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The Intermediary Role of Deep Learning in Financial Resource Allocation

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Abstract

In the context of digital economy development and the advancement of "dual carbon" goals, fintech has become a core driving force for optimizing financial resource allocation. However, there is a structural contradiction between financial agglomeration in the eastern region and inclusive finance lagging in the western region, with a prominent issue of the lack of spatial coordination mechanisms. On the basis of panel data from 31 provinces in China from 2011--2020, this paper explores the impact mechanism of fintech on resource allocation efficiency through the coupling coordination degree model, a three-step regression method for mediating effect testing, and Moran's I analysis. The authors find that fintech indirectly optimizes resource allocation by enhancing the degree of coupling coordination, i.e., "technology-inclusiveness-greenness", with the mediating effect accounting for 52.3%. The degree of coupling coordination exhibited significant regional agglomeration, with a pattern of "high in the east and low in the west" and increasing spatial dependence annually. This research provides micromechanism support for regional financial coordination policy formulation and spatial planning, echoing the requirements of high-quality development.

Keywords

FinTech, green finance, inclusive finance, mediation effect, spatial Moran's I

1. Introduction

In the process of developing the digital economy and achieving the goals of a "carbon peak and carbon neutrality", fintech has become the core driving force for optimizing financial resource allocation by reducing service costs and expanding the coverage of green finance. However, the imbalance in resource allocation among regions is prominent and manifests as a structural contradiction between financial agglomeration in Eastern China and inclusive finance lagging in Western China, highlighting the lack of a spatial coordination mechanism.

Currently, existing articles have achieved certain theoretical breakthroughs. He et al. (2022) demonstrated that deep learning can optimize green credit risk assessment. Wan et al. (2024) first constructed an "Inclusive Finance-Green" coupling model, confirming that fintech improves collaborative efficiency by alleviating resource mismatch. Xu et al. (2025) discovered that green finance policies have cross-regional spillover effects, with a radiation radius of up to 200 kilometers in the eastern region. Xie et al.'s (2024) research analyzed the policy spillover between green finance and inclusive finance through fintech. However, there is currently a lack of empirical testing on the intermediary pathways of the "technology-inclusive finance-green" coupling system, especially a lack of quantitative analysis of the financial spatial coordination mechanism.

Moreover, the integration of financial technology with inclusive finance and green finance has garnered increasing attention. The application of deep learning in green credit risk assessment has enhanced market risk assessment and resource allocation capabilities (He et al., 2022). Coupling models reveal the driving effect of financial technology on inclusive–green synergy (Wan et al., 2024). The spatial spillover of green finance policies indicates interregional influence, whereas dual machine learning and spatial econometric models emphasize the impact of financial technology on regional green energy technology innovation (Xie et al., 2024; Xu et al., 2025). Mediation effect analysis in related fields, such as Wen and Ye (2014), provides a methodological foundation. Research on urban economic resilience and the coupling analysis of the urbanization-ecological environment provide insights into the measurement of spatial effects (Jiang, 2025; Wang et al., 2015). This study fills the gap in the empirical testing of mediation and spatial effects in the nexus of financial technology, inclusivity, and greenness.

Therefore, on the basis of panel data from 31 provinces from 2011--2020, this study first verifies the mediating role of the degree of coupling coordination in the impact of financial technology on resource allocation. It then employs Moran's I index to investigate one of the causes of structural contradictions in China's regions. This article not only provides micromechanism support for national regional coordination policies but also lays a foundation for spatial planning, echoing the high-quality development requirements of the National Development and Reform Commission.

2. Research Methods

2.1 Variable Definitions and Data Sources

2.1.1 Variable Definition

Table 1 provides a detailed introduction to the variables used below. The research sample in this paper is derived from panel data spanning from 2011--2020 and collected from 31 provinces and municipalities directly under the central government (excluding Hong Kong, Macao, and Taiwan region). The data originate primarily from the National Bureau of Statistics and the Digital Economy Research Center of Peking University. Missing data points were filled via linear interpolation. Additionally, all the data were categorized on the basis of specific indicator names, with years listed as column names and administrative divisions listed as row names. These data were then compiled into nine data tables.

