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Bank Geographical Proximity and its Impact on Local Enterprise R&D Investment: A Financial Geography Perspective

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Abstract The purpose of the paper is to investigate the relationship between the geographical proximity of banks to enterprises and the level of R&D investment of enterprises in local governance process by constructing a credit model based on the perspective of financial geography. By using China's 2012–2019 provincial panel data and spatial measurement method, it is possible to demonstrate the process of argumentation. Based on the findings of our research, we found that a regional enterprise's proximity to a bank branch and its cognitive proximity to the bank branch's headquarters positively impact the level of R&D that an enterprise in the region is able to achieve. There is also a spatial spillover effect associated with the geographic and cultural proximity between bank branches and their headquarters. In conclusion, to give full play to the financial support role of banks in the R&D of enterprises in various regions of China, the impact of geographical proximity on financial activities and the optimization of the geographical distribution structure of the banking industry is suggested to be noticed.

Keywords: • R&D investment • geographical proximity • local governance • financial geography • spatial measurement

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1 Introduction

Recent economic developments in China have slowed down and the country has entered a "new normal" period. In order to achieve industrial restructuring and upgrading, enterprises must increase R&D investment. Banks serve the national innovation strategy and provide financial assistance for the real economy in various regions of China as its leading financial system. Currently, most academic and industry discussions focus on national differences in R&D and less attention is given to regional differences.

According to Hugh T Patrick's "demand following" theory, enterprises will generate demand for finance as the economy continues to develop so that "Demand-following" characteristics of finance appear in the economy. In response to international competition and domestic economic development, Chinese banks have carried out a series of market-oriented reforms since the mid-1990s. Banking autonomy has been constantly improved, and economic considerations have gradually been included in location selection. Geographically, there is a distinct imbalance in the Chinese banking industry in the Eastern region, leading to a difference in geographical proximity (Liu & Zeng, 2022), between enterprises and banks. Despite dramatic and unceasing economic development in central and western regions, the banking industry has not followed the economic development pattern, nor has it transformed its financial resources in central and western regions in accordance with changing demand (Liu & Zeng, 2022). In this way, the geographical distribution of financial resources doesn't match the needs of real economic development (Wang, J. Wu, Wu, Zheng, & Huang, 2021).

Financial resources will automatically and quickly flow to the most efficient areas to satisfy local economic development financial needs if the financial environment is geographically homogeneous. A bank only converts deposits into loans neutrally. Enterprises have been restricted in gathering, disseminating, and interpreting soft information because of the geographical heterogeneity of the financial environment. A bank's proximity to an enterprise affects both the degree of information asymmetry and the allocation of credit resources in this situation. No longer are banks neutral when it comes to regional economic development. Since enterprise R&D investment plays an important role in economic transformation and upgrading, the geographic proximity of banks and enterprises will affect the level of financial support given to R&D by banks in different regions, affecting the level of enterprise R&D investment. A paper like this tends to discuss this. By understanding how proximity between banks and enterprises influences R&D investment for enterprises in various regions and its mechanism, this paper believes that the financial supply side will be reformed from the perspective of optimizing its geographical layout, matching the financial development to the needs of the real economy, and promoting various regions.

There are theoretical and practical implications for the transformation and upgrading of infrastructure (Wang, Wu, Wu, Zheng & Huang, 2021).

The following part of this paper is arranged as below: The second part reviews the relevant literature, and the third part analyzes the relationship between the geographical proximity of the bank and the regional enterprise R&D investment by constructing the theoretical model, and proposes the corresponding hypothesis; The hypothesis proposed in the third part is verified by using the provincial panel data of China; the conclusions are drawn and policy recommendations and given in the fifth part in this paper.

2 Literature review

In the context of social governance, the rapid development of information and communications technology (ICT) and the corresponding relaxation of relevant government regulations have contributed to the expansion of the geographical scope of banking business. In various countries, the banking sector has changed geographically. Geography is once again a factor in credit activity. Global attention. Research on related topics typically focuses on two areas: the role and importance of geographic proximity in modern financial activities, and how geographic proximity affects bank performance. The first angle is to focus on specific geographical locations and their location differences, and study the impact of different locations and geographical factors on the resource endowment and behavioral decision-making of enterprises. At the national level, different countries are located in different geographical locations, and their economic levels, resource distribution, cultural customs and social structures will also be different, so there are also differences in the behavioral decisions and economic effects of enterprises. Therefore, in the strategic decision-making of enterprises, they will consider factors such as national location, longitude and latitude differences in a certain sense. Ma (2015) believed that when Chinese enterprises are engaged in overseas infrastructure construction, they should be more deployed in countries on transportation arteries and nodes such as the “Belt and Road”, so as to better play the effect of interconnection. In terms of specific locations and regional levels, the differences in geographical location will have different impacts on the production, operation and decision-making behavior of enterprises. Li, Huang, Chen, and Zhang (2014) empirically found that service enterprises that set up subsidiaries in first-tier cities such as Beijing, Shanghai, Guangzhou, and Shenzhen can often make full use of the service resources of the cities where they are located, thereby increasing the revenue and value of the enterprises. Bolton, Freixas, Gambacorta, and Mistrulli (2016) empirically found that enterprises located in first-tier cities are more likely to receive the attention of multiple parties, the information transmission efficiency is relatively higher, and the long-term earnings response coefficient of enterprises is also higher. Yazdanfar and Oehman (2015) conducted an empirical study of a sample of firms and found that the cost of financing through equity was relatively low in regions where social responsibility participation was generally high and intensive. Hughes (2023) used a sample of U.S. firms to correlate geographical location with firm IPO underpricing, and empirically found that firms located in rural areas had significantly lower IPO underpricing than those in urban areas, which reflected the motivation of investors in rural areas to pay more attention to and invest in local firms. The impact on the behavior of enterprises is analyzed from the difference in the distance between enterprises and specific locations, such as enterprises and specific cities, enterprises and government departments, parent and subsidiary companies, enterprises and banks, enterprises and customers, etc. Some scholars focus on the geographical distance between enterprises and specific cities (e.g., central cities, financial cities), etc. Ding, Wu, and Long (2023) took China's GEM enterprises from 2014 to 2018 as a sample, and found that the financial development level of the central city has a certain "spillover effect" and "radiation effect", so the closer the enterprises are to the central city, the higher the information flow efficiency and the lower the information asymmetry, which in turn makes the liquidity level of their stocks also enhanced.

