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How does digital finance affect industrial transformation?

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ABSTRACT

With the continuous advancement of technological revolution and industrial transformation, digital finance supported by big data and artificial intelligence has become an important engine for promoting carbon neutrality. We measured the industrial structure transformation index (ISU) of 30 provinces in China, and discussed the spatial spillover effect and transmission mechanism between digital finance and ISU using the spatial Durbin model. The research results demonstrate that the digital finance development can significantly improve the local ISU. Interestingly, the impact of digital finance on the ISU of adjacent areas has a significantly negative spatial spillover effect, which still exists under the different spatial weight matrix. Digital finance can improve ISU by improving green technology innovation, upgrading industrial structure, and alleviating capital allocation. We also found that the higher degree of marketization and environmental regulation can increase the positive influences of digital finance on ISU. This research proves the effectiveness of the digital finance in improving energy efficiency, and it encourages policymakers around the world to rely on digital finance to promote ecological governance and achieve high-quality economic development.

KEYWORDS

Digital finance; Industrial structure transformation; Threshold model; Spatial correlation; China

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1. Introduction

The acceleration of industrialization has brought unprecedented development opportunities to countries around the world, and has also triggered serious environmental problems (Iyaji, 2011; Ren et al., 2021a). With global warming and the frequent occurrence of extreme natural disasters, a series of international environmental laws, including the "Kyoto Protocol", "Paris Agreement", and "the World Environmental Pact", were promulgated to address extreme climate change and environmental pollution (Wu et al., 2021a; Yang et al., 2022). As the largest developing country, China's economy has grown at an average annual rate of 9.4% between 1978 to 2020. In 2019, the per capita GDP was close to US$10,000, exceeding the average level of upper-middle-income countries and creating a "China development miracle" (Hao et al., 2022). However, the growth model at the expense of natural resources and the ecology has made the problems of energy depletion and environmental pollution increasingly prominent (Wang et al., 2022a; Ren et al., 2022). The inefficient utilization of fossil energy inevitably leads to a decline in environmental quality. Taking PM2.5 as an example, the number of days where PM2.5 was the main pollutant accounted for nearly 80% of heavy pollution days in 2019, which was far higher than that in 2018 (nearly 60%). In response to the challenges of climate change and environmental issues, the environment department and firms have continuously increased their investment in pollution control (Zhou et al., 2022; Hao et al., 2023). The environmental pollution control investment in China increased from 116.67 billion yuan in 2000 to 953.9 billion yuan in 2017, which shows China's determination to environmental remediation.

The industrial structure upgrading is an important form of maintaining sustainable economic development (Wang and Wang, 2021). In the context of international circulation, China's industrial structure upgrade has entered a period of accelerated advancement (Liu et al., 2022b). Building a modern industrial system is the basis and core of promoting high-quality economic development. For a long time, the mismatch of financial resources has been restricting the development of China's industrial structure upgrade (Xi and Zhai, 2022). With the massive release of the digital economy dividend, the digital inclusive finance has the advantages of wider coverage, lower service cost and higher financial penetration (Hao et al., 2023; Sun and Tang, 2022). It provides more enterprises with fair and equal access to financial services, effectively lowers the threshold of financing, alleviates financial exclusion to a greater extent, and improves the efficiency of financial resource allocation (Hasan et al., 2022; Wu et al., 2022). Digital inclusive finance can break the limitation of time and space, and promote the sharing of information across regions. The impact of digital inclusive finance on industrial structure is not only intra-regional, but also cross-regional. Therefore, it is necessary to incorporate spatial correlation into the analytical framework to explore the impact of digital inclusive finance on the upgrading of industrial structure within and between regions at both theoretical and empirical levels (Hong et al., 2022).