Table 1: Introduction to Variables

variable type	variable name	symbolic representation	Main constituent indicators
independent variable	Comprehensive score of financial technology	X	Digital Inclusive Finance Index
			Number of internet plus access ports per 10,000 people
dependent variable	Efficiency of financial resource allocation	Y	Comprehensive score of green finance
			Comprehensive score of inclusive finance
mediating variable	coupling coordination degree	M	Comprehensive score of financial technology
			Comprehensive score of green finance
			Comprehensive score of inclusive finance
control variable	urbanization rate	U	Urban population and permanent resident population
	GDP per capita	G	Local GDP and permanent resident population
	Proportion of revenue from the tertiary industry	T	Income from the tertiary industry and GDP

First, this study uses the min–max normalization method to standardize all the collected initial data. The specific formula used is as follows:

$$x' = \frac{x\text{-}min(x)}{max(x)\text{-}min(x)} \tag{1}$$

In this context, 'x' represents any data point in each table, 'max(x)' represents the maximum value of all the data points in the column where the data point is located, and 'min(x)' represents the minimum value of all the data points in the column where the data point is located. Through this normalization process, the original data can be uniformly mapped to the interval [0, 1], eliminating the impact of dimensional differences among different indicators on subsequent calculations.

Second, this paper uses standardized data to calculate the comprehensive scores of inclusive finance (designated P), green finance (designated G), and fintech (designated F) for each region over the years through the weighted average method. The specific formula is as follows:

$$P=\sum_{j=1}^{n} w_j x'_{ij,P},\ G=\sum_{j=1}^{m} w_j x'_{ij,G},\ F=\sum_{j=1}^{k} w_j x'_{ij,F} \tag{2}$$

where xij, P', xij, G', and xij, F' represent the standardized values of the j-th inclusive finance, green finance, and fintech indicators in the *i-th* region, respectively; wj is the weight of the corresponding indicator. This paper adopts the equal weight method (i.e., wj=1/n, wj=1/m, wj=1/k), where n, m, and k are the numbers of inclusive finance, green finance, and fintech indicators, respectively; the value range of P, G, and F is [0,1], and a higher value indicates a better development level in the corresponding field.

2.2 Model and Method

(I) Coupling coordination degree model

The coupling coordination degree is used to measure the level of coordinated development among the systems of financial technology, inclusive finance, and green finance. This paper comprehensively measures it through two indicators: the degree of coupling (C) and the degree of coordination (D). The specific calculation formula is as follows:

Coupling degree formula:

$$C=(F\times P\times G)^{\frac{1}{3}} \tag{3}$$

Among them $C\in[0,1]$, the closer the value of C is to 1, the greater the degree of coupling and correlation among the three systems.

The comprehensive development level formula is as follows:

$$T=\alpha F+\beta P+\gamma G \tag{4}$$

Among them, $T\in[0,1]$ represents the overall development level of the three systems; α, β, γ for the purpose of combining research focus with literature conventions, this paper adopts $\alpha=\beta=\gamma=1/3$.

The coupling coordination degree formula is as follows:

$$D=\sqrt{C\times T} \tag{5}$$

Among them $D\in[0,1]$, the closer the value of D is to 1, the higher the level of coordinated development among the three systems. According to the D value, the coordination level is as shown in Table 2:

Table 2: Evaluation criteria and division basis

level	Division basis
Extreme imbalance	$D\leqslant0.1$

Severe imbalance	$0.1<D\leqslant 0.2$
Moderate imbalance	$0.2<D\leqslant 0.3$
Mild imbalance	$0.3<D\leqslant 0.4$
forced coordination	$0.4<D\leqslant 0.5$
Junior Coordinator	$0.5<D\leqslant 0.6$
Intermediate Coordination	$0.6<D\leqslant 0.7$
Good coordination	$0.7<D\leqslant 0.8$
High-quality coordination	$0.8<D\leqslant 1$

(II) Mediating effect test via the three-step regression method

To verify the mediating effect of the degree of coupling coordination (*M*) on the impact of financial technology (*X*) on the efficiency of financial resource allocation (*Y*), this paper adopts a three-step regression method to construct the following model:

Step 1: Test the total effect

$$Y=cX+\varepsilon_1 \tag{6}$$

where Y is the efficiency of financial resource allocation, X is the comprehensive score of financial technology, c is the total effect coefficient, and ε_1 is the random error term.

