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Insurance density and the digital economic development: a China perspective

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ABSTRACT

The digital economy is an important starting point for China's high-quality economic development, and insurance density is a key variable for measuring the development of the insurance industry. Can increasing insurance density promote digital economic development? Based on China's provincial digital economic development index from 2013 to 2021, this study explores this question. The results show that a positive U-shaped nonlinear relationship between insurance density and digital economy, and there is an inflection point in insurance density. When insurance density is lower than the inflection point, an increase in insurance density will inhibit digital economic development; when it exceeds the inflection point, a further increase in insurance density will promote digital economic development. Furthermore, there is a positive U-shaped nonlinear relationship between insurance density and traditional technological innovation, which is conducive to digital economic development. As such, insurance density affects digital economic development through the transmission of traditional technological innovation. The findings have reference significance for developing countries to improve their insurance penetration rate and develop their digital economy to promote economic development.

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1. Introduction

Since the G20 Digital Economy Development and Cooperation Initiative was adopted at the G20 Summit in Hangzhou in 2016, many countries have prioritised digital economy. Digital economy can improve total factor productivity (Yoon, 2018), may solve the problem of weak economic growth (Gruber, 2019), plays a leading role in China's current economic development (Li & Ding, 2020), and is an important driver of economic growth in China (Tong & Zhang, 2020). Accordingly, the State Council of the People's Republic of China has issued the *14th Five-Year Plan for the Development of Digital Economy* to promote digital economic development. Meanwhile, insurance has become an integral part of the modern economic system

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(Song et al., 2019) and can promote economic growth through risk transfer and asset allocation (Haiss & Sümegi, 2008; Lee et al., 2016).

Accordingly, what is the relationship between insurance density and digital economy? Can increasing insurance density promote digital economic development? These questions relate to the influencing factors of digital economy, on which the extant literature has conducted much research. For example, digital economic development can be affected by technologies including information and communication technology (ICT) (Marshall et al., 2020; Tahir et al., 2018), blockchain, big data (Ma et al., 2019; Popkova & Sergi, 2020), population structure, education level (Marshall et al., 2020), regional differences (Mitrović, 2020), tax policies (Bacache-Beauvallet & Bloch, 2018), and industrial policies (Gruber, 2019). Meanwhile, banks' use of the Internet for financial innovation (Tahir et al., 2018) can promote the development of financial technology, which is conducive to digital economic development (Chen et al., 2022).

However, little research has explored the relationship between insurance density and digital economy. As the largest developing country, China actively promotes digital economic development, and its insurance density is continuously increasing. Economic growth is important for all countries worldwide, especially developing countries. Digital economy is a new driving force of economic growth, and increasing insurance density can promote economic growth. Based on China's practice, it is of great practical significance for all countries, especially developing countries, to clarify the relationship between insurance density and the digital economic development, so as to obtain policy enlightenment related to insurance density and digital economy. Therefore, this study uses Chinese provincial panel data and a theoretical analysis to assess the impact of insurance density on the digital economy and its mechanism.

This study's contribution is as follows. First, based on the impact of insurance on factors such as savings, consumption, and willingness to take risks, this study empirically assesses the relationship between insurance density and the digital economic development to enrich the literature related to the impact of insurance density on economy. Second, based on the nonlinear impact of insurance on traditional technological innovation and the promotion of traditional technological innovation on digital economy, this study empirically assesses how insurance density affects digital economy via traditional technological innovation, so as to enrich the literature on the influencing factors of digital economy. Third, China is the largest developing country, and its digital economy ranks second worldwide. Thus, the conclusions of this study have important reference significance for developing countries.

2. Hypotheses development

2.1. Analysis of the influence of insurance density on digital economy

Insurance density has a double effect on China's digital economic development. On one hand, increasing insurance density is inconducive to China's digital economic development. In the process of market-oriented reform, the uncertainty of China's macro-economy has increased, which has improved China's preventive savings motivation and increased its savings rate (Chamon & Prasad, 2010). This has resulted in high savings, which, in turn, supports high investment and high economic growth (Horioka & Wan, 2007). Insurance is an important part of the modern economic system and is the basic means of risk management (Song et al., 2019). Risk transfer helps to disperse the impact of macroeconomic uncertainty on Chinese people in the process of China's market-oriented reform (Haiss & Sümegi, 2008), reduce Chinese people's concerns about uncertainties (e.g. medical care, pensions, and unemployment), and effectively transfer and lower these uncertain risks to weaken Chinese people's preventive savings motivation (Yin & Yan, 2020; Zhang, 2018). Therefore, insurance can significantly reduce China's savings rate (Yin & Yan, 2020). Insurance density reflects both the degree of residents' insurance participation and the popularity of insurance in a region (Nan et al., 2020). The higher the insurance density, the deeper the degree of Chinese people's participation in insurance, and the lower the savings rate. The reduction of the savings rate is inconducive to China's digital economic development. The reasons are as follows. First, digital economic development requires enterprises' investment in tangible assets, such as ICT equipment; intangible assets based on digital technologies, such as artificial intelligence (AI), blockchain, big data, cloud computing, and the Internet of Things (IoT) (Chen et al., 2022); and human capital investment, such as digital talent. Thus, the reduction of the savings rate will be inconducive to enterprises' investment, which is inconducive to digital economic development. Second, stable macroeconomic growth can provide a good external environment for enterprises to conduct digital transformation, which is conducive to macro-level digital economic development. Overall, insurance reduces the savings rate, which is inconducive to the stable growth of China's macro-economy, which is inconducive to digital economic development.

