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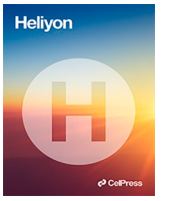

Research article

Mechanism research on digital inclusive finance promoting high-quality economic development: Evidence from China

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ABSTRACT

This article aims to precisely evaluate the catalytic impact of digital inclusive finance on economic growth, enhance the implementation of policies pertaining to digital inclusive finance, and foster high-quality economic development. Based on China's provincial panel data and the digital inclusive finance index from 2011 to 2021, this research investigates the influence of digital inclusive finance on high-quality economic development and the associated underlying mechanisms. The findings suggest that digital inclusive finance exerts a notable spatial impact on high-quality economic development. Moreover, there is heterogeneity in the spatial effects between different dimensions of digital inclusive finance and high-quality economic development. Through the threshold model and intermediary effect model, it is found that the Internet penetration rate has a dual-threshold effect on the impact of digital inclusive finance on promoting high-quality economic development. Specifically, digital inclusive finance contributes to elevating the level of high-quality economic development through its role in promoting the transformation of consumption structure. The findings of this study offer valuable insights for countries aiming to attain high-quality economic development through the enhancement of digital inclusive finance.

1. Introduction

Since the 21st century, big data and cloud technology have clearly become the major trends in technological development. The integration of digital technology with inclusive finance has given rise to digital inclusive finance. In comparison to traditional inclusive finance, digital inclusive finance can further reduce the cost of financial products, expand the coverage of inclusive finance, enabling more residents, especially those in rural and remote areas, to access financial services. This, in turn, promotes high-quality economic development.

In recent years, with the development of China's Internet and mobile payments, digital inclusive finance has developed rapidly in China. Benefiting from the digital economy and information technology, digital inclusive finance helps reduce the financing threshold for small and medium-sized enterprises, alleviating the issues of "difficulty in financing" and "expensive financing." It also helps enhance the financial industry's innovation capability, generating a variety of financial products to meet the diverse financing needs of enterprises. At the same time, digital inclusive finance plays an important role in optimizing industrial structure and upgrading,

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narrowing the urban-rural income gap, improving the quality of residents' consumption, and enhancing technological innovation capabilities. It is dedicated to promoting high-quality economic development in China. Achieving high-quality economic development will help alleviate challenges such as China's excessive energy consumption and severe environmental pollution, contributing to the sustainable development of the Chinese economy. Therefore, studying the promoting role and internal mechanism of digital inclusive finance in high-quality economic development has important academic value and practical significance for realizing high-quality development in China and economic growth in developing countries.

Through a review of the relevant literature on digital inclusive finance and high-quality economic development, we find that geographical patterns [1,2], industrial structure [3], tax policies [4,5], foreign direct investment [6–8], and other factors will have a significant impact on economic growth. Scholars have explored the coordinated development of finance and the economy from the financial perspective. Dabla-Norris et al. [9] measured the level of financial development based on financial accessibility, depth of financial use, and financial intermediation rate, and used a general equilibrium model to demonstrate that financial development would drive regional GDP growth, with the degree of impact varying between different countries. Ren Taizeng and Yin Zhigao [10] empirically tested the relationship between digital inclusive finance and inclusive growth of the Chinese economy using fixed-effects and Probit models. Gao Xin and Li Guoquan [11] used kernel density estimation, traditional Markov chains, and spatial Markov chains to analyze the spatiotemporal distribution characteristics of digital inclusive finance. By embedding the "symbiosis of economy and finance" theory, they constructed a symbiosis index to depict the symbiotic state of digital inclusive finance and regional economic development at the provincial level.

In general, the current research on the relationship between digital inclusive finance and high-quality development is relatively abundant. However, most studies focus on the bidirectional relationship between the two, and there is relatively little research on whether the economic activities of digital inclusive finance have spatial correlation with geographical location and whether the impact of digital inclusive finance on high-quality development has mediating or threshold effects. To delve into the spatial relationship between digital inclusive finance and high-quality development, analyzing the driving effect of consumption structure and internet penetration rate on economic growth, exploring new paths for the high-quality development of the economy in developing countries. This paper first measures the comprehensive index of high-quality economic development from the five aspects of innovation, coordination, green development, openness, and sharing to rigorously and comprehensively reflect the high-quality development level of various provinces in China. Secondly, it studies the relationship between digital inclusive finance and high-quality development from the perspective of spatial econometrics and discusses their heterogeneity from the spatial correlation of geographical location. Finally, when considering how digital inclusive finance affects the high-quality development of each province, the paper further evaluates the transmission effects of upgraded consumption structure and internet penetration rate on the impact of digital inclusive finance on the high-quality development of each province using the mediating effect model and threshold model.

2. Theoretical analysis and research hypotheses

This paper aims to explore the relationship between digital inclusive finance and high-quality economic development. Due to the multidimensional nature of digital inclusive finance, this paper reviews the literature on the relationship between financial development and economic growth, which can be summarized in two aspects. First, financial development promotes economic growth [12,13]. The development of information technology improves the financing environment for various enterprises, alleviating financing constraints [14,15], increasing the sources of funds for small and medium-sized enterprises, and promoting stable economic growth. The digital characteristics of inclusive finance reduce the information asymmetry between financial institutions and green companies, improve the financing efficiency of enterprise development, reduce the risk of financial companies, and provide sufficient and stable financial support for small and medium-sized enterprises. In addition, the "catfish effect" of digital inclusive finance reduces financing costs such as communication and transaction costs, meaning that the cost of obtaining funds for small and medium-sized enterprises has been reduced, and more fiscal funds will be used for scale development. In conclusion, digital inclusive finance promotes high-quality economic development. Second, geographical differences hinder the popularization of digital finance, and regions with lower economic levels often occupy financial resources, preventing enterprises in other regions from obtaining funds. This inefficient allocation hinders the development of green economy. Therefore, this paper proposes hypothesis 1.

H1. Digital inclusive finance has a significant promoting effect on high-quality economic development and exhibits spatial heterogeneity.