Scholars hold different views on the influence of finance on industrial structure upgrading, mainly including the promotion theory and the inhibition theory. Scholars who hold the promotion theory have studied the paths of financial promotion for industrial structure upgrading from multiple perspectives, and believe that the paths of financial promotion for industrial structure optimization include capital formation and guidance mechanism and credit mechanism (Hasan et al., 2022). Further research finds that financial agglomeration provides diversified options for enterprise financing, lowers the financing critical value and saves financing cost, which is conducive to optimizing the allocation efficiency of resources and thus promoting industrial structure upgrading (Ziolo et al., 2017). In contrast, the suppression theory focuses on the issue of financial development appropriateness, arguing that if financial development is far ahead of industrial development, it may have a negative impact on industrial structural upgrading (Arcand et al, 2015).

Although the relationship between finance and industrial structure upgrading is a relatively popular issue in academic circles, the existing literature lacks a study on its impact on regional industrial structure upgrading from the perspective of digital inclusive finance. Financial inclusion, proposed by the United Nations in 2005, refers to a financial system that provides convenient financial services at an affordable cost to all social classes and groups in need of financial services (Dev, 2006). Inclusive finance covers a wide range of financial services, including payment and credit. It applies a variety of digital and intelligent tools such as big data, cloud computing and intelligent algorithms to promote financial innovation through digital financial services (Aisaiti et al., 2019). Moreover, it has the characteristics of low cost and wide range, which provides effective solutions to the problems in inclusive financial services and strengthens the inclusiveness of finance (Ketterer, 2017). Therefore, digital inclusive finance has received wide attention from all walks of life. Academic research on digital inclusive finance has focused on the impact of digital inclusive finance on commercial banks' efficiency and commercial bank risk (Pazarbasioglu et al., 2020), innovation and entrepreneurship (Wang and Zhang, 2022), urban-rural income gap and inclusive growth (Yao and Ma, 2022), residential consumption (Li, 2021) and carbon emissions (Wang et al, 2022b).

Although some scholars have started to pay attention to the relationship between digital inclusive finance and industrial structure, the existing literature has not sufficiently studied the possible spatial spillover effects of digital inclusive finance. To enrich the available literature, the present research makes three major contributions. First, digital finance and ISU are contained in the unified theoretical and empirical framework. It helps to enrich and expand the breadth and depth of research in the field of ISU. Second, to solve the endogeneity problem, the spatial Durbin model is used to test the spatial spillover effects between finance and ISU. Simultaneously, the mediation effect is applied to discuss the impact mechanism of the two variables. These models not only address the spatial spillover effects between variables, but also examine the channels of influence of digital finance on ISU. Third, the threshold model is introduced to test the effect of digital finance on ISU from the perspectives of environmental regulation and marketization process. This article evaluates the industry transformation role of digital finance from multiple perspectives.

2. Theoretical analysis and research hypothesis

Compared with traditional finance, digital inclusive finance has the features of easy access, low-cost and wide coverage (Du et al., 2022; Wang and Guo, 2022). It can provide enterprises with more convenient, efficient and accurate financing and information services, and a broader financing platform (Li and Li, 2022). In view of the above-mentioned characteristics of digital inclusive finance, the path of digital inclusive finance influencing the upgrading of regional industrial structure mainly includes the following aspects.

First, digital inclusive finance influences the upgrading of industrial structure through resource allocation effect (Hong et al., 2022). Digital inclusive finance is a product of the digital economy, relying on information technology, which effectively alleviates the long-standing financial exclusion of "ownership discrimination" and "scale discrimination" in the financial market (Wen et al., 2022). In addition, due to the iterative optimization of algorithms and the rapid upgrade of computer technology, digital inclusive finance can quickly and accurately match the demand side of the industry chain, reduce the information asymmetry between supply and demand, and lower the financing threshold and capital cost of enterprises (Liu et al., 2021). Digital finance reduces transaction costs, improves financing efficiency, optimizes resource allocation, and promotes industrial structure optimization and upgrading (Lee et al., 2022).