Step 2: Test the effect of the independent variables on the mediating variable

$$M=aX+\varepsilon_2 \tag{7}$$

where M is the degree of coupling coordination ε_2, a is the effect coefficient of financial technology on the degree of coupling coordination, and it is the random error term.

Step 3: Test the mediating effect and direct effect

$$Y=c'X+bM+\theta_7 urban+\theta_8 pgdp+\theta_9 third+\varepsilon_3$$

where b represents the effect coefficient c' of the degree of coupling coordination on the efficiency of financial resource allocation and represents the direct effect coefficient of financial technology on the efficiency of financial resource allocation; $third pgdp urban$ represents the urbanization rate, per capita GDP, and the proportion of revenue from the tertiary industry, respectively (control variables); $\theta_8 \theta_7$ and θ_9 represent the coefficients of the control variables; and ε_3 represents the random error term.

The formula for calculating the proportion of the mediating effect is as follows: proportion of the mediating effect = $\frac{|a\times b|}{|a\times b|+|c'|}\times 100\%$. If b both a and are significant and if the c' absolute value is less than the c absolute value, then there is a partial mediating effect.

(III) To assess spatial autocorrelation and examine the regional agglomeration characteristics of coupling coordination, this paper employs the global Moran's *I* index to measure the degree of spatial autocorrelation. The calculation formula is as follows:

$$I=\frac{n\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}(x_i-\bar{x})(x_j-\bar{x})}{\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}\sum_{i=1}^{n}(x_i-\bar{x})^2} \tag{7}$$

where *n* represents the number of regions (*n*=31 in this paper); *xi* and *xj* are the coupling coordination degree values of region *i* and region *j*, respectively; $\bar{x}$ is the mean value of the coupling coordination degree of all regions, that is, $\bar{x}=\frac{1}{n}\sum_{i=1}^{n}x_i$; w_{ij} is the element of the spatial weight matrix, and in this paper, a binary adjacency weight matrix is adopted (i.e., if region i is adjacent to region j, $w_{ij}=1$; otherwise, $w_{ij}=0$, and $w_{ii}=0$).

The correspondence between the results and conclusions of Moran's I index is shown in Table 3:

Table 3: Correspondence between Moran's I judgment criteria and conclusions

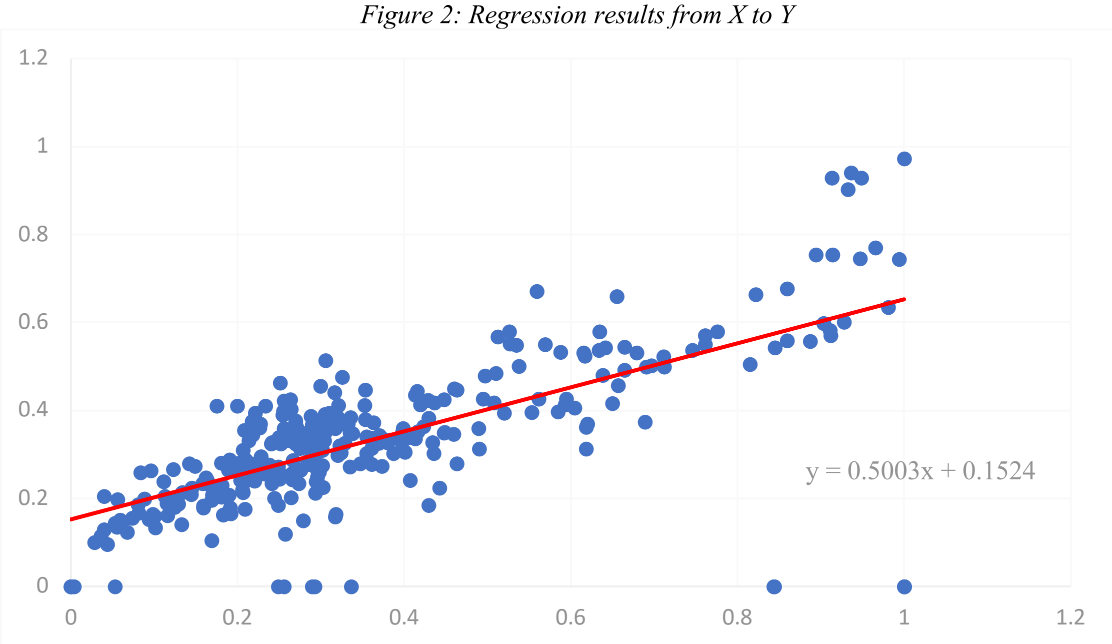
criteria for judgment	Conclusion
$I > 0$	There is positive spatial autocorrelation, meaning that high-value areas are adjacent to each other (clustering feature)
$I < 0$	There is negative spatial autocorrelation, which means that high-value areas are adjacent to low-value areas (discrete feature)
$I = 0$	In the absence of spatial autocorrelation (random distribution), the significance of I is determined through the Z test. If $P \leq 0.05$, then spatial autocorrelation is significant.

