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The Spatial Spillover Effect of High-Tech Industry Agglomeration on Technological Innovation Capability—An Example from the Yangtze River Economic Belt

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Abstract: *The development of high-tech industries has become an important manifestation of the scientific and technological strength and innovation development of each country. Based on the spatial Durbin model, an empirical study was conducted on the spatial spillover effects of high-tech industry agglomeration on technological innovation in 11 provinces and cities in the Yangtze River Economic Belt from 2010 to 2020. It is found that the agglomeration degree of the Yangtze River Economic Belt is in the eastern, northwestern, central and southwestern regions in descending order; there is a positive spatial autocorrelation effect between the agglomeration of high-tech industries and technological innovation capacity, but this relationship is gradually weakening; there is a significant positive spatial spillover effect of the agglomeration of high-tech industries on improving technological innovation capacity, and this effect is more obvious between regions.*

Keywords: *High-tech industrial agglomeration; technological innovation; spatial spillover effects*

1. Introduction

At present, with the increasing international competition, science and technology innovation has become an important indicator of a country's competitive strength. As a knowledge and technology-intensive industry, the high-tech industry has become an important support for technological innovation in all countries. To support technological innovation, China's central and local governments are vigorously developing R&D bases and industrial parks for high-tech industries. By 2020, the business revenue of China's high-tech industries will reach RMB 17.46 trillion, an increase of 134% over 2010, and the total profit will reach RMB 1.24 trillion, an increase of 154% over 2010. The development of high-tech industries cannot be separated from the industrial agglomeration model. Through industrial agglomeration, technological resources can be integrated, production costs can be reduced and the technological spillover effect of high-tech industries can be strengthened, thus enhancing innovation efficiency and promoting economic upgrading.[1] High-tech industry agglomeration can also promote the development of high-tech industries. High-tech industry clustering can also promote cooperation and exchange between high-tech enterprises, complement each other's advantages and improve innovation output.[2] After years of development, the phenomenon of high-tech industrial agglomeration in China has become more and more obvious, and the issue of high-tech industrial agglomeration and innovation has become a hot topic of concern for many scholars.

There are different voices in academic circles on whether industrial agglomeration can promote technological innovation. Research by Yang Haochang and other scholars shows that high-tech industrial agglomeration can effectively promote technological innovation, and that this effect varies significantly across regions, with the promotion effect being more pronounced in the eastern region.[3] Qu Chenyao and other scholars have calculated that high-tech industrial agglomeration can significantly improve the efficiency of technological innovation, with the most significant improvement in the eastern region.[4] The effect is most pronounced in the eastern region. Shi Xiaoli et al. found that the degree of specialisation of high-tech industrial agglomeration can significantly promote technological innovation development.[5] The study by Shi Xiaoli et al. In a double test, Du Jiang et al. found that industrial agglomeration has a non-linear U-shaped effect on technological innovation from the perspective of threshold effect, and that specialisation agglomeration can enhance technological innovation from the perspective of spatial effect, while diversification agglomeration has a suppressive effect.[6] In terms of spatial effects, it was found that specialisation agglomeration could enhance technological innovation,

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while diversification agglomeration had an inhibiting effect. The spatial effect found that specialisation agglomeration enhances technological innovation while diversification agglomeration inhibits it.[7] Xu Dan et al. Xu Dan et al. used the Yangtze River Delta urban agglomeration as a study to find that the agglomeration of high-technology industries has a hindering effect on innovation capability in the early stage, significantly increases innovation capability in the rapid development stage, and inhibits it in the mature stage. [8]

All in all, academics have not yet reached a consensus on the impact of industrial agglomeration on technological innovation. Based on this, the article takes a spatial spillover perspective as the basis for an in-depth discussion on high-tech industrial agglomeration and technological innovation capability. Through an empirical analysis of high-tech industries in 11 provinces and cities in the Yangtze River Economic Belt from 2010 to 2020, the spatial spillover effect of high-tech industry agglomeration on technological innovation capability is explored, and relevant suggestions are made based on the findings, aiming to provide strong support for the long-term development of the high-tech sector in the Yangtze River Economic Belt.