3 Research

Asymmetry in information is the root cause of external financing premiums and financing constraints for companies (Carlstrom & Fuerst, 1996). R&D activities of enterprises are riskier than general economic activities, making information exchange between enterprises and financial institutions particularly important for financial support of R&D. The purpose of this paper is to point out that in order to achieve this goal, it is necessary to break into the theoretical model of the information exchange cost between enterprises and banks, and analyze the relationship between the geographical proximity of banks and enterprises and the level of R&D investment in regional enterprises. It is important to make the following assumptions before building the model in order to make it easier to analyze.

Assumption 1: Banks control all financial resources in Area P, and their deposit interest rate for deposits is r, which is determined by the bank headquarters (decision-making department) in Area C, while their branch offices (operations department) are located in Area P.

Assumption 2: The corporate net rate of return is greater than zero. The profit of the P region has a probability distribution function and a corresponding probability density function. The enterprise enters into a repayment contract with the bank. When the enterprise's net rate of return is R, the bank collects the loan interest at the rate of R.

Assumption 3: In light of the fact that there is an information asymmetry between the bank branches and the enterprise, when the enterprise's net profit rate < R, if the bank branch needs to know the real income of the enterprise, loan for the information collection for per unit should be paid. Bank unit loan income is a monotonously decreasing function of bank information collection costs.

Assumption 4: After the bank branch collects the relevant information of the loan application enterprise, it needs to report the relevant information to the headquarters, and the headquarters decides whether to approve the loan application of the enterprise and then the branch implements the relevant decision. Due to the principal-agent problem in this process, the headquarters has to pay supervision costs per unit loan to the branch. Based on the above assumptions, the income function of a bank's unit loan Π in the P area is:

$$\begin{aligned}\Pi = \Pi\left(R,\beta_{p}\right) &= R\left(1-F\left(R\right)\right)+\int_{0}^{R}\left(\omega-\beta_{p}\right)dF\left(\omega\right)\\ &= R-\int_{0}^{R}F\left(\omega\right)d\omega-\beta_{p}F\left(R\right)\end{aligned} \tag{1}$$

The total cost function V of a bank's unit loan in the P area is:

$$V = r+\beta_{c} \tag{2}$$

By Assumption 3, other conditions are unchanged, and constant, there is a unique value in the value range, so that the bank unit loan income is equal to the total cost of the unit loan, that is

$$\Pi\left(\beta_{P}^{*}\right)=V\left(\beta_{c}\right) \tag{3}$$

The maximum information collection cost β_{p}^{*} allowed for a regional bank to provide loans for corporate R&D (i.e., the threshold for banks to provide loans), when $\beta_{p} > \beta_{p}^{*}$, companies in the region will not be able to obtain loans. Since the information exchange between banks and enterprises in the credit process exists between the branch structure of enterprises and banks, and also exists between bank branches and bank headquarters, this paper divides the geographical proximity of banks and enterprises into geographical proximity between banks and branches of banks and headquarters. The geographical relationship between the branch office and the bank headquarters is close to two aspects, and then the impact on information exchange is analyzed separately. The geographical environment restricts soft information dissemination, the information collection cost of bank branches in the process of corporate loan is affected by the geographical factors of both parties. The higher the geographical proximity, the smaller the information collection cost of bank branches to enterprises. So, for a specific area, there is:

$$\beta_{\rho} = \beta_{\rho}^{f} \times Ope \tag{4}$$

In the formula, β_{ρ}^{f} A bank branch generates a basic cost in order to collect information about the loan application of the enterprise in order to process it. β_{ρ}^{f} value is only related to the degree of information transparency of the enterprise itself, and is not affected by the geographical proximity of the two parties; Ope indicates the geographic proximity between enterprises and bank branches in the region. The smaller Ope , the closer the geographical proximity, the smaller the distance between the two sides, that is

$$\beta_{p}^{*} = \beta_{p}^{f*} \times Ope \tag{5}$$

In the formula, β_{p}^{f*} is the critical value of β_{ρ}^{f} . For a particular region, Ope depends on the location of the region in the geographical distribution of the national banking industry, when $\beta_{\rho}^{f} > \beta_{p}^{f*}$, companies in that region will not be able to obtain loans. In the same way as formula (4), the supervision cost of the branch headquarters to the branch is also affected by the geographical factors of the two parties. The higher the geographical proximity, the smaller the supervision cost of the branch headquarters to the branch. For a specific area, there is

$$\beta_{c} = \beta_{c}^{f} \times Fun \tag{6}$$

In the formula, β_{c}^{f} represents the basic cost of information exchange between the bank's decision-making department and the operation department. β_{c}^{f} is only related to the bank's internal control level. The higher the bank's internal control level, the smaller the amount; the bank's branch office and its headquarters are geographically close to each other. There is a strong correlation between the proximity of two sides and the smaller the distance between them.

It can be known from formula (6) that when the other conditions are the same in the two regions, if the geographical proximity between the regional 2 enterprises and the bank branches is higher than that of the region 1, that is $Ope_2 < Ope_1$, The threshold value of the bank's branch office for the collection of enterprise standard information $\beta_{p2}^{f*} > \beta_{p1}^{f*}$. Assuming two regions β_{ρ}^{f} probability distribution function is $G\left(\beta_{p}^{f}\right)$, it can be known from the nature of the monotonically increasing probability distribution function that $\beta_{p2}^{f*} > \beta_{p1}^{f*}$, thus $G\left(\beta_{p2}^{f*}\right) > G\left(\beta_{p1}^{f*}\right)$.