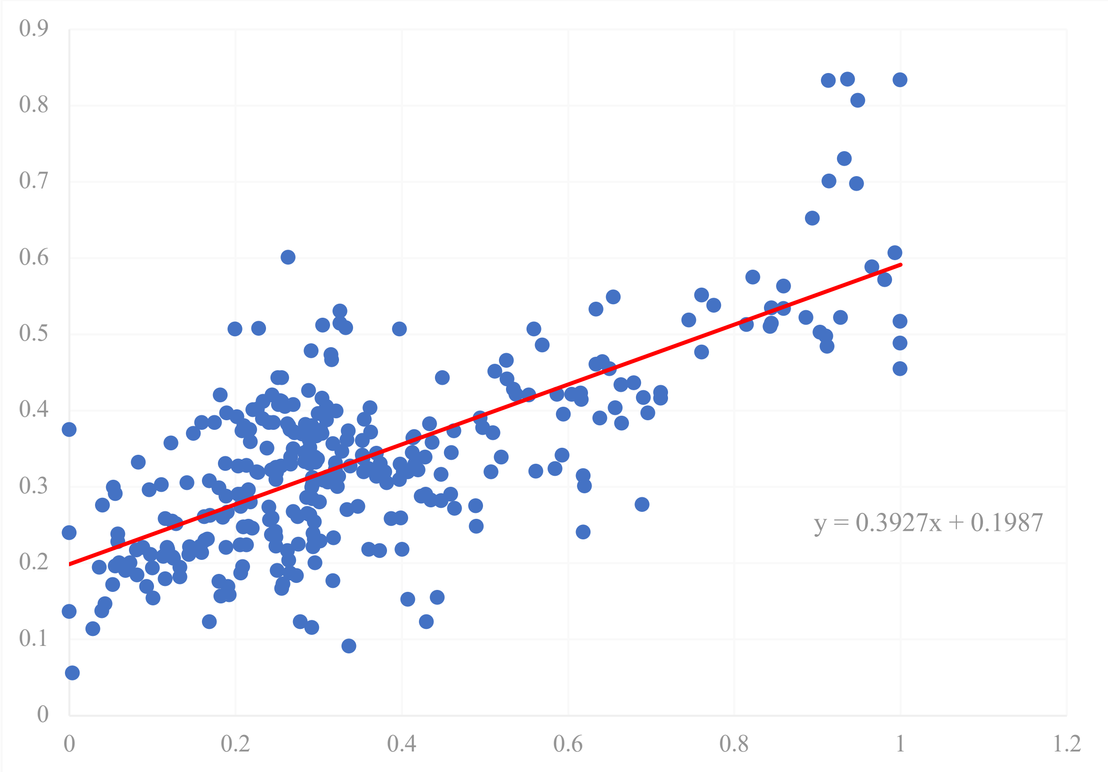
3. Research Results

3.1 Mediation Effect Test Results

This study obtained the following results through regression analysis of the independent variables, dependent variables, and mediating variables. As shown in Figure 1, the slope of the fitted straight line of the scatter points is 0.5003, so the regression coefficient from X to M is 0.5003, denoted as a.