There is a non-linear relationship between financial development and economic growth [16,17]. Financial development helps alleviate consumer liquidity constraints and stimulates consumer demand. However, with the improvement of information technology, consumption products are increasingly concentrated on digital products. It can be seen that the impact of financial development on economic growth is uncertain. In the early stages of internet development, some enterprises used a large amount of financial resources for market arbitrage, attempting to gain high profits instead of using credit resources for technological research and development in enterprise production, thus achieving the green transformation and upgrading of enterprises [18]. In addition, the "inclusivity" of the internet allows inefficient and backward enterprises to encroach on the financial resources of small and medium-sized enterprises, reducing the financing efficiency of green enterprises and hindering high-quality economic development. As the internet develops to a certain extent, its positive impact on the economy gradually becomes apparent. The internet penetration rate helps to lower the innovation threshold for regional enterprise financing constraints, stimulates innovation vitality in the field of green technology in the region [19,20]. This helps to overcome spatial limitations in financial accessibility, achieve "inclusive" financial services in remote areas, address the problem of "difficult and expensive financing".

H2. The internet penetration rate can impact the relationship between digital inclusive finance and high-quality economic development.

How does inclusive digital finance impact the high-quality development of the economy? Based on existing research, the intrinsic mechanism through which inclusive digital finance promotes the development of a green economy may manifest in consumers. The optimization and upgrading of consumption structure will contribute to realizing inclusive digital finance and promoting high-quality economic development. Inclusive digital finance not only facilitates the transformation of the green production methods of enterprises but also, through the rational allocation of fiscal resources, promotes the optimization and upgrading of consumption structure. The current smart integration of digitalization will enhance the level of information technology innovation, fostering the development of a green economy. With the improvement of economic development and the standard of living, residents' consumption is shifting from being primarily focused on basic living needs to placing greater emphasis on quality of life and developmental needs. This enhances the efficiency of resource allocation, stimulates the vitality of enterprises' green technological innovation, and promotes high-quality economic development [21–23]. Therefore, this paper proposes hypothesis 3.

H3. Inclusive digital finance can indirectly enhance high-quality economic development by promoting the upgrading transformation of consumption structure.

3. Variable selection and model specification

3.1. Variable selection and data sources

3.1.1. Dependent variable: high-quality economic development

Currently, there is no unified standard in the academic community for measuring the high-quality development of the economy. Most scholars measure the level of high-quality development by constructing an indicator system based on comprehensive evaluation methods. The selection of primary indicators is based on the "high-quality development concept," focusing on innovation, coordination, green, openness, and sharing. In the selection of secondary indicators, the criteria chosen by each scholar are not unique. In view of this, this study, based on principles such as data availability, scientificity and comparability, uses the high-quality development indicator system constructed by scholars such as Wei Min as the foundation, details are provided in Table 1 [24]. In the innovation dimension, considering that economic development and capital investment will promote scientific and technological levels to some extent, secondary indicators such as "Regional GDP growth rate" and the "Technical trade activity rate" are included. In the coordination dimension, the "Demand structure" is added to reflect the coordination between internal and external demand. In the openness dimension, considering that countries with a high degree of marketization usually tend to carry out market-oriented reforms and strengthen international integration, the "Degree of marketization" is added. In the sharing dimension, the concept of sharing mainly includes common prosperity, resource sharing, and social justice. Therefore, the indicators in the sharing dimension are set as "Share of workers' compensation"," Elasticity of personal income growth", "Rural-urban consumption gap" and "The share of private fiscal expenditure".

The entropy weight method, based on the concept of information entropy, objectively quantifies the relationships between various indicators, avoiding the interference of subjective evaluation and improving the objectivity of the evaluation results. Based on the principle of data availability, this study uses panel data from 30 provinces in China (excluding Tibet and Hong Kong, Macao, and

Table 1
High quality development index system.

Dimensions	Indicators	How indicators are measured	Efficacy
Innovative development	Regional GDP growth rate	Regional GDP growth rate	Positive
	R&d investment intensity	R&D expenditure of industrial enterprises/regional GDP	Positive
	Investment efficiency	Investment rate/regional GDP growth rate	Negative
	Technical trade activity rate	Technology transaction turnover/regional GDP	Positive
Coordinated development	Demand structure	Total retail sales of consumer goods/regional GDP	Positive
	Urban-rural structure	Urbanization rate	Positive
	Government debt burden	Government debt/regional GDP	Negative
	Industrial structure	Tertiary industry as a share of GDP	Positive
Green development	Energy consumption per unit of GDP	Total energy consumption/regional GDP	Negative
	Elasticity coefficient of energy consumption	Energy consumption growth rate/regional GDP growth rate	Negative
	Wastewater per unit of output	Wastewater discharge/regional GDP	Negative
	Exhaust gas per unit of output	Sulfur dioxide emissions/regional GDP	Negative
Open development	Degree of marketization	Regional marketization index	Positive
	Proportion of foreign investment	Actual utilization of foreign investment/regional GDP	Positive
	Foreign trade dependence	Total imports and exports/regional GDP	Positive
Shared development	Share of workers' compensation	Worker's compensation/regional GDP	Positive
	Elasticity of personal income growth	Growth rate of per capita disposable income/regional GDP	Positive
	Rural-urban consumption gap	Consumption expenditure of urban residents/Consumption expenditure of rural residents	Negative
	The share of private fiscal expenditure	Private fiscal expenditure/total fiscal expenditure	Positive

Taiwan) and employs the entropy weight method to measure the index of high-quality economic development.

In the first step, we apply the efficiency coefficient method to normalize all secondary indicators. Positive indicators are standardized using Eq. (1), while negative indicators are standardized using Eq. (2).

$$X_{ij} = \frac{X_{ij} - \min\left(X_{ij}\right)}{\max\left(X_{ij}\right) - \min\left(X_{ij}\right)}, \tag{1}$$

$$X_{ij} = \frac{\max\left(X_{ij}\right) - X_{ij}}{\max\left(X_{ij}\right) - \min\left(X_{ij}\right)}, \tag{2}$$

Where, i represents various indicators, j represents different provinces, and X_{ij} signifies the i-th indicator for province j. This approach serves to reduce the relative disparities among provinces.