On the other hand, increasing insurance density is conducive to China's digital economic development. The reasons are as follows. The first reason relates to the role of risk-taking. Since insurance has the function of risk transfer (Haiss & Sümegi, 2008), participating in insurance can effectively improve Chinese people's risk awareness (Nan et al., 2020) and willingness to take risks. Digital economic development is always accompanied by risk (Chen et al., 2022). Increasing insurance density will increase the degree of Chinese people's participation in insurance and improve their willingness to take risks. This will provide support for Chinese people to take the risks associated with both digital technological innovation and digital transformation innovation, thus promoting macro-level digital economic development.

The second reason relates to consumption promotion. Increasing insurance density and insurance popularity will create a social safety net; therefore, Chinese people will have more optimistic expectations for the future, which will stimulate increased immediate consumption expenditure (Nan et al., 2020). The uneven development of China's digital economy has originated from the consumption-oriented tertiary industry (Chen et al., 2020); for example, the vigorous development of two leading digital economy enterprises: Alibaba and Tencent. This means that increasing insurance density and promoting immediate consumption expenditure can provide strong market demand for digital economic development and thus stimulate its development.

The third reason relates to the driving role of specific insurance products. Liability insurance is mainly for senior management who are investigated for personal compensation liability due to alleged negligence or misconduct in the normal performance of their duties, which an insurance company will pay for (Hu et al., 2019). Digital economic development depends on the implementation of enterprises' digital economy-related innovation, which is always accompanied by risk (Chen et al., 2022). The increase in insurance density and Chinese people's awareness of insurance has popularised senior management's liability insurance and exempted the risk liability arising from the implementation of enterprises' digital economy related-innovation, which, in turn, has encouraged senior management to promote digital economy innovation, which is conducive to macro-level digital economic development.

In summary, insurance density both inhibits and promotes China's digital economic development. When insurance density reduces the savings rate, Chinese people spend part of their savings on immediate consumption expenditure (Nan et al., 2020) and the other part on buying stocks and corporate bonds (Zhang, 2018). However, few enterprises can list and issue corporate bond due to China's high conditions. Therefore, it is difficult for savings spent on stocks and corporate bonds to flow to small- and medium-sized enterprises (SMEs), which contribute to 60% of the gross domestic product (GDP), making it hard to promote China's digital economic development. Meanwhile, only part of the savings spent on immediate consumption expenditure can promote digital economic development. Accordingly, the reduction of both insurance density and the savings rate is inconducive to digital economic development. Therefore, inhibiting China's digital economic development of insurance density will play a dominant role in reducing the savings rate. While willingness to take risks is an important factor for Chinese people to implement digital economic innovation, it must have supportive resources, such as capital and digital talent. Therefore, based on the improvement of Chinese people's insurance willingness, insurance density has a relatively long-term role in promoting digital economic development. The promoting China's digital economic development of insurance density is small in the early process of reducing the savings rate, but its continuous improvement will gradually increase so that its promoting role will become dominant. A similar process exists for the popularisation of senior management's liability insurance. In the early stage, the increase in insurance density has a difficult role in promoting digital economic development. Yet with this increase, senior management's liability insurance will gradually become recognised, and the role of insurance density in promoting digital economic development will first become more apparent and then become dominant.

Overall, this study believes that the early stage of the gradual insurance density increase will have a dominant role in restraining digital economic development. The continuous increase in insurance density will have a dominant role in promoting digital economic development. Therefore, this study proposes the following hypothesis:

H1: There is a positive U-shaped nonlinear relationship between insurance density and digital economic development. There is an inflection point in insurance density. On both sides of the inflection point, insurance density will reduce and promote digital economic development.

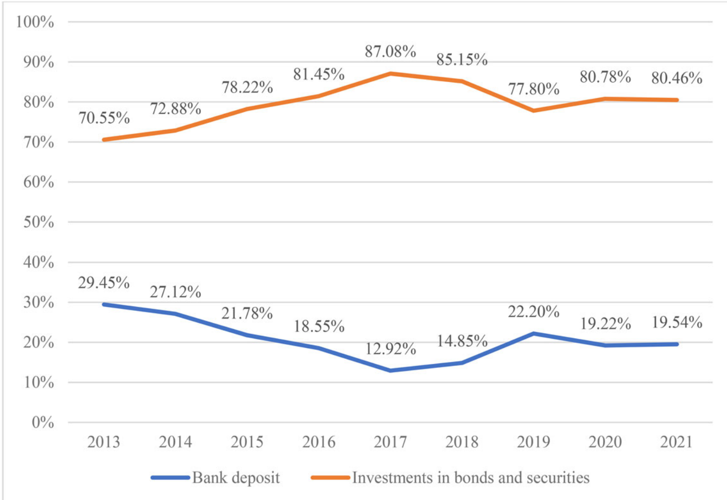

Figure 1. Capital utilisation of Chinese insurance companies from 2013 to 2021.
Source: China Banking and Insurance Regulatory Commission.

