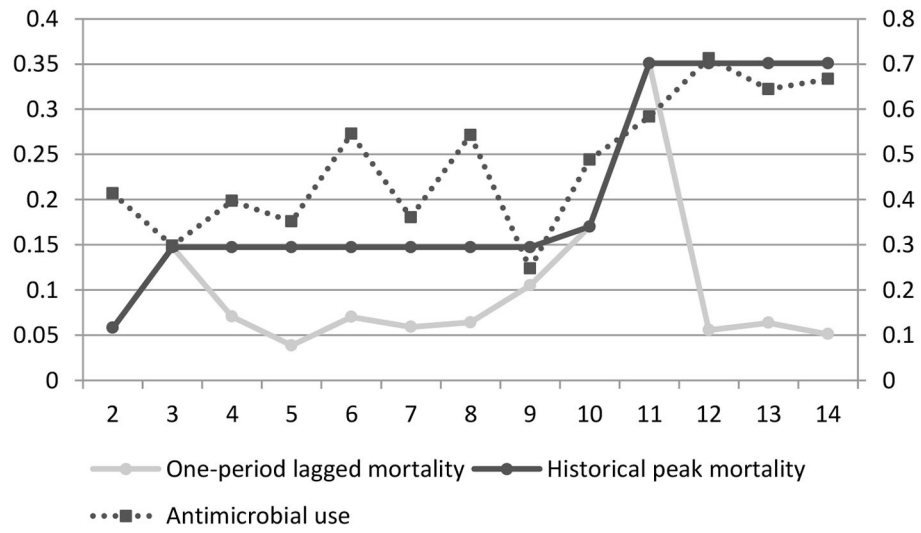

FIGURE 2
Broiler mortality and current antibiotic use by an individual farmer. The horizontal axis represents batches of broilers, the left vertical axis represents the mortality, and the right vertical axis represents the cost of antibiotics per broiler (yuan/broiler).

Fixed effects of broiler breed, chick-receiving month, and chick-receiving year were also included in the model to control unobservable factors.

Model (1) is essentially a dynamic panel data model as the antibiotic use is affected by the antibiotic use in the previous period. Naik and Moore (31) suggested using fixed effects estimation for this model. They believed that fixed effects could eliminate individual heterogeneity and the impact of previous behavioral characteristics not captured by one-period lagged variables. However, fixed-effects estimation is questioned in two ways: First, although fixed effects control for unobservable heterogeneity that does not change with time between individuals, they cannot address endogeneity caused by omitted variables that change with time. Second, fixed-effects dynamic panel models are biased in finite samples (32).

To this end, the System Generalized Method of Moment (GMM) approach was used to test robustness in this study. System GMM corrects the bias of fixed effect estimates in finite samples and is robust to weak instruments. It uses moment conditions in both difference and level equations and the first

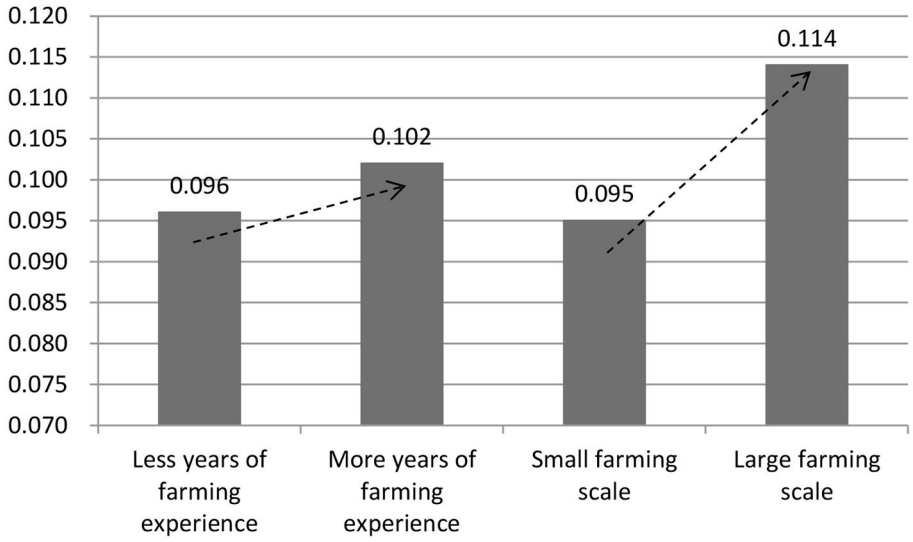

FIGURE 3
Broiler mortality and current antibiotic use by an individual farmer.

differences of lagged variables as instruments for level variables in the level equation, thus being more effective than difference GMM estimation.

Variable definitions and descriptive statistics

Since production risks are almost always related to adverse events that have not yet occurred and are hypothetical, therefore cannot be directly observed (33). A few researchers measured this risk by risk perception (34), but this approach has drawbacks, such as subjectivity and strong endogeneity. Some researchers used objective output data to represent current and/or future production risks. An early representative study by Anderson and Griffiths (35) examined the effect of production risk on inputs by measuring the mean and variance of crop yields. In addition to the mean and variance of output, Falco et al. (36) also measured downside risk to output, expressed by the skewness of output. A decrease in output skewness implies an increased downside risk to output, which is an increased probability that the output is below the mean given the mean and variance (36, 37). Building on the existing literature, this study measures production risk by historical peak and mean mortality, assesses the ratchet effect, and examines the impact of historical peak mortality on farmers' current antibiotic use. In period *t*, the historical peak mortality is the highest mortality experienced by farmers before period *t*.

The definitions and descriptive statistics of key variables in the model are shown in Table 1. The average age of the sampled farmers was 45 years. They generally had 5 years of farming experience and a mean farming capacity of nearly 20,000 broilers per batch. The broilers were divided into fast, medium and slow-growing, with an average rearing period of 61, 80, and 94 days, respectively. Most farmers raised medium-growing broilers, followed by slow-growing. In addition to the use of antibiotics, disease prevention measures implemented by farmers as required by the company included vaccination and disinfection.

Empirical analysis

General results

As shown in Table 2 (column 1), the ratchet effect in antibiotic use was estimated by System GMM. Two-step estimation was used for regression. Two and three-period lagged antibiotic use were instrumental variables for one-period lagged antibiotic use. For standard deviations in the two-step estimates, finite-sample corrections were made per Windmeijer (38) to correct possible downward bias. Sargan's test of System GMM estimates suggests that the instruments are generally valid. The test for residual serial correlation indicates no second-order serial correlation in the differenced residuals. Thus, it can be concluded that there is no serial correlation in the error term of the original model. The *p*-value of the Wald test indicates that the model is overall significant.

As shown in column (1), the coefficient of historical peak mortality is significant and positive at the 5% level. Specifically, each additional unit of the historical peak mortality was associated with an increase of 0.140 yuan/broiler in current

TABLE 1 Variable definitions and descriptive statistics.

Variable	Definition	Mean	Standard deviation
Antibiotic use	Current antibiotic cost (yuan/broiler)	0.334	0.135
Historical peak mortality	The highest mortality in the past (number of deaths/number of chicks received)	0.097	0.079
Historical mean mortality	Mean mortality in the past	0.063	0.037
One-period lagged antibiotic use	One-period lagged cost of antibiotics (yuan/broiler)	0.330	0.129
Age	Age of household head (years)	44.961	7.214
Years of farming experience	Years of engaging in contract farming	5.153	2.782
Scale of farming	Current number of chicks received (10 thousands)	1.776	1.078
Vaccination	Current vaccination cost (yuan/broiler)	0.191	0.072
Disinfectant use	Current disinfectant cost (yuan/broiler)	0.018	0.017
Rearing density	Current number of chicks/housing area (broilers/square meter)	12.273	2.400
Medium-growing broilers	Whether the breed is medium-growing broilers (1 = yes; 0 = no)	0.460	0.498
Fast-growing broilers	Whether the breed is fast-growing broilers (1 = yes; 0 = no)	0.303	0.460

antibiotic. Chah et al. (39) stated that farmers were not ready to risk losing their chickens and the main concern about production risks contributed to the farmers' heavy use of antibiotics. In addition, the impact of one-period lagged antibiotic use on current antibiotic use was significant and positive at the 1% level (0.144). The above results indicate that antibiotic use by Chinese farmers has a strong path dependence on historical peak mortality and also shows a significant habit-forming effect, thus confirming a ratchet effect in antibiotics use.

Moreover, only the coefficients of historical peak mortality, one-period lagged antibiotic use, and rearing density are significant and positive. Intensive farming generally suffers from high stocking densities, increasing the risk of disease transmission (40). Therefore, reducing rearing density is an effective way to reduce antibiotic use. The historical mean mortality had no significant effect on current antibiotic use. It suggests that farmers are more sensitive to extreme mortality events than the average historical mortality level.

Table 2 also reports the regression results for the fixed effects. As shown in column (2), the coefficients of historical peak mortality and one-period lagged antibiotic use are no longer significant, and the latter is negative. With relatively few years of panel data, the fixed-effect estimates of the lagged explained variables are biased downwards (41). Therefore, the endogeneity of habit formation cannot be ignored.

Next, the continuous historical peak mortality was transformed into a series of dummy variables based on a certain "threshold" value. It helps determine how high the historical peak mortality needs to change the current antibiotic use, resulting in a ratchet effect. Determining this value guides apposite practice. Companies can predict the trend of antibiotic use by farmers according to the mortality, and develop accurate antibiotic use reduction plans in advance. The "threshold" values selected in this study are 0.10, 0.11, 0.12, 0.13, 0.15, 0.17, 0.19, and 0.21. The first value, 0.10, is slightly above the mean historical peak mortality, 0.11 is the 75th percentile of historical peak mortality, and 0.21 is close to the 95th percentile. The results are shown in Table 3. If the historical peak mortality value is higher than 0.13, it might have a significant positive impact on the current antibiotic use[1]. The value of 13% is the 94th percentile of one-period lagged mortality, which can be considered an extreme mortality event.

1 A threshold model should have been used to examine the threshold effect of historical peak mortality. However, the it requires balanced panel data, which result in the loss of a large number of samples because sampled farmers reared different batches of broilers. To be specific, as 18% of sample farmers reared no more than 4 batches of broilers, 25% reared 5–7 batches, 42% reared 8–10 batches, and the left 15% reared 11–14 batches, at least half of the sampled would be lost. Therefore, we choose to create a series of dummy variables to measure the threshold effect. To verify the robustness of the threshold effect, we also adopted a fixed-effect panel threshold model proposed by Hansen (42). To reduce sample attrition, farmers that reared 8 and more batches were kept and batches above 8 were dropped. We first test for one, two and three-threshold models through a bootstrap procedure. The test statistics suggest the presence of one significant threshold value, which is 0.143. With the estimated threshold values, a fixed-effect panel threshold model is estimated. Results show that when the historical peak mortality is lower than 0.143, the coefficient of historical peak mortality on antibiotic use is 0.135 and significant at the 10% level. On the other hand, if the historical peak mortality is higher than 0.143, the coefficient of historical peak mortality on antibiotic use increases to 0.307 and is significant at the 1% level. By contrast, the impact of historical peak mortality on antibiotic use is much greater when historical peak mortality is relatively high. In general, the panel threshold model yields consistent estimates with the analysis that uses a series of dummy variables. As the sample size is cut (at least halved) when using the panel threshold model, we stick with the estimation with a series of dummy variables. Due to space limitations, detailed results are not reported and can be obtained from the authors.

TABLE 2 The impact of historical peak mortality on current antibiotic use.

	Current antibiotic cost (yuan/broiler)	
	(1)	(2)
Historical peak mortality	0.140**	0.023
	(0.070)[a]	(0.030)
Historical mean mortality	−0.239	0.247***
	(0.176)	(0.072)
One-period lagged antibiotic use	0.144***	−0.005
	(0.029)	(0.013)
Age	−0.013	0.036***
	(0.009)	(0.006)
Years of farming experience	−0.003	−0.048***
	(0.010)	(0.006)
Scale of farming	−0.003	−0.004
	(0.005)	(0.003)
Vaccination	0.041	−0.027
	(0.029)	(0.022)
Disinfectant use	−0.011	0.128
	(0.118)	(0.079)
Rearing density	0.002*	0.002***
	(0.001)	(0.001)
Fixed effect[b]	Yes	Yes
Constant term	0.834**	−1.099***
	(0.350)	(0.248)
Sample size	8,045	8,045
Wald test	157.71***	—
R-squared	—	0.034
Number of farmers	1,526	1,526
Estimator	System GMM	Fixed effect

[a]Numbers in parentheses are the standard errors of the estimated coefficients. *, **, *** indicate significance at the 10%, 5%, and 1% levels, respectively. [b]Fixed effects include breed, month, and year fixed effects. Correlation coefficients are not listed due to space limitations. The same applies to the following tables.

How much economic loss do farmers incur with mortality higher than 13%? According to the settlement data provided by the companies, the average production cost per broiler (including only direct materialized costs, such as costs of chicks, feed, and medicines) was 19.102 yuan, the average selling price per broiler was 21.469 yuan, and the average gross profit per broiler was 2.368 yuan. To simplify the analysis, it is assumed that broilers die just before being delivered as grown broilers. In this case, the gross profit is reduced to 0 yuan when the mortality reaches 11%. If labor, fixed asset depreciation, fuel, and water and electricity costs (approximately 1 yuan/broiler in total) are deducted, farmers would already suffer great losses. Assuming that broilers die in the middle of the production process, the average production cost per dead broiler would be approximately 9.551 yuan. In this case, the gross profit is reduced to 0 yuan when the mortality reaches 20%. Therefore, a higher than 13% mortality is likely to cause farmers' profits to drop below zero. This study indicates that the experience of fruitless labor in farming can lead farmers to over-rely on antibiotics to reduce production risks.

Intertemporal changes in the ratchet effect

If the ratchet effect is long-standing, it causes high resistance to reducing antibiotic use. Therefore, it is necessary to explore the persistence of the ratchet effect. To this end, a historical peak mortality duration variable is created, and the interaction between the historical peak mortality and duration is added to the basic model. After a peak mortality occurred, the historical peak mortality would remain unchanged unless new higher mortality occurred. The data shows that three-fifths of the sample farmers experienced 1–2 stepwise increases in historical peak mortality during the sample period. On average, peak mortality was replaced by a higher mortality after 4–5 periods. If the historical peak mortality occurred in the previous period, the duration variable takes the value 1; if the historical peak mortality occurred in the period before last, the duration variable takes the value 2 and so forth.

In addition, the continuous duration variable was transformed into a series of dichotomous variables based on a certain "threshold" value to examine further the short-term and long-term effects of historical peak mortality. Specifically, the dichotomous variables are whether peak mortality lasts for 2 periods or more, likewise repeated for 2–6 periods.

The results are shown in Table 4. As shown in column (1), the interaction between historical peak mortality and duration is significant and positive. It indicates that the impact of historical peak mortality on current antibiotic use increases with the increase in farming experience. The duration is a dummy variable in columns (2)–(6). When the duration exceeds 5 periods, the interaction coefficient between historical peak mortality and duration is large and significant (positive) at the 1% level. It indicates that historical peak mortality lasting for more than 5 periods leads to increased antibiotic use. Therefore, the longer the duration of the historical peak mortality, the higher the antibiotic use. The possible reason is that the longer the duration, the higher the value of the historical peak mortality. In other words, the duration indirectly reflects the historical peak mortality level.

Notably, the one-period lagged mortality was lower than the historical peak mortality during the duration. Even if the

TABLE 3 Threshold effect of historical peak mortality on current antibiotic use.

	Current antibiotic cost (yuan/broiler)							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
(A certain value)[b]	0.10	0.11	0.12	0.13	0.15	0.17	0.19	0.21
Historical peak mortality above a certain value	0.001	0.008	0.009	0.022*	0.035**	0.052**	0.060**	0.060**
	(0.009)	(0.009)	(0.010)	(0.012)[a]	(0.013)	(0.015)	(0.017)	(0.019)
Historical mean mortality	0.015	−0.085	−0.085	−0.143	−0.184	−0.216	−0.235	−0.223
	(0.150)	(0.155)	(0.153)	(0.153)	(0.154)	(0.147)	(0.146)	(0.147)
One-period lagged antibiotic use	0.128**	0.138**	0.137**	0.140**	0.142**	0.144**	0.142**	0.140**
	(0.030)	(0.030)	(0.030)	(0.029)	(0.029)	(0.029)	(0.029)	(0.029)
Control variable	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sample size	8,045	8,045	8,045	8,045	8,045	8,045	8,045	8,045

[a]Numbers in parentheses are the standard errors of the estimated coefficients. *, ** indicate significance at the 10%, 5%, and 1% levels, respectively. [b]The mean historical peak mortality was 0.097, with a 75th percentile of 0.111, a 90th percentile of 0.168, and a 95th percentile of 0.219.

TABLE 4 Intertemporal changes in the impact of historical peak mortality on current antibiotic use.

