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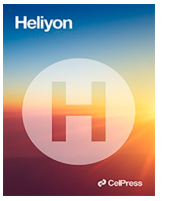

Digital financial inclusion and quality of economic growth

Wenzhi Xi [a], Yingdong Wang [b,*]

[a] School of Statistics and Mathematics, Zhongnan University of Economics and Law, Wuhan, 430073, China
[b] School of Finance, Zhongnan University of Economics and Law, Wuhan, 430073, China

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ABSTRACT

Recently, digital financial inclusion has experienced rapid growth, introducing transformative changes to the finance industry. Its attributes of low cost, extensive coverage, and efficient cross-temporal and spatial information dissemination have had a significant impact on both economic growth and social development. This study, using China's provincial panel data, measures the quality of economic growth based on technological innovation, coordinated development, environmental protection, opening to the outside world, and people's livelihood. It verifies the impact of digital financial inclusion on the quality of economic growth by utilizing the panel fixed effect model, mediation effect model, panel threshold model, and spatial Durbin model. Digital financial inclusion has a positive impact on the quality of economic growth, particularly in the eastern region and regions with high marketization. It can effectively promote the quality of economic growth by stimulating entrepreneurial vitality, and has had a positive and increasing non-linear effect on the quality of economic growth over the past few years. Moreover, digital financial inclusion can promote the quality of economic growth in neighboring regions. Therefore, the quality of economic growth can be significantly improved by expanding the coverage breadth and usage depth of digital financial inclusion.

1. Introduction

Recently, the Organization for Economic Cooperation and Development (OECD) indicated the untapped potential of the digital economy and the far-reaching implications of digital transformation for economic growth and social development. Especially, digital financial inclusion can promote innovation in the finance industry and meet the capital needs of the long-tail market, thereby improving the quality of economic growth [1–3]. Compared with traditional finance, digital financial inclusion emphasizes accurate risk control and effective information exchange using advanced tools and technologies such as the Internet, big data, and cloud computing, so that all social groups can enjoy equal, convenient, efficient, and affordable financial products and services [4,5]. This will produce historical changes in the finance industry and lead to greater economic development [6,7].

Digital financial inclusion encompasses a variety of financial services, such as mobile payment, online loan, online insurance, online fund, etc. On the one hand, it has expanded the coverage of financial services via the Internet and established a robust financial system, especially in underdeveloped regions with scarce financial resources [8]. On the other hand, it identifies customer information through big data, reduces the potential credit discrimination of traditional financial institutions against low-income groups, and improves the risk control ability of the finance industry [9]. Therefore, digital financial inclusion can provide more convenient and

* Corresponding author. School of Finance, Zhongnan University of Economics and Law, 182# Nanhu Avenue, Wuhan, 430073, Hubei, China.
E-mail addresses: xiwenzhi1997@gmail.com (W. Xi), yingdongwang@126.com (Y. Wang).

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effective financial services for all strata and groups of society. This is conducive to improving the efficiency of financial services for the real economy and sharing the fruits of economic development for all.

The advancement of digital financial inclusion holds immense potential for facilitating the provision of efficient, affordable, convenient, and accessible financial products and services to small and medium-sized enterprises and individuals with limited income. This advancement has the potential to improve the access to financial services in underdeveloped regions, while improving the efficacy of financial services for the real economy. Ultimately, these developments significantly foster high-quality economic development. Clarifying the mechanism of digital financial inclusion promoting the quality of economic growth is necessary to understand the vigorous development of digital financial inclusion, deepen the reform of the financial supply side, and accelerate economic transformation. It has considerable theoretical and practical significance for promoting digital financial inclusion and improving the quality of economic growth.

The objective of our study is to explore how digital financial inclusion affects the quality of economic growth? If the effect is confirmed, what is the underlying mechanism? What are the external conditions for the effect of digital financial inclusion on the quality of economic growth? What is the trend of the effect of digital financial inclusion on the quality of economic growth? Will the impact of digital financial inclusion on the quality of local economic growth have a radiation effect on the quality of economic growth in nearby areas? Although information technologies such as the Internet have made significant contributions to the society, and digital financial inclusion has gradually become a crucial part of the national economy, very little empirical research has been conducted to accurately assess the impact of digital financial inclusion on the quality of economic growth. Our study helps clarify the intrinsic mechanism and external conditions required for digital financial inclusion to affect the quality of economic growth. In this manner, this study provides valuable policy references regarding how to unleash the power of digital financial inclusion to drive the quality of economic growth. First, we identify the causal relationship and underlying mechanism between digital financial inclusion and the quality of economic growth. Second, we analyze the heterogeneity of digital financial inclusion on the quality of economic growth from the perspective of geographical location and marketization degree. Third, we discuss the non-linear and spatial spillover effects between them. In general, our research can further clarify the mechanisms of digital financial inclusion to promote the quality of economic growth. It has immense theoretical and practical significance for promoting the development of digital financial inclusion and improving the quality of economic growth.

Compared with the existing research, our study makes three significant contributions. First, previous studies have mainly discussed the impact of digital financial inclusion on financial efficiency [10], enterprise innovation [11], consumption structure [12,13], and sustainable development [14]. However, research on the impact of digital financial inclusion on the quality of economic growth is relatively scarce. We use the panel data of 30 provinces in China from 2011 to 2017 to explore the impact of digital financial inclusion on the quality of economic growth and its internal mechanism. We find that digital financial inclusion improves the quality of economic growth by stimulating entrepreneurial vitality, and this positive effect is more pronounced in the eastern as well as more market-oriented regions. Thus, our empirical evidence enriches the emerging literature on digital financial inclusion and the quality of economic growth.

Second, our study provides a feasible and comprehensive method for measuring the quality of economic growth. We construct an index system of economic growth quality from the five dimensions, and reasonably measure the quality of economic growth by combining the subjective weighting and the entropy weight method. Many previous studies predominantly focus on economic indicators when assessing the quality of economic growth, often overlooking crucial dimensions such as social, cultural, and environmental factors [15–17]. Our study aims to address this limitation by developing the index system that incorporates five dimensions, allowing for a more comprehensive and well-rounded measurement of the quality of economic growth. By incorporating these additional dimensions, our approach provides a more comprehensive and reasonable assessment of the multifaceted nature of economic growth quality.

Third, our research has significant policy implications for guiding the sustainable and well-regulated advancement of digital financial inclusion and fostering high-quality economic development. We find that digital financial inclusion has a significant and continuous positive impact on the quality of economic growth. Additionally, it has a positive effect on the quality of economic growth in neighboring regions. Therefore, government departments should guide the society to increase investment in information technology, particularly by expediting the commercialization of 5G networks, establishing comprehensive big data models, and leveraging artificial intelligence applications. These measures can effectively promote the development of digital financial inclusion, and thereby, contribute to more substantial endeavors toward high-quality economic development. Additionally, government departments should endeavor to coordinate the implementation of new infrastructure projects across various regions, thus maximizing the spatial spillover effect of digital financial inclusion on the quality of economic growth.