Second, digital inclusive finance influences the upgrading of regional industrial structure through demand effect (Li et al., 2022). The inclusive nature of digital inclusive finance provides new ways to reduce financial poverty. Numerous studies have also confirmed that digital inclusive finance can increase the income sources and income scale of disadvantaged groups, narrow the income gap and achieve inclusive growth (Yu and Wang, 2021; He et al., 2022). The increase in income can promote consumption upgrading through the transmission mechanism of production restructuring and industrial upgrading (Yu et al., 2021; Yang et al., 2021).

Third, digital inclusive finance affects the upgrading of regional industrial structure through the effect of technological progress. Technological innovation is an important driving force to promote the upgrading of industrial structure. Finance has always been an important guarantee for the development of innovation, and innovative activities cannot be carried out without financial development (Ayyagari et al, 2011; Hsu et al, 2014). Digital inclusive finance provides a broader investment portfolio to help investors control their investment risks through the innovation of financial services, and guides them to participate in innovative projects with good profit prospects by means of portfolio investment. Moreover, digital finance implements strict risk management to provide stable financial support for continuous innovation (Feng et al., 2022). Therefore, it can promote the improvement of technological innovation capacity (Sun and Tang, 2022).

Innovation is the core element affecting industrial structure upgrading, and the effective supply of finance will directly affect the development of innovative activities (Lin and Ma, 2022). However, the long-term inadequate supply of traditional financial services makes enterprises face serious external financing constraints, which greatly weakens innovation ability (Cao et al., 2021). Compared with the exclusivity of traditional finance, digital finance expands the breadth and depth of financial services, reduces financial transaction costs, and improves the external financing environment of enterprises (Wang et al., 2022b). Convenient financing channels and low financing costs meet the capital needs of enterprises in production and operation, value chain reshaping (Feng et al., 2022). In this case, it facilitates enterprises to focus more financial and human resources on technological innovation activities, improves the independent innovation capability and upgrades the industrial structure (Ahmad et al., 2021). At the same time, the development of digital finance can also help regional enterprises to carry out information technology analysis work by providing high-quality technical tools to achieve the effective identification of the optimal path of technological innovation evolution and improve the production and technological innovation decisions of enterprises (Razzaq et al., 2023).

3. Methodology and data

3.1. Research method

3.1.1. Basic model

To discuss the relationship between digital finance and ISU, the benchmark linear model (1) was constructed. Considering that the ISU may be influenced by the earlier stage, the $GTFEEISU_{it-1}$ is added to the model:

$$ISU_{it} = \beta_0 + \beta_1 ISU_{it-1} + \beta_2 DF_{it} + \beta_3 URB_{it} + \beta_4 GOV_{it} + \beta_5 FI_{it} + \beta_6 OPEN_{it} + \beta_7 RK_{it} + \mu_i + v_t + \varepsilon_{it} \quad (1)$$

where DF indicates digital finance; X represents control variable, including urbanization level (URB_{it}), government fiscal support (GOV_{it}), financial development (FI_{it}), opening level ($OPEN_{it}$), and capital mismatch (RK_{it}).

3.1.2. Spatial Durbin model

To accurately analyze the spatial effects between digital finance and ISU, we construct the following spatial measurement model based on a multi-dimensional spatial weight matrix.

$$ISU_{it} = \alpha + \rho \sum_{j=1}^{N} W_{ij}\, ISU_{jt} + \beta_1 DF_{it} + \beta_2 URB_{it} + \beta_3 GOV_{it} + \beta_4 FI_{it} + \beta_5 OPEN_{it} + \beta_6 RK_{it} + \beta_7 \sum_{j=1}^{N} W_{ij}\, DF_{jt} + \mu_i + v_t + \varepsilon_{it} \quad (2)$$

Where, ρ is the spatial spillover coefficient of ISU; W_{it} is the spatial weight matrix. The 0-1 matrix (W_{ij}^{G}) and the economic matrix (W_{ij}^{E}) are selected to analyze the spatial effect. In the above matrix, if area i and area j border, then W_{ij}^{G}=1, otherwise W_{ij}^{G}=0. The reciprocal of the economic development level gap between the two provinces is used to measure the economic weight matrix (W_{ij}^{E}).