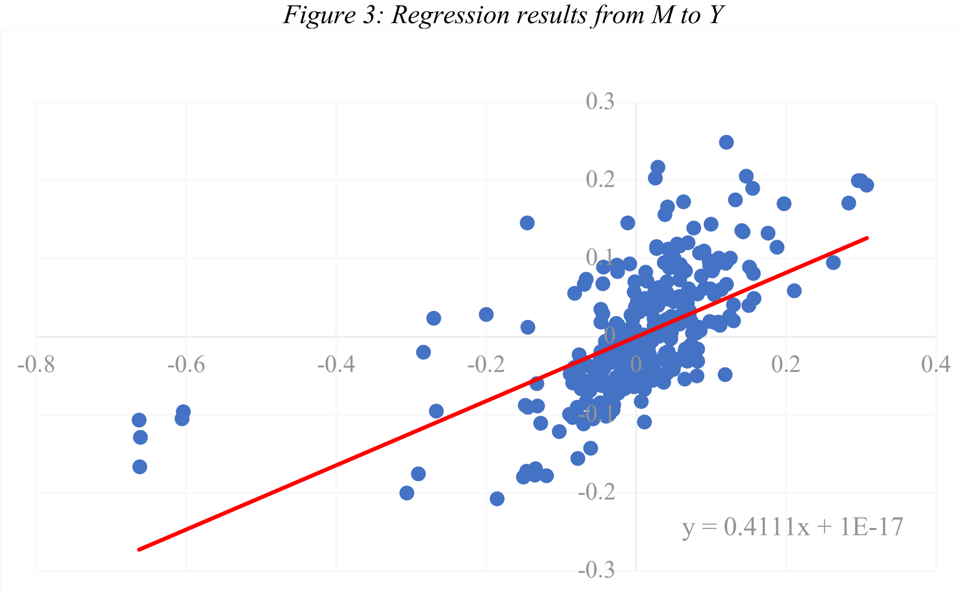
Figure 2: Regression results from X to Y





As shown in Figure 2, the slope of the fitted straight line of the scatter points is 0.3927, so the regression coefficient from X to Y is 0.3927, denoted as c.

Figure 3: Regression results from M to Y



As shown in Figure 3, the slope of the fitted straight line for the scatter points is 0.4111; hence, the regression coefficient from M to Y is 0.4111, denoted b. When the regression from M to Y is studied, the obtained results are shown in Table 4.

Table 4: Regression results

	Coefficients	standard error	t Stat	P value
Intercept	0.143386	0.012467	11.50105	<0.01
Coupling coordination degree (M)	0.403666	0.029955	13.47583	<0.01
Fintech score (X)	-0.0578	0.023128	-2.4993	<0.01
GDP per capita	0.219988	0.035765	6.150956	<0.01
urbanization rate	0.042501	0.037288	1.139801	0.255267

Proportion of the tertiary industry	0.022906	0.025492	0.898564	0.369596

As shown in the figure, the regression coefficient for X reaching Y without the mediation of M is -0.0578, denoted as c'.

On the basis of the three-step mediation effect test method mentioned above, the following results are shown in Table 5.

Table 5: Numerical Data Collection

result	numerical value
a	0.5003
b	0.4111
The absolute value of c	0.3927
The absolute value of c	0.0578

Table 5 clearly shows that when the product of a and b is greater than 0, the absolute value of c is less than the absolute value of c', and the ratio of a multiplied by b to c is approximately 52.3%. Thus, fintech indirectly optimizes resource allocation by promoting the degree of coupling coordination between inclusive finance and green finance, and the degree of coupling coordination plays a partial mediating role in the relationship between fintech and resource allocation efficiency.