The rest of the article is organized as follows. Section 2 reviews the related literature and develops our main hypothesis. Section 3 illustrates the measurement of the quality of economic growth, and Section 4 discusses the data and models. Section 5 presents empirical results and discussions between digital financial inclusion and the quality of economic growth, while Section 6 reports the conclusions and implications.

2. Literature review

2.1. Digital financial inclusion

In recent years, the market scale of digital financial inclusion has continued to expand. Additionally, significant innovation has occurred regarding the types of products and services, showing a diversified, customized, and standardized financial development

pattern. Digital financial inclusion can be defined as achieving the goal of financial inclusion by vigorously developing digital finance to reduce the cost of financial services and expand the coverage of financial customers [18]. Das and Christie (2019) indicated that disruptive technology is the power source of digital financial inclusion [5]. Khera et al. (2022) found that the large-scale application of advanced technology in the finance industry and the popularization of digital financial services are the key driving forces of financial inclusion [19].

Many studies have investigated the inclusiveness, innovation, and risk control of digital financial inclusion. From the perspective of inclusiveness, Ren et al. (2018) argued that digital financial inclusion can effectively alleviate financial exclusion in society [20]. He and Li (2020) identified that online social interaction promotes the participation of rural households in digital financial inclusion, thus increasing the depth and breadth of digital financial inclusion [21]. From the perspective of innovation, Buchak et al. (2018) believed that financial technology (fintech) has filled the gaps in the traditional finance industry and energized financial markets [22]. Boot et al. (2021) suggested that the rapid popularization of digital financial inclusion may reconstruct the business model of traditional banks horizontally and vertically [7]. Li et al. (2023) opined that digital financial inclusion can address capital misallocation and improve financial efficiency, as well as promote green innovation of enterprises by mitigating the financing challenges associated with green projects [23]. Yang et al. (2022) confirmed that digital financial inclusion has a positive impact on enterprise innovation, creating opportunities for the implementation of enterprise innovation projects [18]. Hence, digital financial inclusion can induce historic changes to the finance industry and other industries by facilitating the adoption of novel technologies within the financial landscape [6].

From the perspective of risk control, Ozili (2018) indicated the prevalence of data security vulnerabilities in digital finance and the imperfection of the regulatory system of digital finance [4]. Yue et al. (2022) found that digital finance increases the risk of households falling into debt traps while achieving financial inclusion [24]. Yao et al. (2020) also confirmed that the fintech industry has high risks and is affected by both past developments and internal macroeconomic conditions [25]. However, Cheng and Qu (2020) employed the web crawler technology and word frequency analysis to construct and measure the bank fintech index, finding that bank fintech significantly reduces the credit risk of Chinese commercial banks [26]. Zhang et al. (2020) indicated that fintech can mitigate the pre-risk of credit activities and has no significant impact on post-loan risks related to credit activities [27]. Li et al. (2022) confirmed that bank fintech can improve operating income and capital adequacy ratio, optimize business performance, and improve risk control ability to reduce banks' risk-taking [28]. Generally, although digital financial inclusion compensates for the shortcomings of traditional finance, it also creates new financial risks such as transaction fraud, customer data leakage, and insufficient investor protection.

2.2. Quality of economic growth

Existing studies have mostly focused on the pace of economic growth based on the growth rate of the gross domestic product (GDP) [29,30], and discussed the impact of inflation [31], foreign trade [32], environmental changes [33–35], factor mobility [36], and happiness inequality [37] on economic growth. In the context of improved levels of economic development, deterioration of environmental problems, and widening of the rich-poor divide, the quality of economic growth has been receiving increasing academic attention.

In the study of the quality of economic growth, its measurement remains the primary issue. Recently, the relevant literature has also discussed the index system and the measurement method of the quality of economic growth. Huang et al. (2020) employed the improved G1 method based on the grey correlation degree to perform a five-dimensional measurement of the quality of economic growth: innovation development, urban-rural coordination, ecological environment, opening to the outside world, and people's livelihood [38]. Kong et al. (2021) measured the quality of economic growth based on the efficiency, stability, and sustainability of economic growth using the principal component analysis [39]. From the perspective of influencing factors, the existing research discusses the impact of industrial agglomeration [40], transportation infrastructure [41], environmental regulation [42–44], import technology [45], and other factors on the quality of economic growth.

2.3. The relationship between finance and economic growth

Sufficient research has been conducted on the finance-economic growth relationship, mainly including the financial deepening and financial repression theories. Agnello et al. (2012) found that financial reform is conducive to improving income inequality for economic development [46]. Asteriou and Spanos (2019) confirmed that pre-crisis financial development can promote economic growth, but post-crisis financial development can hinder economic activity [47]. Wong et al. (2021) indicated that the spatial agglomeration of financial services has a positive impact on the quality of urban economic growth [48]. Gao et al. (2022) identified that green finance reduces environmental pollution by adjusting the industrial structure and promoting technological progress, thereby improving the quality of economic growth [49]. Chen and He (2022) indicated that financial resilience is a necessary condition for promoting the quality of economic growth, and stable growth is a significant channel between financial resilience and the quality of economic growth [50].

However, research on digital financial inclusion and economic growth is scarce. Current research focuses on the influence of digital financial inclusion on consumption, income, and development imbalance. Liu et al. (2021) argued that digital financial inclusion makes a significant contribution to economic growth [51]. Li and Wu (2020) used the panel data of the China Household Finance Survey to conclude that digital financial inclusion can promote household consumption [12]. Yu et al. (2022) suggested that digital financial inclusion affects the consumption structure of rural residents by improving income, convenience, and liquidity [13]. Yu and Wang (2021) indicated that digital financial inclusion effectively reduces the regional development imbalance and the urban-rural

income gap [52]. Xu et al. (2023) confirmed that digital financial inclusion can improve the level of household income and improve risk resistance, which is immensely significant for reducing poverty and preventing its return [53].

2.4. Hypothesis development

Existing research widely acknowledges that information asymmetry and high transaction costs are significant obstacles impeding the ability of traditional finance to foster economic development [54–56]. From the perspective of the credit rationing theory, information asymmetry complicates the achievement of equilibrium between borrowers and lenders, thereby hindering traditional financial institutions from effectively supporting the growth of the real economy [57,58]. The transaction cost theory also highlights the notable deficiencies of traditional financial institutions in serving vulnerable groups, such as small and micro enterprises [59,60]. These deficiencies stem from the higher transaction costs and lower returns associated with providing services to these groups. By employing digital technology, digital financial inclusion presents a transformative shift from traditional finance, addressing the challenges posed by information asymmetry and transaction costs [61–65]. It fosters improved access and affordability of financial services, particularly benefiting vulnerable groups.