Furthermore, we decompose the total effect into direct and indirect effects with the help of a partial derivative. Referring to the practice of Le-Sage and Pace (2010), the Eq (2) is transformed into a partial derivative matrix, and formula (1) is transformed into:

$$ISU_{it} = (1 - \rho * W_{it})^{-1}(\alpha \ln S_t + \beta W \ln S_t)\mu^* + (1 - \rho * W_{it})^{-1} \times \omega\varphi_M \quad (3)$$

In the formula, φ_M is the vector of M×1 order ISU; ω is a constant term; μ^* is a disturbance term; and lnS_t is an M×K dimensional matrix composed of explanatory variables. By introducing the strong assumption that the unit cross-section values are not correlated with each other through the spatial model, the partial derivative matrix applicable to this article is expanded, and the partial derivative matrix of the dependent variable $GTFEE_{it}$ for the K-th independent variable at T is:

$$\left[\frac{\partial lnGTFP}{\partial lnS_1^K} \cdots \frac{\partial lnGTFP}{\partial lnS_N^K}\right] = (1 - \rho * W)^{-1} \begin{bmatrix} \alpha_K & W_{12}\beta_K & \cdots & W_{1M}\beta_K \\ W_{21}\beta_K & \alpha_K & \cdots & W_{2M}\beta_K \\ \vdots & \vdots & \ddots & \vdots \\ W_{M1}\beta_K & W_{N2}\beta_K & \cdots & \alpha_K \end{bmatrix} \quad (4)$$

Note that the average value of the sum of diagonal elements in model (4) is the direct spillover effect, while the average value of the sum of other nondiagonal elements is the indirect spillover effect.

3.1.3. Threshold model

To study the impact of digital finance on ISU under environmental regulation. Referring to Wu et al. (2021b), the threshold model is established:

$$ISU_{it} = \alpha + \beta_1 ISU_{it-1} + \beta_2 DF_{it} \cdot I(q_{it} \le c) + \beta_3 DF_{it} \cdot I(q_{it} > c) + \sum_{k=1}^{4} \delta_k X_{kit} + \alpha_i + v_t + \varepsilon_{it} \quad (5)$$

3.2. Selection of variables

Industrial structural upgrade. The upgrading of industrial structure is an important dimension of industrial structure adjustment, which mainly refers to the process of industrial structure development. When industries with higher labor productivity account for a larger share, we can consider the regional industrial structure to be more advanced. To reasonably measure the upgrading of industrial structure, referring to Liu et al. (2008), the weighted value of the proportion of each industry multiplied by its labor productivity is chosen to measure the upgrading of industrial structure. The specific calculation formula is:

$$upq_{i,t} = \sum_{m=1}^{3} y_{i,m,t} \times lp_{i,m,t} \qquad m = 1,2,3 \quad (6)$$

Where, $y_{i,m,t}$ is the proportion of the m industry in the i region to GDP, and $lp_{i,m,t}$ is the labor productivity of the m industry in the i region. The calculation formula is as follows:

$$lp_{i,m.t} = \frac{Y_{i,m,t}}{L_{i,m,t}} \quad (7)$$

$Y_{i,m,t}$ represent the added value of the m-th industry in the i area, and $L_{i,m,t}$ represent the employees of the m-th industry in the i area.

Digital finance (DF). The Digital Inclusive Finance Index, jointly compiled by the Institute of Digital Finance of Peking University and Ant Financial Services Group, is used to measure the overall development level of digital finance in China (Li et al., 2020). The index measures the breadth of coverage, depth of use and degree of digitalization of digital finance, along with sub-indexes such as payment, insurance, monetary funds, credit services, investment and credit. The index covers 31 provinces, 337 cities at prefecture-level and above, and about 2,800 counties in Chinese Mainland, which is conducive to understanding the developing status and trend of digital inclusive finance in China. In this paper, we divide the digital finance index by 100 to improve the accuracy and rationality of the analysis.