2.2. Traditional technological innovation mechanism

The above analysis shows that insurance density can reduce the savings rate, increase risk-taking, and promote specific insurance products. These effects impact traditional technological innovation; that is, technological innovation other than digital technological innovation (e.g. AI, blockchain, big data, cloud computing, and IoT). On one hand, increasing insurance density is inconducive to traditional technological innovation. Banks constitute the main body that absorbs Chinese savings, and bank savings deposits dominate Chinese savings (Zhang, 2018). China is a bank-led financial system, and bank loans are the most important financing choice for Chinese enterprises, accounting for the vast majority of their debt financing patterns (Li & Cao, 2009). Without financial support, such as bank loans, traditional technological innovation is difficult (Neff, 2003) because it plays an important role in such innovation (Kaplinsky, 2003). Meanwhile, insurance density reduces China's savings rate, which, in turn, reduces bank loans (i.e. the funding source for traditional technological innovation), rendering it inconducive for traditional technological innovation. Regarding insurance companies' use of funds, most of the premium income collected by insurance companies is invested in securities, such as bonds and stocks (Figure 1). However, China's high listing and bond issuance conditions make it difficult for insurance companies' investment in bonds, stocks, and other securities to flow to SMEs which are the main forces of traditional technological innovation. Therefore, insurance companies' use of funds cannot promote traditional technological innovation.

On the other hand, increasing insurance density is conducive to traditional technological innovation. Innovation is a process in which people propose new ideas to change products, services, and processes (Amabile et al., 2005) and is a high-risk activity (Sweetman et al., 2011). Therefore, traditional technological innovation has a long cycle and high risk (Ma & Li, 2019). Accordingly, traditional technological innovation requires the willingness to take risks. Increasing insurance density can enhance risk-taking, improve willingness to take risks, and thus promote traditional technological innovation. Senior management's liability insurance can also provide protection for executives to implement and promote traditional technological innovation. Therefore, based on the role of senior management's liability insurance, improving insurance density can promote traditional technological innovation. Moreover, SMEs constitute the main force of China's traditional technological innovation. Based on credit guarantee insurance, insurance companies share the risk of bank loans; realise the three wins of SMEs, banks, and insurance companies (Ding et al., 2021), and alleviate the financing constraints of SMEs, thus facilitating traditional technological innovation. Therefore, increasing insurance density has popularised credit guarantee insurance, eased SMEs' financing constraints, and improved the level of traditional technological innovation. Although the scale of traditional technological innovation enterprises is small, their products often have strong uniqueness and occupy an oligopoly market structure. Purchasing insurance products will enable enterprises to take radical actions, such as expanding production in the competition, to occupy a larger market share (Tan, 2016) and promote their implementation of traditional technological innovation. Accordingly, increasing insurance density is conducive to traditional technological innovation.

Traditional technological innovation is conducive to digital economic development. Digital economy includes two dimensions: digital industrialisation and industrial digitalisation (Chen et al., 2022). First, Digital industrialisation, referred to the gradual development and expansion of the ICT industry, is promoted through traditional technological innovation in the ICT industry. Moreover, the traditional technological innovation of other industries generates new demand for the ICT industry (thus stimulating its technological innovation), which promotes digital economic development.

Second, traditional technological innovation is conducive to industrial digitalisation. Traditional technological innovation refers to the increase in enterprises' innovation investment, the emergence of enterprises' new products and models, and the intensification of industry competition (Chen & Zhang, 2021). Enterprises will deeply integrate AI, blockchain, cloud computing, big data, and other technological innovations with their production and business activities and implement all-round digital transformation to enhance product competitiveness. To cope with the intensification of industrial competition brought about by traditional technological innovation, enterprises will actively implement digital transformation to promote industrial digitalisation and digital economic development.

Third, digital industrialisation and industrial digitalisation are simultaneously promoted through traditional technological innovation. Based on the forms of imitation innovation, induced innovation, and integrated innovation, traditional technological innovation has a demonstration effect. This can improve enterprises' level of risk-taking (Chen & Zhang, 2021) and provide risk-taking willingness, so as to implement digital industrialisation and industrial digitalisation innovation and promote digital economic development.

In summary, insurance density both inhibits and promotes traditional technological innovation. China has high savings, so it is relatively easy to increase the insurance density and decrease the savings rate. Therefore, insurance density has a leading role in inhibiting traditional technological innovation in the early stage. Conversely, in addition to the willingness to take risks, traditional technological innovation requires supportive resources, such as knowledge accumulation, innovative talent accumulation, and financial support. Improving insurance density and promoting traditional technological innovation based on the willingness to take risks is a long-term process. Similarly, there is a relatively long-term process for the popularisation of senior management's liability insurance, credit guarantee insurance, and insurance products for traditional technological innovation enterprises, as these require the continuous improvement of insurance density. Therefore, this study believes that in the early stage, increasing insurance density plays a dominant role in inhibiting traditional technological innovation. The continuous increase in insurance density plays a dominant role in promoting traditional technological innovation. This study believes that there is a positive U-shaped nonlinear relationship between insurance density and traditional technological innovation, and traditional technological innovation is conducive to digital economic development. Therefore, this study proposes the following hypothesis:

> **H2**: Insurance density affects traditional technological innovation with the positive U-shaped nonlinear relationship, therefore affects digital economic development.

3. Data, methods, and variables

3.1. Data

The Fifth Institute of Electronics of the Ministry of Industry and Information Technology and the Zero-One think-tank jointly released *the China Digital Economy Development Index Report* (2022), which calculated the provincial digital economic development index, at *2022 China Digital Economy Innovation and Development Conference*. Based on 40 original indicators (e.g. number of supercomputing centres and digital technology patent applications), the provincial digital economic development index comprehensively measures digital economic development level in 31 Chinese provinces (excluding Hong Kong, Macao, and Taiwan) from 2013 to 2021. The index is the only digital economic development measure officially released by China at present. Therefore, this study chooses the index as the proxy variable for the level of digital economic development to conduct an empirical test based on the provincial insurance density and the digital economic development index from 2013 to 2021. The data required to calculate the insurance density could be traced back to 2007. To maximise the sample size, this study conducts a mechanism test based on the 2007–2021 data. Other data are collected from the People's Bank of China, the National Bureau of Statistics, and the Wind Database, and the land area data are obtained from the Baidu Encyclopaedia. To eliminate the influence of outliers, this study winsorises the continuous variables by 1%.