Based on the above theoretical analysis, digital financial inclusion affects the quality of economic growth from three aspects. First, the application of advanced technology in digital financial inclusion has resulted in the innovation of the products and services of traditional finance, reduced the cost of financial services, and expanded the coverage of financial customers, which is conducive to the sustainable development of the real economy [66]. Second, digital financial inclusion can integrate scattered resources in the society and meet customer needs in long-tail markets to effectively improve supply and demand imbalance and resource mismatch in financial markets. Additionally, it covers underdeveloped regions and low-income groups, balancing inter-regional economic development [52]. Third, digital financial inclusion can ease the liquidity constraints and introduce low-threshold investment products, tap potential consumer demand, and absorb idle funds in the society to promote economic development [13]. We propose the following research hypothesis:

H1. Digital financial inclusion is positively related to the quality of economic growth.

From the perspective of influence mechanism, numerous studies have identified that digital financial inclusion provides funding sources for entrepreneurial activities and stimulates diversified demand in the market, which promotes new enterprises [51,67,68]. Furthermore, the enhancement of entrepreneurship also helps drive the quality of economic growth. Entrepreneurship is an endogenous force for economic growth and a significant driver of employment, industrial restructuring, environmental protection, etc. [69–71]. Therefore, digital financial inclusion promotes the quality of economic growth by stimulating entrepreneurial vitality in the society [72]. The second research hypothesis is as follows:

H2. Digital financial inclusion stimulates entrepreneurial vitality in the society, thereby promoting the quality of economic growth.

Tobler's First Law of Geography states that all things are spatially correlated with other things. Many studies have confirmed that digital financial inclusion has the characteristics of cross-space-time transmission and significant spatial effects [73–75]. Owing to the continuous expansion of the Internet and big data, digital financial inclusion has spillover effects on other industries, resulting in greater value for participants. Thus, it may have a non-linear or even geometric impact on the quality of economic growth. Additionally, as stated above, digital financial inclusion has the characteristics of cross-space-time transmission. It has significantly improved the efficiency of information exchange and expanded the coverage of financial services through modern information technology. This has strengthened the spatial correlation of economic activities between regions and promoted the quality of economic

Table 1
High-Quality Development Index evaluation system.

Primary indicators	Secondary indicators	Tertiary indicators
Innovation (Technological innovation)	Innovation input	R&D funding input intensity
		R&D personnel input intensity
	Innovation output	Number of patents granted per 10,000 people
		Proportion of income of high-tech industry
Coordination (Coordinated development)	Industry coordination	Industrial structure rationalization index
		Industrial structure advanced index
	Urban-rural coordination	Proportion of consumption level of urban and rural residents
		Proportion of urban and rural income level
Green (Environmental protection)	Green life	Forest coverage rate
		Harmless treatment rate of household garbage
	Energy consumption	Energy consumption per unit of GDP
		Electricity consumption per unit of GDP
	Environmental governance	Comprehensive utilization rate of general industrial solid waste
		Investment in environmental pollution control as a proportion of GDP
Open (Opening to the outside world)	Foreign trade	Total imports and exports as a percentage of GDP
	Foreign investment	Foreign direct investment as a percentage of GDP
Sharing (People's livelihood)	Economic sharing	GDP per capita
		Per capita expenditure on public services
	Social sharing	Number of health institutions
		Per capita education expenditure

growth. Consequently, digital financial inclusion has a positive spatial spillover effect on the quality of economic growth. We propose Hypothesis 3, as follows:

H3. Digital financial inclusion has a positive and increasing impact on the quality of economic growth, and a positive spatial spillover effect on the quality of economic growth in neighboring regions.

3. Measurement of the quality of economic growth in China

The quality of economic growth implies not only GDP growth, but also technological innovation, coordinated development, environmental protection, opening to the outside world, and people's livelihood. Drawing on the ideas of Huang et al. (2020) and Lin and Zhou (2022) [38,76], this study constructs the High-Quality Development Index based on the five dimensions of innovation, coordination, green, open, and sharing, to evaluate the quality of economic growth in China. The index evaluation system includes five primary indicators, 11 secondary indicators, and 20 tertiary indicators (Table 1), encompassing the economy, the environment, life, etc.

The subjective and objective methods are applied to measure the quality of economic growth. First, the entropy weight method is used to assign weight to each tertiary indicator. It serves to calculate the information entropy value of each evaluation index based on the original observation value, and measure the relative change degree of the index with the information entropy value to determine the objective weight of the index [77]. Second, the five primary indicators are assigned 20% subjective weight, which shows that the five aspects have the same importance. Finally, the specific index score of each evaluation object is multiplied by the subjective weight and objective weight of the index, and the final score of the evaluation object is obtained. This study uses China's provincial panel data from 2011 to 2017 to measure the high-quality development index of China's provinces, including the total index and the indexes of five dimensions. All data in Table 1 have been derived from the Easy Professional Superior (EPS) database and the China Statistical Yearbook.

4. Data and methodology

4.1. Data

China's provincial panel data from 2011 to 2017 are adopted in this study. Excluding Tibet, where there is a lack of data, 30 provinces (cities, autonomous regions) have been selected as research samples, and 210 sample values have been obtained. The data used in this study are obtained mainly from the EPS database, China Statistical Yearbook, China Basic Statistical Units Yearbook, Statistical Reports on Internet Development in China, and Peking University Digital Inclusive Finance Index of China.[1] The Peking University Digital Financial Inclusion Index of China has been jointly compiled by the Institute of Digital Finance of Peking University and the Ant Financial Services Group.

4.2. Model specification

To prevent endogeneity problems caused by omitted variables, this study uses the panel fixed effect model[2] (Eq. (1)) to analyze the impact of digital financial inclusion on the quality of economic growth. We also included the province fixed effects and year fixed effects to capture regional-specific and year-specific factors.

$$HQD_{i,t} = \beta_0 + \beta_1 DFI_{i,t} + \beta_2 X_{i,t} + \delta_i + \delta_t + \varepsilon_{i,t} \tag{1}$$

where, the dependent variable $HQD_{i,t}$ is the quality of economic growth of province i in year i. Additionally, innovation ($INN_{i,t}$), coordination ($COO_{i,t}$), green ($GRE_{i,t}$), open ($OPE_{i,t}$), and sharing ($SHA_{i,t}$) are also taken as dependent variables for the regression analysis. The independent variable $DFI_{i,t}$ signifies digital financial inclusion index. $DFI\_BRE_{i,t}$ and $DFI\_DEP_{i,t}$ are also used as independent variables to analyze the effects of the coverage breadth and usage depth of digital financial inclusion on the quality of economic growth. $X_{i,t}$ represents the set of control variables, δ_i controls the province fixed effects, δ_t controls the year fixed effects, and $\varepsilon_{i,t}$ is the clustering robust standard error.