The closer the geographical distance between the enterprise and the bank branch, the higher the proportion of enterprises that can obtain bank financial support. Reflects the R&D credit threshold of a region. The closer the geographical distance between regional enterprises and bank branches, the lower the transaction costs caused by the bank's collection and supervision of enterprise information, and the lower the R&D financing costs of enterprises in the region. At the same time, it means that banks can do better. To grasp the information of enterprise R&D projects, the degree of information asymmetry between the two sides is low, and the value and risk assessment accuracy of the bank to the enterprise R&D projects are high. Therefore, from the perspective of transaction cost and risk control, the location advantage lowers the threshold for banks to obtain bank financial support for R&D investment in a certain region, and the level of R&D investment in this region is higher. For regions with low geographic distance between banks, the lack of bank-to-business information will lead to conservative lending behavior, which will increase the financing constraints faced by firms in the region, resulting in companies having to increase the proportion of cash flow and leading to the abandonment of investments in R&D projects. Even if they have a positive NPV. Therefore, this suggests that the geographical proximity between different regions and bank branches will play an important role in determining the extent to which banks provide financial support for R&D projects in certain regions, and thus the level of R&D investment by firms in these regions, given limited credit resources. Therefore, this paper proposes hypothesis 1: the geographical proximity of regional enterprises and bank branches will affect the level of R&D investment in the region and is positively correlated with the level of R&D investment in the region.

From the formula

$$\frac{\partial \beta_p^{f*}}{\partial Fun} = -\frac{\beta_c^f}{Ope \times F(R)} < 0 \tag{7}$$

It can be seen from formula (7) that when the other conditions in the two regions are the same, if the geographic proximity between the branch offices of the regional 2 and their headquarters is higher than that of the region 1, thus $Fun_2 < Fun_1$, bank internal supervision cost $\beta_{p2}^{f*} > \beta_{p1}^{f*}$. Assume all regions β_p^f probability distribution functions are $G\left(\beta_p^f\right)$, according to the nature of the monotonically increasing probability distribution function, $\beta_{p2}^{f*} > \beta_{p1}^{f*}$, thus $G\left(\beta_{p2}^f\right) > G\left(\beta_{p1}^f\right)$.

In reality, on one hand, the closer the geographical proximity between a bank branch and its headquarters, the fewer the principal-agent issues stemming from information asymmetry within the bank. Consequently, the bank's headquarters can place greater trust in the corporate information reported by the regional branch, enabling them to make informed credit decisions, lower the barriers for loan applications, and engage in regional research and development (R&D). On the other hand, the geographical proximity of bank branches to their headquarters actually mirrors the influence of regional roots on financial activities. Given that bank headquarters and branches are often situated in different regions, the closer the regional branches are to their headquarters, the smaller the disparities in economic and social environments between the region and the bank's headquarters. This alignment reduces the divergence between the bank's business objectives and the local economic development goals, fostering a strong consistency that, in turn, provides ample financial support for R&D by local companies. It is evident that the geographical distance between regional bank branches and their headquarters will impact the proportion of enterprises in the region that can receive banking financial support, and subsequently influence the level of corporate R&D investment in the area. Therefore, this paper posits Hypothesis 2: The geographical distance of regional bank branches from their headquarters will affect the level of R&D investment in the region and is positively correlated with the level of R&D investment in the region.

4 Discussion

In order to verify the assumptions listed above, this paper uses 2012–2019 China provincial panel data to empirically analyze the above assumptions. Considering the interdependence and spatial spillover relationship between R&D between regions, this paper uses spatial measurement methods to avoid the estimation bias caused by missing variables. To this end, this paper firstly builds the basic model based on theoretical analysis, and then tests the spatial effects of key variables and basic models to determine the necessity and rationality of using spatial econometric models. On this basis, this paper selects the appropriate spatial econometric model. Verify the relevant assumptions.

4.1 Construction of basic measurement models and data description

4.1.1 Model building

Based on the assumptions, build a basic measurement model such as formula

$$RD_{it} = \alpha + \beta_1 Ope_{it} + \beta_2 Fun_{it}^{p} + \beta_3 Fun_{it}^{c} + \beta_4 K_{it} + \mu_{it} \quad (8)$$

In the above formula, the level of enterprise R&D investment RD_{it} of province i in the period t is interpreted as the geographical proximity between the province and the bank branches (Ope_{it}) and the proximity of the bank branches to their headquarters (Fun_{it}^{p} , Fun_{it}^{c}) and a set of control variables (K_{it}). Among them, because the enterprise and the branch of the bank are in the same area, the geographical proximity is measured by the spatial distance index Ope_{it} . While the branch of the bank and its headquarters are often in different regions, the proximity of the two depends on the spatial distance and the socio-cultural differences between the two places (Alessandrini, Croci, & Zazzaro, 2009), therefore the spatial distance indicator Fun_{it}^{p} and socio-cultural differences indicator Fun_{it}^{c} of the two locations are measured individually.

In addition, based on the previous theoretical analysis and existing research, this paper selects the scientific research level, macroeconomic environment, financial development level, and number of foreign banks as the control variables. According to formula (8), except for the geographical proximity factors Ope and Fun , the factors affecting the level of R&D investment of enterprises in a region are the probability distribution function of the profit level of the enterprise $F(\omega)$ in the region, the bank deposit interest rate r, and the bank's internal control level of the regional branches β_c^f . It is believed that $F(\omega)$ is related to a region's general level of science research as well as macroeconomic conditions. Generally speaking, a region is considered to be more competitive if its overall level of scientific research is higher, if its macroeconomic environment is more stable, and if its R&D investment is more profitable, so it is likely to be able to bear higher financial transaction costs to obtain bank credit than what it might otherwise. β_c^f is determined by the level of financial development in the region, a higher level of financial development means a good financial environment and an advanced financial system, while a good financial environment and an advanced financial system can effectively improve the level of internal control of banks (Ge & Qiu, 2007). To a lesser extent, the influence of geographical factors on transaction costs. The lower the bank deposit interest rate r, the lower the bank's operating costs, which in turn allows more companies to obtain loans. However, as far as China is concerned, the deposit interest rates in different regions are not much different, so this article will not discuss further on this issue. As a conclusion, according to existing research, with the increasing number of foreign banks in China, the role of foreign banks in China's economic development cannot be ignored. As foreign banks mainly follow and serve foreign companies, the more foreign banks in a region, the more favorable it is for R&D investment by foreign companies in the region, and then promote the R&D activities of local companies through demonstration effects and the flow of scientific and technological personnel (Xiao, Lin & He, 2009), and thus improves the overall R&D investment level of enterprises in this region.

