Spatial Correlation and Its Driving Reasons for Chinese Provincial Digital Finance

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Abstract—**In this study, we examine the spatial correlation between China's regional digital financial development and its driving factors based on a network perspective and relational data. Based on the 2011-2020 digital financial inclusion index for 31 Chinese provinces (autonomous regions and municipalities directly under the central government), compiled by Peking University, and Pearson's correlation coefficient method and SNA method to analyze the data. Based on the quantitative analysis, Chinese provincial digital financial development shows a significant "center (eastern provinces) - edge (central and western provinces)-unbalanced spatial distribution pattern. The correlation relationship and spillover effect of interprovincial digital financial development are prominent. It is important to note that there is a low degree of spatial correlation, no pronounced hierarchical structure or redundancy in the spatial spillover network, and a good degree of robustness in the spatial spillover network. In China, digital financial development mainly occurs in the developed coastal provinces along the east coast, while the central and western provinces are on the periphery of this development. Eastern provinces serve as intermediaries and centers for digital financial development, attracting the inflow of factors and resources from the central and western regions. All 31 provinces are divided into four different types of blocks, each with a different status and role in the spatial spillover network. Each block has its own functions and comparative advantages. The short geographical distance between the provinces, the large gap in economic development and informatization levels, the similarity in financial literacy and the small income gap are all conducive to facilitating digital finance spillovers from the provinces and narrowing the gap in digital finance development between the provinces. The findings may have a positive impact on the ability of policymakers to promote the harmonious development of digital finance at the provincial level in China.**

Index Terms—**Digital finance, spatial spillover, impact factors, social network analysis**

I. Introduction

With the in-depth promotion of China's "Internet Plus" strategy, the extensive application of the Internet in economic and social fields has given birth to a series of new "Internet Pluse" economic models; thus, the Chinese digital finance industry came into being. The digital finance industry is a new financial industry that incorporates artificial intelligence, mobile payments, big data technology, cloud computing, blockchain, and other digital information technologies with traditional finance. Compared to traditional finance, the superiority of digital finance lies in breaking through the limitations of time and space. As a result of digital finance, institutions are not required to be established, financial services are provided more widely, the costs and thresholds of financial services are minimised, and financial resources are allocated more efficiently and conveniently in relatively remote areas, thus expanding the universality and inclusiveness of financial services as never before [1-4]. Different provinces in China have differing levels of information technology and financial development, resulting in differences in the development of digital finance in different provinces. Accelerating the development of digital finance in different provinces in China in a high-quality coordinated manner presents a major challenge. Therefore, promoting a balanced and high-quality development of digital finance across all provinces, it is necessary to explain the spatial spillover effects and influencing factors of China's digital financial development based on the scientific layout of digital financial development space.

At present, there are few research references on the spatial spillover of digital finance and its development impact in China, and the existing references mainly use parametric econometric models to study the spatial spillover and its influencing factors [5-7]. In spite of this, with the development of Internet-based information and communication technologies, the process of network convergence is accelerating, there are complex network relationships between individuals and groups in the regional network, and the parametric econometric model cannot accurately analyse the non-independent relationships in the economic and social environment, so we cannot have a clear understanding of the complex network relationships and Effects of digital finance development on spatial correlations at the provincial level. In contrast, the social network analysis (SNA) method is capable of overcoming the limitations of parametric econometric methods in order to analyze the spatial complexity of relationships and spatial spillover effects of digital financial development in regions; the SNA method can also overcome the autocorrelation of parametric econometric models to achieve hypothesis testing of the relationship between matrix-relational data and obtain relatively unbiased regression estimates [8-12].

The relationship strength matrix of provincial digital financial development from 2011 to 2020 is derived based on the network perspective and relationship data by using the Pearson correlation coefficient method. Then, using the SNA method, analysis of the structural characteristics of provincial digital financial development is based on the construction of a spatial correlation network. Lastly, we analyze the data using the Quadratic Assignment Procedure (QAP) method to explore the drivers of spatial associations of provincial digital financial development in China.