To further test the influence mechanism between them, the following mediating effect model (Eq. (2) and (3)) is constructed:

$$ENT_{i,t} = \beta_0 + \beta_1 DFI_{i,t} + \beta_2 X_{i,t} + \delta_i + \delta_t + \varepsilon_{i,t} \tag{2}$$

$$HQD_{i,t} = \beta_0 + \beta_1 DFI_{i,t} + \beta_2 ENT_{i,t} + \beta_3 X_{i,t} + \delta_i + \delta_t + \varepsilon_{i,t} \tag{3}$$

where, $ENT_{i,t}$ is entrepreneurial vitality, measured by the ratio of the number of corporate units established each year to the local workforce aged 15 to 64. Considering that there may be a non-linear effect between digital financial inclusion and the quality of

[1] Specifically, the number of corporate units established each year is derived from the China Basic Statistical Units Yearbook. The Internet penetration rate is derived from the Statistical Reports on Internet Development in China. The data for the High−Quality Development Index and other variables are derived from the EPS database and the China Statistical Yearbook.

[2] We also conducted the Hausman test and obtained a p value of 0.0000. So, the original hypothesis is strongly rejected and the fixed effect model should be adopted.

economic growth, this study builds the following single threshold model by referring to the panel threshold model (Eq. (4)) proposed by Hansen (1999):

$$HQD_{i,t} = \beta_0 + \beta_1 DFI_{i,t} I(DFI_{i,t} \le \gamma) + \beta_2 DFI_{i,t} I(DFI_{i,t} > \gamma) + \beta_3 X_{i,t} + \delta_i + \delta_t + \varepsilon_{i,t} \quad (4)$$

where, $I(\cdot)$ is the indicator function that takes the value of 1 if the conditions in parentheses are met, and 0 otherwise. $DFI_{i,t}$ is the threshold variable and γ is the threshold value to be estimated. Hansen's (1999) model requires that the independent variable be strongly exogenous to ensure the consistency of the estimators [78]. Therefore, we use the first-differenced GMM (FD-GMM) estimation to address the possible endogeneity of the panel threshold model [79,80].

To further analyze the spatial spillover effect of digital financial inclusion on the quality of economic growth, we construct the spatial Durbin model (Eq. (5)).

$$HQD_{i,t} = \beta_0 + \rho WHQD_{i,t} + \varphi_1 WDFI_{i,t} + \varphi_2 WX_{i,t} + \beta_1 DFI_{i,t} + \beta_2 X_{i,t} + \delta_i + \delta_t + \varepsilon_{i,t} \quad (5)$$

where, ρ is the spatial autoregressive coefficient of the quality of economic growth, W is the spatial weight matrix, φ_1 is the coefficient of the spatial interaction term of digital financial inclusion, $X_{i,t}$ is a series of control variables, and φ_2 is the coefficient of the spatial interaction term of a series of control variables. Additionally, we select the geographical weight matrix to construct the spatial Durbin model.

4.3. Variable selection and definition

In our study, the dependent variable is the quality of economic growth in each region, which is measured by the High-Quality Development Index calculated in Section 3. The independent variable is the degree of development of digital financial inclusion, measured using the Digital Financial Inclusion Index. The index includes the Digital Financial Inclusion Index, Digital Financial Coverage Breadth Index, and Digital Financial Usage Depth Index. Among them, the coverage breadth of digital financial inclusion is measured based on the account coverage of digital finance. The usage depth of digital finance is measured based on the specific use of digital financial services by users, including payment, credit, monetary fund, insurance, credit, and investment business. Additionally, we select human capital, government intervention level, infrastructure level, and capital investment ratio as control variables. All variables are defined in Table 2.

4.4. Descriptive statistics

Table 3 shows descriptive statistics for all variables. During the sample period, the average value of the *HQD* index and its five dimensions of 30 provinces in China are 4.740, 1.193, 0.591, 1.430, 0.522, and 1.004 respectively, and the difference between their maximum and minimum values is significant. The mean values of the total index, coverage breadth, and usage depth of digital financial inclusion are 172.059, 151.497, and 168.576, respectively. The average values of human capital, government intervention level, infrastructure level, and capital investment ratio are 9.228, 0.245, 0.921, and 0.793 respectively.

4.5. Correlation analysis

To analyze the correlation between variables, we use the Pearson correlation test. As shown in Table 4, there is a correlation between the dependent variable and the independent variable. Additionally, the correlation coefficients between variables are not more than 0.8, so there is no high correlation between variables. This can well avoid multicollinearity in the regression models.

Table 2
Variable definitions.

Variable types	Variables	Symbols	Variable explanations	Units
Dependent variables	Quality of economic growth	*HQD*	High-Quality Development Index	–
	Innovation	*INN*	Innovation Index	–
	Coordination	*COO*	Coordination Index	–
	Green	*GRE*	Green Index	–
	Open	*OPE*	Open Index	–
	Sharing	*SHA*	Sharing Index	–
Independent variables	Digital financial inclusion	*DFI*	Digital Financial Inclusion Index	–
	Digital financial coverage breadth	*DFI_BRE*	Digital Financial Coverage Breadth Index	–
	Digital financial usage depth	*DFI_DEP*	Digital Financial Usage Depth Index	–
Mediator variable	Entrepreneurial vitality	*ENT*	Number of corporate units established/local workforce	–
Control variables	Human capital	*HUM*	Per capita education years	Year
	Government intervention level	*GOV*	Fiscal expenditure/GDP	%
	Infrastructure level	*INF*	Road mileage/land area	1/10,000 km
	Capital investment ratio	*CAP*	Capital investment/GDP	%

Table 3
Descriptive statistics.