3.2. Models

3.2.1. Model for H1

To test H1, this study refers to Chen et al. (2022) and designs the following two-way fixed effects (FE) model:

$$deco_{it} = \alpha_0 + \beta_1 * Ins_{it} + \beta_2 * Ins2_{it} + \eta * X + \alpha_i + \lambda_t + \varepsilon_{it} \quad (1)$$

where $deco_{it}$ is the digital economic development level of the i-th province in the t-th year, α_0 is the intercept term, α_i is the individual effect of the i-th province, λ_t is the year effect of the t-th year, and ε_{it} is a random error term. Ins_{it} is the dependent variable, denoting the insurance density of the i-th province in the i-th year, and β_1 is its coefficient. $Ins2_{it}$ is the quadratic term of Ins_{it}, and β_2 is its coefficient. If β_2 is significantly positive, insurance density and digital economy development have a positive U-shaped nonlinear relationship. If β_1 is significantly different from 0, the inflection point is not at the origin. X are the control variable (defined below).

3.2.2. Models for H2

To test H2, this study refers to Chen et al. (2022) and designs the following models:

$$deco_{it} = \alpha_0 + \beta_1 * Ins_{it} + \beta_2 * Ins2_{it} + \eta * X + \alpha_i + \lambda_t + \varepsilon_{it} \quad (2)$$

$$Inlev_{it} = \alpha_0 + \beta_1 * Ins_{it} + \beta_2 * Ins2_{it} + \eta * X + \alpha_i + \lambda_t + \varepsilon_{it} \quad (3)$$

$$deco_{it} = \alpha_0 + \beta_1 * Ins_{it} + \beta_2 * Ins2_{it} + \delta * Inlev_{it} + \eta * X + \alpha_i + \lambda_t + \varepsilon_{it} \quad (4)$$

In Equation (3), $Inlev_{it}$ is the intermediary variable (i.e. the level of traditional technological innovation). First, this study estimates Equation (2) without adding the intermediary variables. If the coefficient β_1 of insurance density Ins_{it} is significant, insurance density has a total effect on digital economy development, and a follow-up analysis is performed. Second, Equation (3) determines the impact of insurance density on the intermediary variables. Third, after adding the intermediary variables, this study estimates Equation (4). If the coefficient β_1 in Equation (3) and the coefficient δ in Equation (4) are significant, an intermediary effect exists. If the coefficient β_1 in Equation (4) is significant, then $Inlev_{it}$ is part of the intermediary effect. Otherwise, $Inlev_{it}$ plays a full intermediary role. Fourth, if there is only one significant between β_1 in Equation (3) and δ in Equation (4), this study tests for the intermediary effect using Sobel's test.

X in Equations (2) and (4) denotes the control variable, which is the same as that is Equation (1). X in Equation (3) is the control variable, as explained below.

3.2.3. Variables

Based on the literature, this study's dependent, intermediary, and control variables are shown in Table 1.

3.2.4. Dependent variables

The dependent variable is the level of digital economic development (*deco*). This study divides the provincial digital economic development index of 31 provinces between 2013 and 2021 by 1000 to obtain *deco* as the proxy variable for the level of digital economic development. By taking the natural logarithm of this index, *rdeco* is obtained for the robustness check.

Table 1. Variable definitions.

	Variable name	Variable symbol	Variable definition	Reference
Independent variables	Level of digital economic development	*deco*	*deco2013* / 1000, *deco2013* is China's provincial digital economy index released by the Fifth Research Institute of the Ministry of industry and Information Technology	New in this article
		rdeco	Ln(deco*2013*)	
Dependent variables	Insurance density	*Ins*	Ln(*dens*), *dens* is the per capita premium income and its unit is yuan / 10000 per person	Wang and Wu (2019)
Control variables	Population density	*popdens*	Ln(permanent population / land area)	Arcand et al. (2015), Chen et al. (2022)
	Population growth rate	*gpop*	New population / population of last year * 100	
	Urbanisation rate	*rcity*	Urban population / permanent population of each province * 100	
	Fiscal decentralisation	*fiscd*	Fiscal revenue / national fiscal revenue * 100	
	Financial decentralisation	*fd*	Loan balance / national loan balance * 100	
		fd2	Quadratic term of *fd*	
	Industrial structure level	*ind_str*	1 * proportion of primary industry +2* proportion of secondary industry +3* proportion of tertiary industry	
	Economic development level	*prgdp*	Real GDP per capita (2007 as base period)	
	Government intervention	*gov*	Fiscal expenditure / GDP * 100	
Intermediary variables	Traditional technological innovation level	*inlev*	(Number of patent applications of various types minus number of digital technology patent applications) / permanent population	Zhang (2019)
		rinlev	(Number of discover patent applications minus number of digital technology patent applications) / permanent population (robustness check)	
New control variables for mechanism test	Fiscal investment in technology	*scspd*	Fiscal technology expenditure / fiscal expenditure	Li and Yang (2019)
	Foreign direct investment	*pfdi*	Ln(actual foreign direct investment) (2007 is the base period)	
	Population size	*pop*	Ln(permanent population)	
	Financial development	*finance*	(Loan balance) / GDP	

Source: China Banking and Insurance Regulatory Commission.