In the second step, determining the contribution of indicators using Eq. (3). As the development directions of various provinces are not uniform, E_j can be used to represent the contribution of all indicators to X_j.

$$E_j = -K\sum_{i=1}^{n}\frac{X_{ij}}{\sum_{i=1}^{m}X_{ij}}ln\left(\frac{X_{ij}}{\sum_{i=1}^{m}X_{ij}}\right), \tag{3}$$

Where $K = \frac{1}{ln(n)}$, and n represents the number of secondary indicators, ensuring that E_j is greater than 0 and less than 1.

In the third step, we determine the weights of the five primary indicators (innovation, coordination, green development, openness, and sharing) using the entropy method. This process allows us to calculate the value coefficients for each indicator, the specific calculation process is described in Eq. (4).

$$w_j = \frac{1 - E_j}{\sum_{j=1}^{19}\left(1 - E_j\right)}, \tag{4}$$

In the fourth step, the high-quality economic development index for each province is calculated using the linear weighting method in Eq. (5).

$$Z_j = \sum_{i=1}^{19}\left(\frac{X_{ij}}{\sum_{i=1}^{m}X_{ij}}\right) \times w_j, \tag{5}$$

Where, Z_j represents the high-quality economic development index of province j, while w_j denotes the indicator weight for province j.

The data used in the calculation process are sourced from the "China Statistical Yearbook" and the statistical yearbooks of each province (city).

3.1.2. Explained variables and control variables

The primary explanatory variable in this paper is the Digital Inclusive Finance Index (DIFI). Given the multitude of factors influencing high-quality economic development, our study includes labor force capital level (labor), urban population density (people), government support (govern), energy structure (ES), and social consumption (consume) as control variables. Detailed explanations for the control variables can be found in Table 2. The data for the Digital Inclusive Finance Index are obtained from the Digital Finance Research Center at Peking University, while data for the control variables are extracted from the RESSET Macro-Economic Database.

3.1.3. Threshold variables and mediator variables

Given that the development of digital inclusive finance hinges on a robust internet infrastructure, our paper chooses the number of

Table 2
Explanation of variables.

Variable name	Instructions	Evaluation indicators
labor	Human capital level	Number of college graduates by province and city
people	Urban population density	The ratio of urban population to the land area of the administrative area in each province or city
govern	Government support	Spending by provinces and municipalities as a share of GDP
es	Energy mix	The proportion of fiscal environmental protection expenditures of provinces, cities and local governments in total fiscal expenditures
consume	Social consumption	Proportion of social retail consumption in GDP by province and city

broadband internet access users as a threshold variable. This choice enables us to investigate whether there exists a threshold effect of internet penetration rate in the promotion of high-quality economic development by digital inclusive finance.

Additionally, as residents' consumption levels have improved, there have been shifts in consumption structure. This paper investigates the mediating role of consumption structure upgrading in the process of digital inclusive finance promoting high-quality economic development. Consumption structure upgrading is chosen as the mediator variable and is measured by the proportion of development and enjoyment-oriented consumption expenditure in total consumption expenditure. Data for the threshold and mediator variables are obtained from the "RESSET Macro-Economic Database," and any missing values in the data are imputed using interpolation methods.

3.2. Variable selection and data sources

Due to the unavailability of the most recent data for the Digital Inclusive Finance Index and the statistical data for most provinces in 2022, we have chosen to utilize provincial panel data from 2011 to 2021 for constructing the econometric model. The model is configured as follows:

3.2.1. Spatial durbin model for enhancing high-quality economic development through digital inclusive finance

Following the practices of previous relevant studies, this paper initially sets up the panel spatial Durbin model in Eq. (6):

$$ecogrp_{it} = \alpha + \rho_i Wecogrp_{it} + \beta_1 difi_{it} + \rho_i Wdifi_{it} + \beta_2 control_{it} + \rho_i Wcontrol_{it} + \varepsilon_{it} \tag{6}$$

Where, i represents provinces, t represents years, α is the constant term, W is the spatial weight matrix, ρ_i is the spatial autoregressive coefficient, $control_{it}$ stands for control variables, and ε_{it} represents the random error term.

In subsequent empirical analyses, this paper exclusively focuses on the nested weight matrix derived from regional and economic factors. This matrix is presented as Eq. (7):

$$W = \left(w_{ij} \times \left(1 - \left| \frac{\overline{PGDP} - GDP_J}{\overline{PGDP} + GDP_J} \right| \right) \right), \tag{7}$$

Where, w_{ij} denotes a binary adjacency matrix, with $w_{ij} = 1$ indicating adjacent provinces and $w_{ij} = 0$ indicating non-adjacent provinces. $\overline{PGDP}$ represents the average per capita GDP of provinces over a specific period.

3.2.2. Panel threshold model for the impact of internet penetration rate on high-quality economic development

Prior research has shown that the thriving digital economy leads to reduced financing costs and service fees for financial institutions. Consequently, digital inclusive finance, utilizing the internet, establishes a mutually beneficial connection between the supply and demand aspects of inclusive finance. Thus, an increase in internet penetration rate can further enhance the role of digital inclusive finance in advancing high-quality economic development. To investigate whether the internet penetration rate indeed amplifies the promotional impact of digital inclusive finance on high-quality economic development, and inspired by Hansen [25], we construct the following threshold model in Eq. (8):

$$ecogrp = \theta_0 + \theta_1 difi_1 \cdot I(IP \le \gamma_1) + \ldots + \theta_{19}\beta_{19} \cdot I(IP \le \gamma_{19}) + \alpha_j control_j + \varepsilon \tag{8}$$

Where, γ represents the threshold value, and *control* denotes the control variable sinfluencing high-quality economic development.