4.1.2 Variable design

Ope_{it} expresses as the reciprocal of the number of banking outlets per capita in the province, the formula for the calculation is as follows:

$$Ope_{it} = \frac{1}{\frac{Branches_{it}}{Pop_{it}}} = \frac{Pop_{it}}{Branches_{it}} \tag{9}$$

In this formula, $Branches_{it}$ stands for the number of business outlets for all commercial banks in the province, Pop_{it} stands for the number of urban population (10,000 people).[1] The smaller Ope_{it}, the shorter the distance between the province's businesses and bank branches, the higher the geographic proximity of the two. Fun_{it}^{p} is expressed by the weighted sum of the spatial distances of the banking outlets of the province from their headquarters, and the calculation formula is as follows:

$$Fun_{it}^{p} = \sum_{b=1}^{B}(\frac{Branches_{it}^{b}}{\sum_{b=1}^{B_j} Branches_{it}^{b}} \times D_{j}^{bp} \tag{10}$$

As shown in the formula, *B* indicates how many banks have branches in province *i*, how many banks there are in province *i*, and how far the bank branches are from its headquarters in province *j* in province *i*. An indication of the distance between an administrative center (provincial capital) distance indication[2]. The smaller Fun_{it}^{p}, the higher degree of the geographic proximity of the province's bank branches and their headquarters space.

Similar with Fun_{it}^{p}, Fun_{it}^{c} is calculated by the weighted sum of the cultural differences between the banking outlets in the province and the location of their headquarters as follows:

$$Fun_{it}^{c} = \sum_{b=1}^{B}(\frac{Branches_{it}^{b}}{\sum_{b=1}^{B_j} Branches_{it}^{b}} \times D_{jt}^{bc} \tag{11}$$

In the formula, D_{jt}^{bc} represents the socio-cultural differences between province *i* and province *j* where bank b is located during period *t*. As this article mainly examines the impact of social culture on finance, D_{jt}^{bc} is expressed in terms of regional commercial cultural differences. The calculation formula is:

$$D_{jt}^{bc} = \left| \frac{P_i^I}{P_i^C} - \frac{P_j^I}{P_j^C} \right| \tag{12}$$

In the above formula, P_i^I , P_i^C are the number of private investors and the urban population in province i^3 ; P_j^I , P_j^C are the number of private investors and the urban population in province j respectively. The smaller Fun_{it}^c , the higher the geographic proximity of the province's bank branches and the social and cultural level of their headquarters. The specific meanings of the explained variables, explanatory variables and control variables are shown in Table 1.

Table 1: Variable description

	Heading	Definition	Implication
Explained variable	***RD***	Enterprise R&D investment level indicator, expressed by the ratio of R&D expenditure and GDP of industrial enterprises in each province	The higher the value, the higher the R&D investment level of the province (city, district).
Explanatory variables	***Ope***	Indicator of the geographical proximity of enterprises and bank branches expressed as the reciprocal of the number of bank branches per 10,000 people in each province.	The smaller the value, the higher the geographic proximity between the province (city, district) enterprise and the bank branch
	Fun^p	Geo-proximity indicators of bank branches and their headquarters space are weighted and expressed by the spatial distance between each province and the location of the bank's headquarters in the province.	The smaller the value, the higher the geographic proximity between the branch of the province (city, district) and its headquarters.
	Fun^c	The geographical proximity indicator of the bank branch and its headquarters 'culture is weighted and expressed by the socio-cultural differences between the provinces and the location of the bank's headquarters operating in the province.	The smaller the value, the higher the geographic proximity of the province's (city, district) bank branches to the social and cultural level of its headquarters.
Control	***Wzyh***	Indicators of the number of	The larger the value, the greater the

	Heading	Definition	Implication
variables		foreign banks, expressed by the number of foreign banks in each province	number of foreign banks in the province (city, district)
	Gdpr	Macroeconomic environmental indicators, expressed as the GDP growth rate of each province	The larger the value, the better the macroeconomic environment of the province (city, district)
	Gxsl	Scientific research level indicators, expressed by the number of universities in each province	The higher the value, the higher the scientific research level of the province (city, district)
	Fir	Credit scale indicator, expressed as the ratio of total loan to GDP in each province.	The larger the value, the larger the credit scale of the province (city, district)

4.1.3 Data source, variable descriptive statistics and data stability test

Throughout this article, data taken from the websites of the National Bureau of Statistics and the China Banking Regulatory Commission, the websites of local banks, the Wind database, as well as the yearbooks of provinces and cities are cited. It should be noted that the data of the five major state-owned banks, the twelve joint-stock banks, and numerous city commercial banks located in various provinces and cities (business outlets) that have been used by ***Ope***, $\boldsymbol{Fun^p}$, $\boldsymbol{Fun^c}$ is deducted by the author according to "Institutional Holding Certificates List" and “Institutional Withdrawal List” provided by the websites of provincial and municipal banking supervision bureaus. For each of the variables, descriptive statistics are shown in Table 2. In summary, it is evident from Table 2 that each one of the major explanatory variables, as well as the dependent variable, have large standard deviations for their respective parameters. Therefore, the panel data is used for demonstration to fully reflect the heterogeneous characteristics of different regions. In addition, since panel data is used in this article, the data must be tested for stationarity to avoid the problem of “false regression”. Because the data in this paper is a provincial panel, the number of individual units n is fixed, and the time length T is malleable, $n/T \to 0$. Therefore, the LLC method is used for the data unit root test. As can be seen in Table 3, the test results are presented in a graphical format. At a confidence level of 0.95, it can be concluded that each variable meets the 0-order stability requirement of the panel regression analysis, and it is, therefore, appropriate to conduct a regression analysis based on the analysis results in Table 3.