	Current antibiotic cost (yuan/broiler)					
	(1)	(2)	(3)	(4)	(5)	(6)
		$T = 2$	$T = 3$	$T = 4$	$T = 5$	$T = 6$
Historical peak mortality	0.055	0.037	0.107	0.140**	0.138**	0.131*
	(0.071)	(0.073)	(0.073)	(0.072)	(0.064)	(0.068)
Historical peak mortality * duration[b]	0.060***					
	(0.016)[a]					
Historical peak mortality * lasting for more than T periods		0.136***	0.070*	0.050	0.204***	0.190***
		(0.035)	(0.042)	(0.052)	(0.056)	(0.066)
Historical mean mortality	0.121	0.046	−0.130	−0.219	−0.201	−0.208
	(0.166)	(0.178)	(0.182)	(0.173)	(0.169)	(0.170)
One-period lagged antibiotic use	0.164***	0.151***	0.144***	0.150***	0.159***	0.150***
	(0.028)	(0.029)	(0.030)	(0.030)	(0.028)	(0.029)
Control variable	Yes	Yes	Yes	Yes	Yes	Yes
Fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Sample size	8,045	8,045	8,045	8,045	8,045	8,045

[a]Numbers in parentheses are standard errors. *, **, *** indicate significance at the 10%, 5%, and 1% levels, respectively. [b]"Duration" indicates how long the historical peak mortality in period t lasts. "Lasting for more than T periods" is a dummy variable. If the historical peak mortality in period t lasts for T periods or longer, it takes the value 1, otherwise, it takes 0.

one-period lagged mortality is low, antibiotic use does not decrease and might increase further. This more rigorously verifies the ratchet effect proposed by Duesenberry (9) with the characteristics of "being easy to increase but difficult to decrease."

Results in Table 2 conclude that the higher the historical peak mortality, the higher the current antibiotic use. Combining these with Table 4, farmers increase antibiotic use to a higher level every time the historical peak mortality increases. Hence, these findings rigorously explore habit formation and provide strong empirical evidence for understanding farmers' antibiotic use.

Heterogeneity

Important characteristics of farmers include age, education, years of farming experience, the scale of farming, and the number of household laborers (17, 43). Due to data limitations, the characteristics discussed in this study are age, years of farming experience, and scale of farming. Older farmers are more risk-averse and may be more sensitive to historical peak mortality (44). Due to the learning effect, farmers with longer broiler experience are less sensitive to historical peak mortality. In theory, large-scale farmers have relatively high-risk tolerance and might be more insensitive to historical peak mortality.

TABLE 5 Different effects of historical peak mortality on different categories of farmers.

	Current antibiotic cost (yuan/broiler)		
	(1)	(2)	(3)
Historical peak mortality	0.138*	0.160**	0.129*
	(0.073)[a]	(0.074)	(0.068)
Historical peak mortality * whether being older than 50 years[b]	0.016		
	(0.116)		
Historical peak mortality * whether having more than 7 years of farming experience		−0.075	
		(0.082)	
Historical peak mortality * whether having more than 25,000 chicks			0.129**
			(0.060)
Historical mean mortality	−0.239	−0.251	−0.249
	(0.175)	(0.175)	(0.175)
One-period lagged antibiotic use	0.144***	0.144***	0.142***
	(0.029)	(0.029)	(0.029)
Control variable	Yes	Yes	Yes
Fixed effect	Yes	Yes	Yes
Sample size	8,045	8,045	8,045

[a]Numbers in parentheses are the standard errors of the estimated coefficients. *, **, *** indicate significance at the 10%, 5%, and 1% levels, respectively. [b]"Whether being older than 50 years" takes the value 1 if the age of household head is 50 years and above, otherwise it takes 0. "Whether having more than 7 years of farming experience" takes the value 1 if the household head had more than 7 years of farming experience, otherwise it takes 0. "Whether having more than 25,000 chicks" takes the value 1 if the number of chicks received by the farmer was 25,000 or more, otherwise it takes 0. c. 50 years of age, 7 years of experience, and 25,000 chicks are the 75th percentiles of the corresponding variable. Farmers with more than 25,000 chicks usually own more than two chicken houses.

We tested that heterogeneity by adding the interactions of age, years of farming experience, and farming scale with historical peak mortality to the basic model, are illustrated in Table 5. The impact of historical peak mortality on current antibiotic use is not related to age and farming experience, but only depends on the scale of farming. Specifically, for each additional unit of historical peak mortality, antibiotic use by large-scale farmers increased by 0.299 yuan/broiler, while that by small-scale farmers only increased by 0.177 yuan/broiler. There was no heterogeneity in the effect of historical peak mortality by age and/or years of farming experience. It might be conferred that farmers of different ages or years of farming experience did not experience significant differences in historical peak mortality.

The key results show that farming scale negatively affect antibiotic use, although not significant. This is consistent with numerous studies discussing the relationship between farming scale and pesticide use (23, 45). The reasons for farming scale to promote the reduction of agrochemical use are multi-dimensional. On the one hand, with the increase in farming scale, farmers choose to reduce agrochemical use to reduce material costs. On the other hand, large-scale farmers are more likely to carry out scientific production and management, can better control agrochemical use, and implement more efficient and effective disease prevention and control (45). Furthermore, large-scale farmers are more able to adopt advanced production technology (29), and reduce the incidence of disease by optimizing the production environment, thereby reducing the use of agrochemicals.

However, this study further shows that large-scale farmers use fewer agrochemicals and are more sensitive to historical peak mortality. Although large-scale farmers have a higher risk appetite than small-scale farmers, they are still risk-averse. Large-scale farmers have experienced greater production losses with the same historical peak mortality, which may lead to greater sensitivity to historical peak mortality.

Conclusions

Antibiotic resistance and poultry disease transmission incidents to humans have increased several-fold. Farmer excessively uses antibiotics to reduce mortality rates and increase feed efficiency. A better understanding of the farmers' decision makings of antibiotic use in the production process is necessary for reducing antibiotic use and ensuring the footprints of animal production on human health. This study empirically proves the ratchet effect on farmers' antibiotic application using a data set of 1,526 contract farmers from 2016 to 2018. The study findings offer in-depth understanding of habit formation, ratchet effect, and veterinary antibiotics use and provide cues for policy and practice.

The findings offer insights into theoretical and empirical literature on habit formation and the ratchet effect in many

ways. First, the results showed that the historical peak mortality significantly (positively) affected current antibiotic use, which did not decrease with the farming experience. In other words, significant ratchet effects can occur irrespective of age and experience level as long as they operate on a large scale. Likewise, findings further confirm that Large-scale production is a general trend in the farming industry. Second, the one-period lagged antibiotic use also significantly and positively affected current antibiotic use. Therefore, due to production risks, farmers have a ratchet effect in antibiotic use. As the historical peak mortality increased in a stepwise manner, farmers' antibiotics followed a similar pattern. Third, the historical peak mortality had a greater positive effect on antibiotic use by larger-scale farmers. Larger-scale farmers that experienced high mortality events would maintain higher antibiotic use for a long time. Further, the study extends the application of "Ratchet effect theory" by studying the antibiotic use behavior of broiler farmers.

Based on the findings, we proposed coherent policy actions for farmers, contract companies, the government, and other stakeholders linked to the broiler breeding industry. First, there is a need to effectively improve farmers' production risk management capabilities to reduce the antibiotic resistance risks to animal and human health. For the farmers, efforts should be made to encourage them to enhance farming conditions and sanitation by providing them with better training and the latest technology to reduce the broiler mortality rate. The companies should improve the development and introduction of high-quality chick breeds, thereby preventing extreme adverse events from the source. Second, since the intensity of the ratchet effect on historical peak mortality does not depend on the farmers' age or farming experience, but on the farming scale. Notably, due to habit formation, engaging traditional farmers in large-scale production whose main goal is to avoid risks, it is nearly impossible to reduce veterinary antibiotic use. The contract farming mode might be introduced to organize scattered small farmers' improved market entry and enhanced the surveillance of antibiotic use. Finally, breaking the link between antibiotic use and historical peak mortality is a key issue that the government and companies should focus on by revisiting the flaws and loopholes in the current policies. Especially, in low and middle-income countries where farmers are more sensitive to production risks and possess relatively low knowledge about disease management. After an extreme mortality event occurs, more technical guidance and support should be provided to farmers to improve their rational future disease risk management. Moreover, government could intervene to ensure producer risk transfer through the wider coverage of agricultural insurance in the poultry industry.

This study robustly answers the posited questions, yet it has some limitations, which offer avenues for future research. First, due to data constraints, it overlooks the differences between subtherapeutic and therapeutic antibiotic use. Second, the sampled company only records each farmer's total cost of antibiotics; albeit, most farmers cannot recall the dosage and stated that more than half of antibiotics were used for disease prevention. Thus, future research can accurately examines the cost of antibiotics used and incurred economic losses in mortality when no antibiotics were applied using control designs. Further, the sample data come from the same province in China and contract with the same breeding company; thus it might lack generalizability. Future research should include more farmers in other regions and contracting with different companies to verify the results represented herein. Further, although antibiotic use is discussed in this study, the conclusions can be extended to pesticide use both are damage control inputs. Subsequent research can directly investigate farmers' ratchet effect on pesticide use.

Data availability statement

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

Author contributions

LL: conceptualization, methodology, analysis, writing the original draft, and editing. RY: reviewing, supervision, and funding acquisition. 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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Influence of carbon emission trading policy on residents' health in China

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Residents' health is the basic condition for economic and social development. At present, China's environmental pollution problem is becoming increasingly serious, which not only hinders sustainable economic and social development, but also poses a major threat to public health. Therefore, based on the carbon emissions trading policy implemented in China, this paper explores this policy's impact on residents' health using the DID model and illustrates the moderating effect of environmental pollution. The results show that (1) carbon emissions trading policies can promote the improvement of residents' health; (2) the effect is stronger for western regions and provinces with smaller population sizes after taking control variables into consideration; and (3) environmental pollution has a significant moderating effect on the relationship between carbon emissions trading and residents' health. This research serves as an important reference for expanding the scope of the policy pilot, reducing pollutant emissions, and improving the health of the population.

KEYWORDS

carbon emission trading policy, residents' health, environmental pollution, DID, the moderation effect, China

Introduction

The theme of the *Healthy China* Strategy is "Joint Construction and Sharing, National Health." Although China's reform and opening up has achieved rapid economic take-off, it has also brought about serious ecological damage and environmental pollution, and various diseases caused by environmental degradation have seriously hindered the health of the Chinese population. Health is the livelihood issue most directly and closely related to people's real interests. Only by keeping healthy can residents actively participate in production activities and create greater value. Faced with increasingly serious environmental pollution, China has formulated various environmental regulation

policies and tried to build a benign and sustainable energy ecosystem by promoting low-carbon production and consumption in pilot provinces, with the aim of achieving the goal of "Healthy China" as quickly as possible. Therefore, exploring the intrinsic relationship between carbon emissions trading policies and residents' health, and studying how pilot policies can improve residents' health by reducing environmental pollution, is beneficial to highlighting the importance of environmental regulation implementation and achieving the goal of "Healthy China."

So far, the existing literature has focused on the effects of environmental pollution on residents' health and the effects of environmental regulations on infant mortality, laying the foundation for us to explore the effects of environmental regulations on residents' health. However, there are still the following gaps in the literature: First, most studies on residents' health have been conducted through questionnaires to obtain self-assessed health data or have used mortality rates as a proxy for residents' health indices, with the former being more subjective and the latter potentially having biased findings. Second, there are limited studies on the health effects of environmental regulations in China, especially a lack of studies on market-incentivized regulatory policies. In addition, few studies have analyzed their impact paths, leading to a lack of understanding of the impact mechanisms and health benefits of environmental regulations.

Therefore, the innovation of this paper is mainly reflected in the following three aspects: First, the indicator design is innovative. Referring to the WHO's definition of health, five indicators are selected, and the Topsis method of panel data is used to measure the health level of residents, which objectively reflects the health status of residents in 31 Chinese provinces and cities. Second, the research content is expanded and deepened in comparison with previous studies. From the perspective of health improvement and taking market-oriented environmental regulations as an example, this article analyzes the impact of China's carbon emissions trading policy on residents' health and provides references and suggestions for the construction of China's environmental regulation system. Third, this study offers a novel research perspective. Based on an economics perspective, this article combines front-line knowledge and methods of sociology and environmental science to analyze the impact of the interaction between environmental pollution and environmental regulations on residents' health within the context of and literature on regulatory effects, which enriches and expands existing research.

Literature review and research hypothesis

Research on population health can be traced back to 1972, when Grossman introduced the utility function of health into Becker's household production function and constructed a model of the demand for health capital. The introduction of this function formally opened up research on and exploration of human health. Deng et al. (1) found that adult training had a small positive impact on resident autonomy and a negative impact on resident wellness through a REDCap questionnaire. Ahn et al. (2) believed that long working hours and job-related stress can worsen the health status of residents. Raynor et al. (3) found higher incidence of mental health deterioration in people who were exposed to a COVID-19 shock. Aeschbach et al. (4) selected an active control group for a longitudinal randomized controlled trial and concluded that a tailored MBP may improve certain aspects of resident physicians' positive mental health. Shepley et al. (5) asserted that environmental quality and characteristics can impact both the mental and behavioral health of psychiatric patients. Ke and Chen (6) based on the Health Belief Model, found that residents are living healthier lifestyles after the COVID-19 pandemic in Wuhan, China. Fitzpatrick et al. (7) showed that aboriginal health and mental health problems were more severe in the wake of 2016 Horse River Wildfire in Northern Alberta, Canada. Li et al. (8) claimed that participating in physical exercise can significantly improve the subjective and objective health level of individuals.

Since the industrial revolution, with the progress of society and the development of science and technology, the level of industrialization has been increasing and humanity's ability to exploit natural resources has been rising. As a result, humans have acquired great wealth, but this has come at the price of destroying the natural ecological environment. The decline in environmental quality has caused deterioration of the human living environment, which not only reduces human immunity, but also increases the prevalence of respiratory diseases and the rate of babies suffering congenital defects or health issues, which has a negative impact on human health. For example, the Great Smog of 1952 in London, Photochemical Smog Episode in Los Angeles from 1940 to 1960, Minamata disease incident in Japan in 1956, and Itai-itai Disease in Japan in 1931 have all had demonstrable negative impacts on human health.

Many studies have confirmed that environmental pollution reduces the health status of the population. Qiu et al. (9) found that short-term exposure to elevated concentrations of PM2.5 and NO_2 were significantly associated with an increased risk of hospital admissions for psychiatric disorders among the US Medicare population. Mallongi et al. (10) believed that air pollution not only has a direct impact on human health, but also can damage the environment. Reginold Raja and Antony Selvi (11) argued that environmental pollution, especially land, air, and water pollution, can harm people's health and exacerbate social problems related to environmental pollution. Sekmoudi et al. (12) showed that long-term exposure to exceedance levels of particulate matter elevated humans' morbidity and mortality. Nwani et al. (13) found that environmental pollution as proxied by per capita CO_2 emissions has a negative and

significant effect on health outcomes in Nigeria. Orru (14) mostly focused on mortality, calculated the health effects of future ozone and particulate matter concentrations under various climate scenarios.

In addition to direct effects, some scholars believe that there are also spillover effects of environmental pollution on residents' health. The First Law of Geography states that correlations between geographic phenomena or attributes are common, and correlations are related to geographic distance; in general, the closer the distance, the greater the correlation, and the farther the distance, the greater the variability Tobler (15). Chen et al. (16) suggested that there is a spatial spillover effect of air pollution on public health, i.e., the health of residents in a certain area is not only affected by local air pollution, but also by air pollution in neighboring areas. This spillover effect of pollution on health was verified in studies by Wang (17), Feng et al. (18), and Song and Cui (19).

To reduce the impact of environmental pollution on a population's health, some countries have formulated environmental regulations guided by the externality theory and attempted to limit pollutant emissions through administrative orders. Chay and Greenstone (20) found that the US *Clean Air Act* implemented in 1970 reduced total suspended particulate concentrations and thereby effectively reduced infant mortality; Luechinger (21) found that the *German Desulfurization Policy* significantly reduced SO_2 concentrations and infant mortality, and Greenstone and Hanna (22) found that India's *Catalytic Converter Policy* significantly reduced SO_2 and NO_2 concentrations and thus contributed to a small reduction in infant mortality. McGartland et al. (23) estimated the health benefits of environmental regulations and concluded that reductions in various environmental pollutants can have a beneficial effect on non-cancer health. Tang et al. (24) came to the conclusion that environmental regulations have a significant co-benefit on high-quality environmental development and public health. However, some studies have also concluded that the policy effects of environmental regulation are limited. Zheng et al. (25) found that China's *Air Pollution Control Law* implemented in 2013 has reduced the population formaldehyde PM2.5 concentration, but the mortality rate showed a non-linear corresponding trend.

Based on the above analysis, this paper proposes the following hypothesis: environmental regulation can promote the improvement of residents' health. Environmental pollution has a positive moderating effect on the relationship between environmental regulation and residents' health.

Data sources, variables, and models

Data sources

Considering data availability, completeness, and accuracy, this paper conducts research and analysis based on data from 31 provinces and cities in China from 2009 to 2020. The relevant data are obtained from the China Health Database and the statistical yearbooks of each province and city. For some missing values, the linear interpolation method is used to complete the data.

Variables' selection

Explained variable

The explained variable in this study is resident health (RH). The sum of the individual health of all residents in a country or region is the health status of residents, which is called public health or resident health. The health of residents not only directly affects the happiness of individuals and families, but also affects the social and economic development of the country and/or area. In this paper, the occurrence of diseases among the population is used as a proxy variable for the population's health: the higher the occurrence, the lower the population's health level. Based on the World Health Organization's definition of human health, this paper constructs indicators for measuring the health production function of residents according to the health production function model, and uses the Topsis method of panel data to construct an indicator that can comprehensively measure resident health levels and any changes across different provinces and cities. In this paper, five indicators, namely number of health technicians, number of beds in medical and health institutions, pertussis infection rates, mortality, and average number of times a resident visits a hospital in each region over the study years are used to synthesize the indicator of disease occurrence. Here, the missing values are inferred by linear interpolation.