Capital mismatch (RK). According to the method of Wu et al. (2021b), we approximate the absolute distortion coefficient by calculating the relative distortion coefficient of the factors and then obtains the resource mismatch degree for capital factors.

Green technology innovation (GT). Based on the IPC Green Inventory classification number, we obtain patent data for green technology (Ren et al., 2021). The patent classification codes are obtained according to the guidelines of the "IPC Green Inventory" on the website of the WIPO. The number of patent applications and grants for green technology innovation in various provinces and cities in China over the years can be queried in the patent system database of the State Intellectual Property Office of China according to the international patent classification code, application time and address.

Environmental regulation (ER). Referring to the research of Ren et al. (2020b), we use industrial wastewater emissions, SO2 emissions, and smoke and dust emissions to calculate the comprehensive index of environmental regulation intensity. The larger the comprehensive index, the more pollution emissions and the weaker the intensity of environmental regulations. The specific calculation methods for environmental regulations are as follows. First, standardize the three pollutants:

$$UE_{ij}^{S} = \frac{\left[UE_{ij} - min\left(UE_j\right)\right]}{\left[max\left(UE_j\right) - min\left(UE_j\right)\right]} \tag{8}$$

Where, UE_{ij} is the emission per unit output value of the jth pollutant in province i, and UE_{ij}^{S} is the standardized result of the indicator. The max (UE_j) represents the maximum value of the emission per unit output value of the j pollutant, and min (UE_j) represents the minimum value.

Calculate the weight of various pollutants:

$$W_j = UE/\overline{UE}_{ij} \tag{9}$$

$\overline{UE}_{ij}$ represents the average value of the emission per unit output value in 30 provinces in each year. The comprehensive index of environmental regulation for province i is:

$$ER_i = \frac{1}{3}\sum\nolimits_{j=1}^{3} W_j\, UE_{ij}^{S} \tag{10}$$

Control variables. By referring to Wang et al. (2021), Liu et al., 2022a, and Hao et al. (2020), We add some control variables to the model. We use the ratio of government public fiscal expenditure to GDP to measure the level of fiscal support (GOV). The level of financial development (FIN) is measured by the ratio of the balance of loans of financial institutions to GDP at the end of the year. The actual use of foreign capital as a percentage of GDP is used to measure the degree of openness. The level of urbanization (URB) is measured by the proportion of the urban population in the total population. The descriptive statistics of the variables are reported in Table 1.

Table 1. The statistical description of variables.

Variable	Definition	Obs	Mean	Std. Dev.	Min	Max
DF	Digital finance	270	203.3576	91.56749	18.33	410.28
ISU	Industrial structural upgrade	270	0.8018	0.1431	0.2068	0.9799
URB	Urbanization	270	0.5764	0.1218	0.3496	0.8960
GOV	Government fiscal support	270	0.0292	0.0313	0.0096	0.2180
FIN	Financial development	270	1.4368	0.4411	0.6706	2.5772
OPEN	Economic openness	270	0.0208	0.0190	0.0000	0.1210
GT	Green technology innovation	270	0.0951	0.1329	0.0008	0.7040
ER	Environmental regulation	270	0.5207	0.5333	0.0000	2.5853
RK	Capital mismatch	270	0.2772	0.1758	0.0005	0.8217

4. Empirical results and discussion

4.1. Spatial correlation test

This article uses 0-1 weight matrix to test the Moran's I statistic of the core variable (ISU). Table 2 shows the global Moran's I and Geary's c value of ISU. Overall, the global Moran's I of the core variable (ISU) during 2011 to 2019 is between 0.460 and 0.606. Geary's c also showed that China's ISU exists significant positive spatial autocorrelation. This result shows that the ISU of each province is not randomly distributed in space, but has a strong positive correlation and spatial aggregation.