Table 2: Variable descriptive statistics

Variable	Observations	Mean	Standard deviation	Minimum value	Maximum value
RD	248	89.489	52.501	2.535	214.858
Ope	248	1.526	1.185	0.887	8.151
$\boldsymbol{Fun^p}$	248	1027.532	590.481	175.685	2473.737

Variable	Observations	Mean	Standard deviation	Minimum value	Maximum value
Fun^c	248	3.050	1.154	0.269	5.466
Wzyh	248	26.468	51.863	0.000	261.000
Gxsl	248	78.351	38.993	6.000	162.000
Gdpr	248	0.135	0.068	-0.010	0.320
Fir	248	1.151	0.413	0.533	2.585

Table 3: Data stability test

Variable	Statistics	P value
RD	-2.2446	0.0124
Ope	-18.6104	0.00001
Fun^p	-7.2905	0.00001
Fun^c	-16.9831	0.00001
Wzyh	-5.1047	0.00001
Gxsl	-20.0495	0.00001
Gdpr	-36.0941	0.00001
Fir	-17.8170	0.00001

4.2 Spatial correlation effect test

When the autocorrelation between the cross-section units of panel data follows a certain spatial order (that is, in geographic space or more generally economic and social network space, the cross-section dependence is related to location or distance), the traditional panel regression method ignores space Differences and interactions between units will lead to biased regression results (Hsiao, 2022), and the spatial econometric model can well solve the identification and estimation of spatial differences and correlations in regional econometric problems by introducing spatial weight matrices (Elhorst, 2014). For this reason, it is necessary to test the spatial correlation of each variable before performing the spatial measurement analysis to determine whether it is suitable to establish a spatial measurement model.

Figures 1 to 4 are LISA aggregation diagrams of the R&D investment level (R&D) of enterprises in various regions of China and the average value of the geographical proximity (***Ope***, ***Fun^p***, ***Fun^c***) of corporate and bank branches, bank branches and their headquarters during 2012–2019. As can be seen from Figure 1, the level of R&D investment of enterprises in various provinces and cities in China has gradually decreased from east to west, from the inland to the border, so the dependent variable R&D has obvious regional differences and spatial agglomeration. It can be seen from Figures 2 to 4 that the independent variables ***Ope***, ***Fun^p***, ***Fun^c*** also have obvious spatial order characteristics.

Figure 1: RD LISA aggregate graph

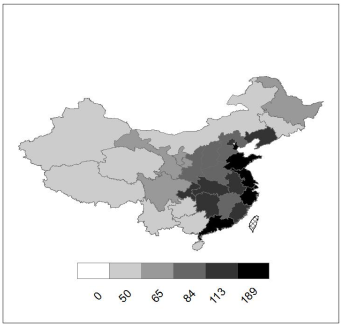


Figure 2: *Ope* LISA aggregate graph

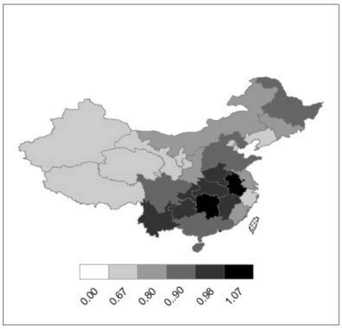


Figure 3: *Fun^p* LISA aggregate graph

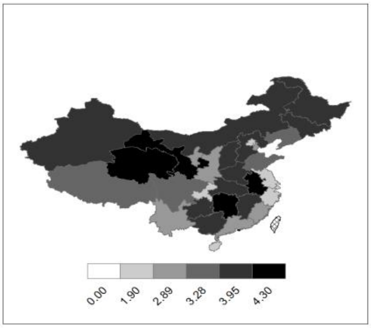
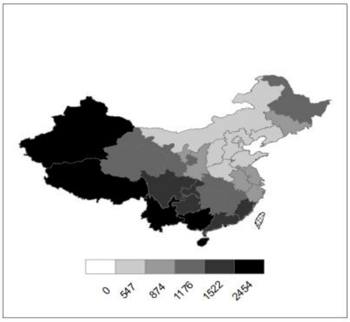


Figure 4: *Fun^c* LISA aggregate graph



The LISA aggregation map reflects the local spatial agglomeration characteristics of each variable, while the global spatial agglomeration characteristics need to be analyzed by using the Moran index (Moran'I). The Moran index is defined as:

$$Moran's\ I = \frac{n\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}\left(x_i - \bar{x}\right)\left(x_j - \bar{x}\right)}{\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}\sum_{i=1}^{n}(x_i - \bar{x})^2} = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}\left(x_i - \bar{x}\right)\left(x_j - \bar{x}\right)}{S^2\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}} \tag{13}$$

Among them, $S^2 = \frac{1}{n}\sum_{i=1}^{n}(x_i - \bar{x})^2$, $\bar{x} = \frac{1}{n}\sum_{i=1}^{n}x_i$, x_i is the observation value of the i-th spatial unit, n is the number of spatial units, w_{ij} is an element of the i-th row and j-th column of the spatial weight w, and represents the spatial relationship between the spatial units i and j. The value range of the Moran index is [-1, 1]. A positive value indicates homogeneous clustering, a negative value indicates heterogeneous clustering. The closer to 0, the weaker the spatial correlation.