Explanatory variables

This study set environmental regulation (DID) as the explanatory variable. Effective environmental regulations can not only improve the ecological environment, but also have an impact on economic growth and industrial structure, which in turn will further affect residents' health. At present, there is no unified environmental regulation index in academic circles. Some scholars have constructed an index system to synthesize a comprehensive index to characterize the intensity of environmental regulation, and some scholars have used environmental regulation policies implemented by a state/country as indicators of environmental regulation. In this paper, we adopt China's state-implemented carbon emission trading pilot policy as a proxy indicator of environmental regulation to judge the impact of environmental regulation policy on the health level of residents.

Moderating variables

This study sets environmental pollution (EP) as the moderating variable. Air pollution is an important risk factor

for the health of the population. Studies have demonstrated that reductions in air pollution can reduce infant mortality Chay and Greenstone (20) and improvement of air quality will reduce the mortality rate of the elderly Cesur et al. (26), an effect primarily driven by reductions in cardio-respiratory deaths. The existing literature mostly uses a single indicator to measure environmental pollution, such as the integrated air pollution index Zhang et al. (27) and PM2.5 Bishop et al. (28). However, environmental pollution not only refers to air, but also involves water, soil, and other aspects, so it is one-sided to measure environmental pollution with a single indicator. In this paper, five indicators, namely chemical oxygen demand, ammonia nitrogen emission, sulfur dioxide emissions, nitrogen oxide emissions, and soot emissions in each region over the study years, are used to synthesize an indicator that can comprehensively represent the environmental pollution status through the Topsis method of panel data. Here, the missing values are inferred by linear interpolation.

Control variables

In addition to the explanatory variables, some extraneous factors have been identified as possibly also affecting the explained variables. If the influence of these potential factors is ignored, the regression results may become inaccurate. Therefore, five control variables were selected in this paper: urbanization rate (URB), which is measured by the proportion of the resident population in the region's urban area to the total resident population; aging of the population (POP), which is measured by the proportion of the population over 65 years old to the total population; health technicians (HTE), which is measured by the number of health technicians per 1,000 people; average number of resident visits (ANR), which is measured by the ratio of the total number of visits to a hospital at the end of the year to the total resident population; and bed utilization rate (BED), which is measured by the ratio of the actual number of hospital beds used to the actual number of beds available during the period. The descriptive statistics of the variables involved in this paper are shown in Table 1.

TABLE 1 Descriptive statistics of variables.

VAR	Obs	Mean	Std. Dev.	Min	Max
ANR	372	5.210	1.842	1.820	11.650
HTE	372	5.987	1.827	2.365	15.460
BED	372	83.779	7.777	48.300	100.000
URB	372	56.020	13.668	22.700	89.600
POP	372	10.127	2.458	1.000	17.600
RH	372	0.413	0.110	0.177	0.732
EP	372	0.260	0.174	0.003	0.820

Model selection

Model for topsis

Topsis is a method of calculating a composite score for different provinces and municipalities by objectively assigning weights to indicators from three-dimensional data containing years, provinces, cities, and indicators. The indicators need to be selected before the measurement can be performed. Here, we assume that there are 12 years and 31 provinces and cities.

The Topsis measurement process is as follows.

First, the data need to be normalized:

$$\text{Positive var}: Std_{ij} = \frac{x_{ij} - min\{x_j\}}{max\{x_j\} - min\{x_j\}} \quad (1)$$

$$\text{Negativevar}: Std_{ij} = \frac{max\{x_j\} - x_{ij}}{max\{x_j\} - min\{x_j\}} \quad (2)$$

After data normalization, the weights of variable j in year i are calculated and denoted as ω_{ij}, where n represents the observed value:

$$\omega_{ij} = \frac{Std_{ij}}{\sum_{i=1}^{n} Std_{ij}} \quad (3)$$

After calculating the weights, the information entropy (e_j) and redundancy (d_j) of the index are calculated, where t represents the year:

$$e_j = -\frac{\sum_{i=1}^{n} \omega_{ij} * ln\omega_{ij}}{lnt} \quad (4)$$

$$d_j = 1 - e_j \quad (5)$$

Then, the weights of the indicators, denoted as ω_j, are calculated:

$$\omega_j = \frac{d_j}{\sum_{j=1}^{m} d_j} \quad (6)$$

Finally, the composite index, denoted as S_i, is calculated:

$$S_i = \sum_{j}^{m} \omega_{ij} * \omega_j \quad (7)$$

Model for DID

Based on the batched pilot time of China's carbon emissions trading policy, this paper constructs three-period panel data, with the seven provinces and cities that have implemented the carbon emissions trading policy as the experimental group and the remaining provinces and cities as the control group. The pilot list contains four municipalities, namely Beijing, Tianjin, Shanghai, and Chongqing, and three provinces, namely Hubei,

Guangdong, and Fujian. The difference-in-differences model is as follows:

$$H_{it} = \alpha_0 + \alpha_1 DID + \alpha_2 X_{it} + \lambda_t + \mu_i + \varepsilon_{it} \quad (8)$$

Where H_{it} represents the health of the population, *DID* is a dummy variable for the carbon trading policy and takes the value of 1 for the year in which the carbon trading policy was implemented and thereafter, otherwise it takes the value of 0. X_{it} represents the control variable. λ_t and μ_i represent the time fixed and provincial and municipal fixed effects, respectively, and ε_{it} represents the random error term.

Model for parallel trend test

As a policy assessment method, the validity of the DID method is based on the parallel trend test, which means that the experimental group and the control group have a common trend of change before the implementation of the carbon emission trading policy, and the trend of change after the policy's implementation exhibits a difference. In this paper, based on the DID model, we use the dynamic effect coefficient method to conduct the parallel trend test, and the regression model is as follows:

$$H_{it} = \alpha_0 + \alpha_k \sum_{t=-4}^{t=6} {DID_{it}}^t + \alpha_2 X_{it} + \lambda_t + \mu_i + \varepsilon_{it} \quad (9)$$

Where ${DID_{it}}^t$ represents the year t of the implementation of carbon emission trading policy in province or city i. The remaining variables are explained in the same way as for model (7). The sample observation period of this paper is 2009–2020, covering 4 years before the implementation of the policy and 6 years after the implementation of the policy in some provinces and cities. In addition, to avoid the effect of cointegration, the year of policy implementation is taken as the base year in this paper and excluded from the regression.

Here, we focus on the confidence interval of the regression coefficient α_k at the 95% confidence level, which reflects the policy's impact on residents' health before and after the implementation of the carbon emissions trading pilot policy. If the confidence interval includes 0, it indicates that there is no significant difference between the experimental group and the control group. If the confidence interval does not include 0, it is considered that there is a significant difference between the experimental group and the control group. If both sides of the confidence interval are <0, it indicates that the implementation of the policy has a negative effect on the occurrence of diseases and a positive effect on the health of the population, and if both ends of the confidence interval are >0, it indicates that the implementation of the policy has a negative effect on the occurrence of diseases and a positive effect on the health of the population.

TABLE 2 Average health value of the population in each city and province.

Province	Mean	Province	Mean	Province	Mean
Xinjiang	0.623	Shanghai	0.436	Guangdong	0.369
Beijing	0.567	Inner Mongolia	0.425	Zhejiang	0.368
Qinghai	0.513	Liaoning	0.424	Anhui	0.364
Tibet	0.502	Yunnan	0.414	Chongqing	0.364
Ningxia	0.500	Sichuan	0.406	Hebei	0.354
Heilongjiang	0.485	Guizhou	0.404	Tianjin	0.345
Gansu	0.462	Hainan	0.401	Jiangxi	0.343
Jilin	0.458	Guangxi	0.373	Henan	0.339
Shanxi	0.454	Hunan	0.373	Shandong	0.327
Shaanxi	0.446	Hubei	0.369	Fujian	0.302
Jiangsu	0.286				

Empirical result

Result of topsis

Result of the occurrence of disease

The Topsis method with panel data was used to calculate the scores of the occurrence of disease in 31 provinces and cities in China from 2009 to 2020, and Table 2 shows the mean values. According to the calculated results, Xinjiang residents have the highest average occurrence of disease score of 0.623; Beijing comes second with an average value of 0.567, and Qinghai comes in third place with an average value of 0.513. The average score of Jiangsu is the lowest, only 0.286, which is <50% of Xinjiang's occurrence of diseases. Overall, the occurrence of diseases in 31 provinces and cities in China are mostly in the range of 0.35–0.46, indicating that the level of residents' health still has much room for improvement.

In terms of specific values, the occurrence of diseases in all provinces and cities gradually improved over time. During the observation period, Hebei, Hunan, and Jiangsu ranked the top three in terms of the average annual growth rate of disease incidence, with growth rates of 8.11, 7.84, and 7.61%, respectively. Shanghai, Ningxia, and Beijing had the flattest average annual growth rates, with 2.89, 2.86, and 0.83%, respectively. These findings indicate that the medical conditions and health care levels in the provinces and cities improved during the observation period, and therefore, the populations' health levels have improved.

Result for environmental pollution

The environmental pollution levels of 31 provinces and cities in China were calculated by the Topsis method from 2009 to 2020, and their average values are shown in Table 3. According

to the calculated results, five provinces have environmental pollution levels over 0.4: Jiangsu ranks first with a score of 0.575, Hubei ranks second with a score of 0.535, Anhui ranks third with a score of 0.472, and Hunan and Shandong have scores of 0.452 and 0.433, respectively. This indicates that the above five provinces have higher environmental pollution levels and greater pressure to reduce carbon emissions. Six provinces and cities have environmental pollution scores below 0.1, namely Beijing, Jilin, Ningxia, Shanxi, Guangxi, and Yunnan. Among them, Yunnan has the lowest level of environmental pollution, only 0.013. This indicates that the environmental quality of these six provinces and cities is relatively high.

In terms of specific values, environmental pollution has worsened over time in some provinces, such as Yunnan, Tibet, and Guangxi. The environmental pollution of other provinces and cities has improved, and the average annual growth rate in environmental pollution is negative. The remaining provinces and cities have improved their environmental pollution conditions with negative average annual growth rates for pollution. Beijing, Shanxi, and Jilin had steady average annual growth rates of −16.3, −13.6, and −11.1%, respectively, whereas Jiangxi had an average annual pollution growth rate of only −0.4%. Despite the increasingly severe environmental pollution in some provinces and cities, China has seen a significant improvement overall in environmental quality and a significant decrease in pollutant emission levels.

TABLE 3 Average environmental pollution in each city and province.

Province	Mean	Province	Mean	Province	Mean
Jiangsu	0.575	Xinjiang	0.310	Guizhou	0.196
Hubei	0.535	Hainan	0.301	Inner Mongolia	0.193
Anhui	0.472	Shanghai	0.291	Sichuan	0.159
Hunan	0.452	Jiangxi	0.264	Gansu	0.157
Shandong	0.433	Tibet	0.262	Heilongjiang	0.109
Shaanxi	0.386	Guangdong	0.259	Beijing	0.099
Hebei	0.381	Henan	0.251	Jilin	0.075
Zhejiang	0.380	Qinghai	0.243	Ningxia	0.052
Liaoning	0.352	Fujian	0.241	Shanxi	0.043
Chongqing	0.337	Tianjin	0.217	Guangxi	0.033
Yunnan	0.013				

Results of DID

In this paper, we use the difference-in-differences method to determine the carbon trading policy's effect on the population's health level. Table 4 shows the regression results of the impact of the carbon emissions trading policy on residents' health. (1) is a DID model without control variables, controlling only for area and time effects, and (2)–(6) are the regression results of gradually including control variables on the basis of (1).

According to Table 4, the estimated coefficients of the carbon emissions trading policy are negative with or without the inclusion of control variables, and they pass the 1% significance test. Thus, it can be concluded that a significant decrease in the occurrence of diseases occurred, which means a significant

TABLE 4 DID regression results.

VAR	RH(1)	RH(2)	RH(3)	RH(4)	RH(5)	RH(6)
DID	−0.058***	−0.037***	−0.037***	−0.033***	−0.029***	−0.032***
	(0.0158)	(0.0107)	(0.0109)	(0.0099)	(0.0086)	(0.0087)
URB		0.007***	0.007***	0.007***	0.002	0.002
		(0.0016)	(0.0016)	(0.0014)	(0.0017)	(0.0017)
POP			−0.002	−0.002	−0.002	−0.002
			(0.0024)	(0.0023)	(0.0024)	(0.0023)
ANR				−0.016***	−0.014***	−0.014***
				(0.0056)	(0.0042)	(0.0041)
HTE					0.021***	0.021***
					(0.0027)	(0.0025)
BED						−0.002*
						(0.0009)
Con	0.421***	0.015	0.045	0.142*	0.285***	0.417***
	(0.0022)	(0.0878)	(0.0937)	(0.0798)	(0.0903)	(0.124)
Obs	372	372	372	372	372	372
R^2	0.936	0.947	0.947	0.950	0.960	0.961

***, **, and * represent statistical significance at the 1, 5, and 10% levels, respectively. The values in parentheses are robust standard errors for clustering to the province level.

increase in residents' health levels in the pilot provinces and cities with carbon emissions trading compared with non-pilot provinces after the implementation of the policy. That is, the implementation of the carbon emission trading pilot policy helps to improve the population's health. After gradually adding control variables, the coefficient of the cross-term decreases, indicating that the net effect of the policy decreases, suggesting that control variables such as the average number of residents' medical visits affect the health status of residents to some extent. However, in general, the carbon trading policy will promote the improvement of the population's health, which confirms the first hypothesis.

Regarding the regression results of the control variables, the increase of the control variables raises the decidable coefficient R^2, indicating that the control variables were effectively selected. Among them, the regression coefficients of urbanization are mostly significantly positive, indicating that the occurrence of diseases rises with the level of urbanization. The coefficient of the proportion of the population over 65 years old does not pass the significance test. The coefficient of average number of resident visits is significantly negative at the 1% level, which indicates that higher the number of resident visits, the worse the residents' health status. The coefficient of bed utilization rate is significantly negative at the 10% level, indicating that the higher the bed utilization rate, the lower the occurrence of disease.

Robustness tests

Parallel trend test

In order to visually examine the impact of China's carbon trading policy on residents' health, this paper plots the dynamic effect coefficients of the impact of this policy on residents' health. Figure 1 depicts the regression coefficients and 95% confidence intervals of the regression coefficient α_k. According to Figure 1, no significant difference existed between the occurrence of diseases in the experimental group and control group before implement of the carbon emissions trading policy. In the first 3 years after the policy was implemented, the difference remained insignificant, but the confidence interval does not contain 0 from the fourth year, indicating that the data used in this paper satisfy the parallel trend hypothesis and there is a 3 year lag in the effect of the carbon emissions trading on residents' health. This verifies the robustness of previous study findings. The existence of such a policy lag may be attributable to the fact that the carbon emissions trading system needs to go through approval, construction, and operation to take full effect; this process will take a certain amount of time. Only after a certain amount of time has accumulated can the policy effect be given full play.

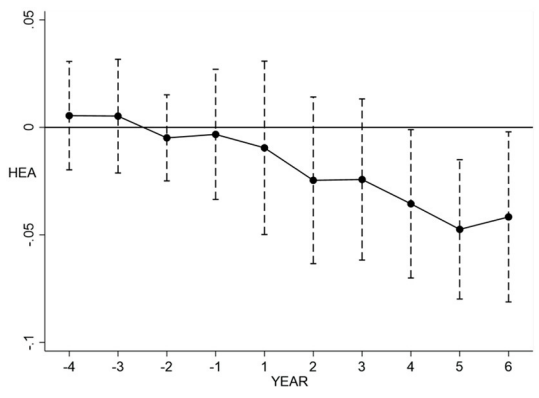

FIGURE 1
Parallel trend test graph.

PSM-DID test

Although the DID method can analyze the net effect of the policy and solve some endogeneity problems, sample selection bias is likely to exist because the pilot regions for implementing the carbon emission trading policy were not randomly determined, and the initial conditions of pilot provinces and cities are significantly different from those of non-pilot provinces and cities. To avoid endogeneity problem caused by sample selection bias, this paper further adopts the PSM-DID model to re-estimate the matched sample values by eliminating observations that do not satisfy the common area assumption based on the nearest-neighbor matching.

According to the results of the equilibrium test for continuous variables, the absolute value of the standard deviation of the control variables after matching is $<20\%$, indicating that the matching is effective; and the probability P of the T-value is much $>10\%$, indicating that the propensity score matching is more effective. Table 5 reports the results of the DID model estimation for the carbon emissions trading policy after sample matching. According to Table 5, the results after controlling for year effects and provincial and municipal effects are generally consistent with the results of the main regression. The results show that the carbon emissions trading policy has a negative effect on occurrence of diseases; that is, the effect on residents' health is significantly positive, which is basically consistent with the results estimated by the DID method. Thus, the robustness of the main regression analysis in this paper, i.e., China's carbon trading policy has contributed to the improvement of the residents' health, is proven.

Tailoring test

To avoid the influence of outliers on the regression results, this paper applies the upper and lower 5% tailing treatment to all continuous variables, and then re-runs the regression. The re-run regression results are shown in Table 6. It is not difficult to find that the regression coefficient of carbon trading policy

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TABLE 5 PSM-DID regression results.

VAR	RH	RH
DID	−0.016*	−0.030***
	(0.0092)	(0.0086)
Cons	0.299***	0.451***
	(0.0081)	(0.1282)
Time*Id	Yes	Yes
Control variables	No	Yes
Obs	177	177
R^2	0.887	0.914

***, **, and * represent statistical significance at the 1, 5, and 10% levels, respectively. The values in parentheses are robust standard errors for clustering to the province level.

TABLE 6 Results of tailoring regression.