3.2.3. Mediation effect model of consumption structure upgrading on high-quality economic development

Based on pertinent research, this paper proposes that digital inclusive finance can impact the high-quality economic development of both local and neighboring provinces by influencing consumption structure. To test this hypothesis, we establish a mediation effect model. The specific model is presented below:

The initial step involves a regression analysis, wherein we examine the relationship between the digital inclusive finance index and the high-quality economic development index. In this analysis, the digital inclusive finance index serves as the independent variable, while the high-quality economic development index functions as the dependent variable, the specific calculation process is set up as Eq. (9):

$$ecogrp = \alpha_0 + \alpha_i difi_i + \eta_j control_j + \varepsilon_0, \{i\epsilon(1,19), j\epsilon(1,5)\} \tag{9}$$

The second step involves a regression analysis, where we assess the relationship between the upgrading of consumption structure and the digital inclusive finance index using Eq. (10). In this analysis, the upgrading of consumption structure serves as the dependent variable, while the digital inclusive finance index is the independent variable:

$$exp = \pi_0 + \pi_i difi_i + \eta_j control_j + \varepsilon_1, \{i\epsilon(1,19), j\epsilon(1,5)\} \tag{10}$$

The third step involves introducing the upgrading of consumption structure as a mediating variable into the regression analysis between the digital inclusive finance index and the high-quality economic development index in Eq. (11):

$$ecogrp = \varphi_0 + \varphi_i difi_i + \mu control_j + \lambda\, exp + \varepsilon_2, \{i\epsilon(1,19), j\epsilon(1,5)\} \tag{11}$$

4. Empirical analysis

4.1. Spatial autocorrelation test

To explore the spatial effects of digital inclusive finance on high-quality economic development, we initially utilize Moran's I index to examine the spatial autocorrelation of both digital inclusive finance and high-quality economic development.

4.1.1. Global spatial correlation analysis

Global spatial autocorrelation assesses the clustering patterns of variables across the entire spatial domain. The test results, as shown in Table 3, reveal that the Moran's I indices for digital inclusive finance and high-quality economic development, spanning from 2011 to 2021, are both positive. This implies that they do not exhibit random spatial distribution but instead demonstrate spatial clustering tendencies.

4.1.2. Local spatial correlation analysis

To further explore the local spatial autocorrelation of digital inclusive finance and high-quality economic development, we separately created Moran's I scatterplots for these variables in 2011, 2015, and 2021. In these scatterplots, the first, second, third, and fourth quadrants represent high-high, high-low, low-low, and low-high clustering patterns, respectively. The results in Fig. (1) and Fig. (2) consistently reveal a similar pattern in Moran's I scatterplots for digital inclusive finance and high-quality economic development across different years. They predominantly fall within the first and third quadrants, with fewer outliers in the second and fourth quadrants. This consistent pattern suggests significant spatial autocorrelation and a positive spatial clustering effect for both digital inclusive finance and high-quality economic development.

4.2. Model identification

Before conducting spatial econometric regression, relevant tests were conducted to determine the optimal model (refer to Table 4). The LM test results indicate that Robust LM-Error passes the test at a 5% significance level, whereas Robust LM-Lag passes the test at a 1% significance level. Hence, it is feasible to choose either the spatial lag model or the spatial Durbin model (SDM). Furthermore, the Wald test results demonstrate that both Wald-error and Wald-lag pass the test at a 1% significance level, indicating that the SDM model will not deteriorate into SEM or SAR models. Moreover, in the selection between fixed effects and random effects, the Hausman test results pass the test at a 1% significance level, leading to the adoption of the fixed effects model.

When choosing models considering time, space, or both fixed effects, both Ind chi2 and Time chi2 tests pass at a 1% significance level, suggesting the adoption of a dual fixed effects model. Further examination of the regression results for the three spatial models with both time and space fixed effects, time fixed effects, and space fixed effects (refer to Table 5) reveals that SDM, SEM, and SAR models all satisfy the criteria for dual fixed effects. However, SDM exhibits a higher R-squared value compared to SEM and SAR models. Hence, selecting the dual fixed effects spatial Durbin model is a more reasonable choice.

4.3. Baseline regression

The empirical results of the spatial Durbin model are presented in Table 6. Model 1 and Model 2 correspond to the regression results without and with control variables, respectively. The regression results demonstrate that the coefficient of digital inclusive finance is positively significant at the 1% level in both Model 1 and Model 2. This implies that the advancement of digital inclusive finance contributes to enhanced economic high-quality development. Specifically, each unit increase in digital inclusive finance corresponds to a 0.074-unit increase in economic high-quality development. Furthermore, the continuous progress of digital inclusive finance not only fosters the expansion of the overall financial scale but also alleviates issues related to financial exclusion. Consequently, it serves as a significant driving force behind economic high-quality development.

Concerning the control variables, the selected variables—human capital level, urban population density, and government support—all exhibited statistical significance in the tests, whereas energy structure and social consumption did not. Among these, the positive coefficient of human capital level implies that an increase in human capital will propel economic high-quality development. This is primarily attributed to the vital role of innovation in economic high-quality development, and the enhancement of human

Table 3
Moran's I Index of Digital financial Inclusion and High-quality development.

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
difi	0.407***	0.416***	0.391***	0.411***	0.389***	0.395***	0.364***	0.344***	0.361***	0.394***	0.319***
	(5.418)	(5.592)	(5.310)	(5.555)	(5.292)	(5.373)	(4.989)	(4.704)	(4.909)	(5.144)	(4.918)
ecogrp	0.254***	0.233***	0.244***	0.247***	0.253***	0.268***	0.267***	0.233***	0.272***	0.243***	0.243***
	(3.996)	(3.677)	(3.803)	(3.747)	(3.775)	(3.349)	(3.677)	(3.900)	(3.922)	(3.567)	(3.577)

Note: ***, **, and * represent significant at 1%, 5%, and 10% levels, respectively, with robust standard error in brackets.