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II. Research methods and sample data

A. Determination of spatial correlations

In this study, we analyzed the spatial spillover network relationship between digital financial development in 31 provinces [13-16] by calculating Pearson's correlation coefficient. Sequences of $X_m(t)=[X_m(1),\cdots,X_m(t)]$ and $X_n(t)=[X_n(1),\cdots,X_n(t)]$ represent the digital finance development index series in province m and province n at time t, respectively. The correlation coefficient between the two provinces can be expressed as follows:

$$C_{mn}=(\left|\overrightarrow{X_m}\cdot\overrightarrow{X_n}\right|-\left|\overrightarrow{X_m}\right|\cdot\left|\overrightarrow{X_n}\right|)\Big/\sqrt{(\overrightarrow{X_m^2}-\left|\overrightarrow{X_m}\right|^2)\cdot(\overrightarrow{X_n^2}-\left|\overrightarrow{X_n}\right|^2)} \quad (1)$$

In equation (1), C_{mn} is the correlation coefficient of two sequence vectors of $\overrightarrow{X_m}$ and $\overrightarrow{X_n}$, the range of correlation coefficients is [-1, 1], and $\left|\overrightarrow{X_m}\right|$ is the expected value of X_m. We can obtain the correlation distance D_{mn} of regional digital finance development by the correlation coefficient C_{mn}, and the correlation distance D_{mn} formula is as follows:

$$D_{mn}=\sqrt{2(1-C_{mn})} \quad (2)$$

In equation (2), the correlation distance ranges from [0, 2], and the main purpose is to verify the three properties that must be satisfied by the Euclidean distance metric.

In accordance with equation (2), relevant distance matrix D for the development of digital finance in each province. We find that the correlation between the digital financial development of the two provinces is highest when the distance value D_{mn} is 0. Additionally, the correlation distance between digital financial development in each province can also be expressed as the inverse of the correlation strength.

$$J_{mn}=1/D_{mn} \quad (3)$$

Equation (3), J_{mn} represents the strength of the digital financial linkages between m and n provinces. In the intensity matrix $J(m,n)=(J_{mn})_{N\times N}$, each element determines the edges of the spatial association network of digital finance, and each province constitutes a node. In order to maintain the accuracy of the overall analysis of the overflow network, we binarise each element of the correlation strength matrix by setting a threshold. Thus, each row element of the intensity matrix has a mean value $J(m,n)$ are set to the threshold so that the intensity matrix $J(m,n)$ can be transformed into a 0–1 asymmetric matrix $\overline{J(m,n)}_{31\times 31}$. Following is a description of the specific binarization method:

$$\overline{J(m,n)}=\begin{cases}1 & J_{mn}\geq\sum_{n=1}^{N}J_{m\cdot}/N\\0 & J_{mn}<\sum_{n=1}^{N}J_{m\cdot}/N\end{cases} \quad (4)$$

In equation (4), $J_{m\cdot}$ is the sum of the elements in each row, and N is the number of elements in a matrix.

B. Methodology for social network analysis

We can analyze and obtain the structural characteristics and influencing factors of the spatial correlation network by calculating the correlation matrix between provinces using equations (1) through (4). On the basis of the SNA method, a directed spatial overflow network is then drawn. The SNA methodology is currently used to describe the relationship between variables in society and the economy. There are now applications of this methodology in the fields of finance, economics, and management science as well as sociology [17-22].

1) Correlation Analysis

There are several metrics that can be used to determine network relevance, including network density, correlation, efficiency, and hierarchy. Using these metrics, it is possible to determine whether the correlation network is dense, structured, and stable. A higher density signifies a stronger correlation network overall; a lower density indicates a weaker correlation network. A network's correlation can be defined as the degree of connectivity between nodes, and it is used to determine the robustness of the network. A network that has a correlation of 1 is robust and highly connected. As a result, at least one node has been excluded from the network. Asymmetric reachability between nodes can be measured using the network hierarchy. As the level of the network increases, the network hierarchy becomes more pronounced, the location of each node varies more, the number of core nodes decreases, and the number of edge nodes increases. A network's efficiency is determined by the number of communication channels connecting the nodes. There are fewer communication channels between nodes when the efficiency is higher, and the associated network is less stable if the efficiency is higher.