VAR	RH	RH
DID	−0.050***	−0.024**
	(0.0167)	(0.0093)
Cons	0.418***	0.480***
	(0.0023)	(0.0989)
Time*Id	Yes	Yes
Control variables	No	Yes
R^2	0.915	0.944

***, **, and * represent statistical significance at the 1, 5, and 10% levels, respectively. The values in parentheses are robust standard errors for clustering to the province level.

is still significantly negative after the tailing treatment, which indicates that the implementation of carbon trading policy led to reduced occurrence of diseases, showing that the policy can contribute to the improvement of the health of the population, which is consistent with the findings of the above study.

Test for heterogeneity and moderating effect

Results of heterogeneity analysis

Regional heterogeneity

The above analysis has shown that China's carbon trading policy has a significant promoting effect on residents' health. This finding gives rise to other questions, such as: Are the health effects still present in different areas? If so, are there significant differences between regions? To further study the regional heterogeneity of the pilot policy, this paper further divides the research sample into three regions, namely Eastern, Central, and Western, and explore the differences of impacts of the carbon emissions trading policy on residents' health in different regions from the perspective of regional heterogeneity. The results are shown in Table 7.

The results show that without considering the control variables, the carbon emissions trading policy's effect on the occurrence of diseases is the largest in the east, second largest in the west, and the smallest in the central region. Thus, the carbon emissions trading policy has differing effects on the occurrence of diseases in different regions. Its effect on the health of residents in the east and west is significantly negative, while not significant in the central region. After considering urbanization level and other control variables, the policy's effect on residents' health is the largest in the west, second largest in the central region, and the smallest in the central region. The policy's effect on residents' health in the central and western regions is the most significant, and the effect in the eastern region is relatively weak. This is probably because the economic development level of the central and western regions is slightly lower than that of the eastern region. The central and western regions are in the primary stage of industrial structure transformation, and the scale of pollutant emissions in that process of industrial development is larger. Therefore, the carbon trading policy has a greater emission reduction effect and a stronger health enhancement effect on populations in those regions. In addition, most of the production sectors in the eastern region have been transferred to the central and western regions, and now the eastern region mainly focuses on the development of high-tech manufacturing and multifunctional manufacturing centers, so the effect of carbon emissions trading on the health of residents is limited.

Scale heterogeneity

Compared with provinces with large populations, provinces with smaller populations have less human capital, a relatively weaker industrial base, and higher health expenditure per capita, which may lead to differences in carbon emission trading pilot policies among provinces with different population sizes. To assess any such impact, this paper further divides the research samples into large and small scales according to the total population. Large provinces are defined as those with a total population exceeding 50 million; otherwise, they are considered small provinces or cities. Then, from the perspective of population size heterogeneity, this paper explores the differences in the carbon emissions trading policy's impact on the health of residents in provinces of different sizes. The results are shown in Table 8.

The regression results show that significant heterogeneity exists in the impact of carbon trading policies on the population's health across provinces of different sizes. When the control variables are not considered, the coefficient and significance level of the impact of carbon emission trading policy on the occurrence of diseases decrease as the increase of population size in each province. After taking the control

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TABLE 7 Results of regional heterogeneity.

VAR	Eastern	Eastern	Central	Central	Western	Western
DID	−0.056***	−0.028*	−0.012	−0.033***	−0.034***	−0.046***
	(0.0161)	(0.0148)	(0.0148)	(0.0072)	(0.0091)	(0.0119)
Cons	0.396***	0.433	0.399***	0.569***	0.465***	0.475**
	(0.0045)	(0.2901)	(0.0005)	(0.1910)	(0.0005)	(0.2253)
Time*Id	Yes	Yes	Yes	Yes	Yes	Yes
Control variables	No	Yes	No	Yes	No	Yes
R^2	0.930	0.958	0.942	0.962	0.961	0.972

***, **, and * represent statistical significance at the 1, 5, and 10% levels, respectively. The values in parentheses are robust standard errors for clustering to the province level.

TABLE 8 Results of scale heterogeneity.

VAR	Large	Large	Small	Small
DID	−0.026*	−0.135	−0.071***	−0.038***
	(0.0136)	(0.1300)	(0.0190)	(0.0122)
Cons	0.359***	0.217	0.450***	0.449***
	(0.0017)	(0.2161)	(0.0027)	(0.1387)
Time*Id	Yes	Yes	Yes	Yes
Control variables	No	Yes	No	Yes
R^2	0.939	0.958	0.929	0.956

***, **, and * represent statistical significance at the 1, 5, and 10% levels, respectively. The values in parentheses are robust standard errors for clustering to the province level.

TABLE 9 Results of moderation effect.

VAR	RH(1)	RH(2)	RH(3)
DID	0.026*	−0.016	0.027*
	(0.0154)	(0.0271)	(0.0154)
EP	−0.506***	−0.520***	−0.497***
	(0.0378)	(0.0384)	(0.0379)
TT		0.167*	
		(0.0885)	
TT-N			0.167*
			(0.0885)
Cons	0.541***	0.545***	0.539***
	(0.0111)	(0.0113)	(0.0111)
Time*Id	Yes	Yes	Yes
Control variables	No	No	No
R^2	0.380	0.386	0.386

***, **, and * represent statistical significance at the 1, 5, and 10% levels, respectively. The values in parentheses are robust standard errors for clustering to the province level.

variables into consideration, the impact of carbon emissions trading policies on the occurrence of diseases was significantly negative in areas with a smaller population size, and the coefficient of impact increased but was no longer significant as the population size increased. This may be because the expansion of population increases pressure on original medical resources in the area. Additionally, the expansion of population scale brings improvements in infrastructure and confers the advantage of agglomeration, which lays a solid foundation for the development of industrial industry. The development of industry further increases environmental pollution, which has a negative impact on the population's health, and thus environmental regulation has a stronger effect on enhancing the population's health in provinces with a smaller population size.

Results of the moderation effect

As an environmental regulation policy, China's carbon emissions trading policy can reduce environmental pollution, which in turn affects the occurrence of diseases. Therefore, this paper first measured the environmental pollution of each province and city through the Topsis method, and then calculated the cross term (*TT*) of carbon trading and environmental pollution to investigate the moderating role of environmental pollution in the process of China's carbon trading policy's ability to improve the health level of residents. The regression model was first tested before conducting the main analysis, and the results of Hausman test rejected the random effect hypothesis; thus, the fixed effect model was chosen. The regression results are shown in Table 9.

According to the results, the coefficient of the interaction term (*TT*) between environmental regulation and environmental pollution is significantly negative at the 10% level, indicating that environmental pollution is a moderating variable on the relationship between the occurrence of diseases and carbon trading policies. Comparing the regression results, the originally significant *did* was not significant after adding the interaction term, which may be due to the high cointegration between the interaction term and the carbon trading and environmental pollution that biased the model estimation. Therefore, we further correct the sample data for centrality and then rerun the regression, and the results are shown in the third column. The result shows that environmental regulation also

becomes significant after decentering, and the new interaction term *TT-N* does not change, suggesting that carbon trading policies can improve the population's health by reducing environmental pollution. This confirms the second hypothesis.

Conclusion and implications

This paper used the data on 31 provinces and cities in China from 2009 to 2020 to study the impact of carbon emission trading policies on residents' health using the difference-in-differences model. The results show that (1) carbon emissions trading policies can promote the improvement of residents' health; (2) this improvement effect is heterogeneous among provinces and cities in different regions and with population sizes, and the effect is stronger for western regions and provinces with smaller population sizes after taking control variables into consideration; and (3) environmental pollution has a significant moderating effect on the relationship between carbon emissions trading and residents' health.

In view of the above conclusion and the actual situation in China, the following insights are obtained in this study and the following recommendations can be made: First, the scope of policy pilots should be expanded, and environmental regulation policies should be implemented. Research shows that the carbon emissions trading policy has a significant effect on the health of residents. Therefore, to reduce the incidence of diseases and improve the population's health, the scope of carbon emissions trading pilot projects can be expanded and regulation can be strengthened to reduce pollutant emissions and achieve a harmonious coexistence between human health and the natural environment. Second, the actual situation and local conditions should be considered. The impact of China's carbon emissions trading policy on the health of residents in different regions and provinces with different population sizes is heterogeneous. Thus, in the process of policy implementation, each region should consider its local conditions, combine the characteristics of the region's economic level, population size, and resource endowment to explore a low-carbon development path suitable for the region, and formulate a more scientific and reasonable carbon emissions trading policy. Third, publicity should be increased regarding the low-carbon concept and offering guidance for residents to live a low-carbon life. Environmental pollution, as a regulating variable, has a moderating effect on the relationship between residents' health and the carbon emissions trading policy. It is possible to provide low-carbon public goods and reasonable subsidies so that the low-carbon concept can be deeply rooted in people's hearts and thus improve residents' health.

There are still some limitations that could be explored in further research. On the one hand, this paper uses the occurrence of diseases as a proxy for population health rather than directly measuring residents' health levels. On the other hand, due to data limitations, the study in this paper is limited to the provincial level, and as micro-entities of pollutant emission, the role of the carbon emission trading policy on the pollution emissions of enterprises should be noticed. We believe that future work will provide useful supplements in these aspects.

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

BG and YF designed the study, performed the research, analyzed data, and wrote the paper. YW and SW collected most of the data. JZ and RJ checked the spelling of the paper and corrected authors the mistakes. JL provided fund support and suggestions response on revising the paper. XZ and HS proposed some countermeasures. WZ and WL verified the authenticity of the data analysis. HH and LJ presented the methodology. 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

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2022.1003192/full#supplementary-material

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Effects of haze pollution and institutional environment on demand for commercial health insurance

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What countermeasures should the public take as they become aware of the dangers of haze pollution? Insurance has the function of risk diversification, and little existing literature has focused on the relationship between haze pollution and commercial health insurance. This paper analyzes the impact of haze pollution on residents' demand for commercial health insurance and the heterogeneous impact of institutional environment using the 2017 China Household Finance Survey cross-sectional data (CHFS). The study finds that haze pollution raises residents' demand for commercial health insurance as their health risk perception level rises. The legal environment, market environment, and traditional culture affect the relationship between haze pollution and the demand for commercial health insurance. Further analysis reveals that the relationship between haze pollution and residents' demand for commercial health insurance can show significant regional heterogeneity, with a significant positive correlation in the eastern region and a significant negative correlation in the central and western regions. In addition, the preventive behaviors adopted by residents in the face of haze pollution can vary significantly depending on individual risk preferences. The findings of this paper are important for the public to take measures to cope with the haze pollution hazards. At the same time, insurance companies should improve their services to meet the needs of the public regarding haze pollution, which will contribute to the healthy development of the insurance industry.

KEYWORDS

haze pollution, risk awareness level, institutional environment, commercial health insurance, China household finance survey

Introduction

The impact of air pollution on residents' physical and mental health cannot be underestimated, and can directly and indirectly cause short-term and even long-term damage to human functions, which in turn increases the health costs of residents and shortens life expectancy *per capita* (Chen et al., 2013). Air pollution causes mostly physiological diseases, and severe air pollution increases the incidence of lung cancer and

other respiratory diseases (Li et al., 2018) and air pollution ranks fourth among the causes of death in China (Wang et al., 2012), and respiratory diseases are also the fourth cause of death from diseases. Song et al. (2019) found haze pollution affects public well-being through its effect on public mental health. Since 2010, when the first entry of "PM2.5" was established in Baidu Encyclopedia, the concern and attention to air pollution has gradually increased in China. This shows that the public's awareness of eco-environmental protection and their own health concerns are gradually increasing. As a risk management tool, insurance is a behavioral choice for the insured to deal with uncertainty. Combined with behavioral finance theory, we know that the decision to purchase insurance is the result of a combination of risk perception, risk management, insurance cognition, and insurance burden, and that this behavior process begins with risk perception. Once the public perceives that their health may suffer from the haze, they may share the risk through health insurance. Therefore, an in-depth analysis of the influencing factors of commercial health insurance is important for the public to cope with risks and promote the development of China's insurance industry.

Currently, most scholars have only discussed the relationship between individual characteristics and risk perceptions. In this paper, we try to analyze the link between the two in a more macro-level institutional context, such as gender, age, income, health status, and education level, will affect their risk cognition level. Most of these characteristics, except gender and age, are subject to the institutional environment. Because the institutional environment surrounds civil society, every step of development must be directly or indirectly affected by the institutional environment. Various formal or informal systems ultimately shape the form and characteristics of civil society (Song et al., 2019). In other words, most of the individual characteristics of the public are determined by the institutional environment. Moreover, a good institutional environment can also reduce the information asymmetry between subjects by establishing effective legal mechanisms, providing clean and efficient public governance, giving full play to the role of the market in resource allocation (Deng et al., 2014), and improve the public's awareness of health risks. Therefore, the role of the institutional environment should be fully considered in analyzing the public consumption behavior of insurance products.

Compared with the existing literature, this paper is innovative in the following aspects: first, while the existing literature focuses more on the immediate defensive behavior of the public (Xu et al., 2017), this paper innovatively explores the preventive behavior of the public from the perspective of commercial insurance. Second, although the existing literature found the relationship between haze pollution and commercial health insurance (Wu et al., 2019), it did not explain and justify the mechanism of action. This paper innovatively uses the Baidu index of air purifiers to confirm that the level of risk perception is an important intermediate path for haze pollution to increase public demand for commercial health insurance. Third, this paper extends the analysis at the institutional environment level, and gives micro-level empirical evidence on the risk-averse function played by insurance products in haze pollution events. Compared with studies in other countries, the impact of the institutional environment on commercial insurance has Chinese characteristics, and the findings of this paper are crucial for the development of the Chinese insurance industry.

Literature and hypotheses

Commercial health insurance has developed rapidly in recent years, but its role in the medical security system is still insignificant because of its low base and low penetration rate. The reasons for this phenomenon can be roughly divided into economic and demographic factors. Hammond et al. (1967) found that increased family income and net assets increase the probability of family commercial insurance purchases. Showers and Shotick (1994) found that insurance demand was positively affected by the age of the head of the household and the family size. According to the theory of planned behavior, the influence process of economic and demographic characteristics on residents' purchase of commercial insurance can be summarized as the logical relationship of "risk cognition response behavior" (Brewer et al., 2004; Dominicis et al., 2015; Ferrer and Klein, 2015; Wu et al., 2019). Risk cognition is the driving factor for residents to adopt risk response behavior, and risk coping behavior is the concrete manifestation of risk cognition.

In haze pollution events, how the public responds depends on their awareness of the hazards of haze. Xie et al. (2014) analyzed the impact of haze pollution on residents' health using the air data of Beijing from January 10 to 15, 2013 and found that a high concentration of haze pollution can cause respiratory diseases such as acute bronchitis and asthma. Moreover, haze pollution will even increase the incidence of lung cancer (Iii and Arden, 2002; Chang et al., 2018). Sun et al. (2022) found consistent associations between haze exposure and acute mental illness, cardiovascular and neurological morbidity and mortality in their study of cross-border flows of haze pollution. It is precise because the public can effectively feel the existence of haze risk, which improves the public's awareness of health risks and urges residents to take coping behavior (Sun et al., 2022). In the short term, residents can alleviate this harm by reducing outdoor activities, purifying indoor air, and increasing the frequency of mask use (Yuming et al., 2015). However, haze pollution is challenging to eliminate quickly, and residents will be exposed to haze pollution for a long time. Combined with the risk avoidance function of insurance, whether the public will convert health risk cognition into insurance product demand is very important for developing commercial health insurance. Some literature (Hines et al., 1987) has found a positive correlation between air quality and health insurance demand, but few scholars in China pay attention to such problems. Therefore, the first research hypothesis of this paper:

> *Hypothesis 1 (H1)*: Haze pollution will promote public demand for commercial health insurance.

The perception of air quality drives the public's response to environmental pollution, and the formation of risk perception depends on people's access to environmental information (Bresnahan et al., 1997; Bamberg and MöSer, 2007; Wu and Li, 2017). An institutional environment surrounds civil society. Various formal (laws, regulations, government administrative policies, etc.) and informal systems (culture, customs, etc.) will affect the public's access to information (Song et al., 2019). Lo (2013) found that the social and cultural environment affects personal perception of risk. Naturally, residents' access to information on haze pollution risk cannot eliminate the impact on the institutional environment. An excellent institutional environment helps the news media transmit information timely, comprehensively, and effectively (Yang and Chen, 2010), reduce the information asymmetry between subjects, meet the public's information needs, and improve the public's awareness of health risks. It can be said that an excellent institutional environment is a prerequisite for the healthy development of the insurance industry. Through empirical analysis, Liu et al. (2010) confirmed that the total provision of information could significantly improve micro health insurance demand. Xu et al. (2017) found through the questionnaire that the higher the public's perception of haze risk and the more thoroughly they understand haze information, they will take more active protection and response measures. Based on the relationship between institutional environment, haze pollution, and commercial health insurance demand, the second assumption of this paper is:

> *Hypothesis 2 (H2):* The institutional environment will affect the relationship between haze pollution and the demand for commercial health insurance.

The development of China's insurance industry shows noticeable regional differences. From the insurance density and insurance depth perspective, the development speed of the eastern region is significantly faster than that of the central and western regions. The existing literature (Zhang et al., 2005; Fan and Wang, 2015; Suo et al., 2015) shows an apparent regional imbalance in the insurance market development. The reason lies in the difference in regional economic development levels. In addition, the difference in social security level is also an important factor causing this phenomenon. However, few scholars pay attention to the role of the institutional environment. Xiao (2007) found that the difference in the development level of the insurance market among regions in China is relatively small due to the difference in economic development level among regions. Furthermore, the factors leading to the difference in the development level of the insurance market among regions are the economic environment, social and cultural environment, legal environment, insurance market environment, and other factors. Similarly, Yan et al. (2021) and Xu et al. (2021) found that low-carbon city construction was overall effective in reducing air pollution in China, but there was significant geographical heterogeneity in this effect. Considering the apparent differences in social systems in different regions, especially between the eastern and central, and western regions, combined with the analysis of hypothesis 2, the third hypothesis of this paper is derived:

> *Hypothesis 3 (H3):* The relationship between haze pollution and the demand for commercial health insurance will show obvious regional heterogeneity.