2. Study design

2.1. Selection of variables

2.1.1. Explanatory variables

Technological Innovation Capacity (ETIC). Patent data is one of the most important sources of technological innovation, and to a certain extent can measure the level of technological innovation in a region, and many scholars in academia use the number of patent applications or grants as an indicator of technological innovation capacity.[9] Many scholars in academia use the number of patent applications or grants as an indicator of technological innovation capacity. Since the number of granted patents is subject to interference from external factors and there is a time lag compared to the number of patent applications, the article uses the Yangtze River Economic Zone (YREC) as a measure of technological innovation capacity.[10] Therefore, the article adopts the number of patent applications for each province and city in the Yangtze River Economic Zone to measure the level of technological innovation, and the number of patent applications is logarithmically processed.

2.1.2. Explanatory variables

The degree of high technology industry agglomeration (HLQ). At present, there are many methods to measure industrial agglomeration, considering the accessibility of data, and drawing on the research of relevant scholars,[1] we adopt the location entropy index to measure the degree of high-tech industrial agglomeration, and the formula is as follows:

$$S_i = \frac{X_{it}/Y_{it}}{X_t/Y_t} \tag{1}$$

where X represents the number of people employed in high-tech industries, Y represents the number of people employed nationally, i represents the region and t represents the year. WhenS_i >1, it indicates that the level of agglomeration is at a high level at this time; whenS_i =1, it indicates that the degree of agglomeration is at the national average level; whenS_i <1, indicating a low level of agglomeration at this time.

2.1.3. Control variables

(1) R&D investment (Fy). Measured by using R&D investment in high-tech industries, it not only reflects the level of capital investment, but also effectively promotes technological innovation, thus facilitating the development of high-tech industries in the region.

(2) R&D personnel input (Ry). The equivalent full-time equivalent of R&D personnel in high-tech industries is used to measure manpower input.

(3) Level of urbanization (Urban). The proportion of urban population is used to measure the level of urbanization development.

(4) Level of government support (GOV). Considering the availability of information, per capita budgetary financial expenditure is used to express the level of government support.

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2.2. Modeling

As technological innovation activities have spatial spillover characteristics, they not only affect the region where they are located, but also have an impact on the surrounding areas.[11] Therefore, a spatial econometric model is used to conduct the study. Considering that the spatial correlation of technological innovation capability is not only influenced by the level of technological innovation in the surrounding areas, but also by the level of high-tech industrial agglomeration in the surrounding areas, it is believed that there is a spatial effect of both high-tech industrial agglomeration and technological innovation capability, so the spatial Durbin model (SDM) is chosen to conduct the study.

$$lnETIC_{it} = \alpha_0 + \rho WlnETIC_{it} + \alpha_1 lnHLQ_{it} + \alpha_2 Z_{it} + \beta_1 WlnHLQ_{it} + \beta_2 WZ_{it} + \varepsilon_{it} \quad (2)$$

where i is the provinces and cities of the Yangtze River Economic Zone, t is time, andα_0 is the constant term, W is the spatial weight matrix, and the most commonly used neighbouring 0-1 weight spatial matrix is used to construct, i.e. the elements corresponding to the matrix of neighbouring provinces and cities are taken as 1 and vice versa, andρ is the spatial autoregressive coefficient, and$\alpha_1\alpha_2\beta_1\beta_2$ represents the elasticity coefficients of the corresponding variables, Z represents the control variables, andε_{it} represents the random error term.

2.3. Data sources

Eleven provinces and cities in the Yangtze River Economic Belt from 2010-2020 were used as the research sample for the measurement analysis. Data were obtained from the 2011-2021 China High Technology Industry Statistical Yearbook, China Science and Technology Statistical Yearbook, Provincial Statistical Yearbooks, and EPS database. To ensure data stability and offset outliers, all data were logarithmically processed.