Table 2. Global correlation test.

	Moran's I					Geary's c				
Year	I	E(I)	SD (I)	z	p-value	I	E(I)	SD (I)	z	p-value
year2011	0.606	1.000	0.149	-2.647	0.004	0.609	1.000	0.101	-3.865	0.000
year2012	0.565	1.000	0.145	-3.006	0.001	0.587	1.000	0.099	-4.172	0.000
year2013	0.564	1.000	0.143	-3.056	0.001	0.590	1.000	0.098	-4.187	0.000
year2014	0.507	1.000	0.140	-3.510	0.000	0.561	1.000	0.097	-4.534	0.000
year2015	0.519	1.000	0.139	-3.451	0.000	0.567	1.000	0.096	-4.499	0.000
year2016	0.460	1.000	0.139	-3.874	0.000	0.526	1.000	0.096	-4.922	0.000
year2017	0.509	1.000	0.142	-3.473	0.000	0.545	1.000	0.097	-4.674	0.000
year2018	0.537	1.000	0.142	-3.259	0.001	0.560	1.000	0.098	-4.500	0.000
year2019	0.516	1.000	0.143	-3.398	0.000	0.541	1.000	0.098	-4.685	0.000

4.2. The estimated results of the spatial Durbin model

The regression results in Table 3 show that there is spatial autocorrelation between ISU in various provinces of China. Therefore, this paper analyzes the impact of local economic growth objectives on ISU based on the 0-1 matrix and the economic matrix. The results show that the regression coefficients of GF are significantly positive under the two spatial weights, indicating that green finance has a positive effect on local ISU. Compared with traditional financial services, digital finance can have a more prominent direct impact on the upgrading of industrial structure in two ways. On the one hand, digital finance not only changes the traditional financial service model, but also effectively reduces the threshold of access to financial services, improves the allocation efficiency of credit resources, alleviates the phenomenon of financial inhibition, and promotes the upgrading of industrial structure and economic structural transformation. On the other hand, digital finance has, to a certain extent, alleviated the information asymmetry within and across industries, reduced the external financing costs of enterprises and promoted industrial transformation.

In addition, it is noteworthy that under the two weight matrices, the coefficient of W*DF is consistently positive. These results suggest that there exists a positive effect between the local green finance and the ISU of the neighboring areas. Furthermore, to accurately measure the spatial spillover effects, referring to method Lesage and Fischer (2008), we use partial differential decomposition to decompose the total effect into direct and indirect effects. The estimated results of the decomposition effect also verify that green finance promotes local ISU, but reduces ISU in neighboring areas.

Table 3. The results of the spatial model.

Variables	Main	Direct	Indirect	Total	Main
DF	0.142***	0.151***	-0.112***	0.054**	0.039**
	(4.240)	(5.272)	(-6.442)	(2.051)	(2.126)
URB	0.307***	0.280***	0.118***	0.148***	0.150***
	(23.94)	(15.24)	(6.80)	(9.28)	(12.85)
GOV	0.075***	0.098***	0.072***	0.044***	0.051***
	(17.14)	(12.71)	(10.37)	(9.71)	(7.93)
FIN	-0.016**	-0.024**	-0.032***	0.003	-0.012***
	(-2.07)	(-2.31)	(-4.22)	(0.78)	(-2.63)
OPEN	0.018***	0.026***	0.025*	0.065***	0.073*
	(3.682)	(3.742)	(1.715)	(3.730)	(1.727)
RK	-0.076***	-0.133***	0.149***	0.060	0.178***
	(-3.212)	(-4.485)	(3.125)	(1.025)	(4.012)
W*DF	-0.075***				-0.032*
	(-5.749)				(-1.648)
Spatial rho	-0.450***				-0.545***
	(-4.272)				(-4.223)
sigma2_e	0.005***				0.001***
	(6.120)				(5.611)
R2	0.7580				0.6626
N	270				270

*Notes: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.*

4.3. The results of mediation model

The above research found that digital finance can promote ISU. However, what is the impact mechanism? The green technological innovation and capital mismatch are used as mediation variables for impact mechanism analysis. The regression results of the mediation effect model are shown in Table 4.