2) Centrality analysis

In order to measure the centrality of nodes, three main metrics are used: point centrality, neighbour centrality, and inter-degree centrality. In a network, point centrality refers to the position of each node. A node with a higher point centrality degree is more likely to be connected with other nodes in the network, indicating that it is located at the centre. In general, it is used to determine the degree to which one node is unaffected by another. A node with higher proximity and centrality is more likely to be influenced by other nodes in the network. The main purpose of mediation centrality is to observe the mediation effect of nodes. In terms of its level of communication with other nodes, the node with a higher level of mediation centrality is more likely to be in the channel of other nodes.

3) Methodology for Block model Analysis

The block model analysis method analyzes social roles in a descriptive and algebraic manner, primarily in order to determine the position of each node. This method of block model analysis is effective in measuring the internal structure of a digital financial association network, as well as the role played by each node and the relationship between them. There are four main types of blocks in the network.

a. Bidirectional overflow block: This block sends more correlation relationships both within and outside the block but receives fewer correlation relationships that are sent from the outer block.

b. Net Benefit Block: This block has a high percentage of internal links and a low percentage of external links. Specifically, the correlation coefficient between internal and external blocks is zero.

c. Intermediate block: This block serves as a bridge between other blocks. Within the block, there are fewer relationships among members; however, there are more correlations with members external to the block. It not only sends relationships to the outer block but also receives relationships from the outer block.

d. Net overflow block: In this block, relationships are primarily sent to external blocks, fewer relationships are sent to internal blocks, and fewer relationships are received from external blocks.

4) QAP Analysis method

The Quadratic Assignment Procedure (QAP) is a non-parametric statistical method primarily used to compare the similarity between elements in two relationship matrices. In order to do this, two matrices are compared and the correlation coefficient is calculated using a nonparametric test. There are two methods that make up the QAP method: correlation analysis and regression analysis. In correlation analysis, the correlation coefficient between two relationship matrices is calculated in order to determine whether there is a correlation between them. By examining the causal relationship between a relationship matrix and multiple relationship matrices, regression analysis can be used to determine whether the evaluation coefficients of a regression model are significant. The QAP method of analysis has two advantages over traditional statistical measures of parameters. First, mutual independence of independent variables is not a necessary option for the QAP method, as a result, the problem of "high correlation" or "multicollinearity" of independent variables is avoided in parameter estimation using traditional measurement techniques. Secondly, the QAP analysis method solves the problem that traditional parameter estimation methods cannot test whether there is a specific causal relationship between a matrix of dependent variables and multiple matrices of independent variables. Therefore, the QAP analysis method has good robustness, which is why we use it to explore the relevance of promoting digital finance at the provincial level in China.

C. Variable measure and sample data

1）Variable Selection Basis

The independent variables used in this paper are used to describe the development of digital finance at the provincial level. Based on the availability and reliability of data and the development process of finance, we will conduct an empirical analysis of 31 Chinese provinces (autonomous regions and municipalities) between 2011 and 2020. The sample data was obtained from the website of Peking University's Institute of Digital Finance (http://idf.pku.edu.cn).

Digital finance is an innovative financial model that can effectively meet the financial service needs of all classes and types of groups on the basis of traditional finance and through integration and Innovation using digital information technologies, such as big data, the Internet, and cloud computing. Digital finance inherently has the development characteristics of traditional finance and digital information technology industry. Therefore, the factors that promote the development of traditional finance or digital information will also affect the development of digital finance.