Research design

Specific performance of "risk cognition response behavior" in haze pollution events

Risk cognition is the internal driving factor of coping behavior, and coping behavior is the specific manifestation of risk cognition. Since it is hard to directly quantify the public's awareness of the risk of haze pollution, we use the Baidu Index of "air purifiers" to measure it indirectly. Generally speaking, the public will pay more attention to the corresponding countermeasures when they fully understand the hazards of haze pollution promptly. Therefore, the larger the Baidu Index of "air purifiers," the higher the public's awareness of the risk of smog.[1]

As shown in Figure 1, from 2011 to 2016, the Baidu Index of "air purifiers" and the premium income of commercial health insurance have shown a geometric growth since 2011, and the growth trend is almost the same. The coupling of the two development trends can preliminarily judge that improving the public's awareness of health risks has effectively transformed into insurance demand, promoting the rapid development of commercial health insurance. From 2016 to 2017, the Baidu Index of "air purifiers" showed an apparent downward trend related to the achievements of the Chinese government in environmental governance in recent years. The haze pollution improvement has reduced the Baidu Index of "air purifiers." At the same time, the growth rate of premium income has also slowed down. The recoupling of the two development trends further verifies the importance of health risk awareness level to the development of commercial health insurance, which supports explaining haze pollution and promotes the demand for commercial health insurance.

1 Baidu index is based on the search volume of Internet users in Baidu as the data, taking keywords as the statistical object, scien-tific analysis and calculation of the weighted sum of search frequency of each keyword in Baidu web search. According to the use of Baidu search sources, the search index is divided into PC search index and mobile search index.

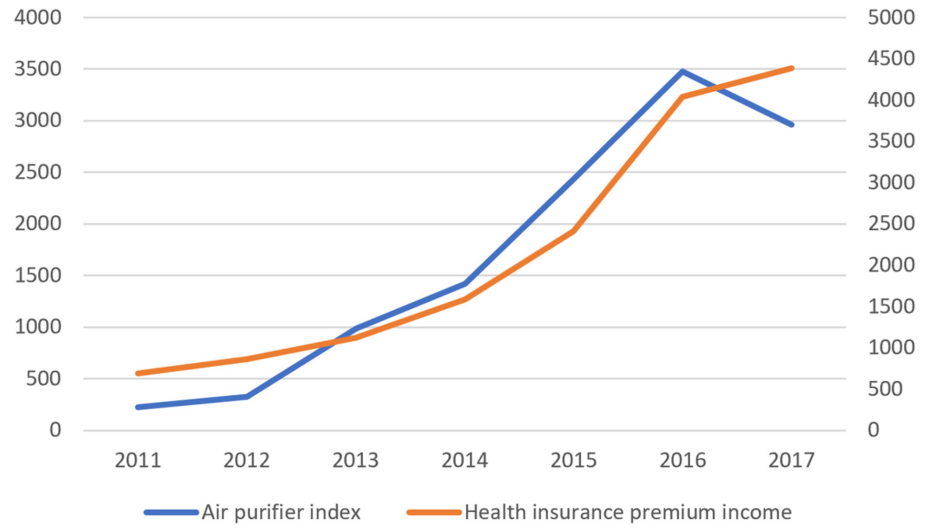

FIGURE 1
Relationship between health risk cognition and coping behavior. The left vertical axis of the figure is the premium income of commercial health insurance, and the right vertical axis is the moving daily average of the Baidu Index of air purifiers. The premium income data comes from the premium income data of insurance companies on the National Bureau of statistics website.

Model

To discuss the influence of haze pollution on family commercial health insurance purchasing behavior, In this paper, we construct the following Probit model by drawing on Yan et al. (2021):

$$\Pr(\text{Insurance}=1)=\varnothing(\alpha+\beta_1 PM2.5+\beta_2 X+\varepsilon)$$

X is the control variable, including family, demographic, and regional economic characteristics. It should be noted that the existing literature found that when individuals perceive that environmental pollution may bring harm to their health, people will pay more attention to environmental problems and are more willing to participate in environmental protection (Xu et al., 2021). However, after the public purchases commercial health insurance, it can produce obvious moral hazards and reduce people's environmental protection behavior. In other words, there may be an endogenous problem of reverse causality between haze pollution and residents' purchase of commercial health insurance. Therefore, this paper will use instrumental variables to deal with this problem. At the same time it is considering the effect of household budget constraints, if a household purchases life insurance, it is likely to reduce the probability of purchasing health insurance. This paper will exclude the effect of the household budget in the robustness test section.

In terms of tool variable selection, the existing literature (Yin et al., 2015; Nardi et al., 2021) shows that the formation of haze weather has both socio-economic and natural factors. However, socio-economic factors in this paper do not meet the conditions for using instrumental variables. Therefore, this paper uses the regional average annual temperature as the instrumental variable of haze pollution. Because the regional temperature is related to the haze weather, there is no apparent connection with the residents' purchase of commercial health insurance. In the robustness test part, this paper also uses the regional average annual temperature and wind speed as the instrumental variables of PM2.5 to test the conclusion again.

Sample and data

The dependent, independent, and control variables are from the fourth round of the China Household Finance Survey project conducted nationwide by the Southwestern University of Finance and Economics in 2017. The samples are distributed in 29 provinces (autonomous regions and municipalities directly under the central government), 355 counties (districts and county-level cities), and 1,428 Village (neighborhood) committees across the country. A total of 40,011 households' microdata are obtained, representing the national and inter-provincial levels. China Household Finance Survey collects household assets and liabilities, income and expenditure, insurance and security, and demographic characteristics. Other provincial-level variable data are collected manually through the China Research Data Service platform (CNRDS), the Statistical Yearbook published by each province, and the website of the CBRC.

Variables

Dependent variables

Commercial health insurance demand measurement (Insurance): This paper uses the answers to the third part of the CHFS (2017) questionnaire on the purchase of commercial insurance

TABLE 1 Descriptive statistics.

Variable Name	Sample size	Mean	Standard deviation	Min.	Median	Max.
Insurance	40,011	0.05	0.22	0	0	1
PM2.5	40,011	0.52	0.5	0	1	1
Temp	40,011	0.51	0.5	0	1	1
Income	39,184	10.62	1.53	0	10.92	15.42
Asset	38,471	12.6	1.94	0	12.85	17.22
Health	40,011	3.17	1.55	1	3	15
Age	40,000	55.2	14.25	3	55	117
Gender	40,010	1.21	0.4	0	0	1
Marry	39,966	2.4	1.24	0	0	1
Education	39,958	9.27	4.16	0	9	22
GDP	40,011	10.23	0.77	7.87	10.33	11.4
Rural	40,011	0.32	0.47	0	0	1
Train	40,011	0.1	0.29	0	0	1

by family members as the basis (there are four answers to this option: commercial life insurance, commercial health insurance, other commercial insurance and none), and takes the family as the research object. If only one family member has purchased commercial health insurance, the value of insurance is 1; If none of the family members have purchased commercial health insurance, the value is 0.

Independent variables

1. Haze pollution measurement (PM2.5). The commonly used index to measure haze pollution is PM2.5 (particles with a diameter of fewer than 2.5 microns are called PM2.5, also known as inhalable lung particles). This paper uses the annual average PM2.5 data of each province provided by the China Research Data Service platform (CNRDS) as the measurement index to measure the haze pollution level. Considering that health risk cognition is a gradual accumulation process, this paper uses the mean value of PM2.5 in each province in the past 3 years as the primary independent variable. The higher the value, the worse the haze pollution; otherwise, the better the haze pollution. To ensure that the analysis results are not affected by the selection of years, this paper will use the PM2.5 mean value of the past 5 years in the robustness test part to verify the conclusion of this paper again, and the other similar variables will be treated the same. This paper, PM2.5 is divided into high and low groups according to the median. In areas more heightened than the median, the value of PM2.5 is 1; For areas below the median, the value of PM2.5 is 0.
2. Institutional environment measurement. This paper measures the institutional environment from two levels: the formal and informal systems. In terms of the formal system, this paper uses the legalization level (Law) and financial industry marketization index (market) of various regions in China compiled by Wang and Fan (2018) to measure the regional formal system environment. The higher the score, the better the formal system environment. On the contrary, the worse the institutional background, The informal system is measured by the number of Confucius and Buddhist temples in each province. The greater the value, the stronger the traditional cultural atmosphere in the region. The samples are also divided into high and low groups for the institutional environment variables by using the median. The high-value group is 1, and the low-value group is 0.

Control variables

Referring to the existing literature (Zhang et al., 2010, 2017; Wang and Fan, 2018), this paper also controls other factors affecting the family's business health needs, including the family's total income, net assets, family size, the family's urban and rural region and the economic environment of the family's region (GDP).As well as the age and age square of the head of household, education, gender, marital status, and health.[2,3,4]

Results

Descriptive statistics

The mean value of Insurance is 0.05, which means that only 5 out of 100 households have purchased commercial life insurance, commercial health insurance, and other commercial insurance, this value indicates that Chinese residents are not sufficiently aware of purchasing insurance on the one hand, and the insurance market in China has an ample development space on the other hand; the mean value of PM2.5 is The mean value of PM2.5 is 0.52, which indicates that air pollution exists in most of China, and the standard deviation is 0.5, which indicates that the haze pollution varies significantly between cities (Table 1).

An empirical analysis of the impact of haze pollution on demand for commercial health insurance

Based on the Probit model, this paper uses instrumental variables to solve the possible endogenous problems in the

2 Urban and rural areas: 1 for rural areas and 0 for cities.

3 The highest education options completed in the questionnaire are: illiterate or semi-illiterate, primary school, junior middle school, high school/technical secondary school/technical school/vocational high school, junior college, undergraduate, master, and doctor. We convert them into years of education, which are 0, 6, 9, 12, 15, 16, 19, and 22 in turn.

4 The question to judge the health status in the questionnaire is: how is your current health status compared with your peers? 1. Very good;2. Very good;3. Good;4. General;5. No. If 1 or 2 is selected, it is regarded as good health. The virtual variable is 1; otherwise, it is 0.

model. Therefore, the Probit + IV model is selected for empirical analysis. Table 2 presents the analysis results of the impact of haze pollution on demand for commercial health insurance. Columns (1) and (2) respectively show the empirical analysis results without introducing control variables and regional effects, and column (3) shows the results after considering both control variables and regional impact. The coefficient of PM2.5 in columns (1) and (2) is significantly positive at the level of 5% and 1%, respectively, and the coefficient of PM2.5 in column (3) is significantly positive at the level of 1%, which is consistent with the expectation of this paper, that is, haze pollution increases the possibility of residents to buy commercial health insurance, and this conclusion will not change due to control variables and regional effects. In addition, the Wald test results reject the hypothesis that there is no endogenous relationship between haze pollution (PM2.5) and the demand for commercial health insurance.

TABLE 2 Impact of haze pollution on demand for commercial health insurance.

Variable Name	(1)	(2)	(3)
	Ivprobit	Ivprobit	Ivprobit
PM2.5	0.177**	0.397***	0.505***
	(2.381)	(5.491)	(5.608)
Income		0.116***	0.119***
		(9.684)	(9.893)
Asset		0.093***	0.098***
		(10.152)	(10.428)
Health		0.057***	0.055***
		(6.586)	(6.339)
Age		0.019***	0.018***
		(3.180)	(3.040)
Age2		−0.000***	−0.000***
		(−6.333)	(−6.202)
Gender		0.043	0.040
		(1.442)	(1.321)
Marry		0.044***	0.045***
		(3.541)	(3.593)
Education		0.026***	0.026***
		(6.939)	(6.958)
GDP		0.009	0.049***
		(0.479)	(2.617)
Rural		−0.114***	−0.114***
		(−3.442)	(−3.409)
Area	Yes	No	Yes
_cons	−1.717***	−4.950***	−5.560***
	(−42.858)	(−18.480)	(−19.464)
N	40,011	37,661	37,661
Pseudo R^2	0.079	0.176	0.321
Wald test	3.38	30.50	38.40
Value of *p*	0.066	0.000	0.000

The values in brackets are *Z* values; *, **, *** It is significant at the level of 10%, 5%, and 1%, respectively.

In the control variables, the coefficients of family income and family net assets are significantly positive at the level of 1%, which means that the increase of family income and net assets will improve the possibility of families buying commercial health insurance. The coefficient of education level is significantly positive at the level of 1%, indicating that high-level education helps to improve the current situation of insufficient demand for commercial health insurance. There is an inverted "U" relationship between the age of the household head and the possibility of commercial insurance participation. The gender of the head of household has no significant impact on the purchase of commercial health insurance. Residents with higher health are more likely to buy commercial insurance. This may be because there are specific access conditions in the health insurance market, that is, residents who meet the health indicators are eligible to buy health insurance; The possibility of purchasing commercial insurance in rural areas is significantly lower than that in urban areas; The development of the regional economy will promote the development of commercial health insurance. Overall, the impact of control variables on demand for commercial health insurance is consistent with existing literature's conclusions (Hammond et al., 1967; Sun and Huang, 2010; Wang and Fan, 2018).

The impact of haze pollution on demand for commercial health insurance: An analysis based on the institutional environment

Analysis based on the formal institutional environment

The institutional environment includes both formal and informal institutional environments. Firstly, this paper analyzes the impact of the formal institutional environment on the relationship between haze pollution and commercial health insurance demand. The coefficient of PM2.5 in columns (1) and (3) of Table 3 is significantly negative at the 1% level, and the coefficient of PM2.5 in columns (2) and (4) is significantly positive at the 1% level. This shows that the difference between the legal environment and the market environment makes the impact of haze pollution on demand for commercial health insurance show apparent heterogeneity. In an excellent formal institutional environment, haze pollution will increase the possibility of residents buying commercial health insurance; on the contrary, it will reduce this possibility.

The public's ideology is subject to the institutional environment. Under different institutional environments, the publics' risk cognition level will naturally differ, resulting in this heterogeneity. Improving the legal and market environments in an environment with a poor formal system will help alleviate the information asymmetry between subjects. The public can obtain information timely and comprehensively, enhance risk cognition, and promote commercial health insurance development. With the gradual transformation of government functions and the

TABLE 3 The impact of haze pollution on demand for commercial health insurance: an analysis based on the formal system.

Variable name	Legal environment		Industry marketization	
	(1)	(2)	(3)	(4)
	Low-value group	High-value group	Low-value group	High-value group
PM2.5	−3.916***	0.154***	−0.809***	0.154***
	(−3.696)	(3.062)	(−3.510)	(3.271)
Income	0.097***	0.119***	0.124***	0.112***
	(4.771)	(7.239)	(6.931)	(6.933)
Asset	0.170***	0.107***	0.126***	0.105***
	(7.106)	(8.899)	(8.398)	(8.385)
Health	0.070***	0.054***	0.038***	0.054***
	(4.224)	(4.493)	(2.978)	(4.587)
Age	0.022**	0.024***	0.015*	0.027***
	(1.992)	(3.168)	(1.764)	(3.235)
Age2	−0.000***	−0.000***	−0.000***	−0.000***
	(−3.620)	(−5.452)	(−3.526)	(−5.559)
Gender	0.039	0.060	0.055	0.055
	(0.682)	(1.565)	(1.213)	(1.354)
Marry	0.009	0.057***	0.036**	0.043**
	(0.397)	(3.551)	(2.003)	(2.441)
Education	0.014*	0.031***	0.024***	0.028***
	(1.925)	(6.320)	(4.132)	(5.386)
GDP	1.139***	0.189***	0.216***	0.217***
	(3.776)	(5.582)	(3.374)	(6.540)
Rural	−0.186***	−0.100**	−0.151***	−0.096**
	(−3.413)	(−2.078)	(−3.152)	(−2.068)
Area	Yes	Yes	Yes	Yes
_cons	−13.894***	−7.245***	−6.622***	−7.395***
	(−5.651)	(−15.475)	(−10.645)	(−15.866)
N	16,499	21,162	17,400	20,261
Pseudo R^2	0.458	0.712	0.469	0.727
Wald test	18.00	8.28	11.03	10.64
Value of *p*	0.000	0.004	0.001	0.001

The values in brackets are *Z* values; *, **, *** It is significant at the level of 10%, 5%, and 1%, respectively.

TABLE 4 The relationship between formal institutional environment and industry supervision level.

Variable Name	Low-value group sample size	Low-value group mean	High-value group sample size	High-value group mean	Inter group mean difference *t*-test
legal environment	17,900	69.821	22,111	138.825	−69.004***
Market environment	18,829	69.873	21,182	141.805	−71.932***

The values in brackets are *Z* values; *, **, *** It is significant at the level of 10%, 5%, and 1%, respectively.

continuous innovation of social management methods, market-oriented means to meet the needs of social management and public services have become an inevitable choice. To fully play the critical role of commercial insurance in the social security system, we must create a good institutional environment.