As this paper mainly studies the influence of the geographical proximity of banks and enterprises on the level of R&D investment of regional enterprises, the "car rules" that reflect spatial proximity are used to establish the weight matrix. For any matrix element w_{ij}, there is

$$w_{ij} = \begin{cases} 1 & \text{Region } i \text{ and Region } j \text{ have a common border} \\ 0 & \text{Region } i \text{ and Region } j \text{ have no common border} \end{cases} \quad (14)$$

Then, referring to the method of scholars such as Arbia (Arbia & Piras, 2005), the cross-section matrix of each year is combined into a diagonal block of blocks in chronological order to perform Moran index analysis of spatial panel data. The specific form of the matrix is as follows:

$$\begin{pmatrix} W_1 & & 0 \\ & \ddots & \\ 0 & & W_T \end{pmatrix}_{NT \times NT} \quad (15)$$

The Moran index analysis results of the explained variables ***RD*** and the main explanatory variables ***Ope***, ***Fun^p***, ***Fun^c*** are shown in Table 4.

Table 4: Moran index test results for each variable

Variable	I	E(I)	sd(I)	z	p-value*
RD	0.418	-0.004	0.045	9.399	0
Ope	0.423	-0.004	0.045	9.550	0
Fun^p	0.679	-0.004	0.045	15.212	0
Fun^c	0.271	-0.004	0.045	6.122	0

From the Moran index and its significance test results, it can be seen that the Moran index of the RD and the main explanatory variables ***Ope***, ***Fun^p***, ***Fun^c*** selected in this paper are significantly positive, indicating that regions with higher levels of variables and lower levels. The regions in China show obvious high-low poles agglomeration, and the spatial correlation effect is significant.

The LISA aggregation graph and Moran index show that there is a significant positive spatial correlation between the R&D level of companies in different regions and the geographical proximity of banks and enterprises, both from a local and global perspective. The geospatial effect should have an impact on the R&D level of companies in each region.

Further, according to the method (Anselin, Bera, Florax & Yoon, 1996) provided by Anselin, the basic econometric model represented by formula (15) is first subjected to OLS mixed regression, and then the spatial effect LM diagnosis is performed based on the regression results. The results of OLS regression and diagnosis of spatial effects are shown in Tables 5 and 6.

Table 5: Basic model regression results and tests

Variable	Index	Standard error	T-statistics	p-value*
Ope	-24.669**	11.752	-2.10	0.037
Fun^p	-0.022***	0.004	-6.080	0.0001
Fun^c	-4.508*	2.338	-1.930	0.055
Wzyh	0.350***	0.049	7.200	0.0001
Gxsl	0.670***	0.075	8.980	0.0001
Gdpr	-44.0979	33.889	-1.300	0.194
Fir	10.5422	6.908	1.530	0.128
Cons	77.29794***	20.810	3.710	0.0001
N (province, city)			31	
T (year)			8	
Observation			248	
R-squared			0.643	

Note: *, **, *** represent for significant at 10%, 5%, and 1% levels.

Table 6: Spatial effect LM diagnosis

Test	Statistics	Freedom	p-value*
Spatial error:			
Moran's I	-1.136	1	1.744
Lagrange multiplier	1.984	1	0.159
Robust Lagrange multiplier	27.502	1	0.0001
Spatial lag:			
Lagrange multiplier	20.837	1	0.0001
Robust Lagrange multiplier	46.356	1	0.0001

This study shows that robust LM diagnosis results for the basic model OLS mixed regression are consistent with the null hypothesis that the robust LM index holds when it comes to testing the spatial error effect, while both indices reject the null hypothesis when it comes to testing the spatial lag effect. As a result, it is necessary to include the spatial effect term in the econometric model in order to explain these findings. To verify the hypotheses that have been proposed above, the next step in this paper is to use a spatial econometric model.

4.3 Analyzing the results of regressions based on spatial econometric models

4.3.1 Spatial measurement model selection

In spatial econometrics, there are a number of spatial econometric models, including the spatial autoregressive model (SAR), the spatial errors model (SEM), and the spatial durbin model (SDM). It is generally accepted that the SDM model has the following general expression:

$$Y_{nt} = \alpha + \rho W_n Y_{nt} + \beta X_{nt} + \theta W_n X_{nt} + \mu_n + \nu_t + \varepsilon_{nt} \quad (16)$$

Y_{nt} is the dimension explanatory variable of $nt \times 1$, X_{nt} is the dimension explanatory variable of $nt \times k$, ε_{nt} is an independent and identically distributed random error vector; $W_n Y_{nt}$ is the space lag term, W_n is the dimension space panel weight matrix, and the construction method is the same as formula (16); μ_n is the dimension individual fixed effect column vector of $n \times 1$, ν_t is The dimension-time fixed effect column vector of $t \times 1$, $\alpha, \rho, \beta, \theta$ are the parameter to be estimated.

According to formula (19), when $\theta = 0$, the SDM model can be transformed into a SAR model, and when $\rho = -\theta\beta$, SDM models can be transformed into SEM models by transforming them into SDM models. There is a consensus among LeSage and Pace that after the constraints imposed by the SDM model on the SAR model and the SEM model, these models can be considered as special cases of the SDM model. A preferred spatial metrology model is selected by considering first the SDM model, and then using the LR test to determine whether a SDM model can be converted to a SAR model or SEM model using the LR test (LeSage & Pace, 2009).

From this, the basic measurement model formula is rewritten as:

$$\begin{aligned} RD_{it} &= \alpha + \rho W \times RD_{it} + \beta_1 Ope_{it} + \beta_2 Fun_{it}^{p} + \beta_3 Fun_{it}^{c} + \\ &\beta_4 X_{it} + g_1 W \times Ope_{it} + g_2 W \times Fum_{it}^{p} + g_3 W \times Fun_{it}^{c} + g_4 W \times X_{it} \end{aligned} \quad (17)$$

As the sample selected in this article includes all 31 provinces and cities in mainland China, rather than a random sample selection, this paper adds a fixed effect term to the econometric model (Elhorst, 2014) and performs Hausman test on it. In terms of fixed effect selection, the test results of fixed-effect F for the basic model in this article are shown in Table 7.