Thus, based on the reference to the existing relevant research literature focusing on the impact of the development characteristics of traditional finance and digital information technology on the differences in the development of digital finance and taking into account the availability and authority of the sample data [4-7], it can be determined that the independent variables affecting the development of provincial digital finance are the level of economic development (defined in terms of regional GDP per capita), the degree of marketisation (defined in terms of the ratio of government financial expenditure to regional GDP), financial literacy (defined by regional average years of education), the degree of informatisation (defined by regional internet penetration), income level (defined by regional disposable income per capita), traditional financial development (defined by regional average years of education), financial literacy (defined by regional average years of financial literacy (defined by regional average years of education), informatisation (defined by regional internet penetration), income level (defined by regional disposable income per capita), traditional financial development (defined by regional financial institutions' assets as a percentage of regional GDP) and geographical factors (defined by regional population density). The data for these explanatory variables were obtained from the China Statistical Yearbook, the China Internet Development Report, the China Financial Statistics Yearbook, and the China Urban Construction Statistics Yearbook.

2）Measure of variables

From the perspective of network and relationship data, we use QAP analysis to analyse the drivers of digital finance development at the provincial level in China, which requires each variable to be transformed into 31 × 31 dimensional relationship matrix data. Therefore, the modified gravity model was selected for the independent variables to measure the relationship gravity matrix of digital finance regional development. The independent variable relationship matrix measurement uses the absolute value of the difference between the mean of the influence variable and the mean of the sample period to construct the difference matrix [15]. Specifically, the mean of each row of the difference network matrix of the variable in the sample period is used as the cut-off point (if it is greater than the mean, it is recorded as 1; otherwise, it is recorded as 0), and the difference matrix of the 1 model is formed.

3）Model setting

In order to determine the influencing factors of China's regional digital financial development, we developed a QAP multivariate empirical regression model. By analyzing the correlation intensity matrix of digital financial development as well as the variable difference matrix of the selected influencing factors, we will be able to identify the mechanisms through which each explanatory variable factor influences regional digital finance development. The specific regression model is set as follows:

$$DFI = f(JG, SC, ED, XH, CY, JF, DJ) \qquad (5)$$

Each variable in equation (5) is a 31×31-dimensional relationship matrix between provinces k and l, $DFI\,(k, l)$ is the correlation relationship intensity matrix for the development of digital finance, $JG(k, l)$ is the economic development difference relationship matrix, $SC(k, l)$ is the marketization degree difference relationship matrix, $ED(k, l)$ is the financial literacy difference relationship matrix, $XH(k, l)$ is the informatization degree difference relationship matrix, $CY\,(k, l)$ is the income level difference relationship matrix, $JF(k, l)$ is the traditional financial development difference relationship matrix, and $DJ(k, l)$ is the difference relationship matrix of geographical factors.

III. EMPIRICAL ANALYSIS

A. Construction of the correlation network

The 1-model asymmetric correlation intensity matrix can be calculated using equations (1) to (4) and then the spatial correlation network map of China's digital financial development can be drawn using the UCINET and Netdraw software packages (see Figure 1). n Figure 1, we can see that there are no isolated provinces in the correlation network, and that the majority of the digital financial development is concentrated in eastern provinces, including Beijing, Jiangsu, Shanghai, Zhejiang, Fujian, Guangdong, and Liaoning, while other central and western provinces are at the edge of the correlation network. China's provincial-level digital financial development correlation network generally shows a spatial distribution pattern of uneven development of "centre (east) - edge (central and western)".