Although an excellent social environment system can improve the public's risk perception level and promote the healthy development of the insurance industry. However, if consumers' rights and interests are not fully guaranteed, and consumers distrust insurance products, even if the public's risk perception level is improved, it is difficult to convert this perception into insurance demand effectively. In other words, whether consumers' rights and interests can be fully protected is a prerequisite for effectively converting risk perception into insurance demand. Therefore, we further examine the protection of consumer rights and interests under the formal institutional environment. In this paper, the number of administrative fines published on the China Banking and Insurance Regulatory Commission (BRC) website in each region is used to measure the level of consumer protection in the region. Generally speaking, the more administrative fines, the higher level of consumer protection in the region, and the healthier the industry development.

Table 4 analyzes the relationship between the formal system and the industry supervision level. It can be seen that the average value of industry fines in the high-value group of the legal environment is 138.825, and the average value in the low-value group is 69.821, and the difference between the two is significant at the level of 1%; In the market environment, the average value of industrial fines in the high-value group is 141.805 and 69.873 in the low-value group. The difference between the two is also significant at 1%, which shows that the better the formal institutional environment, the higher the level of industrial supervision. Only when the rights and interests of consumers can be fully protected can the public's awareness of risk be effectively replaced by insurance demand.

Analysis based on the informal institutional environment

Table 5 shows the impact of cultural differences in the informal system on the relationship between haze pollution and the demand for commercial health insurance. The coefficient of PM2.5 in columns (1) and (3) is significantly positive at the level of 1%. In contrast, the coefficient of PM2.5 in columns (2) and (4) is not significant, which indicates that the impact of haze pollution on household commercial insurance purchase behavior will change due to differences in traditional culture, which is consistent with the second hypothesis of this paper.

Traditional culture, especially the "filial piety" culture in Confucian culture, emphasizes the importance of "family" in social organizations. Families bear important economic transactions, especially the function of risk transfer. Future generations are personalized financial products such as "insurance," "investment," and "pension." In areas with more

TABLE 5 The impact of haze pollution on demand for commercial health insurance: an analysis based on the infomal system.

Variable name	Confucian culture (confucian temple)		Buddhism (temple)	
	(1)	(2)	(3)	(4)
	Low-value group	High-value group	Low-value group	High-value group
PM2.5	0.996***	0.123	11.393***	0.205
	(5.076)	(1.630)	(2.978)	(1.209)
Income	0.154***	0.108***	0.174***	0.108***
	(7.855)	(6.942)	(5.382)	(6.546)
Asset	0.078***	0.117***	−0.085	0.097***
	(5.417)	(9.104)	(−1.203)	(7.151)
Health	0.031**	0.055***	0.040*	0.065***
	(2.217)	(4.926)	(1.740)	(5.177)
Age	0.021**	0.022***	0.040**	0.021***
	(2.365)	(2.648)	(2.414)	(2.691)
Age2	−0.000***	−0.000***	−0.001***	−0.000***
	(−4.581)	(−4.792)	(−3.917)	(−4.813)
Gender	−0.078*	0.125***	−0.125	0.053
	(−1.664)	(3.023)	(−1.224)	(1.304)
Marry	0.043**	0.045**	0.026	0.059***
	(2.358)	(2.548)	(0.857)	(3.505)
Education	0.015**	0.027***	0.003	0.036***
	(2.318)	(5.260)	(0.261)	(7.108)
GDP	−0.091***	0.034	−3.014***	0.066*
	(−2.824)	(0.880)	(−2.875)	(1.777)
Rural	−0.148***	−0.111**	−0.443***	−0.114**
	(−2.730)	(−2.574)	(−3.407)	(−2.324)
Area	Yes	Yes	Yes	Yes
_cons	−4.395***	−5.431***	17.987**	−5.741***
	(−10.253)	(−10.880)	(2.230)	(−11.508)
N	18,529	19,132	17,982	19,234
Pseudo R^2	0.278	0.503	0.591	0.274
Wald test	26.85	5.37	26.17	3.68
Value of *p*	0.000	0.021	0.000	0.055

The values in brackets are *Z* values; *, **, *** It is significant at the level of 10%, 5%, and 1%, respectively.

Confucius temples and monasteries, the influence of traditional culture on public ideology is more obvious. In the face of health risks, even haze pollution increases the public's risk perception level. However, influenced by traditional culture, Chinese families are not sensitive to the need for insurance, and they are more likely to cope with the possible medical burden by increasing savings and family intergenerational payments (Jin et al., 2017). Conversely, where there are fewer Confucian temples and monasteries, Chinese families will resort to more market-based measures to avoid risk, such as increasing the likelihood of buying commercial insurance. Not only that, Confucianism also influences corporate governance (Wei and Yang, 2007).

The impact of haze pollution on demand for commercial health insurance: An analysis based on the regional differences

China has a vast territory, with noticeable economic, cultural, and customs differences in different regions. Table 6 shows the differences in institutional environments in other regions. In terms of formal institutions, whether legal environment or industry marketization level, the mean value of the eastern region is significantly higher than that of the central and western regions, and the mean value difference between the eastern region, central and western regions is significant at the level of 1%. In terms of informal institutions, the average number of Confucian temples and temples in the eastern region is also more than that in the central and western regions (except that there is no difference between the eastern and central regions). Based on the previous discussion, the institutional environment is closely related to the public's risk cognition level, then the regional differences in the institutional environment are likely to be accompanied by the regional differences in the public's risk cognition level. Therefore, we further discussed whether there would be significant regional differences in the impact of haze pollution on demand for commercial health insurance.

From the empirical analysis results in Table 7, the coefficient of PM2.5 in column (1) is significantly positive at the coefficient of 1%, and the coefficient of PM2.5 in column (2) is significantly negative at the level of 1%, which shows that there are noticeable regional differences in the impact of haze pollution on residents' demand for commercial health insurance, which is consistent with the hypothesis of this paper. Specifically, in the eastern region, haze pollution will increase the possibility for residents to buy commercial health insurance, while this impact is not evident in the central and western regions.

In terms of the formal system, through the analysis results in Table 3, we know that if the level of the regional legal environment and market environment is high, haze pollution will increase the possibility of residents buying commercial health insurance. On the contrary, it will reduce this possibility. Combined with the analysis results of Table 6, the eastern part of the legal system level and the degree of marketization is significantly higher than in the Midwest. This explains the impact of haze pollution on the demand for commercial health insurance is stronger than in the Midwest.

In terms of the informal system, haze pollution will promote residents' demand for commercial health insurance in areas less affected by traditional culture. On the contrary, this promoting effect is not apparent. However, the influence of traditional culture in China and the west is weaker than in the East. This is inconsistent with the results in Table 7. The informal system is not the reason for this regional difference.

In terms of control variables, we need to pay attention to the impact of regional economic development on the demand for commercial health insurance. The coefficients of (1) and (2) GDP are significantly positive at the level of 1%, which shows that

TABLE 6 Regional differences in the institutional environment.

Variable name		Inter group mean			*T*-test of mean difference between groups	
		(1)	(2)	(3)	(4)	(5)
		Eastern	Central	Western	Eastern vs. Central	Eastern vs. Western
Formal system	Legal environment	7.599	5.724	5.633	−1.875***	−1.966***
		(1.499)	(0.853)	(1.632)	(0.016)	(0.019)
	Marketization level	8.374	5.979	5.626	−2.394***	−2.747***
		(1.465)	(0.671)	(1.166)	(0.015)	(0.017)
Informal Institution	Confucian Temple	13.677	13.684	12.989	0.006	−0.689***
		(10.19)	(10.487)	(11.194)	(0.124)	(0.131)
	Temple	6.309	5.945	4.280	−0.363***	−2.029***
		(4.685)	(4.733)	(3.460)	(0.057)	(0.055)
	Observations	20,074	10,407	9,530	30,481	29,604

The values in brackets are *Z* values; *, **, *** It is significant at the level of 10%, 5%, and 1%, respectively.

TABLE 7 Regional difference analysis of the impact of haze pollution on demand for commercial health insurance.

Variable name	(1)	(2)
	East	Midwest
PM2.5	0.138***	−2.508***
	(3.432)	(−4.563)
Income	0.111***	0.134***
	(6.763)	(7.025)
Asset	0.100***	0.137***
	(8.308)	(8.009)
Health	0.070***	0.040***
	(5.899)	(2.813)
Age	0.022***	0.044***
	(2.872)	(4.008)
Age2	−0.000***	−0.001***
	(−5.156)	(−5.425)
Gender	0.054	−0.051
	(1.384)	(−0.931)
Marry	0.058***	0.037*
	(3.410)	(1.852)
Education	0.034***	0.022***
	(6.616)	(3.584)
GDP	0.131***	0.911***
	(5.311)	(4.773)
Rural	−0.133***	−0.039
	(−2.689)	(−0.745)
_cons	−6.434***	−13.844***
	(−17.048)	(−7.217)
N	19,224	18,437
Pseudo R^2	0.712	0.212
Wald test	15.33	26.89
Value of *p*	0.00	0.000

The values in brackets are *Z* values; *, **, *** It is significant at the level of 10%, 5%, and 1%, respectively.

regional economic development has improved the residents' demand for commercial health insurance. However, comparing the coefficients of GDP in columns (1) and (2), the coefficient of GDP in the central and western regions is significantly greater than that in the eastern region, which shows that the development gap in the commercial health insurance industry between the west and central regions and the east region will gradually narrow due to economic development.

Further analysis

Individual risk preference differences will affect the public's response to haze risk. For example, different individuals have different perceptions of the profit-loss ratio of risk: some people are sensitive to the benefits of risk, while others may pay more attention to loss. For example, individuals with specific personality characteristics predict risk scenarios more positively or negatively, leading to different behavioral response styles. The existing literature found that risk attitude affects family commercial insurance participation rate (Sun and Huang, 2010). Therefore, we further analyzed the impact of haze pollution on residents' purchase of commercial health insurance under individual risk preference. This paper uses the respondents' answers to lottery choice and investment choice in the questionnaire to measure personal risk preference.[5,6]

5 If there are two lottery tickets for you to choose from if you choose the first one, you have a 100% chance to get 4,000 yuan, if you choose the second one, you have a 50% chance to get 10,000 yuan, and 50% chance to get nothing, which one would you like to choose? 1. First sheet 2. Second sheet. If the respondent chooses 1, the respondent is risk-averse; otherwise, it is risk preference.

6 If you have an asset, what kind of investment project would you like to choose? 1. Projects with high risk and high return; 2. Pro-jects with slightly higher risk and return;3. Projects with average risk and average return; 4. Projects with somewhat lower risk and return; 5. Unwilling to take any risk. If the respondent chooses 1 or 2, the risk preference is 1; otherwise, it is 0; If the respond-ent chooses 1 or 2, the respondent belongs to risk preference type; otherwise, it is risk aversion.

TABLE 8 The impact of haze pollution on demand for commercial health insurance: an analysis based on individual risk preference.

Variable name	(1) Risk aversion	(2) Risk preference	(3) Risk aversion	(4) Risk preference
PM2.5	0.345**	−0.248	0.323*	−0.151
	(2.06)	(−0.89)	(1.74)	(−0.50)
Income	0.092***	0.169***	0.090***	0.095*
	(3.96)	(3.41)	(3.59)	(1.85)
Asset	0.101***	0.055	0.091***	0.065
	(5.57)	(1.41)	(4.68)	(1.49)
Health	0.088***	−0.047	0.085***	−0.017
	(4.80)	(−1.02)	(4.33)	(−0.33)
Age	0.023**	0.049*	0.021*	0.026
	(2.11)	(1.93)	(1.74)	(0.95)
Age2	−0.000***	−0.001**	−0.000***	−0.000
	(−3.80)	(−2.25)	(−3.36)	(−1.40)
Gender	0.058	0.058	0.035	0.039
	(1.04)	(0.49)	(0.57)	(0.29)
Marry	0.076***	0.044	0.084***	0.119*
	(3.07)	(0.76)	(3.16)	(1.95)
Education	0.024***	0.013	0.018**	0.035*
	(3.24)	(0.89)	(2.25)	(1.96)
GDP	0.117***	0.099	0.140***	0.072
	(3.15)	(1.27)	(3.45)	(0.84)
Rural	−0.134*	−0.339	−0.067	−0.199
	(−1.70)	(−1.40)	(−0.82)	(−0.80)
region	control	control	control	control
_cons	−6.226***	−5.909***	−6.215***	−4.962***
	(−11.06)	(−5.42)	(−10.12)	(−4.18)
N	8,803	1,337	8,069	1,146
Pseudo R^2	0.325	0.310	0.311	0.322
Wald test	4.73	0.42	4.00	0.09
Value of *p*	0.030	0.516	0.046	0.760

The values in brackets are *Z* values; *, **, *** It is significant at the level of 10%, 5%, and 1%, respectively.

In Table 8, the coefficient of PM2.5 in columns (1) and (3) is significantly positive at the level of 5% and 10%, respectively, and the coefficient of PM2.5 in columns (2) and (4) is not significant, indicating that the impact of haze pollution on demand for commercial health insurance will be different due to personal risk preference. Specifically, if individuals are risk-averse, haze pollution will promote the need for commercial health insurance. On the contrary, when individuals are risk preference, the impact of haze pollution on demand for commercial health insurance is not significant, consistent with the conclusions of the existing literature. The more risk-averse individuals are, the more willing they are to avoid risks by purchasing insurance.

In addition to purchasing commercial health insurance to deal with the risk of haze pollution, will residents take other countermeasures? The fourth part of the questionnaire asked the respondents about their family health care expenditure last year. Compared with the preventive behavior of buying insurance products, health care expenses can be regarded as an immediate response to health risks. Combined with the public's individual risk preference, this paper further discusses the impact of haze pollution on residents' health care expenditure.[7]

It is shown from the analysis results in Table 9 that the coefficient of PM2.5 in columns (1) and (3) is significantly positive at the level of 1%, while the coefficient of PM2.5 in columns (2) and (4) is not significant, indicating that the impact of haze pollution on residents' health care expenditure will be significantly heterogeneous due to the difference of individual risk preference. Specifically, the risk of haze pollution will increase the health care expenditure of risk-averse individuals, but the impact on risk-averse residents is not obvious. This conclusion echoes the conclusions in Table 8, which shows that the role of individual risk preference in haze pollution events will not be different due to the timeliness of response behavior.

Robustness test

To ensure the reliability of the conclusion, the robustness test is also carried out in the following aspects[8]:

Sample selection. Affected by budget constraints, families' choices of different commercial insurance are mutually exclusive. Specifically, if families buy life insurance, it is likely to reduce the probability of purchasing health insurance. From the sample of this paper, only about 10% of the families who buy personal and commercial insurance can buy two kinds of commercial insurance simultaneously, and about 57% and 33% of the families only purchase life insurance and health insurance. This shows that most families can only buy one kind of insurance. There is an apparent mutual exclusion. To reduce the impact of this mutual exclusion on the conclusion of this paper, we only retain the samples that purchased commercial health insurance and retest the previous finding, and the results have not changed substantially.

Tool variables. Considering that many natural factors will affect haze formation, we use the regional average annual temperature and wind speed as the instrumental variables of PM2.5 and retest the conclusions of this paper, and the results have not changed substantially.

Replace the explanatory variable. Firstly, the mean value of PM2.5 in each province in the past 5 years is selected to replace the explanatory variable; Secondly, this paper uses the market-oriented

7 The health care expenditure here includes the spending on health care and fitness exercise, including purchasing health care products, receiving health care physiotherapy services, running fitness cards, purchasing fitness equipment and food, asking for private education, etc. If the respondent's family had health care expenditure (train) last year, the value of train is 1; other-wise, the value of train is 0.

8 Limited to space, the empirical analysis results of the robustness test are omitted here.

TABLE 9 Effect of haze pollution on family health care behavior.

Variable name	(1)	(2)	(3)	(4)
	Risk aversion	Risk preference	Risk aversion	Risk preference
PM2.5	0.361***	0.198	0.389***	0.259
	(2.687)	(0.864)	(2.879)	(1.096)
Income	0.116***	0.136***	0.141***	0.094***
	(6.461)	(3.449)	(7.118)	(3.267)
Asset	0.096***	0.130***	0.100***	0.125***
	(7.339)	(4.086)	(7.176)	(5.221)
Health	−0.074***	−0.065*	−0.078***	−0.058**
	(−4.559)	(−1.751)	(−4.578)	(−2.003)
Age	−0.038***	−0.014	−0.036***	−0.024**
	(−5.414)	(−0.927)	(−4.790)	(−2.039)
Age2	0.000***	0.000	0.000***	0.000*
	(5.520)	(0.800)	(4.716)	(1.721)
Gender	0.082*	0.175*	0.074	0.041
	(1.861)	(1.770)	(1.623)	(0.492)
Marry	0.033*	−0.028	0.045**	0.008
	(1.917)	(−0.565)	(2.412)	(0.236)
Education	0.060***	0.057***	0.062***	0.048***
	(10.193)	(4.326)	(9.911)	(4.476)
GDP	−0.007	−0.117*	0.029	−0.102**
	(−0.239)	(−1.895)	(0.913)	(−2.063)
Rural	−0.174**	−0.064	−0.134*	−0.439***
	(−2.491)	(−0.355)	(−1.863)	(−3.044)
Area	Yes	Yes	Yes	Yes
_cons	−3.628***	−3.270***	−4.407***	−2.576***
	(−8.445)	(−3.876)	(−9.630)	(−3.787)
N	8,803	1,337	8,038	2,461
Pseudo R^2	0.325	0.310	0.311	0.322
Wald test	7.08	0.91	6.46	2.78
Value of *p*	0.008	0.341	0.011	0.096

The values in brackets are *Z* values; *, **, *** It is significant at the level of 10%, 5%, and 1%, respectively.

total index provided by Fan Gang to replace the institutional environment index and tests the conclusions above, the results are not substantially changed.