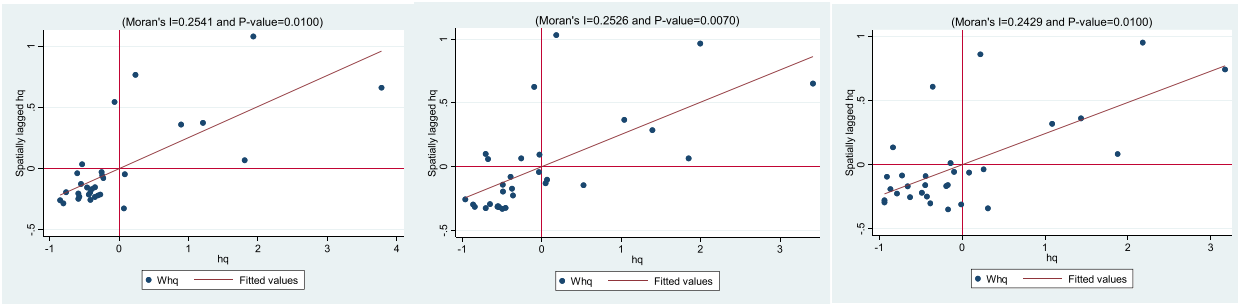

Fig. 1. Moran's I scatter plot for digital financial inclusion in 2011, 2015 and 2021.

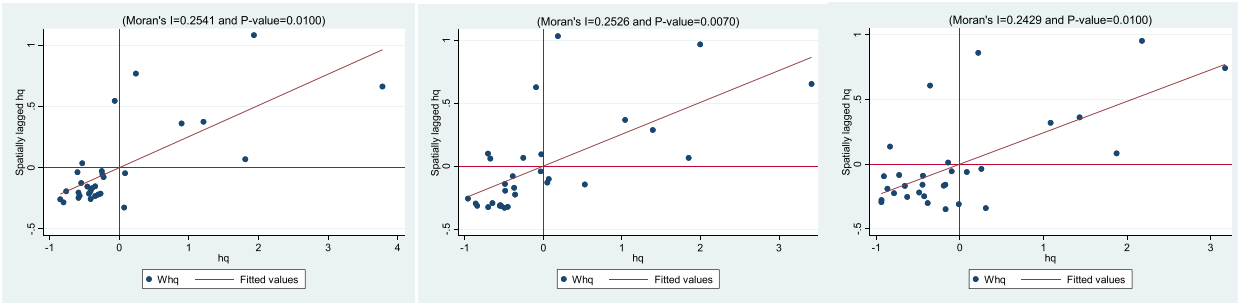

Fig. 2. Moran's I Scatterplot of high-quality development in 2011, 2015 and 2021.

Table 4
Model recognition test results.

Indicators	statistic	*P*-values
Robust LM-Error	5.920	0.015
Robust LM-Lag	20.177	0.000
Wald-error	21.56	0.002
Wald-lag	21.39	0.002
Hausman	300.71	0.000
Ind chi2	8.50	0.000
Time chi2	396.73	0.000

Table 5
Fixed effect estimation results of the three spatial models.

Variables	SDM model			SEM model			SAR model		
	Double fixing	Time Fixed	Space Fixed	Double fixing	Time Fixed	Space Fixed	Double fixing	Time Fixed	Space Fixed
difi	0.006***	0.074	0.004	0.010***	0.081	0.000	0.009***	0.080	0.000
	(0.007)	(0.007)	(0.007)	(0.006)	(0.005)	(0.001)	(0.007)	(0.006)	(0.001)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-sq	0.831	0.000	0.060	0.400	0.786	0.100	0.367	0.778	0.073
LL	219.893	418.320	224.187	230.196	426.258	231.388	230.274	431.298	231.312

Note: ***, ** and * represent significant at 1%, 5% and 10% levels, respectively, with robust standard error in brackets.

capital fosters innovation, thereby advancing economic high-quality development through innovative means. Conversely, the negative coefficient of urban population density suggests that a rise in urban population could impede economic high-quality development. This might be attributed to the heightened energy consumption associated with urban population growth, which is incongruent with the promotion of green development in economic high-quality development. Furthermore, the positive coefficient of government support signifies that an upsurge in the ratio of government fiscal expenditure to GDP will bolster economic high-quality development. When comparing the coefficients of the control variables, the government support coefficient stands out at 12.772, surpassing the coefficients of human capital (1.499) and urban population density (−0.424) significantly, underscoring government fiscal support as the paramount driving force behind economic high-quality development.

Table 6
Baseline regression results.

Variables	Model One		Model Two	
	main	w_x	main	w_x
difi	0.059*** (0.005)	0.021* (0.011)	0.074*** (0.007)	0.100*** (0.022)
lnecogrp			1.499*** (0.229)	3.165*** (0.932)
lnpeople			0.424** (0.203)	0.217 (0.707)
government			12.772*** (1.835)	27.812*** (7.194)
es			0.044 (0.247)	1.820* (0.930)
consumer			1.162 (1.343)	0.498 (5.498)
ProvinceFE	No		No	
YearFE	Yes		Yes	
rho	0.172 (0.131)		0.133 (0.131)	
sigma2_e	1.615*** (0.137)		1.274*** (0.108)	
R-sq	0.682		0.831	
Log-likelihood	450.743		418.320	
N	300		300	

Note: ***, **, and * represent significant at 1%, 5%, and 10% levels, respectively, with robust standard error in brackets.

4.4. Robustness test and endogeneity test

The empirical results of the spatial Durbin model are presented in Table 6. Model 1 and Model 2 correspond to the regression results without and with control variables, respectively. The regression results demonstrate that the coefficient of digital inclusive finance is positively significant at the 1% level in both Model 1 and Model 2. This implies that the advancement of digital inclusive finance contributes to enhanced economic high-quality development. Specifically, each unit increase in digital inclusive finance corresponds to a 0.074-unit increase in economic high-quality development. Furthermore, the continuous progress of digital inclusive finance not only fosters the expansion of the overall financial scale but also alleviates issues related to financial exclusion. Consequently, it serves as a significant driving force behind economic high-quality development.