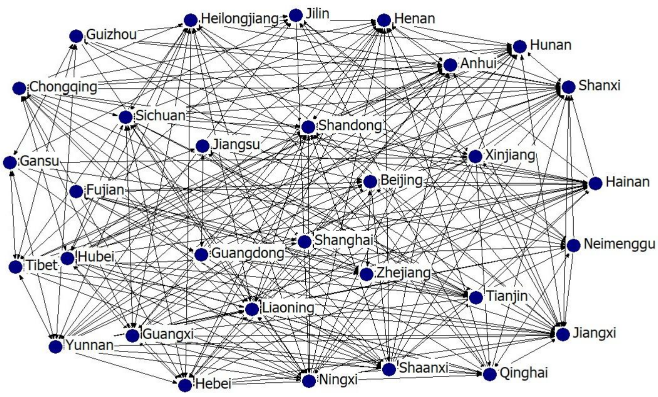

Fig. 1.
The spillover network of Provincial Digital Finance development

B. Analysis of network structure characteristics

We used the UCINET network analysis software package to calculate the value of the structural index of digital financial development related networks in each province in 2011-2020. We found that the maximum number of spillover relationships in the networks related to the development of digital finance is 930, and the actual number of spillover relationships is 356. Therefore, the density of the related network is 0.3828, which indicates that the density of digital financial development in provinces is at a low level. When the correlation degree of the correlation network is 1, it means that digital financial development has a significant spatial spillover effect, and the links between different provinces are accessible and tight. The hierarchical structure of the correlation network is 0, indicating that the spatial correlations and spillovers of digital finance development between provinces are not "hierarchical", and spillover effects can occur at different levels. The network efficiency is 0.5570, and there is moderate redundancy among provinces in the network, indicating that there is no obvious multiple superposition of spatial spillovers of digital financial development, and the corresponding spillover network has good robustness.

C. Centrality analysis of the correlation spillover network

Using the SNA metric, we can determine the degree centrality, the inter-degree centrality, the proximity centrality, and the out-degree and in-degree of each province in the spillover network associated with digital financial development (see Table 1).

TABLE 1 THE NETWORK CENTRALITY ANALYSIS OF DIGITAL FINANCE DEVELOPMENT

Province	Out-degree	In-degree	Degree centrality	closeness centrality	Betweenness centrality
Beijing	15	22	73.33	78.95	2.79
Tianjin	12	20	66.67	75.00	2.29
Hebei	15	0	50.00	66.67	0.57
Shanxi	14	6	46.67	65.22	0.44
Neimenggu	12	21	70.00	76.92	2.06
Liaoning	12	7	40.00	62.50	0.33
Jilin	13	21	70.00	76.92	2.09
Heilongjiang	12	7	40.00	62.5	0.35
Shanghai	15	24	80.00	83.33	3.25
Jiangsu	15	22	73.33	78.95	2.788
Zhejiang	16	24	80.00	83.333	3.25
Anhui	14	7	46.67	65.22	0.44
Fujian	15	22	73.33	78.95	2.788
Jiangxi	13	8	43.33	63.83	0.45
Shandong	14	0	46.67	65.22	0.47
Henan	15	2	50.00	66.67	0.53
Hubei	16	5	53.33	68.18	0.72
Hunan	14	6	46.67	65.22	0.44
Guangdong	16	24	80.00	83.33	3.25
Guangxi	15	3	50.00	66.67	0.59
Hainan	13	15	60.00	71.43	1.35
Chongqing	14	7	46.67	65.22	0.52
Sichuan	15	5	46.67	65.22	0.52
Guizhou	12	21	70.00	76.92	2.09
Yunnan	10	13	43.33	63.83	0.71
Tibet	10	16	53.33	68.18	1.08
Shaanxi	12	9	43.33	63.83	0.64
Gansu	13	23	76.67	81.08	2.61
Qinghai	10	20	70.00	76.92	1.79
Ningxia	10	10	43.33	63.83	0.49
Xinjiang	13	24	80.00	83.33	2.69
Average	13	13	58.49	71.39	1.43

In Table 1, Shanghai, Zhejiang, Guangdong, Beijing, Jiangsu, Fujian, Xinjiang and Gansu are among the top eight provinces in terms of centrality degree, suggesting that these eight provinces have the most direct correlations and spillover effects in the spatial correlation spillover network of China's provincial-level digital financial development. Note that there are two types of correlations in a region: the spillover relationship (point-out degree) and the beneficiary relationship (point-in degree). Guangdong and Zhejiang have the highest number of correlations with 40, of which 16 are spillover relationships and 24 are beneficiary relationships, i.e., the two provinces benefit as a whole. Shanghai, Beijing, Jiangsu, Fujian, Tianjin and Hainan are also beneficial overall. However, there are also spillovers to other central and western provinces.