3.2.5. Independent variables

The independent variable is insurance density (*Ins*). This study refers to Wang and Wu (2019), in which the per capita premium income is calculated with 2007 as the base period and is taken as the natural logarithm to express *Ins*. The quadratic term *Ins2* of *Ins* is added to test the nonlinear relationship between insurance density and digital economy.

3.2.6. Intermediary variables

The intermediary variable is the level of traditional technological innovation (*inlev*). The traditional technological innovation herein refers to other technological innovations than AI, blockchain, cloud computing, big data, and IoT (collectively referred to as 'digital technology'). Therefore, this study refers to Zhang (2019), the number of patent applications of various types minus the number of digital technology patent applications is divided by the permanent population to obtain *inlev* as the proxy variable of the level of traditional technological innovation. Moreover, digital technology innovation is usually an invention rather than a utility model and appearance design. Therefore, the number of patent applications for various types of inventions minus the number of patent applications for digital technology is divided by the resident population to get *rinlev*, and a robustness check is conducted.

3.2.7. Control variables

For Equation (1), this study refers to the literature (e.g. Arcand et al., 2015; Chen et al., 2022) to design control variables, such as population density, population growth rate, urbanisation rate, fiscal decentralisation, financial decentralisation and its quadratic term, industrial structure level, economic development level, and government intervention.

For Equation (3), this study refers to the literature (e.g. Li & Yang, 2019) to design control variables, such as economic development level, foreign direct investment, financial science and technology investment, population size, population growth rate, and financial development.

4. Results

4.1. Descriptive statistics

Table 2 shows the descriptive statistics of the main variables. First, the average of *deco* is 0.1023, the maximum is 0.8325, and the minimum is 0.0159, which is consistent with China's unbalanced development at the provincial level. Second, the average of *Ins* is 7.0110, the maximum is 8.9401, and the minimum is 4.5472, which is also consistent with the basic national conditions of unbalanced development. Third, since the digital economic development index only contains 9 years, there are only 279 observations. Other data cover the 2007–2021 period, totalling 15 years, with 465 observations.

Table 2. Descriptive statistics of variables.

Variables	Obs.	Mean	Std. Dev.	Min.	Max.
deco	279	0.1023	0.1030	0.0159	0.8325
Ins(log)	465	7.0110	0.7842	4.5472	8.9401
inlev(100 pieces / 10000 people)	465	0.1657	0.2018	0.0064	0.9229
popdens(log)	465	5.3110	1.4915	0.9228	8.2818
gpop(%)	465	4.8345	3.0937	−3.3800	11.1700
rcity(%)	465	55.9204	14.2561	22.8381	94.1386
fiscd(%)	465	1.6629	1.3402	0.0527	6.5560
fd(%)	465	3.0720	2.4329	0.0746	10.6052
ind_str(%)	465	2.3593	0.1437	2.1265	3.6275
prgdp(10000 yuan per person)	465	4.2285	2.4567	0.7666	14.5192
gov(%)	465	26.4384	19.0479	8.7435	137.9153
pfdi(%)	465	8.1250	1.6267	3.4986	12.3190
scspd(%)	465	1.9938	1.4212	0.3029	7.2018
pop(%)	465	8.1152	0.8461	5.7333	9.4043
finance(%)	465	1.2960	0.4629	0.5329	3.0829

Source: China Banking and Insurance Regulatory Commission.

4.1.1. Data stability test

The main variables of Equation (1) are *deco* and *Ins*. Before regression, this study selects LLC, IPS, ADF-Fisher, and Fisher-PP to conduct a panel unit root test on the two main variables. Table 3 shows the results.

Table 3 shows that *deco* and *Ins* are first-order stationary. This study uses the Kao test method to test the cointegration of the two variables. The results show that the ADF statistic is 4.9879 and $p < 0.0001$, thus rejecting the original hypothesis that there is no cointegration relationship between these variables. A regression can be conducted.

4.1.2. Benchmark regression

This study refers to Chen et al. (2022) to estimate Equation (1) using FE via the method of gradually increasing the control variables. Table 4 shows the estimated results.

In columns (1)–(4) of Table 4, the coefficients of the independent variable quadratic term *Ins2* are significantly positive at the 1% level, and the coefficients of the primary term *ins* are significantly negative at the 1% level. That is, with an increase in insurance density, the level of digital economic development first shows a downward trend and then an upward trend. Therefore, H1 is supported.

This conclusion is consistent with the theoretical analysis in section 2.1. The risk transfer function of insurance (Haiss & Sümegi, 2008) can disperse the impact of macroeconomic uncertainty on Chinese people in the process of China's market-oriented reform, thereby weakening their preventive savings motivation (Yin & Yan, 2020; Zhang, 2018). Therefore, the higher the insurance density, the lower the savings rate, thus digital economic development will be inhibited. However, based on the risk transfer function of insurance (Haiss & Sümegi, 2008), participating in insurance can effectively improve Chinese people's risk awareness (Nan et al., 2020) and their willingness to take risks, leading to optimistic expectations for the future and stimulating an increase in their immediate consumption expenditure (Nan et al., 2020). Senior management's liability insurance is conducive to relieving executives of their responsibilities that arise from the risks associated with digital economy innovation.

Table 3. Panel unit root test of main variables.