1 To assess the model's reliability, we initially conduct a regression analysis involving a one-year lag in the independent variable. This lag represents the influence of the prior year's digital inclusive finance development on the current year's high-quality economic growth and its correlation with the dependent variable. The findings in Table 7, presented in the first column, reveal that the coefficient for digital inclusive finance from the preceding year stands at 0.022, signifying statistical significance at the 1% level. This suggests that the development of digital inclusive finance in the prior year continues to exert a noteworthy impact on the current year's economic expansion. This reaffirms the reliability and efficacy of the baseline regression estimates.
2 Acknowledging that omitted variables could impact the regression outcomes, this research endeavors to augment the existing set of control variables by incorporating agricultural labor productivity (ALE), clean energy utilization (CEU), the ratio of environmental pollution control investment to GDP (IPCI), the share of soil and water erosion control area (SE), and R&D expenditure as a fraction of GDP (RDGDP). As depicted in the second column, the empirical outcomes remain consistent even after the inclusion of these supplementary control variables. This underscores that digital inclusive finance plays a substantial role in advancing high-quality economic development.
3 In this context, the provincial-level internet penetration rate (IP) will serve as an instrumental variable for digital inclusive finance, aiming to tackle potential endogeneity concerns. An effective instrumental variable must meet both the relevance and exogeneity criteria. On one hand, digital inclusive finance relies on internet penetration for its generation and utilization, demonstrating a strong relevance. Conversely, improvements in internet penetration are not influenced by local economic factors but are primarily shaped by top-down national policies, emphasizing a strong policy orientation. Therefore, the internet penetration rate may effectively serve as an instrumental variable. The results obtained from the instrumental variable method, presented in the third

Table 7
Results of robustness test and endogeneity test.

Dependent variables	Robustness test		Endogeneity test
	One stage lag (1)	Add control variables (2)	Instrumental variables (3)
difi	0.022*** (0.008)	0.029*** (0.006)	0.010*** (0.002)
ale		0.081 (0.072)	
ceu		0.217 (0.293)	
ipci		0.020 (0.055)	
se		0.029 (0.079)	
rdgdp		1.612*** (0.005)	
R-sq	0.896	0.886	0.842
LR statistics	205.620	198.09	202.93
N	300	300	300

Note: ***, **, and * represent significant at 1%, 5%, and 10% levels, respectively, with robust standard error in brackets.

column of Table 7, demonstrate a substantial impact of digital inclusive finance on economic growth. The Anderson test p-value is 0, indicating statistical significance. The Cragg-Donald Wald F-test for the weak instrumental variable is 18.25, surpassing the critical value of 16. This result implies that there are no concerns regarding the strength of the instrumental variable or the identification of a weak instrument. The over-identification test (Sargan test) produces a p-value of 0, providing additional confirmation of the appropriateness of instrumental variable selection.

4.5. Decomposition of spatial effects

The results of the spatial effect decomposition (Table 8) indicate that digital inclusive finance has direct, indirect, and total effects on high-quality economic development, all of which are statistically significant at the 1% confidence level. This suggests that the growth of digital inclusive finance not only improves high-quality economic development within the province itself but also indirectly contributes to the high-quality economic development in neighboring provinces. With each one-unit increase in digital inclusive finance, the high-quality economic development in neighboring provinces experiences an increase of 0.079 units. This phenomenon can be attributed to the digital inclusive finance index encompassing elements related to digital financial coverage, depth of usage, and digitization. Provinces with elevated levels of digital inclusive finance exhibit broader digital financial coverage and higher rates of digital finance utilization. Moreover, owing to the efficient accessibility of internet services, digital inclusive finance in one province tends to extend to neighboring provinces with comparable economic development levels, consequently fostering high-quality economic development in those neighboring regions.

Regarding the control variables, the direct, indirect, and total effects of both human capital level and government support have all been found to be statistically significant at the 1% level. The direct effect of urban population density and the indirect effect of energy structure were significant at the 10% level, whereas none of the three effects of social consumption achieved statistical significance. Among these effects, those of human capital—direct, indirect, and total—are all positive, suggesting that human capital level positively influences the high-quality economic development of both the home province and neighboring provinces with comparable economic levels. This may be attributed to the interdependent and coordinated relationship between economic level and education level. In regions with a specific economic level, college students who receive education often seek employment in areas with similar economic levels. This tendency enhances innovation activity in their chosen employment areas and, in turn, drives high-quality economic development. The direct, indirect, and total effects of government support are all positive, indicating that increased government fiscal expenditure levels are associated with higher levels of high-quality economic development in both the home province and neighboring provinces with similar economic levels. This phenomenon occurs because local governments exhibit a neighboring learning effect in their public expenditure policies. An increase in government expenditure in one area induces neighboring areas with similar economic levels to follow suit, leading to an increase in government expenditure in the latter regions and, consequently, promoting high-quality economic development. The direct effect of urban population density is negative, but the indirect and total effects did not attain statistical significance. This suggests that an increase in urban population primarily restrains the high-quality economic development of the home province, with no significant spatial spillover impact on neighboring provinces.

4.6. Spatial effect heterogeneity analysis

4.6.1. Dimensional heterogeneity analysis of digital financial inclusion

Given that the Digital Inclusive Finance Index comprises dimensions such as digital financial coverage breadth, depth of digital financial usage, and the level of inclusive financial digitization, it is imperative to perform dimension-specific regression analyses on digital inclusive finance. The decomposition results (Table 9) indicate that digital financial coverage breadth exhibits direct, indirect, and total effects that are all statistically significant at the 1% level, with positive coefficients. Additionally, the direct and total effects of digital financial usage depth are statistically significant at the 1% level and possess positive coefficients. This suggests that expanding both the breadth and depth of digital financial coverage can foster high-quality economic development within the province. A plausible explanation for these findings is that provinces with extensive digital financial coverage capitalize on the internet's convenience to offer financial services to provinces with comparable economic profiles, thereby stimulating high-quality economic development in the latter.

Table 8
Decomposition of spatial effects.

Variables	Direct effects	Indirect effects	Total effect
difi	0.073*** (0.007)	0.079*** (0.028)	0.152*** (0.027)
lnecogrp	1.426*** (0.205)	2.549*** (0.743)	3.975*** (0.776)
lnpeople	0.408* (0.214)	0.241 (0.599)	0.166 (0.692)
government	12.269*** (1.790)	22.867*** (6.897)	35.136*** (7.417)
es	0.105 (0.272)	1.677* (0.915)	1.572 (1.071)
consumer	1.042 (1.285)	0.071 (5.034)	0.970 (5.393)

Note: ***, **, and * represent significant at 1%, 5%, and 10% levels, respectively, with robust standard error in brackets.