3. Analysis of High Technology Industry Agglomeration Level Measurement

Table 1: Concentration levels of high-tech industries in 11 provinces and cities in the Yangtze River Economic Belt

Province and city	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Average value	Ranking
Jiangsu	3.34	3.26	3.13	3.03	2.93	2.88	2.74	2.68	2.61	2.43	2.39	2.86	1
Shanghai	3.40	3.53	3.21	3.16	2.45	2.36	2.09	2.06	2.04	1.96	1.77	2.55	2
Zhejiang	1.34	1.15	1.14	1.15	1.12	1.11	1.13	1.17	1.21	1.25	1.25	1.18	3
Jiangxi	0.64	0.67	0.68	0.69	0.76	0.88	0.98	1.06	1.14	1.26	1.32	0.92	4
Chong Qing	0.40	0.48	0.67	0.80	0.87	0.94	1.02	1.06	1.10	1.14	1.36	0.89	5
Si Chuan	0.49	0.61	0.67	0.64	0.62	0.62	0.58	0.61	0.63	0.67	0.71	0.62	6
Hubei	0.44	0.43	0.48	0.51	0.54	0.58	0.59	0.60	0.61	0.61	0.67	0.55	7
Huanan	0.28	0.36	0.38	0.44	0.43	0.44	0.45	0.51	0.57	0.59	0.73	0.47	8
Anhui	0.25	0.24	0.27	0.28	0.34	0.35	0.38	0.40	0.43	0.44	0.64	0.36	9
Guizhou	0.26	0.24	0.17	0.15	0.23	0.28	0.34	0.36	0.39	0.37	0.32	0.28	10
Yunnan	0.07	0.06	0.07	0.07	0.08	0.09	0.10	0.11	0.12	0.13	0.13	0.09	11

According to equation (1), the degree of aggregation of high-tech industries in 11 provinces and cities in the Yangtze River Economic Belt from 2010 to 2020 can be estimated. The specific results are shown in Table 1, which shows that Jiangsu has the highest degree of agglomeration among the 11 provinces and cities in the Yangtze River Economic Belt, with a location entropy of 2.86, while Yunnan has the lowest degree of agglomeration, with a location entropy of 0.09. According to the regional division, the degree of agglomeration is, in descending order, eastern, northwestern, central and southwestern. Among them, only three provinces located in the eastern region, Jiangsu, Shanghai and Zhejiang, have a location entropy consistently greater than 1, and their values are much higher than those of other provinces, which are high agglomeration areas. The location entropy values of Jiangxi Province and Chongqing City have been greater than 1 since 2017 and 2016 respectively, with the phenomenon of clustering of high-tech industries. The rest of the provinces have location entropy values below 1, belonging to low agglomeration areas. From the overall trend of change, Shanghai, Jiangsu and Zhejiang are in a fluctuating decreasing trend, but always greater than 1. This indicates that these three provinces and cities have a high base of high-tech industry agglomeration and have advantages in capital, talents and technology, and can vigorously develop high-tech industries. Jiangxi, Chongqing, Hunan and Anhui are all on a fluctuating upward trend, among which Chongqing has the fastest growth rate, which may be related to the city's vigorous development of high-tech industries in recent years, the establishment of

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R&D bases to attract high-tech enterprises to the park, and the siphoning effect of Chongqing as a municipality directly under the central government. Sichuan, Hubei, Guizhou and Yunnan are also on an upward trend, but the changes are relatively small, and they are relatively stable and fluctuating. Among them, Guizhou and Yunnan have the lowest degree of concentration, and there is a large gap compared with other provinces and cities, indicating that the southwest region lacks corresponding resources such as R&D, which has limited contribution to the development of high-tech industries, making it the region with the lowest degree of high-tech industry development in the Yangtze River Economic Zone.

4. Analysis of spatial spillover effects

4.1. Spatial autocorrelation test

The article uses the global Moran index to measure the degree of high-tech industry agglomeration and technological innovation capability in the Yangtze River Economic Zone. The results show that the Moran 's I values all reach a significance level of 5% and are positive, indicating that there is a positive spatial autocorrelation effect for both high-tech industry agglomeration and technological innovation capability, however, overall this correlation seems to be weakening. The specific measured values are shown in Table 2.