Moreover, from the perspective of proximity centrality and betweenness centrality, the order of provinces is basically the same as that of degree centrality, suggesting that provinces such as Shanghai, Zhejiang, Guangdong, Beijing, Jiangsu, Fujian, Xinjiang and Gansu are more highly correlated with other provinces. They play a crucial role in transmitting spillover correlations in China's digital financial development network.

D. Block model analysis

Following the parameter setting conventions in the literature [16-20], we consider setting the maximum segmentation depth to 2 and the concentration criterion to 0.2; by applying the block model analysis method, we obtain the spatial spillover network divided into four blocks (see Table 2). Within each block, there are 276 correlated spillover relationships between provinces and 199 correlated spillover relationships between blocks. There are fourteen spillover relationships in Block III, sixty-six internal relationships, and forty-seven correlation spillover relationships from external blocks. According to the expected internal relation ratio, block IV also belongs to the two-way spillover block because the actual internal relation ratio is 58.41%.

TABLE 2 THE RESULTS OF BLOCK MODEL ANALYSIS

Block	Number of relations spillover		Number of relations receive	Expected internal relation ratio (%)	Actual internal relation ratio (%)	Roles
	Intra block	Out of block				
Block I	49	4	4	20.00	92.45	Net beneficiary
Block II	4	13	27	3.33	12.90	Two-way spillover
Block III	157	67	23	40.00	87.22	Broker
Block IV	66	14	47	26.67	58.41	Two-way spillover

In Block I, seven provinces are represented, including Beijing, Tianjin, Jiangsu, Guangdong, Zhejiang, Fujian, and Shanghai. There are four spillover relationships in Block I, forty-nine receive internal relationships, and as a result, block I belongs to the "Net beneficiary" block since it has four spillover relationships from external blocks; the expected internal relation ratios are 20%, but the actual internal relation ratios are 92.45%. Block II consists of two provinces, Hainan and Shaanxi. In Block II, there are thirteen spillover relationships, four receiving internal relationships, and 27 spillover relationships from external blocks; the expected internal relation ratio is 3.33%, but the actual internal relation ratio is 12.90%, so block II belongs to the "two-way spillover" block. Block III consists of thirteen provinces, including Chongqing, Heilongjiang, Guangxi, Hebei, Jiangxi, Shandong, Henan, Hubei, Hunan, Shanxi, Anhui, Liaoning and Sichuan. In block III has 67 correlation spillover relationships, one 157 internal relationships and twenty-three correlation spillover relationships from external blocks, block IV also belongs to the "two-way spillover" block with an internal relation ratio of 58.41%. The expected internal relation ratio is 26.67%, but it is actually is 87.22%, so block III belongs to the "broker" block. Block IV consists of nine provinces, including Jilin, Guizhou, Yunnan, Tibet, Inner Mongolia, Gansu, Qinghai, Ningxia and Xinjiang.

To determine the 1-block or 0-block types of each block in the image matrix, the average density (0.3828) of the network is selected as the reference standard to form the image matrix (see Table 3). As seen from the image matrix, the values on the diagonals of the image matrix are all 1, indicating that the digital finance development of each province within each block is significantly correlated, tends to converge under similar structural characteristics, and shows a "club" effect. This makes the development of Chinese provincial digital finance seriously unbalanced, forming a differentiation pattern of "strong in the east and weak in the west". The spatial correlation and spillover of regional digital finance development show the characteristics of "gradient" accessibility. Block III bears the intermediary function of the spatial spillover between blocks II and IV. In contrast, the spatial spillover effects between blocks I, III and IV are realised through the indirect correlation between blocks II and III.