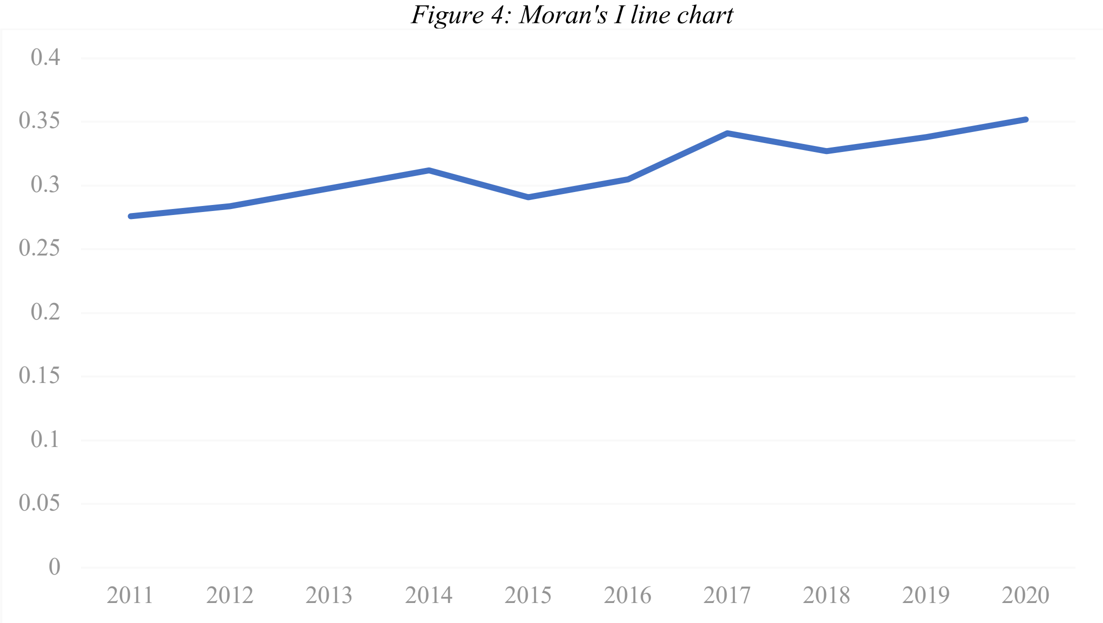
3.2 Moran's I Test Results

In this study, using Moran's I formula mentioned above and the binary spatial weight matrix obtained through statistics, the global Moran's I values from 2011--2020 are calculated and presented in Table 6 below:

Table 6: Statistical table of the global Moran's I index from 2011--2020

Year(s)	Moran's index	P value (rounded to three decimal places)
2020	0.352	<0.001
2019	0.338	0.002
2018	0.327	0.003
2017	0.341	0.001
2016	0.305	0.008
2015	0.291	0.012
2014	0.312	0.006
2013	0.298	0.010
2012	0.284	0.015
2011	0.276	0.018

Figure 4: Moran's I line chart



As shown in Figure 4, the Moran's I index was greater than 0 from 2011--2020, and the p values were all less than 0.05, indicating that the degree of coupling coordination always exhibited regional agglomeration. Moreover, the Moran's I index increased from 0.276 in 2011 to 0.352 in 2020, indicating that spatial dependence has strengthened annually.

4. Conclusion and Outlook

After the aforementioned research is conducted, two core conclusions are drawn: First, fintech not only directly influences the optimization of resource allocation but also indirectly optimizes resource allocation by enhancing the degree of coupling coordination (with the mediation effect accounting for 52.3%). This research result confirms the transmission mechanism of “fintech promoting regional synergy, and regional synergy promoting resource efficiency improvement”. Second, the development of fintech exhibits a certain degree of regional agglomeration, characterized by being “higher in the east and lower in the west”. As evident from the above, the global Moran's I index showed an overall upward trend from 2011--2020, indicating that financial development in various provinces and cities prefers agglomeration, thus forming a pattern of “higher in the east and lower in the west”.

On the basis of the aforementioned research findings, this paper proposes two policy recommendations: First, establish a cross-provincial fintech sharing platform for interprovincial exchanges to mitigate the uneven financial development issues caused by agglomeration. Second, targeted digital infrastructure (5G + blockchain) should be deployed in the western region to promote the development of fintech in the west, thereby enabling one province to cooperate with neighboring provinces. This study did not incorporate economic distance weights (such as GDP flow) in the calculation of spatial effects and Moran's I index. Future research could explore this issue further by integrating the gravity model.

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Conflicts of Interest

The authors declare no conflict of interest.

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