Variables	LLC	IPS	ADF-Fisher	Fisher-PP	Conclusion
deco	1.1491	1.2124	−1.3297	2.0035**	Non-stationary
D(deco)	−8.3703***	−5.7886***	8.1063***	57.1392***	Stationary
Ins	−4.0959***	−0.2597	−3.8251	−1.3998	Non-stationary
D(Ins)	−4.4090***	−6.9803***	4.3569***	18.1214***	Stationary

Note: *** represents < 0.01%; ** represents $p < 0.05$; and the numbers represent statistics and adjusted t-statistics under the LLC test, Z-t-tilde-bar statistics under the IPS test, and the modified inv. chi-squared Pm statistics under ADF-Fisher and Fisher-PP test.
Source: China Banking and Insurance Regulatory Commission.

Table 4. FE regression results of Equation (1).

Variables	(1) *deco*	(2) *deco*	(3) *deco*	(4) *deco*
Ins	−1.0418***	−0.8571***	−1.2652***	−1.1104***
	(0.1340)	(0.1539)	(0.1678)	(0.2624)
Ins2	0.0573***	0.0490***	0.0764***	0.0640***
	(0.0076)	(0.0102)	(0.0109)	(0.0170)
popdens		0.4750***	0.3893**	0.5134***
		(0.1745)	(0.1585)	(0.1796)
gpop		0.0036	0.0062**	0.0074**
		(0.0029)	(0.0029)	(0.0035)
rcity		−0.0069*	−0.0075**	−0.0078**
		(0.0037)	(0.0035)	(0.0037)
fiscd			−0.0076	−0.0191
			(0.0249)	(0.0266)
fd			0.2241***	0.2314***
			(0.0548)	(0.0606)
fd2			−0.0163***	−0.0165***
			(0.0061)	(0.0062)
ind_str				0.0001
				(0.0002)
prgdp				0.0110
				(0.0164)
gov				0.0032***
				(0.0012)
Constant	4.4613***	1.4296	2.9667***	1.6884*
	(0.5645)	(0.9775)	(0.8408)	(0.8919)
Individual FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES
Observations	279	279	279	279
N	31	31	31	31
Adjusted R-squared	0.6213	0.6472	0.7039	0.7081

Note: ***, **, and * represent the significant levels of 1%, 5%, and 10%, respectively. The double clustering robust standard errors are shown in brackets.
Source: China Banking and Insurance Regulatory Commission.

Therefore, an increase in insurance density can promote digital economic development. In the process of increasing insurance density, inhibition plays a leading role. Then, with the continuous increase in insurance density, promotion plays a leading role. Therefore, there is a positive and U-shaped nonlinear relationship between insurance density and the level of digital economic development.

According to the results in column (4), the inflection point of insurance density is 8.6750. When it is lower than 8.6750, increasing insurance density will inhibit digital economic development. When it exceeds 8.6750, increasing insurance density will promote digital economic development. Table 2 shows that the average of insurance density is 7.0110, which is lower than the inflection point. The maximum is 0.8325, which exceeds the inflection point. Therefore, from a national perspective, insurance density restrains digital economic development, while some provinces promote digital economic development.

4.1.3. Robustness check

The double cluster adjustment of standard errors in individual and year can overcome the influence of autocorrelation and heteroscedasticity on statistical inference (Chen et al., 2022). Columns (1)–(4) of Table 4 adopt double clustering standard errors to increase the reliability of the estimation results. Columns (1)–(4) of Table 4 show that the coefficients of the independent variables are significant at the 1% level, which is also a robustness check. This study conducts further robustness checks through endogenous treatment and changing the dependent variables and adding control variables.

4.1.4. Endogeneity problems

Column (4) of Table 4 shows that increasing insurance density will affect digital economic development. The integration of insurance and AI, blockchain, cloud computing, big data, and other technologies has resulted in insurance technology, which has enabled more enterprises to flow into the insurance ecosystem (Wang & Wu, 2019), thereby promoting the development and improvement of insurance density. The deep integration of these technologies with economy has produced a digital economy. The development of digital economy may stimulate the development of AI, blockchain, cloud computing, big data, and other technologies to promote the development and improvement of insurance density. Thus, *Ins* is a suspected endogenous variable.

Here, this study deals with endogeneity based on the instrumental variable (IV) method. First, it follows Chen et al. (2022), in which the natural logarithm of the mean of insurance density in the same year in other provinces is taken to obtain *ivIns* and its square term *ivIns2* as the IV, and uses *weakiv* to test the instrumental variable . The results show that AR $=$ 17.43 and $p < 0.01$, thus the weak instrumental variable hypothesis is rejected; meanwhile, Wald $=$ 35.16 and $p < 0.01$, thus *Ins* and *Ins2* are endogenous. Accordingly, this study uses the IV method to re-estimate Equation (1). Column (1) of Table 5 shows the results. To alleviate the endogeneity of the control variables, this study lags all control variables by one period to re-estimate Equation (1). Column (2) of Table 5 shows the results.

In columns (1)–(2) of Table 5, the coefficients of the quadratic term of the independent variables are significantly positive at the 1% level. Therefore, H1 is tenable and robust when endogeneity is excluded.

4.1.5. Other robustness checks

4.1.5.1. Replacing the dependent variables. This study replaces the dependent variable with *rdeco* and re-estimates Equation (1) with the FE. Column (3) of Table 5 shows the results, and H1 is tenable and robust.

Table 5. Robustness check of Equation (1).

Variables	(1) *deco*	(2) *deco*	(3) *rdeco*	(4) *deco*
Ins	−2.2996***	−1.6402***	−3.4264***	−0.7877***
	(0.5216)	(0.4976)	(0.8513)	(0.1851)
Ins2	0.1346***	0.0952***	0.1838***	0.0469***
	(0.0335)	(0.0309)	(0.0560)	(0.0124)
inlev				0.5457***
				(0.1028)
Individual FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES
Control	YES	YES	YES	YES
Observations	279	279	279	279
N	31	31	31	31
Adjusted R-squared	0.8116	0.8258	0.9386	0.7887

Note: Robust standard errors are shown in brackets.
Source: China Banking and Insurance Regulatory Commission.