Models (1) and (2) test the impact of digital finance on green technological innovation. It shows the regression coefficient of DF is significantly positive, showing that the development of digital finance can significantly improve green technological innovation. This is basically consistent with the existing research conclusions (Cao et al., 2021; Li et al., 2021). We incorporate the digital finance development and two mediation variables into models (2) and (4). It can be found that the coefficient of green innovation is significantly positive, indicating that green technological innovation can effectively improve ISU. It can be concluded that the digital finance improves the ISU by promoting green innovation. First, digital finance promotes green technology innovation. Compared with general technology innovation, green technology innovation is characterized by high input costs, relatively slow profitability, high uncertainty and high risk, which makes enterprises lack incentives to carry out green technology innovation. The development of digital finance has injected new momentum into green technology innovation. First, digital finance extends the reach of traditional finance and increases the possibility of small businesses to enjoy fair financial services. Second, digital finance enriches the access to data and information and reduces the degree of information asymmetry. It reduces the cost of public participation in environmental monitoring, curbs environmental corruption, and pushes enterprises to increase R&D of green technologies to cope with the digital external environment. Therefore, digital finance has a positive promotional effect on green technology innovation.

It is worth noting that when capital misallocation is used as a mediation variable, the results of model (3) and model (4) show that digital finance can increase ISU by reducing capital mismatch. In fact, with the support of digital financial innovation, digital finance supported by internet information technology reduces information asymmetry, increases the speed of capital flow. Digital inclusive finance can effectively solve the problem of information asymmetry between financial institutions and enterprises, which is conducive to solving the financing constraints of enterprises. Digital inclusive finance reduces transaction costs in the process of capital allocation mainly in the following ways: First, online transactions break through regional restrictions, broaden the scope of business radiation, and reduce the cost of raising funds. Second, digital finance can reduce the cost of obtaining enterprise information and the cost of loan approval by controlling the risk through cloud computing. Third, digital inclusive finance services provide credit services online without relying on physical branches, which effectively reduces the operating costs of financial institutions.

Table 4. Estimation result of the mediation effect.

Variable	(1)	(2)	(3)	(4)
	GT	ISU	RK	ISU
GT		0.333***		
		(3.403)		
RK				-0.128***
				(-3.601)
DF	0.041***	0.210***	-0.182**	0.015*
	(3.125)	(4.661)	(-2.575)	(1.753)
URB	0.021***	0.024***	0.020***	0.038***
	(4.144)	(3.857)	(6.266)	(4.108)
GOV	0.018***	0.031***	0.035***	0.051***
	(2.864)	(3.500)	(4.314)	(4.156)
FIN	0.086***	-0.090**	-0.029***	0.015*
	(2.595)	(-2.286)	(-2.808)	(1.764)
OPEN	0.0003***	-0.006***	-1.670***	0.005***
	(2.747)	(-5.309)	(-2.752)	(2.898)
_cons	0.379***	0.339***	0.665***	0.598***
	(14.724)	(10.405)	(7.815)	(5.737)
R2	0.5102	0.8320	0.2606	0.7012
N	270	270	270	270

*Notes: * p < 0.1, ** p < 0.05, *** p < 0.01.*

4.4. The results of dynamic threshold effect

The realization of sustainable economic development is inseparable from the reversing effect of environmental regulations on ISU. As the global environment continues to deteriorate, environmental regulation has become an important policy tool for countries around the world to improve the effectiveness of environmental governance. Therefore, we hold the view that the effect of digital finance on ISU may be influenced by the intensity of environmental regulations.