Table 9
Decomposition results of spatial effects by dimension of digital financial inclusion.

Core explanatory Variables	Direct effects	Indirect effects	Total effect
coverage_breadth	0.021*** (0.005)	0.055*** (0.021)	0.076*** (0.021)
usage_depth	0.077*** (0.006)	0.018 (0.018)	0.095*** (0.014)
digitization_level	0.004 (0.005)	0.013 (0.015)	0.017 (0.014)
Control	Yes	Control	Yes
Province FE	No	Province FE	No
Year FE	Yes	Year FE	Yes
N	300	N	300

Note: ***, **, and * represent significant at 1%, 5%, and 10% levels, respectively, with robust standard error in brackets.

4.6.2. Dimensional heterogeneity analysis of high-quality economic development

Economic high-quality development comprises five developmental concepts. To further investigate whether digital inclusive finance exhibits varying spatial effects on different dimensions of high-quality development, we conduct a spatial effect heterogeneity analysis. The spatial effect decomposition results for various dimensions of high-quality development are presented in Table 10. Regarding the total effects, the influence of digital inclusive finance on innovation, coordination, openness, and shared development has all been found to be statistically significant at the 1% level, with positive coefficients. Concerning direct effects, digital inclusive finance's influence on innovation, coordination, green development, and open development has all been found to be statistically significant at the 1% level, with positive coefficients. As for indirect effects, the coefficients associated with innovation, coordination, and shared development are all positive and demonstrate statistical significance. However, there is no statistically significant impact on green and open development.

4.7. Further study: threshold effect and intermediary effect

4.7.1. Empirical test of threshold effect

As previously discussed, it is clear that digital inclusive finance can substantially elevate the level of high-quality economic development. The internet penetration rate serves as the cornerstone for the development of digital inclusive finance. Consequently, the subsequent step involves examining whether the internet penetration rate could potentially constrain the efficacy of digital inclusive finance. Employing the internet penetration rate as a threshold variable, we utilize the Bootstrap method to simulate the likelihood ratio 200 times, generating threshold effect test results for the internet penetration rate (Table 11). The results show that the single-threshold effect model test for the internet penetration rate is statistically significant at the 5% level, thus rejecting the null hypothesis of no threshold. The two-threshold model test results are statistically significant at the 1% level, rejecting the single-threshold hypothesis. However, the three-threshold model does not achieve significance in the test. Consequently, the subsequent analysis will be conducted based on the two-threshold model.

In the estimation results of the two thresholds (Table 12), the first threshold is 95.5, and the second threshold is 2668.25, corresponding to 0.955 million and 26.6825 million internet broadband users, respectively. Both threshold values are within the 95% confidence interval, indicating the authenticity and effectiveness of the threshold results. The reason for the presence of an internet penetration rate threshold is that, to enhance the effectiveness of digital inclusive finance, it is imperative to not only develop and enhance digital financial service platforms from the "provider" perspective but also eliminate obstacles to digital financial access from the "user" perspective. Only when the target audience can access digital financial products more conveniently can digital inclusive finance genuinely realize its potential.

The estimation results of the dual-threshold model (Table 13) reveal that the influence of digital inclusive finance on high-quality economic development varies across distinct levels of internet penetration rate. At a relatively low internet penetration rate (IP $\leq$ 95.500), the estimated coefficient of digital inclusive finance on high-quality economic development is significantly positive at the 1% significance level, signifying that digital inclusive finance stimulates high-quality economic development in this phase. At a moderate internet penetration rate (95.500 $<$ IP $\leq$ 2668.250), the estimated coefficient is significantly positive at the 10% significance level.

Table 10
Decomposition results of the spatial effects of high-quality development by dimension.

Explained variables	Direct effects	Indirect effects	Total effect
Innovation	0.119*** (0.020)	0.130** (0.057)	0.249*** (0.050)
Coordination	0.066*** (0.006)	0.090*** (0.022)	0.156*** (0.020)
green	0.011*** (0.004)	0.006 (0.014)	0.005 (0.014)
Open	0.174*** (0.020)	0.007 (0.061)	0.167*** (0.058)
Shared	0.001 (0.017)	0.097* (0.055)	0.098* (0.053)
Control	Yes		
Province FE	No		
Year FE	Yes		
N	300		

Note: ***, **, and * represent significant at 1%, 5%, and 10% levels, respectively, with robust standard error in brackets.

Table 11
Test results of threshold effect.

Threshold variable	Threshold number	F-number	P value	Threshold	
				1%	5%
Internet penetration (IP)	Single threshold	4.823**	0.040	8.890	4.157
	Double sill	16.647***	0.000	1.689	0.080
	Three threshold	0.000	0.155	0.000	0.000

Note: F value, P value and critical value in the table are all the results obtained by Bootstrap repeated sampling 200 times. ***, ** and * represent significant at 1%, 5% and 10% levels respectively.

Table 12
Estimated values of threshold variables.

Threshold variable	Threshold value	Estimates	95% confidence interval
Internet penetration (IP)	Threshold value 1	95.500	[60.900, 3186.100]
	Threshold value 2	2668.250	[60.900, 3186.100]

Table 13
Estimated results of Internet penetration threshold.

Threshold variable: Internet Penetration (IP)	Estimated coefficient
IP 95.500 or less	0.009*** (0.003)
95.500 < IP 2668.250 or less	0.001* (0.001)
IP > 2668.250	0.004*** (0.001)

Note: ***, **, and * represent significant at 1%, 5%, and 10% levels, respectively, with robust standard error in brackets.

This indicates that the stimulating impact of digital inclusive finance on high-quality economic development begins to diminish after surpassing the initial threshold of internet broadband user access. In other words, when the number of internet broadband users exceeds 0.955 million but remains below 26.6825 million, each unit increase in digital inclusive finance will result in a 0.001-unit rise in high-quality economic development. At a high internet penetration rate (IP > 2668.250), the estimated coefficient is significantly positive at the 1% level, exceeding the estimated coefficient at the moderate internet penetration rate level. Hence, digital inclusive finance can consistently promote high-quality economic development in provinces only when the internet penetration rate reaches a specific threshold.