Table 2: Moran index measure values

Year	High-tech industrial clustering	Technological innovation capabilities
	Moran's I Index	Moran's I Index
2010	0.504	0.382
2011	0.457	0.319
2012	0.450	0.309
2013	0.448	0.336
2014	0.423	0.266
2015	0.400	0.279
2016	0.376	0.246
2017	0.374	0.249
2018	0.369	0.205
2019	0.359	0.197
2020	0.327	0.207

4.2. Test of model applicability

After the LM and Robust LM tests, the findings exhibited a 10% significance, which suggests that a spatial econometric model is essential. To determine whether to use a fixed effects model, the Hausman test found that the p-value significantly negated the original assumptions, so the final decision was made to use a fixed effects model. After LR validation, the results showed that the SDM model could not be refined to a SLM model and SEM model and that this assumption was negated at the 1% significance level. Therefore, the spatial Durbin model under fixed effects was chosen to carry out the study in order to obtain more accurate conclusions.

4.3. Regression analysis

The SDM model was validated for three types of fixed effects by using STATA 15.1 software. As can be seen from Table 3, the goodness-of-fit R2 for the time effect is 0.930, the goodness-of-fit R2 for the spatial fixed effect is 0.835 and the goodness-of-fit R2 for the double fixed effect is 0.825; therefore, the time fixed effect model was chosen to carry out the empirical study. The coefficient of the spatial lag term reflecting whether there is a spatial effect on technological innovation capabilityρ The value of -0.6557, verified by 1% significance, indicates that the spatial spillover effect of technological innovation capability among provinces and cities in the Yangtze River Economic Zone is significant. With the control variables considered, the estimated coefficient of high-tech industrial agglomeration is 0.4437, indicating that high-tech industrial agglomeration has a positive effect on enhancing technological innovation capability in the region. The regression coefficient of the spatial lag term of high-tech industrial agglomeration is 0.8402, indicating that high-tech industrial agglomeration has a significant positive spillover effect on enhancing technological innovation in the surrounding regions. In conclusion, it is verified that high-tech industrial agglomeration is of great significance in promoting the development of technological innovation in the surrounding region.

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Table 3: SDM model estimation results

Variables	Time fixed effects	Spatial fixation effect	Double fixed effect
lnHLQ	0.4437***	0.3445***	0.4376***
	(0.0914)	(0.1128)	(0.1268)
lnFy	0.5543***	0.1777	0.1994*
	(0.1129)	(0.1214)	(0.1182)
lnRy	0.4170***	0.3379***	0.3881***
	(0.1172)	(0.1030)	(0.1022)
lnUrban	-1.6941***	-0.6473	-1.0957*
	(0.4079)	(0.6492)	(0.6128)
lnGOV	-1.1744	1.0059	1.2970
	(1.3264)	(2.7571)	(2.4958)
WxlnHLQ	0.8402***	0.6063***	0.7535***
	(0.2158)	(0.2212)	(0.2759)
WxlnFy	-0.0685	0.2452	0.3256
	(0.2961)	(0.2265)	(0.3079)
WxlnRy	0.8002***	0.2387	0.4221*
	(0.2478)	(0.2019)	(0.2234)
WxlnUrban	-3.7484***	-3.6612***	-3.8505***
	(0.7981)	(0.8737)	(1.0450)
WxlnGOV	6.5090**	9.5263***	6.9404
	(2.6668)	(3.6562)	(5.0328)
rho	-0.6557***	0.0580	-0.3590***
	(0.1252)	(0.1124)	(0.1338)
sigma2_e	0.0365***	0.0256***	0.0193***
	(0.0048)	(0.0033)	(0.0025)
R^2	0.930	0.835	0.825

Note: * represents p < 0.1, ** represents p < 0.05, *** represents p < 0.01, standard error in brackets, same below

4.4. Decomposition of spillover effects

The spatial spillover effect can more clearly reflect the degree of influence of the level of high-tech industrial agglomeration on the technological innovation capacity of the surrounding areas, and this effect can be divided into direct and indirect effects. As can be seen from Table 4, after the 1% significance test, the total effect of high-tech industrial agglomeration reaches 0.7922, while the direct effect is 0.3454, which indicates that with the increase of high-tech industrial agglomeration, the level of technological innovation in the region will also be improved, while the indirect effect reaches 0.4467, which indicates that there is an obvious spatial spillover effect of high-tech industrial agglomeration on the improvement of technological innovation, and this spillover effect far exceeds the intra-regional effect. And this spillover effect far exceeds the intra-regional effect.