Variables	Observations	Mean	Std.Dev.	Min	Max
HQD	210	4.740	2.188	1.944	13.915
INN	210	1.193	1.107	0.118	6.301
COO	210	0.591	0.186	0.257	1.159
GRE	210	1.430	0.298	0.675	2.094
OPE	210	0.522	0.595	0.055	2.760
SHA	210	1.004	0.419	0.351	2.901
DFI	210	172.059	77.742	18.330	336.651
DFI_BRE	210	151.497	74.543	1.960	316.118
DFI_DEP	210	168.576	78.517	6.760	396.049
ENT	210	17.743	11.742	3.341	61.778
HUM	210	9.228	0.927	7.589	13.227
GOV	210	0.245	0.102	0.110	0.627
INF	210	0.921	0.494	0.089	2.101
CAP	210	0.793	0.243	0.240	1.469

Note: 1. *HQD* is the quality of economic growth, in which *INN*, *COO*, *GRE*, *OPE*, and *SHA* are innovation, coordination, green, open, and sharing, respectively. 2. *DFI*, *DFI_BRE*, and *DFI_DEP* are digital financial inclusion, digital financial coverage breadth, and digital financial usage depth, respectively. 3. *Hum* is human capital, *Gov* is government intervention level, Inf is infrastructure level, and *Cap* is capital investment ratio.

5. Results and discussion

5.1. Baseline regression results

Table 5 shows the baseline regression results of the panel fixed effect model. From Panel A, the regression coefficients of digital financial inclusion on the quality of economic growth and its five dimensions are all positive at the 1% significant level. Therefore, digital financial inclusion not only has a significant positive impact on the quality of economic growth, but also promotes technological innovation, coordinated development, environmental protection, opening to the outside world, and people's livelihood. Panels B and C present the regression results with *DFI_BRE* and *DFI_DEP* as explanatory variables, respectively. The regression results present that the improvement of coverage breadth and usage depth of digital financial inclusion can significantly promote the quality of economic growth and the development of its five areas. There may be two reasons for the results. First, the coverage breadth of digital financial inclusion refers to the account coverage of digital finance. The improvement of the coverage breadth can better alleviate financial exclusion and meet the financial needs of underdeveloped areas and low-income people, so as to effectively address the problem of uncoordinated and unbalanced development. Second, the usage depth of digital financial inclusion is reflected in the use of digital financial services such as payments, credit, money funds, insurance, credit, and investment business. The continuous increase of the usage depth can further establish a perfect digital financial inclusive system and better support the development of the real economy. The above results suggest that vigorously developing digital financial inclusion is an effective method of promoting the quality of economic growth.

To address the possible endogenous problems, the number of fixed telephone users (*IV1*), per capita post and telecommunications business volume (*IV2*), and Internet penetration rate (*IV3*) are selected as instrumental variables for the two-stage least squares (2SLS) regression. On the one hand, they have a strong correlation with digital financial inclusion. On the other hand, they have little direct impact on the quality of economic growth. Therefore, they are effective instrumental variables. When using the above three instrumental variables for the 2SLS regression, digital financial inclusion has a significant positive correlation with them. As shown in Table 6, the regression coefficients of digital financial inclusion are positive at the 1% significant level. After addressing the endogenous problems, our results remain robust.

Table 4
Correlation coefficient test.

	HQD	DFI	ENT	HUM	GOV	INF	CAP
HQD	1.000						
DFI	0.434***	1.000					
ENT	0.672***	0.753***	1.000				
HUM	0.782***	0.418***	0.484***	1.000			
GOV	−0.415***	−0.064	−0.146**	−0.368***	1.000		
INF	0.604***	0.260***	0.386***	0.426***	−0.588***	1.000	
CAP	−0.681***	0.079	−0.151**	−0.581***	0.564***	−0.477***	1.000

Note: 1. *HQD* is the quality of economic growth. 2. *DFI* is digital financial inclusion. 3. *Hum* is human capital, *Gov* is government intervention level, Inf is infrastructure level, and *Cap* is capital investment ratio. 4. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively, with standard errors in parentheses.

Table 5
Baseline regression results.

Variables	HQD (1)	INN (2)	COO (3)	GRE (4)	OPE (5)	SHA (6)
Panel A: Regression results of *DFI* as the explanatory variable						
DFI	0.068***	0.026***	0.003***	0.010***	0.017***	0.012***
	(0.0048)	(0.0034)	(0.0004)	(0.0011)	(0.0015)	(0.0010)
HUM	0.477***	0.175**	0.089***	−0.085***	0.076**	0.221***
	(0.1020)	(0.0845)	(0.0101)	(0.0247)	(0.0353)	(0.0212)
GOV	3.542***	0.836	0.387***	−1.526***	1.924***	1.922***
	(0.7795)	(0.6036)	(0.0638)	(0.2221)	(0.2129)	(0.1964)
INF	0.476***	0.408***	0.024*	−0.138***	0.205***	−0.023
	(0.1227)	(0.0946)	(0.0138)	(0.0401)	(0.0427)	(0.0396)
CAP	−1.276**	−0.977***	−0.128***	0.379***	−0.760***	0.210*
	(0.5320)	(0.3394)	(0.0427)	(0.0963)	(0.1433)	(0.1073)
Constant	−3.275***	−1.497*	−0.469***	1.917***	−0.919**	−2.307***
	(1.1374)	(0.8947)	(0.1085)	(0.2623)	(0.3704)	(0.2204)
R^2	0.902	0.779	0.850	0.457	0.859	0.825
Obs	210	210	210	210	210	210
Panel B: Regression results of *DFI_BRE* as the explanatory variable						
DFI	0.068***	0.026***	0.003***	0.010***	0.017***	0.012***
	(0.0048)	(0.0034)	(0.0004)	(0.0011)	(0.0015)	(0.0010)
HUM	0.477***	0.175**	0.089***	−0.085***	0.076**	0.221***
	(0.1020)	(0.0845)	(0.0101)	(0.0247)	(0.0353)	(0.0212)
GOV	3.542***	0.836	0.387***	−1.526***	1.924***	1.922***
	(0.7795)	(0.6036)	(0.0638)	(0.2221)	(0.2129)	(0.1964)
INF	0.476***	0.408***	0.024*	−0.138***	0.205***	−0.023
	(0.1227)	(0.0946)	(0.0138)	(0.0401)	(0.0427)	(0.0396)
CAP	−1.276**	−0.977***	−0.128***	0.379***	−0.760***	0.210*
	(0.5320)	(0.3394)	(0.0427)	(0.0963)	(0.1433)	(0.1073)
Constant	−3.275***	−1.497*	−0.469***	1.917***	−0.919**	−2.307***
	(1.1374)	(0.8947)	(0.1085)	(0.2623)	(0.3704)	(0.2204)
R^2	0.902	0.779	0.850	0.457	0.859	0.825
Obs	210	210	210	210	210	210
Panel C: Regression results of *DFI_DEP* as the explanatory variable						
DFI_DEP	0.033***	0.012***	0.002***	0.006***	0.008***	0.005***
	(0.0036)	(0.0022)	(0.0002)	(0.0007)	(0.0009)	(0.0009)
HUM	0.896***	0.334***	0.106***	−0.025	0.183***	0.297***
	(0.1303)	(0.0919)	(0.0111)	(0.0263)	(0.0379)	(0.0232)
GOV	3.917***	0.980	0.415***	−1.431***	1.999***	1.954***
	(0.8736)	(0.6217)	(0.0669)	(0.2355)	(0.2341)	(0.2229)
INF	0.466***	0.402***	0.015	−0.169***	0.217***	0.001
	(0.1408)	(0.0874)	(0.0142)	(0.0439)	(0.0537)	(0.0445)
CAP	−1.996***	−1.243***	−0.135***	0.350***	−0.981***	0.014
	(0.6791)	(0.3915)	(0.0387)	(0.1030)	(0.1827)	(0.1396)
Constant	−5.405***	−2.306**	−0.583***	1.529***	−1.424***	−2.621***
	(1.5240)	(1.0148)	(0.1152)	(0.2928)	(0.4339)	(0.2775)
R^2	0.855	0.754	0.851	0.459	0.808	0.761
Obs	210	210	210	210	210	210