TABLE 3 DENSITY MATRIX AND IMAGE MATRIX

Block	Density Matrix				Image Matrix			
	Block I	Block II	Block III	Block IV	Block I	Block II	Block III	Block IV
Block I	1.000	0.857	0.044	0.000	1	1	0	0
Block II	0.500	1.000	0.769	0.000	1	1	1	0
Block III	0.000	0.308	0.923	0.120	0	0	1	0
Block IV	0.000	0.000	0.402	0.792	0	0	1	1

E. Analysis of the driving reasons for spatial spillover

In Table 4, the QAP correlation analysis of provincial digital financial development in China is presented on the left side, and the results show that at the 5% level there is a significant positive correlation between the intensity matrix of provincial digital financial development and the difference matrix of each explanatory variable. This indicates that these factors, such as economic development, the marketisation process, financial literacy cultivation, information technology construction, the urban – rural income gap, traditional financial development and geographical factors, have positively driven the influence of spillovers related to provincial digital financial development. This makes the spillover of regional digital finance development more inclined to extend to provinces with a higher degree of economic development, better market soft environment, higher financial literacy, better information construction, smaller income gap, and more reasonable population distribution, It also confirms the unbalanced spatial distribution pattern of the development spillover network of regional digital finance, which is "east (center) - midwest (periphery)". Compared to the eastern region, the foundation of digital financial development in the central and western regions is relatively poor, and there is a large development gap with the eastern region, which hinders the spillover and expansion of regional digital financial development.

TABLE 4 QAP ANALYSIS OF RELATED DRIVING FACTORS AFFECTING THE CORRELATION OF CHINESE PROVINCIAL GIGITAL FINANCE DEVEIOPMENT

Explanatory variable	Correlation analysis		Regression analysis			
	correlation coefficient	p value	regression coefficient	p value	Probability 1	Probability 2
JG (*k*, *l*)	0.521	0.000	0.392	0.000	0.000	1.000
SC (*k*, *l*)	0.103	0.052	-0.099	0.018	0.982	0.018
ED (*k*, *l*)	0.199	0.012	-0.052	0.089	0.911	0.089
XH (*k*, *l*)	0.344	0.000	0.082	0.036	0.036	0.965
CY (*k*, *l*)	0.444	0.000	-0.050	0.094	0.906	0.094
JF (*k*, *l*)	0.175	0.024	0.032	0.194	0.194	0.807
DJ (*k*, *l*)	0.332	0.000	-0.113	0.009	0.991	0.009

The right-hand side of Table 4 shows the QAP regression analyses of the spillover drivers associated with digital financial development at the provincial level. Probabilities 1 and 2 in Table 4 represent the probability that the absolute value of the estimated coefficients is not less than the observed estimated coefficients and greater than the observed estimated coefficients, respectively, after random substitution of the matrix. The QAP regression judgment coefficient is usually less than the least squares regression judgment coefficient, so the QAP regression judgment coefficient R^2 is 0.298, which indicates that the selected explanatory variables explain 29.8% of the difference in regional digital finance development. The regression results show that all variables passed the significance test at a level of at least 10%, except for the variable relating to traditional financial development. The coefficients of the difference matrix, including marketization degree, financial literacy, income level and geographical factors, are significantly negative, indicating that a similar marketization degree, similar financial literacy, small income level gap and short geographical distance between the provinces are conducive to the correlation interaction and spatial spillover of Chinese provincial digital finance development. However, the regression coefficients of the difference matrix between the level of economic development and the degree of informatization are all significantly positive, indicating that there is a large gap between the level of regional economic development and informatization, which is conducive to promoting spatial spillovers of regional digital financial development.