Conclusion

This paper finds that the level of health risk perception is an essential factor influencing commercial health insurance. The higher the level of risk perception, the higher the demand for insurance. At the same time, this result changes due to the difference in institutional environment; in a high-level legal environment and market environment, haze pollution will promote the development of commercial health insurance, while traditional culture will hinder the risk-averse function of commercial health insurance against haze pollution. Further analysis finds that the preventive measures taken by residents in the face of haze pollution will differ according to individual risk preferences. For risk-averse residents, haze pollution increases their probability of purchasing commercial health insurance. Conversely, it decreases the such probability.

Currently, the public is more concerned about the effects of haze pollution on physical health, and there seems to be no answer as to what countermeasures should be taken. The findings of this paper provide a reference for the public to use commercial health insurance to prevent haze pollution. For insurance companies, they should further improve their insurance services to meet the public's demand for haze pollution, which will help the healthy development of the insurance industry.

Data availability statement

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

Ethics statement

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. Written informed consent from the patients/participants or patients/participants legal guardian/next of kin was not required to participate in this study in accordance with the national legislation and the institutional requirements.

Author contributions

Data collection and analysis were performed by PJ. The first draft of the manuscript was written by PJ and JY. PJ and JY commented on previous versions of the manuscript. All authors contributed to the article and approved the submitted version.

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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Consumer motivation for organic food consumption: Health consciousness or herd mentality

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Whether health awareness is self-awareness or conformity awareness is a question worth discussing. Especially under the current trend of organic food consumption, whether it is driven by health consciousness or herd mentality is worth exploring. This is not only about the government's formulation of health policies for the industry (for example, paying more attention to health standards), but also about the sustainable development of organic food consumption (for example, suppliers highlighting their own health advantages). However, there is still little research in this area. Based on data from 1,658 respondents in four first-tier cities in China, this paper explores whether consumers are consuming organic food under health consciousness or herd mentality. This paper uses a logit model to explore the key causes of health consciousness or herd mentality, and uses a propensity score matching (PSM) method to measure the impact of health consciousness and herd mentality on organic food consumption, comparing the effects across age and education groups. The results show that: (1) Individual characteristics, family characteristics, health status, volition, social trust and market education significantly influenced consumers' health consciousness or herd mentality; (2) The main motivation for organic food consumption is health consciousness, but herd mentality plays a role of amplifying this effect.

KEYWORDS

consumer motivation, organic food consumption, propensity score matching, health consciousness, herd mentality

Introduction

Organic food, known as ecological or biological food, is a relatively unified international term for uncontaminated natural food. Organic food usually comes from organic agricultural production systems and is produced according to international organic agricultural production requirements and corresponding standards (1). In domestic and international literature, organic food is sometimes translated as organic product, but this paper does not distinguish between them, so organic product is equivalent to organic food.

In recent years, people are more concerned about their health than ever before. Public opinions on food safety have continued to emerge. Food safety has become one of the most realistic issues in society and of utmost concern to residents.

In such an environment, people have taken the consumption of organic food as an alternative to avoid the food safety problems. According to the World of Organic Agriculture Statistics and Emerging Trends 2022 (WOASET 2022) published by the Swiss Research Institute of Organic Agriculture (FiBL) and IFOAM – Organics International, over 74.9 million hectares of organic agricultural land were recorded in 190 countries in 2020.

China is a country that has paid more importance to the public's health and food safety. The Health China Initiative (2019–2030) issued by the Chinese government advocates the need for a sensible and reasonable diet. The Chinese government has made efforts to improve the quality of agricultural products and food safety. According to the WOASET 2022, organic agricultural land of China was over 2.4 million hectares, ranking second in Asian, and organic food market reached 10.2 billion Euros.[1] Organic vegetables are the typical examples. They are becoming increasingly popular among the public due to their unique safety and health characteristics. Now there has been a huge potential demand for organic vegetables in China.

However, there is a serious information asymmetry in the organic food market, for the variety of organic vegetables is vast, and the cost for consumers to fully understand these various organic food products is high (2). It is difficult for consumers to make rational consumption decisions, and they may adopt a follow-the-leader strategy under the influence from people around them. Clarifying the drivers of organic food consumption and identifying the key factors influencing consumers' consumption, are important to ensure stable growth in organic food demand, prevent price fluctuations and guide the high quality development of the industry (3). Therefore, which force is behind the high growth in organic food consumption in China: The awakening of health consciousness or the influence of herd contagion? And how do these two forces influence consumption? Answering these questions and exploring the mechanisms are the task of this paper.

First, let's discuss the literature of research on the development of organic food industry. The existing literature on the industrial development and market consumption of organic food can be broadly divided into two dimensions: macro level and micro level. At the macro level, scholars have focused on the exploration of industrial policies, supply and demand equilibrium, and price fluctuations. At the micro level, the focus is on the analysis of organic vegetable production behavior, mainly concerning about the production intentions, technical efficiency of production and key influencing factors (4). These studies revealed real-life problems on the supply side of organic food industry, such as poor resource endowment, sloppy cultivation management and high yield fluctuations, and gave policy recommendations tailored to local conditions, which serve as a guide for the development of organic food industry. However, microscopic research on the demand side, such as consumers' consumption of organic food, is relatively lacking (5). Although some studies in green product consumption areas had regarded organic food as a characterization indicator, but these studies contributed little to guiding the organic food industry (6, 7). In order to promote the high-quality development of the organic food industry, there is still need to explore the motivation mechanism of consumers' organic food purchasing behavior (8, 9).

Second, let's discuss the consumer behavior in organic food. At present, there is rich existing literature on consumer behavior, pathways of action and influencing factors. The studies have evolved from the founding of consumer behavior in the 1970's (10) to the theories of planned behavior (11) and the consumer culture (12), and to the currently prevalent views on irrational behavior (13). Based on general psychological characteristics of individuals and external factors, deep-seated explanations of consumers' internal perspective are analyzed to reveal consumer decision-making processes, including attitudes, preferences, relationships and choices. However, there is room for improvement in the existing empirical evidence: (1) In terms of research methodology, the existing literature mostly adopts Logit and Probit methods, incorporating herding behavior as a dummy variable into the equation and directly comparing the differences in individual rational and irrational behavior, and ignoring the heterogeneity between different groups. (2) In terms of research content, the existing literature focuses on a single discussion of the rational person hypothesis or the irrational hypothesis; human decision-making is influenced by the interaction of individual rationality and sociality, and needs to be considered in an integrated manner (12). In the studies on China, most of the existing literature uses primary research data from provinces, but the vast size of China makes it difficult to reflect geographical differences in the samples from the level of provinces.

In order to uncover the motivations for organic food consumption, this paper will explore the key triggers of health awareness and herding behavior based on data from 1,658 respondents in four first-tier cities in China: Beijing, Shanghai, Guangzhou and Shenzhen. This study will measure the effects of health awareness and herding behavior on organic food consumption using the propensity score matching (PSM) method. The study will also use primary data from field research, take into account the heterogeneity of different groups, and consider the interactive effects of human decisions. The findings of this paper will be useful in broadening the research on the effect of health concepts on organic food consumption. It can be helpful to the government's formulation of health policies for the industry and the sustainable development of organic food consumption.

1 https://knowledge4policy.ec.europa.eu/publication/world-organic-agriculture-statistics-emerging-trends-2022_en

Economic explanations and research hypotheses

In order to clarify the influence of personal health awareness and herd mentality in organic food consumption, the information waterfall model constructed by Anderson and Holt (14) is used in this paper. It is assumed that residents have two choices of consuming and not consuming organic food, denoted as strategy Y and strategy N respectively, i.e., the strategy set R = {Y, N} and the actual action v ∈ R. The prior probabilities that residents consume organic food or not are set as P(Y) and P(N), and P(Y) + P(N) = 1, which represents the residents' initial consumption attitude. When consumers believe that consumption of organic food brings higher utility than similar products, we have P(Y) > P(N), and *vice versa* (15).

Let $\delta_i = (y, n)$, $i = 1,2, \ldots, n$ be the private information of resident i about the consumption of organic food, $\delta_i = y$ means that the utility of organic food is higher than that of similar products, $\delta_i = n$ means that the utility of consuming organic food is lower. Since private information is incomplete information about the decision outcome, we set p_i as the probability that resident i's private information is consistent with the decision outcome (16). Then we have

$$P\left(v|\delta_i = y\right) = \begin{cases} p_i, & v = y \\ 1 - p_i, & v = n \end{cases}$$

$$P\left(v|\delta_i = n\right) = \begin{cases} 1 - p_i, & v = y \\ p_i, & v = n \end{cases}$$

Private information is consistent with the decision outcome while p_i takes values closer to 1, and private information is inconsistent with the decision outcome while p_i takes values closer to 0.5. It is assumed that the public information is published as a Bayesian rule (there is a sequential order), while the later decision maker can observe the information of the earlier decision maker and adjust their options (17). Before resident i, there are already K individuals choosing organic food consumption and M choosing alternatives, i.e., K + M = i-1. Then, the probability that resident i's judgment of the kth other resident's organic food consumption is accurate can be expressed as p'_{ik}, and the probability that the mth individual chooses not to consume organic food can be expressed as p'_{im}. Then p'_{ik}, $p'_{im} \in (0,1)$, $k = 1,2,\ldots, K$; $m = 1,2, \ldots, M$. Thus, the probability of consumer organic food consumption can be expressed as:

$$P\left(Y|K, M, \delta_i = y\right) = \frac{P\left(K, M|Y\right) P\left(Y\right) p_i}{P\left(K, M|Y\right) P\left(A\right) p_i + P\left(K, M|N\right) P\left(N\right) \left(1 - p_i\right)}$$

$$= \frac{1}{1 + \frac{1}{\left(\prod_{k=1}^{K} \frac{p'_{ik}}{1-p'_{ik}} \times \prod_{m=1}^{m} \frac{1-p'_{im}}{p'_{im}} \times \frac{P(Y)}{1-P(Y)} \times \frac{p_i}{1-p_i}\right)}}$$

Where $\frac{P(Y)}{1-P(Y)}$ is the ratio of organic food consumption group to non-organic food consumption group in the initial state (18), the size of which is determined by the environment in which the residents live; $\frac{p_i}{1-p_i}$ and $\frac{1-p_i}{p_i}$ are the ratios of organic food consumption to non-organic food consumption in the private information display, reflecting the health consciousness of individuals or not; $\prod_{k=1}^{K} \frac{p'_{ik}}{1-p'_{ik}} \times \prod_{m=1}^{m} \frac{1-p'_{im}}{p'_{im}}$ is the ratio of organic food consumption to non-organic food consumption for others in the public information display, reflecting the impact of group organic food consumption behavior, i.e., herd mentality. Thus, the probability of organic food consumption can be expressed as an interaction of environmental characteristics (19), personal health awareness and herding behavior: $P(Y|K, M) \propto$ *Environmental features* × *Personal Health Awareness* × *Herd mentality*.

In summary, this paper proposes the following hypotheses:

1. Personal health awareness has a significant positive effect on organic food consumption.
2. The herd mentality of the population has a significant positive impact on the consumption of organic food.
3. Environmental characteristics have a significant impact on organic food consumption.
4. Personal characteristics, family characteristics, regional characteristics, volitional attributes and health status have significant effects on herding mentality.
5. Individual characteristics, family characteristics, regional characteristics, quality of will, health status, etc. have significant influence on health awareness.

Then we focus on the interpretation of hypotheses 4 and 5.

First, we explain the hypotheses 4. Consumer beliefs indirectly influence consumption intentions and behavior through individual characteristics and socio-cultural factors (such as gender, age, education, income, experience) (20). Psychological research defines herding as an individual's adherence to the social norms of the group to which he or she belongs (21) and herding as a way for consumers to change their attitudes, product evaluations and purchase decisions by referring to the product evaluations or purchase behavior of the group (22). This is manifested in the decision to follow the behavior of others by considering their preferences as a predetermined solution (23). It is the intersection of the dimensions of under-information and following in terms of identification and measurement (24). The former is the belief that other people's preferred choices or opinions are often

TABLE 1 Regional distribution of the sample.

City	District	Sample size	City	District	Sample size
Beijing	Chaoyang District	114	Shanghai	Jing'an District	103
	Haidian District	113		Xuhui District	107
	Daxing District	102		Minhang District	109
	Xicheng District	105		Hongkou District	111
Guangzhou	Yuexiu District	113	Shenzhen	Futian District	69
	Hazhu District	105		Nanshan District	115
	Liwan District	101		Longhua District	86
	Tianhe District	112		Guangming District	93

correct or better, and that information in a state of information ambiguity motivates herding behavior; the latter is the belief that other people's opinions or preferences are not necessarily better, and that herding is a way of being socially accepted. The latter believe that the opinions or preferences of others are not necessarily better and that herding is a way of being accepted by the social group so as not to be rejected or punished (25). Of course, consumers do not herd for all products, and are less likely to herd for products that are used to express personal identity and highlight individual differences, such as clothing or music genres (26). Consumer behavior research has found that both stable personal characteristics and variable environmental factors drive consumers to be more or less herd-oriented. For example, consumer characteristic needs (27), volitional attributes (28) and cultural background (29) are all personal attributes of herding consumers that have been explored by scholars. Therefore, this paper proposes the hypothesis 4.

Second, we explain the hypotheses 5. The Health Belief Model suggests that individuals' perceptions of the likelihood and severity of illness are the driving force behind health behavior, and that personal and social characteristics "behind" the level of perception indirectly influence individual health behavior (30). Health food consumption is one of the many health behaviors that are indirectly influenced by health consciousness (31). As consumers become more health conscious, their need for health information increases. With objective and rational knowledge of food products, their choice behavior is less likely to follow objective rules and be blind (32). With regard to the factors influencing health awareness, a large number of scholars have verified that personal characteristics, family characteristics and health status play significant roles in health awareness and have explored regional differences in this relationship (33). Therefore, this paper proposes the hypothesis 5.

3. Research design

3.1. Data source and sample description

The data used in this paper are derived from household research conducted in June and July 2021 in four first-tier Chinese cities, including Beijing, Shanghai, Guangzhou and Shenzhen. The research used a combination of multi-stage stratified sampling and random sampling principles, with 3 to 4 randomly selected sample districts and counties in each city, 3 to 5 randomly selected natural villages or streets in each sample district and county, and 10 to 15 randomly interviewed consumers. A total of 30 districts and counties were involved in the survey, and a total of 1,713 questionnaires were distributed and collected, excluding samples with missing data, 1,658 valid questionnaires were distributed, with an effective rate of 96. 83%, which has good representativeness. The regional distribution of the sample is shown in Table 1.

In terms of organic food consumption, 1,479 respondents had consumed organic food (89.19%), and organic food accounted for 5.49% of food consumption on average; among them, 595 (35.91%) were consumers with an awakened sense of personal health while 350 (21.08%) were consumers with a herd mentality. In terms of individual characteristics, 816 (49.21%) of the respondents were male and 842 (50.79%) were female; the average age of the respondents was 32.77 years; and the average level of education was concentrated in the bachelor's degree (28.28%).

3.2. Variables and descriptive statistics

1. Dependent variable. The dependent variable in this paper is the share of consumers' organic food consumption in food consumption, which is a dimensionless continuous variable and requires no special treatment (25).

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TABLE 2 Results of descriptive statistics for variables.

Variable groups	Variables	Variable indicators	Sample size	Mean	Variance	Minimum	Maximum
Effectiveness indicators	Organic food as a share of food consumption	%	1,658	5.494	9.477	0	80.6
Subgroup indicators	Derived from health awareness	0 = No; 1 = Yes	1,658	0.361	0.483	0	1
	Derived from herd behavior	0 = No; 1 = Yes	1,658	0.232	0.406	0	1
	Gender	0 = Female;1 = Male	1,658	0.492	0.500	0	1
	Age	—	1,658	32.771	18.530	16	90
Individual characteristics	Married or not	0 = No; 1 = Yes	1,658	0.704	0.457	0	1
	Education level	0 = No education; 1 = primary school; 2 = lower secondary school; 3 = upper secondary school; 4 = specialist; 5 = Bachelor; 6 = Master; 7 = Doctor	1,658	3.521	1.532	0	7
Family characteristics	Number of family members	—	1,658	3.713	1.478	1	15
	Number of dependents	—	1,658	1.153	1.238	0	6
	Household income	1 = less than 10,000; 2 = 1 to 20,000; 3 =2 0 to 30,000; 4 = 30 to 40,000; 5 = 40 to 50,000; 6 = 50,000 or more	1,658	4.491	1.732	1	6
Health status	Self-evaluation	0 = very poor; 1 = relatively poor; 2 = fair; 3 = better; 4 = very good	1,658	2.877	0.814	0	4
	Whether to be concerned about health	discrete values from 0 to 6, where 0 = no attention at all; 6 = extremely attentive; the higher the value, the stronger the degree of attention	1,658	3.287	1.547	0	6
Quality of will	Adherence to a healthy lifestyle	0 = poor; 1 = medium; 2 = good; 3 = excellent; 4 = very good	1,658	2.873	1.531	0	4
Social trust	Level of trust in traceability system	0 = Very distrustful; 1 = Relatively distrustful; 2 = No Feelings; 3 = more trusting; 4 = very trusting	1,658	2.677	0.802	0	4
	Whether to trust organic food	0 = Very distrustful; 1 = Relatively distrustful; 2 = No Feelings; 3 = more trusting; 4 = very trusting	1,658	2.614	0.867	0	4
Marketing education	Whether to see organic food related advertisements	0 = not available; 1 = less often; 2 = generally; 3 = more often; 4 = often	1,658	1.789	1.268	0	4

2. Core independent variables. The core independent variables chosen for this paper are "health consciousness" and "herd mentality" of consumers.