Table 7: Individual fixed effect, time fixed effect, and two-way fixed effect test

Test	F-value	P-value
Individual fixed effect	63.94	0.00001
Time-fixed effect	3.04	0.0004
Two-way fixed effect	0.98	0.5034

There are two types of fixed effects, one way and two-way, that are rejected in Table 7, and one way and two-way fixed effects are accepted. The common unobservable factors are mainly institutional factors when it comes to the issues discussed in this article. This is regardless of the topic, whether it is investment in R&D by corporations or scientific research, and whether it is economic and financial factors. From a national perspective, China's institutional factors have a relatively uniform time-varying trend, despite some differences between provinces and cities when looking at institutional factors within the country. Due to this, it is necessary to control the fixed effect of time so that the explanatory variables do not encounter any endogenous problems. Additionally, Lee & Yu demonstrated from a measurement perspective that when there are relatively large numbers of individuals in the observation data N compared to the number of periods T in a spatial measurement model with fixed effects, the lack of time fixed effects will lead to errors (Lee & Yu, 2010) as the number of individuals in the observation data N is relatively large compared to the number of periods T in the observation data. Taking into account the fact that the data in this paper is based on inter-provincial panel data for thirty-one provinces and cities across mainland China during the period 2012 – 2019, this paper considers that the time-fixed effect is appropriate. In order to test the validity of the model setting and the robustness of the regression results, this paper also regresses the SAR model and SEM model corresponding to formula (17). The regression results are shown in Table 8.

Table 8: Spatial econometric model regression results

Variable	SAR	SEM	SDM	
			Main	Wx
W*R	0.192^{***}		-0.385^{***}	
	(0.0505)		(-4.240)	
$W*\varepsilon$		-0.511^{***}		
		(-4.30)		
Ope	-37.12^{***}	-38.37^{***}	-51.17^{***}	-19.54
	(-3.36)	(-3.66)	(-4.869)	(-0.803)
Fun^p	-0.0239^{***}	-0.0189^{**}	-0.0132^{**}	-0.0131^{*}
	(-6.98)	(-6.54)	(-2.478)	(-1.917)
Fun^c	-5.871^{**}	-9.669^{***}	-6.083^{***}	-21.97^{***}
	(-2.25)	(-3.95)	(-2.690)	(-3.663)
Wzyh	0.369^{***}	0.374^{***}	0.299^{***}	-0.0402
	(8.15)	(7.96)	(7.008)	(-0.581)
Gxsl	0.601^{***}	0.861^{***}	0.688^{***}	0.789^{***}

Variable	SAR	SEM	SDM	
			Main	Wx
	(8.59)	(10.43)	(10.50)	(4.819)
Gdpr	114.5**	81.64*	46.86	73.56
	(2.10)	(1.67)	(0.974)	(0.891)
Fir	-4.345	8.306	-4.325	30.18**
	(-0.59)	(1.21)	(-0.665)	(2.389)
N (province, city)	31	31	31	
T (year)	8	8	8	
Observations	248	248	248	
R-squared	0.643	0.648	0.710	
Hausman	21.84	30.12	41.52	
(Fixed vs random)	[0.0052]	[0.0002]	[0.0003]	
LR test		93.04		
(SAR vs SDM)		[0.000]		
LR test		94.20		
(SEM vs SDM)		[0.000]		

Note: *, **, *** represent significance at 10%, 5%, and 1%, respectively, with t values in parentheses and p values in square brackets.

It appears that the SAR, SEM, and SDM models are consistent when we look at the coefficient sign and change range of the estimation results of the three models. As a consequence, the spatial metrology model was able to estimate the results robustly. According to the Hausman test and the LR test for spatial econometric model selection, the SDM model with fixed time effects, which was used to examine the research problem in this paper, is the best spatial econometric model for this study. Accordingly, this article mainly focuses on analyzing the regression results of the SDM model as a whole.

4.3.2 Analysis of regression results

LeSage and Pace (2009) pointed out that the spatial regression model expands the information set by introducing neighboring area information, which is why it is necessary to divide the impact of the respective variables on the dependent variable into average total effects, average direct effects, and average indirect effects when analyzing them. Averaging the total effect of the independent variable on the dependent variable provides an indication of the long-term equilibrium effect of the independent variable, whereas decomposing the average total effect from the source provides an indication of the average direct effect and average indirect effect. Generally, the average direct effect of a variable is determined by the effect of the dependent variable of the unit on the independent variable of the unit. There is an indirect effect of the independent variable of the adjacent unit on the dependent variable of the adjacent unit called the mean indirect effect (Del Bo & Florio, 2012).

Consequently, this paper, which is based on the regression results of the SDM model above, further deduces the average total effect, average direct effect, and average indirect effect of the independent variable on the dependent variable by using formula (17) as well as the statistical significance of these effects. A summary of the results can be found in Table 9 of the report:

Table 9: Mean direct effect, mean indirect effect, mean total effect

Variable	Average direct effect	Mean indirect effect	Average total effect
Ope	-50.61***	-0.577	-51.19***
	(-4.253)	(-0.0289)	(-3.142)
Fun^p	-0.0129**	-0.00596	-0.0188***
	(-2.233)	(-0.883)	(-5.760)
Fun^c	-4.288*	-15.56***	-19.85***
	(-1.880)	(-3.346)	(-4.240)
Wzyh	0.313***	-0.127***	0.186***
	(7.389)	(-2.603)	(2.917)
Gxsl	0.644***	0.428***	1.072***
	(10.68)	(4.131)	(9.898)
Gdpr	45.77	39.36	85.13
	(0.912)	(0.592)	(1.340)
Fir	-6.580	26.00**	19.42**
	(-0.927)	(2.388)	(2.135)

Note: *, **, ***represent significance at the 10%, 5%, and 1% levels, respectively, with t values in parentheses.