IV. Discussion and Conclusions

In order to fully understand the spatial correlation of China's digital financial development, and the driving influences that lead to spatial spillovers, we use the Pearson correlation coefficient method and the SAN method. It is found that the spatial correlation of China's provincial digital financial development has an unbalanced spatial correlation characteristic of "centre-edge". Therefore, the network of digital financial development has significant cross-provincial spatial correlation and spillover effects. However, the correlation of digital financial development spillover networks across provinces is weak. The spatial spillover network lacks hierarchical structure and redundancy. The eastern regions of Beijing, Shanghai, Guangdong, Zhejiang, Jiangsu, Tianjin, Shandong and Fujian are at the centre of the digital finance correlation network and have the greatest impact on the digital finance development of the provinces and even the whole country. They not only play the intermediary transmission role of a "bridge" but also play a central role in the association network. At the same time, the provinces with fewer sending relationships than receiving relationships are mainly concentrated in the developed eastern coastal regions, constantly attracting the inflow of resource elements for digital financial development in other provinces. The other provinces are mainly located in the central and western regions, and the relationship between sending and receiving is greater than that between receiving and receiving. Therefore, they should make full use of their advantages in the network centre position, continuously optimise the competitive atmosphere and environment of the financial market, improve the efficiency of financial services, strengthen the innovation and integration of digital technology and financial products, and continuously improve the quality of the development of digital finance. On the other hand, the development level of digital finance in the provinces at the edge of the network is low. They should continue to cultivate effective demand and improve the quality of supply to avoid the excessive flow of key elements for their own development to the developed eastern provinces. In addition, they should take the initiative to strengthen the construction of new infrastructure and new financial infrastructure and moderately expand the scale and scope of financial business. The level of digital financial development should be gradually improved.

We divide China's 31 provinces into four different blocks in the spillover network by applying the block model analysis method. At this point, policymakers should give full play to the functional advantages of the "two-way spillover" and "net-beneficiary" provinces in the digital financial development network, strengthen the alliance and cooperation with other provinces, and actively guide the dominant participation and learning consciousness of the "broker" provinces. In order to continuously improve the level of digital financial development, provinces lagging behind in digital financial development should learn, digest and absorb the results of the innovative development of digital finance in developed provinces when formulating regionally differentiated digital financial development policies, and adjust measures according to local conditions, such as making full use of the advantages of the region, actively developing the tertiary industry, improving the informatisation level and gradually narrowing the development gap with developed provinces, so as to ultimately promote the coordinated development of digital finance at the provincial level in China.

We find that the spatial correlation spillover of digital financial development is highly correlated with the differences in influencing factors across provinces, which include economic development, marketisation process, financial literacy improvement, informatisation, income level disparity, traditional financial development and geographical distance. These factors have contributed positively to the spillover and expansion of digital financial development. Therefore, provinces should increase the degree of marketisation and continuously optimise the soft environment for market competition and factor flows. In particular, the central and western provinces should make great efforts to cultivate and raise the level of financial literacy of the whole population, improve the ability to introduce, digest and absorb digital financial development technologies and products, vigorously develop education, take advantage of the national financial tilt, raise the income of the population, reduce financial exclusion and the income level of the population in the developed eastern provinces, and actively seek the radiation of digital financial development of the geographically similar developed provinces. Therefore, we should promote the formation of a national digital finance development culture and atmosphere; we should achieve leapfrogging and catching up in our own informatization construction; we should promote the formation of a two-way virtuous circle of inclusive financial product supply and service cost reduction; and we should promote the expansion of digital finance services and products from developed areas to remote areas. At the same time, the developed eastern provinces should also continue to upgrade their quality and play a leading role.

Those provinces with strong innovation power are encouraged to lead and prioritize the development of digital finance, strengthen the leadership role of "bridge" provinces in the network, and radiate and drive the capacity of neighbouring and backward provinces to undertake, absorb, digest, and transform. There is a need for provinces with a lower level of digital financial development to actively explore and expand their own spillover channels, absorb and utilize the spillover effects of other provinces, and continuously improve their digital financial development level. In the implementation process, more attention should be given to the interregional linkage effect, and a regionally coordinated development pattern of staggered competition, complementary advantages and joint promotion should be formed.

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