Note: 1. *HQD* is the quality of economic growth, in which *INN*, *COO*, *GRE*, *OPE*, and *SHA* are innovation, coordination, green, open, and sharing, respectively. 2. *DFI*, *DFI_BRE*, and *DFI_DEP* are digital financial inclusion, digital financial coverage breadth, and digital financial usage depth, respectively. 3. *Hum* is human capital, *Gov* is government intervention level, Inf is infrastructure level, and *Cap* is capital investment ratio. 4.***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively, with standard errors in parentheses.

5.2. Heterogeneity analysis

Owing to differences in geographic location and degree of marketization, digital financial inclusion of each province presents different development patterns. The 30 provinces are grouped and regressed separately according to the differences in geographical location and marketization index (see Table 7). From Columns (1) to (3), compared with the central and western regions, the positive effect of digital financial inclusion on the quality of economic growth is greater in the eastern region. In Columns (4) and (5), provinces with higher marketization have a greater role in promoting the quality of economic growth than those with lower marketization. As provinces with higher marketization have better market mechanisms, digital financial inclusion can better optimize the allocation of resources in these markets.

5.3. Mechanism analysis

This study uses Eqs. (2) and (3) to test the influence mechanism (see Table 8). In Column (1), digital financial inclusion has a significant positive impact on entrepreneurial vitality. In Column (2), the coefficients of digital financial inclusion and entrepreneurial vitality are 0.050 and 0.076, respectively, at the 1% significance level. This shows that digital financial inclusion promotes the quality

Table 6
Instrumental variables regression.

Variables	IV1	IV2	IV3
	HQD (1)	HQD (2)	HQD (3)
DFI	0.219***	0.098***	0.081***
	(0.0535)	(0.0071)	(0.0068)
HUM	−0.635	0.254**	0.381***
	(0.4257)	(0.1107)	(0.1207)
GOV	4.965**	3.827***	3.664***
	(1.9716)	(0.8863)	(0.7859)
INF	−1.200*	0.141	0.333**
	(0.6822)	(0.1725)	(0.1579)
CAP	4.863*	−0.047	−0.751
	(2.5413)	(0.4000)	(0.4629)
Constant	−2.392	−3.099***	−3.200***
	(2.3501)	(1.0758)	(1.0801)
R^2	0.263	0.877	0.897
Obs	210	210	210

Note: 1. *IV1*, *IV2,* and *IV3* are the number of fixed telephone users, per capita post and telecommunications business volume, and Internet penetration rate, respectively. 2. *HQD* is the quality of economic growth. 3. *DFI* is digital financial inclusion. 4. *Hum* is human capital, *Gov* is government intervention level, Inf is infrastructure level, and *Cap* is capital investment ratio. 5.***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively, with standard errors in parentheses.

Table 7
Heterogeneity analysis.

Variables	East	Central	West	Higher marketization	Lower marketization
	HQD (1)	HQD (2)	HQD (3)	HQD (4)	HQD (5)
DFI	0.064***	0.035***	0.027***	0.062***	0.040***
	(0.0091)	(0.0054)	(0.0053)	(0.0076)	(0.0044)
HUM	0.804***	−0.340***	0.346***	0.701***	0.183***
	(0.1599)	(0.1255)	(0.0494)	(0.1520)	(0.0620)
GOV	−4.166**	−6.675***	0.309	−1.658	0.535
	(1.8622)	(2.0686)	(0.5617)	(2.2165)	(0.5158)
INF	0.059	−0.545***	0.669***	0.143	0.195
	(0.4085)	(0.1895)	(0.0702)	(0.3073)	(0.1179)
CAP	−1.560	0.865***	0.249	−1.509	0.316
	(1.2237)	(0.3088)	(0.3182)	(1.0078)	(0.2918)
Constant	−3.949**	6.447***	−1.460***	−3.347*	−0.326
	(1.9461)	(1.3410)	(0.4811)	(1.8347)	(0.6239)
R^2	0.885	0.763	0.912	0.892	0.792
Obs	77	56	77	105	105

Note: 1. *HQD* is the quality of economic growth. 2. *DFI* is digital financial inclusion. 3. *Hum* is human capital, *Gov* is government intervention level, Inf is infrastructure level, and *Cap* is capital investment ratio. 4.***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively, with standard errors in parentheses.

of economic growth by stimulating local entrepreneurial vitality.

5.4. Non-linear effect analysis

The threshold variable *DFI* passes a single threshold test using the bootstrap method with 1000 replications, and the threshold value is 285.277. There is a non-monotonic relationship between digital financial inclusion and the quality of economic growth. Then, *DFI_BRE* and *DFI_DEP* replace *DFI*, and both tests pass significantly. The results of the panel threshold model in Table 9 show that the coefficient of digital financial inclusion is 0.004 points below the threshold (*DFI*≤285.277), and the one is 0.006 above the threshold value (*DFI* >285.277). It can be seen that the higher the degree of development of digital financial inclusion, the greater the promotion effect on the quality of economic growth. In Columns (2) and (3), its coverage breadth and usage depth also show a positive and increasing non-linear effect on the quality of economic growth over the past few years.

The panel model with threshold effects proposed by Hansen (1999) has been widely used in empirical research [78], but the fixed effect estimator of the model requires that the covariates are strongly exogenous for the estimator to be consistent. However, this strong externality may be restrictive; therefore, Seo and Shin (2016) proposed the FD-GMM estimation for addressing endogenous independent variables and endogenous threshold variables [80]. In Table 10, the number of fixed telephone users is treated as a tool variable to address the endogeneity problem using the FD-GMM estimation. The results show that the regression coefficient of digital financial inclusion above the threshold value is higher than its coefficient below the threshold value. This further confirms the

Table 8
Mechanism analysis.