4.1.5.2. Adding control variables. The theoretical analysis in section 2.1 shows that traditional technological innovation is conducive to digital economic development. This study takes *inlev* as an intermediary variable; it is not listed as a control variable. Under the control of *inlev*, FE is used to re-estimate Equation (1). Column (4) of Table 5 shows the results, and H1 is tenable and robust.

5. Mechanism tests

The the theoretical analysis in section 2.2 shows that insurance density affects digital economic development via traditional technological innovation. The conduction mechanism is tested based on Equations (2)–(4).

5.1. Data stability test

The main variables in Equations (3) and (4) are *deco*, *Ins*, and *inlev*. Table 3 tests the stationarity of *deco* and *Ins*. LLC, IPS, ADF-Fisher, and Fisher-PP are selected to perform a panel unit root test on *inlev*, and the results are shown in Table 6.

Table 6 shows that *inlev* is first-order stationary, while Table 3 shows that *deco* and *Ins* are first-order stationary. Here, this study uses the Kao test method to conduct a cointegration test on *inlev* and *Ins*. The results show that the ADF statistic is 3.9864 and $p < 0.0001$, rejecting the original assumption that there is no cointegration relationship between the variables. There is a cointegration relationship between *inlev* and *Ins*, and Equation (3) can be used for regression estimation. This study uses the Kao test method to conduct a cointegration test on *deco*, *inlev*, and *Ins*. The results show that the ADF statistic is 4.2708 and $p < 0.0001$, rejecting the original assumption that there is no cointegration relationship between the variables. There is a cointegration relationship between *deco*, *inlev,* and *Ins*, and Equation (4) can be used for regression estimation.

Table 6. Panel unit root test of main variables.

Variables	LLC	IPS	ADF-Fisher	Fisher-PP	Conclusion
inlev	11.8480	19.2624	−5.2601	−5.3546	Non-stationary
D(inlev)	−2.2459**	−4.7099***	3.6427***	18.2878***	Stationary

Source: China Banking and Insurance Regulatory Commission.

5.2. Empirical test

This study takes *inlev* as the intermediary variable and uses FE to estimate Equations (2)–(4). Panel A of Table 7 shows the results. The coefficient of *Ins* in path A is significant at the 1% level, indicating that a total effect exists. The coefficient of *Ins* in path B is significant at the 1% level. The coefficient of *inlev* in path C is significant at 1% level, indicating the existence of an intermediary effect. According to paths B and C, there is a positive U-shaped nonlinear relationship between insurance density and traditional technological innovation, which affects digital economic development. Therefore, H2 is tenable.

This study replaces the dependent variable with *rdeco*, takes *inlev* as the intermediary variable, and uses FE to estimate Equations (2)–(4). Panel B of Table 7 shows the results. This study then takes *deco* as the dependent variable, *rinlev* as the intermediary variable, and uses FE to estimate Equations (2)–(4). Panel C of Table 7 shows the results. Finally, this study unifies the time interval as 2013 – 2021 and uses FE to estimate Equations (2)–(4). Panel D of Table 7 shows the results. Panels B, C, and D show that H2 is tenable and robust.

When estimating Equation (3), insurance density will affect traditional technological innovation. Traditional technological innovation is usually protected in the form of patents, yet the cost of patent protection is high, so the role of patent protection in promoting traditional technological innovation is often constrained. As such, insurance companies have developed patent enforcement insurance (Lanjouw & Schankerman, 2004). Traditional technological innovation also affects the development of insurance products, thus affecting insurance density. Therefore, there will be a two-way causal relationship between insurance density and traditional technological innovation, thus making insurance density(*Ins*) endogenous. Moreover, when estimating Equation (4), traditional technological innovation will promote digital economic development. Conversely, digital economy compresses the spatiotemporal distance; this is conducive to knowledge dissemination and can thus promote traditional technological innovation. As such, a two-way causal relationship will also form between digital economy and traditional technological innovation, thus *inlev* is endogenous. Using *ivIns* and its quadratic term *ivIns2* as instrumental variables, this study uses the IV method to re-estimate Equations (2) and (3). Columns (1)–(2) of panel E in Table 7 show the results. This study refers to Chen et al. (2022) and takes the mean of *inlev* of the other provinces in the same year as *ivInlev*, together with *ivIns* and *ivIns2,* and uses the IV method to re-estimate Equation (4). Column (3) of panel E in Table 7 shows the results, and H2 is tenable and robust when endogeneity is excluded.

Table 7. Estimated results of mechanism test.