4.7.2. Empirical test of mediating effect

Some scholars have discovered that digital inclusive finance can enhance shared development across regions. The optimization of consumption structure plays a mechanistic role in this phenomenon. Shared development is a crucial component of high-quality economic growth. Hence, it is of considerable research importance to investigate whether digital inclusive finance fosters the improvement of consumption structure within the high-quality economic development context and whether it serves as an intermediary transmission mechanism.

In the mediation effect regression results, Model 1 examines how digital inclusive finance affects high-quality economic development before considering mediator variables. Model 2 focuses on how digital inclusive finance influences the improvement of consumption structure. Model 3 provides a comprehensive view of how digital inclusive finance affects high-quality economic development, considering consumption structure as a mediator variable. The results (Table 14) demonstrate that digital inclusive finance has a significant impact on the upgrading of consumption structure at a 10% significance level, suggesting that increased digital inclusive finance levels promote the transformation and improvement of consumption structure. After introducing the consumption structure mediator variable, the positive impact of digital inclusive finance on high-quality economic development continues to be significant. Furthermore, the regression coefficient for the improvement of consumption structure is also significantly positive, suggesting that digital inclusive finance positively influences high-quality economic development through the enhancement of consumption structure. After introducing the improvement of consumption structure, the regression coefficient for digital inclusive finance decreases from 0.101 to 0.069, suggesting the existence of partial mediation effects. This suggests that digital inclusive finance not only directly promotes high-quality economic development but also indirectly impacts the level of high-quality economic development through the enhancement of consumption structure.

Table 14
Regression results of intermediary effect.

Variables	Model One	Model Two	Model 3
	ecogrq	exp	ecogrq
difi	0.101*** (0.024)	0.001* (0.000)	0.069*** (0.026)
exp			15.935*** (4.456)
Control	Yes		
Province FE	No		
Year FE	Yes		
N	180		

5. Conclusions and recommendations

5.1. Conclusions

This paper begins by applying the entropy method to compute the comprehensive index of high-quality economic development for each province. Next, it investigates the spatial impacts of digital inclusive finance on high-quality economic development and conducts a spatial heterogeneity analysis of digital inclusive finance and high-quality economic development. Lastly, it examines the threshold effect of internet penetration rate and the mediation effect of consumption structure enhancement in the promotion of high-quality economic development by digital inclusive finance. The paper concludes with the following findings:

1 Digital inclusive finance can foster high-quality economic development and has notable spatial impacts. Its development not only elevates the level of high-quality economic development within the province itself but also contributes to the high-quality economic development of neighboring provinces.
2 Within the three dimensions of digital inclusive finance, broad digital financial coverage enhances high-quality economic development both within the province itself and in neighboring provinces with similar economic levels. The depth of digital financial usage, on the other hand, primarily impacts high-quality economic development within the province itself, while the degree of digitization shows no significant effect.
3 Internet penetration rate exhibits a dual-threshold effect on the impact of digital inclusive finance on high-quality economic development promotion, with stability in its effectiveness occurring only after surpassing the second threshold.
4 Digital inclusive finance enhances high-quality economic development by driving a transformation in consumption structure. The growth of development and enjoyment-oriented consumption within the structure enhances this effect, while subsistence-oriented consumption inhibits it.

5.2. Recommendations

Based on the aforementioned research conclusions, this article proposes the following recommendations to maximize the role of digital inclusive finance in promoting dynamic high-quality economic development in China:

1 Collaborative efforts among multiple stakeholders are imperative for fostering the development of digital inclusive finance. While digital inclusive finance indeed contributes to high-quality economic development, a closer examination reveals that the breadth and depth of digital financial coverage play a more significant role in driving economic growth. Hence, it is crucial to mobilize various sectors of society to facilitate the advancement of digital inclusive finance. For instance, at the community level, organizing digital inclusive finance lectures and various awareness-raising activities can enhance public education and understanding. In the corporate sector, allocating additional research funds for the development of digital payment software can extend the reach of digital inclusive finance to households, providing residents with greater convenience in their daily lives and, in turn, fostering economic development.
2 Fostering the Development of Digital Inclusive Finance through Multi-Regional Collaboration. Empirical research has shown that digital inclusive finance has spatial spillover effects on high-quality economic development. To effectively harness these spillover effects, local governments should first enhance cooperation and exchange with neighboring regions. This can be achieved by implementing corresponding preferential policies that facilitate the cross-regional flow of talent and technology. Secondly, local governments should improve digital infrastructure, including internet connectivity, to accommodate the spatial spillover effects associated with digital inclusive finance. Finally, they can capitalize on the leading demonstration and ripple effects observed in regions with advanced digital finance to stimulate the development of surrounding areas.
3 Advancing the Development of Digital Inclusive Finance through Diverse Avenues. Economic growth is traditionally driven by consumption, investment, and exports. However, recent global changes and the impact of the COVID-19 pandemic have reduced the effectiveness of investment and exports. Consequently, there is a need to prioritize economic development through the lens of consumption. Leveraging the intermediary and threshold effects, integrating household consumption with the internet can yield significant results with minimal effort. Therefore, government initiatives should focus on enhancing internet infrastructure, allocating increased funding for digital technology research and development, actively promoting internet accessibility, and

enabling broader public access to digital inclusive finance services via internet technology. This approach facilitates the transformation of consumer spending habits, thereby propelling high-quality economic development through increased consumption.

Data availability statement

The data that support the findings of this study are available on request from the corresponding author, upon reasonable request.

CRediT authorship contribution statement

Enze Li: Validation, Project administration, Methodology, Funding acquisition, Formal analysis, Conceptualization. **Yuanxiu Tang:** Writing – review & editing, Writing – original draft, Visualization, Investigation. **Yiwei Zhang:** Validation, Conceptualization. **Jiahui Yu:** Validation, Supervision, Software, Resources, Data curation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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