Variables	ENT (1)	HQD (2)
DFI	0.231***	0.050***
	(0.0358)	(0.0038)
ENT		0.076***
		(0.0058)
HUM	0.355	0.450***
	(0.9726)	(0.0683)
GOV	11.338	2.683***
	(7.9529)	(0.4215)
INF	2.733**	0.269***
	(1.2261)	(0.0892)
CAP	1.010	−1.352***
	(4.5138)	(0.3324)
Constant	−9.964	−2.520***
	(10.6475)	(0.6917)
R^2	0.712	0.950
Obs	210	210

Note: 1. *ENT* is entrepreneurial vitality, and *HQD* is the quality of economic growth. 2. *DFI* is digital financial inclusion. 3. *Hum* is human capital, *Gov* is government intervention level, Inf is infrastructure level, and *Cap* is capital investment ratio. 4.***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively, with standard errors in parentheses.

Table 9
Estimation results of the panel threshold model.

Variables	DFI (1)	DFI_BRE (2)	DFI_DEP (3)
Threshold value γ	285.277***	268.390***	317.581***
*DFI*I (DFI* $\leq \gamma$*)*	0.004*** (0.0005)		
*DFI*I (DFI* $> \gamma$*)*	0.006*** (0.0005)		
*DFI_BRE*I (DFI_BRE* $\leq \gamma$*)*		0.004*** (0.0005)	
*DFI_BRE*I (DFI_BRE* $> \gamma$*)*		0.007*** (0.0005)	
*DFI_DEP*I (DFI_DEP* $\leq \gamma$*)*			0.003*** (0.0004)
*DFI_DEP*I (DFI_DEP* $> \gamma$*)*			0.004*** (0.0004)
Control variables	YES	YES	YES
R^2	0.826	0.848	0.797
Obs	210	210	210

Note: 1. *HQD* is the quality of economic growth. 2. *DFI*, *DFI_BRE*, and *DFI_DEP* are digital financial inclusion, digital financial coverage breadth, and digital financial usage depth, respectively. 3. *I (·)* is the indicator function that takes the value of 1 if the conditions in parentheses are met, and 0 otherwise. 4. γ is the threshold value to be estimated. 5.Control variables include human capital, government intervention level, infrastructure level, and capital investment ratio. 6.***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively, with standard errors in parentheses.

Table 10
FD-GMM estimation results.

Variables	DFI (1)	DFI_BRE (2)	DFI_DEP (3)
*DFI*I (DFI* $\leq \gamma$*)*	0.001 (0.0007)		
*DFI*I (DFI* $> \gamma$*)*	0.003** (0.0012)		
*DFI_BRE*I (DFI_BRE* $\leq \gamma$*)*		−0.003** (0.0014)	
*DFI_BRE*I (DFI_BRE* $> \gamma$*)*		0.006*** (0.0018)	
*DFI_DEP*I (DFI_DEP* $\leq \gamma$*)*			0.001*** (0.0003)
*DFI_DEP*I (DFI_DEP* $> \gamma$*)*			0.004*** (0.0015)
Control variables	YES	YES	YES
Number of moment conditions	51	51	51
Obs	210	210	210

Note: 1. *HQD* is the quality of economic growth. 2. *DFI*, *DFI_BRE*, and *DFI_DEP* are digital financial inclusion, digital financial coverage breadth, and digital financial usage depth, respectively. 3. *I (·)* is the indicator function that takes the value of 1 if the conditions in parentheses are met, and 0 otherwise. 4. γ is the threshold value to be estimated. 5.Control variables include human capital, government intervention level, infrastructure level, and capital investment ratio. 6.***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively, with standard errors in parentheses.

non-linear characteristics of the increasing marginal effect of digital financial inclusion.

5.5. Spatial econometric analysis

To analyze the spatial spillover effect of digital financial inclusion on the quality of economic growth, we construct the spatial Durbin model. Before using spatial econometric methods, it is necessary to test the spatial autocorrelation of the quality of economic growth. We use the geographical weight matrix to calculate *Moran's I* of the annual quality of economic growth, and find that they are significantly greater than 0. This shows a spatial positive correlation between the quality of economic growth in China, that is, the regions with higher quality of economic growth come together.

Considering the limited significance of the regression coefficients of the explanatory variables of the spatial econometric model, we further explain the direct and indirect effects of the spatial Durbin model. As shown in Table 11, digital financial inclusion not only has a significant positive direct effect on the quality of economic growth, but also has a significant positive spatial spillover effect (indirect effects) on the quality of economic growth in neighboring regions. The possible reason is that digital financial inclusion has the characteristics of cross-temporal and spatial information dissemination and significant network effects. Therefore, the development of local digital financial inclusion can promote the quality of economic growth in neighboring regions.

5.6. Discussion and research implications

Recent studies have mainly explored the positive role of digital financial inclusion in reducing regional development imbalance, narrowing the urban-rural income gap, protecting the environment, and promoting residents' consumption [12,13,81–83]. First, different from the existing research, we confirm a positive correlation between digital financial inclusion and the quality of economic growth. Additionally, digital financial inclusion promotes technological innovation, coordinated development, environmental protection, opening to the outside world, and people's livelihood. This indicates that digital financial inclusion is a crucial factor in the promotion of the quality of economic growth. Numerous studies have identified that digital financial inclusion is conducive to promoting economic growth, reducing carbon dioxide emissions, alleviating poverty, etc. [51,75,84]. However, a few studies have indicated that although digital financial inclusion can stimulate economic growth, it can also cause a surge in carbon dioxide emissions and reduce environmental quality [85]. Our research supports the argument that digital financial inclusion can achieve a win-win situation between economic development and environmental protection, and comprehensively improve the quality of economic growth. Therefore, governmental departments must encourage the application of advanced science and technology in the financial field, and provide sufficient trial and error opportunities and a good innovation environment for the development of digital financial inclusion.

Second, stimulating entrepreneurial vitality is significant for digital financial inclusion to promote the quality of economic growth. Additionally, the positive effect of digital financial inclusion on the quality of economic growth is more significant in the eastern region and regions with high degree of marketization. This is probably because a robust information infrastructure and effective market mechanisms can better deliver the advantages of digital financial inclusion, resulting in greater economic development. Xu et al. (2023) found that digital financial inclusion improves household income levels by promoting entrepreneurship and employment [53]. Yang et al. (2022) suggested that digital financial inclusion improves women's job flexibility and encourages their entrepreneurship [67]. According to Chen et al. (2022), the development of digital financial inclusion requires a solid foundation of the traditional financial system to fully play its role [86]. These studies support our results to some extent. Therefore, governmental departments must accelerate the construction of information infrastructure and foster a favorable market environment.