A consumer is considered to be health conscious if he or she (1) knows about organic food and the nutritional value of it and (2) insists on buying organic food even if others around him or her buy other similar products.

If (1) they have not heard of organic food or do not know about its nutritional value (2), they will buy organic food even when others around them buy organic food. They are considered to be a health conscious consumer and are classified as experimental group 2. Other consumers are classified as experimental group 0.

3. Control variables. In order to clarify the factors influencing consumers' beliefs about organic food consumption, individual characteristics, family characteristics, health status, quality of will, social trust and market education were selected as control variables. Four variables were selected for individual characteristics: gender, age, marital status, and education level. The differences in physiological characteristics and life experiences of different gender and age groups will result in different consumption beliefs (25). The marriage will also reshape individuals' perceptions and attitudes toward food and drink, and consumers with a high level of education will be more receptive to knowledge and have a healthier consumption philosophy. Three variables were selected for household characteristics (26): (1) Number of family members, number of dependents and household income. The number of people in the household influences the information received and the food consumption decision to a certain extent; (2) Families with a large number of dependents have to pay more attention to the health needs of the elderly and children (27); (3) The level of income determines the consumer class to which they belong, and there are differences in the consumption philosophy of different classes. The respondents' health status was characterized by two variables (28): (4) self-rated health and health concern, with those who were unwell and those who were concerned about their health caring more about their diet structure. The quality of will was characterized by adherence to a healthy routine (29), with those who were strong-willed being more likely to adhere to a good routine. In terms of social trust, those who trust in traceability and organic food are more likely to consume organic food and consume more of it. The market education selection focuses on the attention paid to organic food advertising, and advertising can effectively guide the public's consumption philosophy (30). The assignment notes and descriptive statistics of the above variables are shown in Table 2.

A counterfactual analysis framework for consumer psychology based on propensity score matching is proposed. The dummy variables were used to indicate whether the respondents belonged to the health consciousness, herd consumption or control group.

The specific analysis steps are as follows.

First, the covariates xi were selected, and exogenous influences on consumption beliefs and behavior, including individual characteristics, family characteristics, health status, volition, social trust, market education, and regional characteristics, were included in the model to meet the negligibility assumption.

Second, propensity scores were calculated. A Logit regression model was used to estimate the propensity score for respondent i's health awareness and the propensity score for herding behavior.

Third, the propensity scores were matched. (1) Selection of matching methods. There is some bias in the results of different matching methods for the same sample, but the methods themselves are not better or worse, and if similar or consistent findings can be obtained using multiple matching methods, the results are robust. Therefore, in order to ensure the reliability of the findings, five mainstream methods were selected for matching. The first method is k nearest neighbor matching, which finds the nearest individuals in different groups with different inclination scores, and sets $k = 4$ for 1-to-4 matching so as to minimize the mean squared error. The second method is Caliper matching, which matches different groups of individuals within absolute distance, and uses the default caliper range of 0.05 radius. The third method is bootstrap matching, which uses the default 1:1 proximity matching method and performs 500 times to obtain the mean value after sampling. (2) Test for balance. Once an accurate propensity score estimate is obtained, the matched experimental and control groups are tested for equilibrium of the covariate xi to ensure that the sample is equally distributed between the experimental and control groups.

Finally, mean treatment effects were calculated. This includes the average effect of the experimental group (ATT), the average effect of the control group (ATU) and the average effect of the full sample (ATE). The ATT for Experimental Group 1 represents the effect of personal health awareness on buckwheat consumption, the ATT for Experimental Group 2 represents the effect of herding behavior on buckwheat consumption, the ATU for the control group represents the mean value of the proportion of buckwheat consumed by the population when no action is taken, and the ATE for the full sample reflects the mean value of buckwheat consumption for a random sample. As this paper focuses on the contribution of health awareness and herding behavior to the consumption of mixed grains, it focuses on the comparison of the two experimental groups and therefore uses ATT for the analysis.

3.3. Analysis of the factors influencing consumer psychology

In order to achieve sample matching, this paper analyzed the key factors affecting consumption beliefs, and the results

TABLE 3 Logit regression results for consumer beliefs.

Variable groups	Variables	Health awareness		Herd mentality	
		Regression coefficient	dy/dx	Regression coefficient	dy/dx
Individual characteristics	Gender	−0.336*** (−2.790)	−0.067*** (−2.820)	−0.076 (−0.580)	−0.015 (−0.580)
	Age	0.029*** (5.430)	0.006*** (5.640)	0.002 (0.270)	0.000 (0.270)
	Married or not	0.242 (1.360)	0.048 (1.360)	0.035 (0.180)	0.007 (0.180)
	Education level	0.136*** (2.880)	0.027*** (2.910)	−0.149*** (−2.940)	−0.030*** (−2.980)
Family characteristics	Number of family members	0.216*** (2.610)	0.025*** (2.640)	0.056 (1.040)	0.011 (1.040)
	Number of dependents	−0.195*** (−3.320)	−0.039*** (−3.360)	−0.119* (−1.849)	−0.019* (−1.859)
	Household income	−0.039 (−1.428)	−0.009 (−1.338)	0.019 (0.498)	0.003 (0.498)
Health status	Self–evaluation	0.225*** (2.998)	0.044*** (3.029)	0.098 (1.119)	0.019 (1.119)
	Whether to be concerned about health	0.004 (0.149)	0.002 (0.148)	0.073* (1.668)	0.016* (1.677)
Quality of will	Adherence to a healthy lifestyle	0.369*** (4.509)	0.074*** (4.619)	0.355*** (3.969)	0.071*** (4.059)
Social trust	Level of trust in traceability system	0.203** (2.169)	0.039** (2.189)	0.091 (0.869)	0.018 (0.879)
	Whether to trust organic food	0.139 (1.519)	0.026 (1.519)	−0.096 (−1.009)	−0.019 (−1.019)
Marketing education	Whether to see organic food related advertisements	0.217*** (4.510)	0.043*** (4.462)	0.248*** (4.593)	0.051*** (4.839)
Model parameters	Constants	−5.443*** (−10.500)		−2.375*** (−4.350)	
	Pseudo R^2	0.1543		0.0618	
	LR chi^2 (15)	317.09		96.13	
	N	1,489		1,218	

*, **, and ***Indicate that the estimates are significant at the 10, 5, and 1% levels respectively, with the t-statistic in parentheses.

TABLE 4 PSM matching results.

Projects	Matching samples	Unmatched samples	Total
Control group	597	0	597
Experimental group 1 (health awareness)	687	6	693
Experimental group 2 (submissive behavior)	368	0	368
Total	1,652	6	1,658

of logit estimation for personal health awareness and herding mentality are shown in Table 3. Pearson test and VIF test were conducted on the independent variables, and there was no multicollinearity problem.

Table 3 shows that differentiated individual characteristics, family characteristics, health status, quality of will, social trust and market education are important factors in consumer health awareness and herd mentality. There is no significant difference in herd consumption; education is a key factor in health awareness and herd mentality, with more educated groups being more health conscious and less likely to herd. Household characteristics show that consumers from large families are more health conscious, but those from households with a large number of dependents,

TABLE 5 Results of balance tests before and after matching of health awareness explanatory variables.

Matching method	Quasi$-R^2$	LR statistic	Standardized deviation (%)
Before matching	0.138	319.37	29.3
K Nearest neighbor matching	0.008	18.29	4.0
Caliper match	0.005	9.32	2.7
Within caliper k nearest neighbor matching	0.003	8.27	3.1
Kernel matching	0.006	12.37	4.0

The Bootstrap matching method was performed 500 times and the results of the parameters are not shown due to space constraints.

TABLE 6 Results of balance tests before and after matching of followership behavior explanatory variables.

Matching method	Quasi$-R^2$	LR statistic	Standardized deviation (%)
Before matching	0.059	98.93	17.2
K Nearest neighbor matching	0.007	4.88	3.2
Caliper match	0.003	3.17	1.3
Within caliper k nearest neighbor matching	0.005	6.17	3.1
Kernel matching	0.003	3.3	2.8

The Bootstrap matching method was performed 500 times and the results of the parameters are not shown due to space constraints.

such as the elderly and young children, are less health conscious.

The reasons for this are that: On the one hand, it is the access to information while having a large family helps to increase knowledge of health information, and on the other hand, it is the access to time constraints while consumers with large families have a heavier household burden and less time to take care of their dietary health (31). In terms of health status, consumers who feel good about themselves are more health conscious, but the more they care about their health, the more likely they are to follow the trend of consumption. In terms of quality of will and social trust, strongwilled consumers are more pronounced in both health awareness and herd consumption; those who have a high level of trust in the food safety traceability system have a significantly higher proportion of health awareness awakening, reflecting that those who trust the food safety system are more rational consumers (32). In terms of market education, the more advertising education received, the more health conscious consumers are, but also the more likely they are to follow the herd. In summary, Hypothesis 4 and Hypothesis 5 were tested.

4. Measuring the effect of health consciousness and herd mentality on organic food consumption

4.1. Analysis of PSM matching results

In this paper, the fitted values of the conditional probabilities pi for respondent i's personal health awareness and herd mentality, i.e., the propensity score, were calculated based on the estimation results of the consumption belief equation. The maximum loss of samples in the matching method chosen for the study was 6, still retaining 1,652 matched samples with good matching results (see Table 4).

4.2. Equilibrium tests

In order to ensure the reliability of the matching results and to satisfy that there were no significant differences in the influencing factors except for the differences in organic food consumption, a balance test of the covariates was required (33). The results are shown in Tables 5, 6. After sample matching, the standard deviation of the explanatory variables for health consciousness decreased from 29.3 to 2.7–4.0%; the overall bias was significantly reduced and all were within the 10% good standard line of the balance test; the $Quasi - R^2$ decreased from 0.138 before matching to 0.003–0.008 after matching; and the LR statistic decreased from 319.37 to 8.27–18.29. The standard deviation of the explanatory variables for follower behavior decreased from 17.2 to 1.3–3.2%; the $Quasi - R^2$ decreased from 0.059 before matching to 0.003–0.007 after matching; and the LR statistic decreased from 98.93 to 3.17-6.17. In terms of the deviation of each explanatory variable in the two experimental groups from the control group, except for the health consciousness education and market education of the awakened group, there were no significant differences. Together, this suggests that the propensity score matching method significantly reduced the differences in the distribution of explanatory variables between the two experimental groups

TABLE 7 Results of heterogeneous group differences.

Heterogeneous variables	Classification criteria	Health awareness		Herding behavior	
		Mean treatment effect	Standard deviation	Mean treatment effect	Standard deviation
Gender	Male	3.933***	0.849	2.876***	1.008
	Female	2.989***	0.838	1.948***	0.698
Age	35 years old and below	1.897**	0.594	0.641	0.714
	35 to 45 years old (inclusive)	2.919**	1.498	1.593	2.113
	45 to 55 years old (inclusive)	4.173***	1.367	4.279**	1.689
	55 years old and above	2.498**	1.189	3.998***	1.453
Education level	Primary and below	1.608	2.107	5.583**	2.196
	Lower secondary	2.389*	1.492	3.258**	1.387
	High School	3.914***	0.979	1.509*	0.939
	University and above	1.814***	0.734	1.953*	1.009

*, **, and *** indicate that the estimates are significant at the 10%, 5%, and 1% levels respectively.

and the control group, and largely eliminated the bias caused by sample selection.

4.3. The effect of health consciousness and herd mentality on organic food consumption

The propensity score matching model estimated a net effect of 3.259 for the effect of personal health awareness on organic food consumption, indicating that after accounting for the bias in consumer health awareness, concern for dietary health contributed to a significant increase of 3.259% in the proportion of consumers consuming organic food. This confirms hypothesis 1.

The net effect of herding behavior on consumers' organic food consumption was 2.152, indicating that, after taking into account the herding mentality bias of consumers, following the herd contributed to a significant increase of 2.152% in the proportion of consumers consuming organic food; so the hypothesis 2 was verified. The net effect of health awareness was significantly higher than that of herding behavior, reflecting the fact that health awareness is the main driver of organic food consumption in China, but herding also plays an amplifying role.

It is worth noting that the increase in demand driven by health consciousness is a rational decision driven by consumers' objective perception of dietary health, and that demand for organic food driven by this driver is relatively stable, while organic food consumption driven by herd mentality tends to fluctuate according to the shift in consumption hotspots (33).

The degree of influence of health awareness and herd mentality varies considerably between different types of consumers, depending on their socio-cultural, educational and life experiences (16). In this paper, we will further explore the cohort differences among different types of consumers, based on Bootstrap method with 500 samples, and finally estimate the cohort difference comparison results of the effect of individual health awareness and herding behavior on organic food consumption as shown in Table 7.

First, the net effect of organic food consumption, both in terms of health consciousness and herding behavior, is higher for men than for women. This reflects the fact that men have a relatively homogeneous diet, preferring to consume large quantities of a few foods, while women have a more diverse food choice, consuming more varieties but smaller quantities. Second, in terms of age structure, the net effect of health awareness on organic food consumption tends to increase and then decrease with the accumulation of life experience and the objective needs of the body. The net effect of health awareness on organic food consumption is greatest among consumers aged 45–55. Again, the net effect of health consciousness on organic food consumption tends to increase and then decrease with education level. There was no significant difference between the primary school and below educated group and the control group, where health consciousness awareness did not affect their organic food consumption; the highest effect of health consciousness on organic food consumption was observed for the high school educated group; while the significant effect of health consciousness on organic food consumption was lower for the university and above educated group. The highly educated group is more diversity-oriented and moderately increases organic food consumption (34). Finally, the net effect of herding behavior on organic food consumption tends to decrease with increasing education,

indicating that the level of education influences consumers' learning and vision to a certain extent, and the net effect of herding behavior decreases with higher education levels. Hypothesis 3 was verified.

5. Conclusions and recommendations

Based on data from 1,658 respondents in four first-tier cities in China, this paper explains whether consumers' organic food consumption is motivated by health awareness or herding behavior. This paper uses a logit model to explore the key triggers of health awareness and herding behavior, and uses the propensity score matching (PSM) method to measure the effects of health awareness and herding behavior on organic food consumption. The effects of health awareness and herding behavior on organic food consumption were measured using the Propensity Score Matching (PSM) method and were compared across age and education groups. The study shows that individual characteristics, family characteristics, health status, volition, social trust and market education significantly influenced consumers' health awareness and herding behavior; the main driver of organic food consumption was health awareness, but herding also played a role in amplifying the effect.

Based on the above findings, this paper proposes the following recommendations to further optimize consumers' dietary structure and promote the quality development of the organic food industry.

1. We should give full play to the driving role of the awakening of health awareness in the growth of coarse grain consumption, strengthen dietary health education, and advocate healthy consumption and rational consumption. As education is the foundation of the country and the key to improving the quality of the people, we can promote healthy diet and improve the "online + offline" official publicity system of food culture education, so that the improvement effect of health awareness awakening can be fully released.

2. We should face up to the herd mentality to the grain industry. The role of promotion is to make proper use of herd psychology to increase market demand while taking preventive measures. The increased demand for herd consumption is easy to fade with the transfer of consumption hotspots, resulting in large fluctuations in market prices and affecting the steady development of the grain industry. Therefore, it is necessary for the government to guide consumption trends and prevent the market impact caused by the frequent switching of consumption hotspots between different foods. The government should regulate product advertising, punish false and exaggerated publicity, and avoid price fluctuations caused by false propaganda that is caused by follower consumption.

3. We should focus on the information needs of special groups and do a good job of point-to-point assistance. For groups who have no time to take care of healthy diets due to heavy family burdens and high support pressure, relevant government departments can push healthy and reasonable dietary structures for them through service platforms such as text messages. For middle-aged and elderly groups who are easy to consume herdly, we should actively carry out the activity of "guiding and protecting the rights of elderly consumer subjects," and improve the dietary guidance of middle-aged and elderly consumer groups.

Data availability statement

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

Ethics statement

The studies involving human participants were reviewed and approved by Ethics Committee of Shenzhen Polytechnic, China. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

Author contributions

First draft writing: JW. Review writing: YX and TL. All authors contributed to the article and approved the submitted version.

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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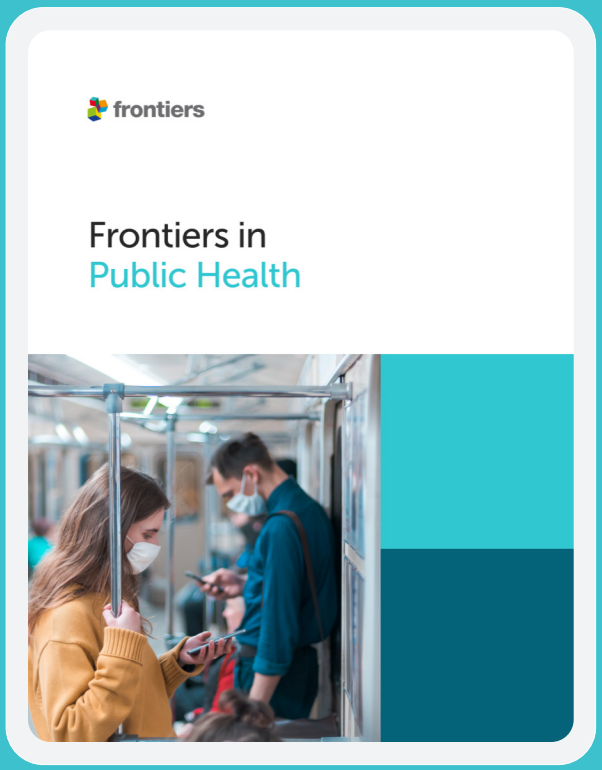

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