Panel A			
	Path A	Path B	Path C
Variables	*deco*	*inlev*	*deco*
Ins	−1.1104***	−0.4759***	−0.7877***
	(0.2624)	(0.1128)	(0.1851)
Ins2	0.0640***	0.0254***	0.0469***
	(0.0170)	(0.0078)	(0.0124)
inlev			0.5457***
			(0.1028)
Individual FE	YES	YES	YES
Year FE	YES	YES	YES
Control	YES	YES	YES
Observations	279	465	279
N	31	31	31
Adjusted R-squared	0.7081	0.8390	0.7887

Panel B			
	Path A	Path B	Path C
Variables	*deco*	*inlev*	*deco*
Ins	−3.4264***	−0.4759***	−3.0512***
	(0.8513)	(0.1128)	(0.8504)
Ins2	0.1838***	0.0254***	0.1639***
	(0.0560)	(0.0078)	(0.0561)
inlev			0.6345***
			(0.1864)
Individual FE	YES	YES	YES
Year FE	YES	YES	YES
Control	YES	YES	YES
Observations	279	465	279
N	31	31	31
Adjusted R-squared	0.9386	0.8390	0.9409

Panel C			
	Path A	Path B	Path C
Variables	*deco*	*rinlev*	*deco*
Ins	−1.1104***	−0.1530***	−1.0392***
	(0.2624)	(0.0476)	(0.2394)
Ins2	0.0640***	0.0070**	0.0609***
	(0.0170)	(0.0034)	(0.0158)
rinlev			0.6424***
			(0.1899)
Individual FE	YES	YES	YES
Year FE	YES	YES	YES
Control	YES	YES	YES
Observations	279	465	279
N	31	31	31
Adjusted R-squared	0.7081	0.7080	0.7266

Panel D			
	Path A	Path B	Path C
Variables	*deco*	*inlev*	*deco*
Ins	−1.1104***	−0.8936***	−0.7877***
	(0.2624)	(0.2955)	(0.1851)
Ins2	0.0640***	0.0494***	0.0469***
	(0.0170)	(0.0187)	(0.0124)
inlev			0.5457***
			(0.1028)

(*continued*)

Table 7. Continued.

Panel D			
Variables	Path A *deco*	Path B *inlev*	Path C *deco*
Individual FE	YES	YES	YES
Year FE	YES	YES	YES
Control	YES	YES	YES
Observations	279	279	279
N	31	31	31
Adjusted R-squared	0.7081	0.7888	0.7887

Panel E			
Variables	Path A *deco*	Path B *inlev*	Path C *deco*
Ins	−2.2996***	−1.1135***	−1.9161***
	(0.5216)	(0.2487)	(0.5198)
Ins2	0.1346***	0.0497***	0.1149***
	(0.0335)	(0.0147)	(0.0331)
inlev			0.5600***
			(0.0865)
Individual FE	YES	YES	YES
Year FE	YES	YES	YES
Control	YES	YES	YES
Observations	279	465	279
N	31	31	31
Adjusted R-squared	0.8116	0.9154	0.8596

Note: For Equation (3), this study uses *weakiv* to test the instrumental variables. The results show that AR = 20.53 and $p < .01$, thus rejecting the hypothesis that *ivIns* and *ivIns2* are weak instrumental variables; meanwhile, Wald = 20.50 and $p < .01$, thus *Ins* and *Ins2* are endogenous. For Equation (4), this study uses *weakiv* to test the instrumental variables. The results show that AR = 26.50 and $p < .01$, thus rejecting the hypothesis that *ivIns*, *ivIns2,* and *ivinlev* are weak instrumental variables; meanwhile, Wald = 89.99 and $p < .01$, thus *Ins*, *Ins2,* and *inlev* are endogenous.
Source: China Banking and Insurance Regulatory Commission.

6. Conclusion and insights

As an important part of the modern financial system, insurance can reduce the cost of innovation failure by transferring risk, thereby promoting innovation. The deep integration of economy with technological innovation achievements in AI, blockchain, cloud computing, and big data has resulted in a digital economy. Digital economy is a new driving force and an indispensable starting point for high-quality economic development in China. However, digital economic development is inseparable from the support of insurance. Insurance density reflects the popularity of the insurance industry and is a key variable for measuring the insurance industry's development. Can increasing insurance density promote digital economic development? Under the context that all countries strive to develop their digital economy and digital economy is becoming a new driving force of economic growth, research on this issue has great reference significance worldwide, especially for developing countries, to achieve economic growth.

Therefore, based on a theoretical analysis of balanced panel data of 31 Chinese provinces from 2007 to 2021, this study uses an individual and year two-way FE model to study the impact of insurance density on digital economic development.

The results show that first, there is a positive U-shaped nonlinear relationship between insurance density and digital economic development: with an increase in insurance density, the digital economic development level first decreases and then increases. The inflection point of insurance density is 8.6750. When it is lower than 8.6750, an increase in insurance density will inhibit digital economic development. When it exceeds 8.6750, a further increase in insurance density will promote digital economic development. Second, there is a positive U-shaped nonlinear relationship between insurance density and the traditional technological innovation level. Insurance density also affects digital economic development through the transmission of traditional technological innovation.

Based on the conclusions herein, this study proposes the following suggestions. First, the positive U-shaped relationship between insurance density and digital economic development means that countries worldwide, especially developing countries, should implement relevant mechanisms when using the role of insurance to promote digital economic development. For example, by actively developing insurance technology, accelerating the popularisation of insurance products, and continuously improving insurance density with the aid of digital technologies (e.g. AI and big data), so as to cross the inflection point and enter the stage of promoting digital economic development as soon as possible. Second, the positive U-shaped nonlinear relationship between insurance density and traditional technological innovation is conducive to economic growth. Therefore, countries worldwide, especially developing countries, should pay attention to the negative impact on traditional technological innovation in the process of increasing insurance density when encouraging their insurance companies to develop insurance products that promote traditional technological innovation. This will avoid excessive loss of savings, which is detrimental to traditional technological innovation. Third, traditional technological innovation is conducive to digital economic development. Digital technology innovation, such as AI and big data, is the technical driving factor of digital economy and is conducive to its development. Therefore, countries worldwide, especially developing countries, should pay simultaneous attention to traditional technological innovation and digital technological innovation as these cannot be neglected.

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