To confirm this hypothesis, this article uses the environmental regulations intensity as threshold variables to test the possible non-linear relationship between digital finance and ISU. According to the Ward statistical value and P-value test results of different threshold values, we found that with environmental regulation strength as the threshold variable, digital finance has passed the threshold effect test (Table 5). This verifies that when the degree of the level of environmental regulation are in different threshold ranges, the impact of digital finance on ISU has obvious non-linear characteristics (Table 6). Columns (3) and (4) show the estimation results using environmental regulation as the threshold variable. When the environmental decentralization exceeds the threshold value, the positive impact of green finance on ISU gradually increases. In other words, environmental regulations can strengthen the role of digital finance in improving ISU. A significant reason for this result is that achieving economic green transformation requires a lot of environmental investment and efficient environmental supervision. Strict environmental regulations can stimulate green investment and pollution control of enterprises. With the help of big data and information sharing platforms, digital finance can guide social funds to flow into green industries and accelerate the formation of the green industrial system.

Table 5. The threshold effect test.

Variables	Model	Threshold	Wald	P	Lower	Higher
ER	SYS-GMM	0.2406	30.4258	0.0000	0.0019	1.7636
	DIF-GMM	0.2406	30.4258	0.0000	0.0019	1.7636

Table 6. The result of threshold models.

Variable	ER	
	SYS-GMM	SYS-GMM
ISUit-1	0.9860***	1.1771***
	(10.68)	(6.96)
URB	-0.1361	-0.3221
	(-0.81)	(-1.44)
GOV	-0.0702	0.2107
	(-0.57)	(1.00)
FIN	0.0246	0.0535
	(0.83)	(1.13)
OPEN	-0.6497	0.0478
	(-1.40)	(0.51)
$DF(q_{it} \leq C)$	0.0111*	0.0255**
	(1.74)	(2.25)
$DF(q_{it} > C)$	0.0131***	0.0270***
	(3.37)	(2.71)
_cons	0.0114	
	(0.29)	
AR(1)	-3.28	-2.94
	[0.001]	[0.003]
AR(2)	-0.34	0.13
	[0.734]	[0.895]
Hansen test	9.42	9.09
	[0.400]	[0.106]
N	330	330

*Notes: * p < 0.1, ** p < 0.05, *** p < 0.01.*

5. Conclusion

Taking the data of Chinese provinces as the research sample, we quantitatively analyze the relationship between digital finance and ISU. The empirical results show that digital finance has promoted the improvement of local ISU. However, digital finance reduces ISU in neighboring areas. Digital finance can improve ISU through green innovation and industrial upgrading and capital allocation. Additionally, with the improvement of the marketization and environmental regulation, the role of digital finance in improving ISU is gradually increasing. Therefore, we provide the following policy recommendations.

Firstly, it is necessary to vigorously develop digital inclusive finance to strengthen the service function of finance and promote the structural adjustment and optimization of the financial system. The government should strengthen the function of digital inclusive finance in allocating resources and supporting science and technology innovation to provide accurate financial services and guarantee for promoting the innovation-driven development strategy.

Second, our research confirms that digital inclusive finance can promote the upgrading of industrial structure. Therefore, it is necessary to continue to expand the width and depth of the development of digital inclusive finance, enhance the degree of digital support with the help of new digital technologies such as mobile Internet and big data, continuously innovate digital financial products, stimulate the vitality of digital inclusive financial entities, and give play to the role of digital inclusive finance in promoting the upgrading of industrial structure.

Third, in order to enhance the radiation effect of the central region to the surrounding areas and reduce the siphon effect, the government should improve the institutional design, encourage cross-regional economic and financial cooperation, and optimize the spatial layout of financial resources. In addition, it is necessary to promote the flow of financial resources to the less developed areas in the surrounding economy, optimize the allocation of financial resources in these regions, and give full play to the regional radiation effect of digital inclusive finance business.

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Declaration of Competing Interest

All the authors claim that the manuscript is completely original. The authors also declare no conflict of interest.

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