Finally, digital financial inclusion can promote the quality of economic growth in neighboring regions. Many studies have confirmed that digital financial inclusion and the quality of economic growth have significant spatial autocorrelation [74,87], and digital financial inclusion has a positive spatial spillover effect on farmers' income growth [88]. Aziz and Naima (2021) concluded that although digital services have improved the access to financial services, these services have not been fully utilized due to a lack of basic connectivity, financial literacy, and social awareness [89]. This implies that government and financial institutions must strengthen the exchange and cooperation of digital financial inclusion between regions. Additionally, they must improve the efficiency of resource allocation between regions to exert the spatial spillover effect of digital financial inclusion on the quality of economic growth.

Our study provides substantial empirical evidence to show that digital financial inclusion promotes the quality of economic growth. However, there are two limitations. First, we use the Peking University Digital Financial Inclusion Index of China to measure digital financial inclusion. However, owing to the unavailability of data and the unmatched data of different institutions, the index only uses the data of a representative digital financial institution. Therefore, it cannot fully reflect the integrity of the development of digital financial inclusion. Second, we find that digital financial inclusion can promote the quality of economic growth by stimulating entrepreneurial vitality. However, there may be more potential transmission mechanisms between digital financial inclusion and the quality of economic growth, which need to be further explored.

In general, our study has significant research implications. First, we establish a systematic, scientific, typical, dynamic, and operable index evaluation system for the quality of economic growth. Additionally, we employ the more objective entropy method to measure the quality of economic growth in China's provinces, and thereafter, provide a feasible measure for the empirical study of the quality of economic growth. Second, we explore the transmission mechanism and spatial spillover effect of digital financial inclusion on the quality of economic growth, which is conducive to enriching the theoretical discussion and empirical evidence in this field. Third, our study is helpful to understand the historical opportunity of the rapid development of science and technology, vigorously promote digital financial inclusion to improve the efficiency of financial institutions and financial markets, promote the

Table 11
Spatial effect estimation results.

	Direct effect	Indirect effect	Total effect
Variables	HQD (1)	HQD (2)	HQD (3)
DFI	0.002*	0.002**	0.003***
	(0.0010)	(0.0007)	(0.0005)

Note: 1. *HQD* is the quality of economic growth. 2. *DFI* is digital financial inclusion. 3. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively, with standard errors in parentheses.

transformation and upgrading of the finance industry, and make digital financial inclusion better promote economic and social development.

6. Conclusions and policy recommendations

6.1. Conclusions

Based on the provincial panel data of China from 2011 to 2017, this study combines the subjective weighting method and the entropy weight method to measure the quality of economic growth. Additionally, it empirically tests the impact of digital financial inclusion on the quality of economic growth by utilizing the mediation effect model, the panel threshold model based on the FD-GMM estimation, and the spatial Durbin model. The conclusions are as follows. First, digital financial inclusion has a significant positive impact on the quality of economic growth, which is more obvious in the eastern region and regions with high marketization. Second, digital financial inclusion can stimulate entrepreneurial vitality, thereby improving the quality of economic growth. Third, digital financial inclusion and its coverage breadth and usage depth have had a positive and increasing non-linear effect on the quality of economic growth over the past few years. Fourth, digital financial inclusion can not only improve the quality of local economic growth, but also promote the quality of economic growth in neighboring regions. Therefore, the quality of economic development can be significantly improved by continuously developing digital financial inclusion.

6.2. Policy recommendations

Based on our findings and the actual situation of digital financial inclusion, we propose policy recommendations to promote digital financial inclusion and the quality of economic growth. These can be used by the government to formulate policies aligning with local advantages and guide the finance industry to adopt suitable development strategies.

First, it is essential to encourage digital financial inclusion innovation and vigorously develop related technologies and business models of digital financial inclusion. The technological and business model innovations are conducive to meeting the financial needs of small enterprises and low-income groups, thereby expanding the customer base and market share of digital financial inclusion. Therefore, government departments must encourage the attempt and application of advanced science and technology in the financial field, and provide sufficient trial and error space and a favorable innovation environment for the development of digital financial inclusion. Additionally, traditional financial institutions should use emerging information technology to improve the drawbacks of traditional financial services and enhance their service efficiency, thus promoting innovation in the finance industry. The continuous innovation of digital financial inclusion can drive the innovation and development of the entire society.

Second, it is necessary to accelerate the construction of digital financial inclusion infrastructure, strengthen inter-regional exchanges and cooperation, and form a coordinated development pattern among regions. Strengthening infrastructure is conducive to giving full play to the role of digital financial inclusion in promoting economic growth in remote areas. This will further enhance the entrepreneurial vitality of underdeveloped areas and alleviate the imbalance in economic and social development. Strengthening the exchange and cooperation of digital financial inclusion between regions can improve the efficiency of resource allocation between regions. This could exert the spatial spillover effect of digital financial inclusion on the quality of economic growth. Therefore, relevant departments must ensure high-quality Internet connectivity, promote technologies such as big data and artificial intelligence, and support digital financial inclusion to accelerate economic development.

Third, it is essential to develop a regulatory system to prevent the possible risks associated with digital financial inclusion. Owing to the low service threshold and high openness of digital financial inclusion, the market is prone to information risk, credit risk, etc. Governmental departments must optimize laws and regulations related to digital financial inclusion to regulate market behavior and protect consumers' rights and interests. Additionally, the finance industry must improve its self-supervision and keep the bottom line of morality and risk, so as to promote the standardization, stabilization, and security development of digital financial inclusion. The improvement of the regulatory system is fundamental to the stable development of digital financial inclusion. Additionally, it ensures that digital financial inclusion promotes the quality of economic growth.

6.3. Future research directions

Presently, digital financial inclusion and technological innovation are undergoing rapid development. Therefore, future research can be conducted in the following directions. First, data of banks, securities, insurance, financial technology companies, etc., should be

collected—as much as possible. Thereafter, an index system should be constructed to comprehensively summarize the development level of digital financial inclusion. It would provide a more scientific and reasonable measurement index for the quantitative research of digital financial inclusion. Second, future research should investigate the risks associated with digital financial inclusion; construction of digital financial inclusion supervision system; improvement of laws and regulations related to digital financial inclusion; regulation of market behavior; and protection of consumers' rights. Third, the research on digital financial inclusion should delve into the micro level and explore the impacts of digital financial inclusion on enterprises and individuals, as well as its internal mechanism. Finally, digital financial inclusion includes various services, such as mobile payment, online loan, online insurance, online fund, etc. Therefore, future research on digital financial inclusion should include different financial products and services.

Author contribution statement

Wenzhi Xi: Conceived and designed the experiments; Wrote the paper.

Yingdong Wang: Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Data availability statement

Data will be made available on request.

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Declaration of competing interest

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