The following information can be obtained from Table 9:

1) According to the ***Ope*** effect, the total amount of R&D investment of a regional enterprise in the region is significantly lower when compared to a bank branch, which indicates that a regional enterprise's R&D investment in the region will be higher than the geographical proximity between the enterprise and the bank branch. Hypothesis 1 passes verification, which means that there is a positive impact on the level of R&D investment of enterprises in a region due to the geographical proximity between those enterprises and bank branches in that region.

2) As a result, both ***Fun^p*** and ***Fun^c*** have a significant negative effect on the level of R&D investment of the firm in a regional region, which suggests that the closer a regional bank branch is to its headquarters, the greater its level of R&D investment in the region. In other words, Hypothesis 2 is verified, since whether you look at it from a spatial or cultural standpoint, a regional bank branch's proximity to its headquarters has a positive impact on the level of R&D investment of enterprises in the region, regardless of the perspective of spatial or cultural distances.

3) As a result of ***Ope***, ***Fun^p*** direct effects being significantly negative, and the indirect effects not passing the significance test, it is evident that the spatial distance between the headquarters of bank branches and the enterprises in a region

of China as well as the proximity between the bank branches and the central government are the main reasons for these negative effects. Furthermore, this region shows that in China there is not a great deal of financial synergy between neighboring provinces, and there are obvious administrative barriers or boundaries between financial activities within the region. *Regardless of whether Function has direct or indirect effects, the significance test has been passed by Function, and the indirect effects are significantly larger than the direct effects of Function. Thus, it becomes clear that the proximity of bank branches to their headquarters not only affects the level of R&D investment of enterprises in the region, but also has a significant positive spillover effect in terms of space.* Further, this evidence confirms the theory of Andre Torre that, as opposed to artificial institutional arrangements, the influence of social and cultural similarities on financial activities is more likely to cross administrative boundaries and form regional linkage effects (Torre & Rallet, 2005).

4) As far as the control variables are concerned, the total effects of ***Wzyh***, ***Gxsl*** and ***Fir*** have passed the test, indicating that the number of foreign banks, overall scientific research level, and credit scale have a significant positive impact on regional R&D investment levels; while the total effect of ***Gdpr***, Neither the direct effect nor the indirect effect passed the test, indicating that the economic environment is not necessarily related to the level of corporate R&D. Further analysis, this article believes that the provinces with higher current economic growth are mostly middle-western provinces with late-developing advantages, but these provinces have lower industrial levels, and the relationship between the macroeconomic environment and corporate R&D investment levels is weak. The macroeconomic environment, therefore, has a negligible impact on the level of R&D on regional enterprises from the point of view of a national perspective.

5) Regression results. From the perspective of the results of control variables, the direction of the role of the government and banks is basically consistent with the expected direction and expected results of the regression results. The specific results show that the regression coefficients of corporate profitability, enterprise size and geographical proximity of banks all show positive numbers, and the data analysis shows that the investment of enterprises from neighboring banks has a role in improving the R&D level of enterprises, and the government can effectively promote the development of enterprises by guiding banks to invest in enterprises. The debt-to-debt coefficient ratio of enterprises is negative, but it is not significant, indicating that the part-time governance mode of local governments is not conducive to the development of enterprise research investment.

5 Conclusions

The purpose of this study is to conduct a theoretical and empirical analysis based on the perspective of financial geography to understand the relationship between the geographical proximity of banks and enterprises in relation to the level of R&D investment of regional enterprises. There was a positive correlation between the geographical proximity of banks and enterprises in a region and the level of R&D of enterprises in that region, according to the study. There is a significant correlation between the level of R&D investment in a region and the proximity between a company's headquarters and the bank's branches or between both and the bank's headquarters. In addition, there is evidence that the spatial spillover effect of R&D activities of banks in neighboring areas has a direct impact on the impact of R&D activities of corporations. One of the most significant positive spatial spillover effects on corporate research and development is associated with the close proximity of bank branches to their headquarters on a human level.

Based on the above conclusions, this article believes that in order to better serve the R&D and industrial upgrading of enterprises in various regions, China's banking industry should pay attention to the role of geographical proximity in financial activities, optimize the geographical distribution structure of the banking industry, and strengthen financial interaction between adjacent regions. To this end, this article makes the following recommendations:

First, encourage the development of local banks. Local banks not only have a high degree of geographic proximity between their branches and enterprises, but the geographic proximity of their head offices and branches is higher than the geographic proximity of national bank branches that set up branches across regions. Therefore, we should encourage the development of local banks, make full use of their geographical proximity with local enterprises be familiar with the characteristics of local knowledge, and establish stable and reliable communication mechanisms with local enterprises to minimize the degree of information asymmetry between banks and enterprises. Well meet the financing needs of local enterprises, especially small and medium-sized enterprises.

Second, strengthen regional cooperation between banks and enterprises. The geographical proximity between regions with close spatial and cultural similarity is relatively high, so the current "bank-policy barriers" that define service areas according to administrative regions should be broken, and inter-provincial bank-enterprise cooperation that is spatially close, culturally close, and economically close should be strengthened. , Encourage and guide powerful local banks to provide cross (administrative) district financial services, and make full use of the information advantages brought by geographical proximity to serve national and regional coordinated development strategies.

Third, actively promote the informatization construction and flat management reform of banks. On the one hand, using technological means such as the Internet and big data to alleviate the restrictions on geographic information on information transmission and reduce information friction between banks and enterprises and internal levels of banks; on the other hand, it is urgent to promote the flat management of banks according to current economic development needs. Reform and optimization of the organizational structure system, improvement of the efficiency of internal information transfer of operating banks in remote locations, and reduction of the divergence of interests between levels due to geographical factors are also crucial.

Notes:

[1] As the main object of this article is commercial banks, which are mainly distributed in cities and towns, the urban population is selected here.
[2] The distance between the provincial and municipal administrative centers is calculated using the Jenness arcview gis extension.
[3] The article uses the data of the population of the cities and towns instead of the population of the villages since private investors are mostly concentrated in cities and towns.

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