Specifically, high-tech industrial agglomeration can significantly enhance technological innovation capacity, which not only integrates resources among enterprises and reduces enterprise costs, but also provides more opportunities for technological innovators and promotes exchanges and cooperation. The spatial spillover effect of high-tech industry agglomeration is much more significant than the direct effect, i.e. the agglomeration of high-tech industry in the region can significantly enhance the technological innovation capacity of the surrounding areas, thus bringing more economic development opportunities. This is due to the "factor crowding effect" of agglomeration, which leads to the diffusion of resources to the outside world in search of higher efficiency, thus driving the development of the surrounding areas.[12] Therefore, the clustering of high-tech industries can significantly improve the level of technological innovation and promote cooperation and development in neighbouring regions. For the control variables R&D funding, R&D personnel investment, urbanization level and government support level, R&D funding has a direct effect on the level of regional technological innovation, with an effect of 0.6274, while the indirect effect is -0.3517, which indicates that increasing the investment in R&D funding can effectively improve the level of technological innovation in the region The direct effect of R&D personnel investment is 0.3330 and the indirect effect is 0.4178, which indicates that increasing the investment in R&D personnel can promote the cooperation and competition among R&D personnel, thus The spatial spillover effect on the surrounding areas is greater, because the cooperation and competition among personnel will improve the overall level of local enterprises while generating more stimulation for inter-regional enterprises, promoting the technological innovation development of enterprises in the

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surrounding areas; the direct and indirect effects of urbanization level are both less than 0, which indicates that the increase of urbanization level will have a negative impact on the technological innovation capacity of the region and the surrounding areas. while the effect of government support is not obvious for the region where it is located, but the greater the support, the greater will be the positive spillover effect on the technological innovation capacity of the surrounding areas.

Table 4: Decomposition of SDM model effects

Variables	Total effect	Direct effects	Indirect effects
lnHLQ	0.7922***	0.3454***	0.4467***
	(0.2069)	(0.0765)	(0.1534)
lnFy	0.2757	0.6274***	-0.3517*
	(0.2250)	(0.0986)	(0.1874)
lnRy	0.7507***	0.3330***	0.4178**
	(0.2088)	(0.1054)	(0.1744)
lnUrban	-3.3402***	-1.2401***	-2.1001***
	(0.7152)	(0.3853)	(0.5683)
lnGOV	3.1552**	-2.3743	5.5295**
	(1.4322)	(1.7255)	(2.5203)

5. Research conclusions and insights

5.1. Research findings

The article is based on relevant data from 11 provinces and cities in the Yangtze River Economic Belt for the period 2010-2020, and ultimately draws the following conclusions:

First, the highest average degree of concentration of high-tech industries in the provinces and cities of the Yangtze River Economic Belt is in Jiangsu Province, and the lowest is in Yunnan Province. By region, the highest degree of agglomeration is in the eastern region, followed by the northwestern and central regions, and the last is the southwestern region. By agglomeration trend, the eastern region is on a downward trend, but still belongs to the high agglomeration region, while the rest of the regions are on an upward trend, and Jiangxi in the central region and Chongqing in the northwestern region have the fastest growth rate, and have seen high agglomeration in recent years, while Guizhou and Yunnan in the southwestern region are on a slow rise and tend to be stable.

Secondly, there is a positive spatial autocorrelation effect between high-tech industry agglomeration and technological innovation capability in the Yangtze River Economic Zone, but the overall trend is decreasing. High-tech industry agglomeration has a significant spatial spillover effect on the enhancement of technological innovation capability, and this spillover effect far exceeds the intra-regional effect. The investment in R&D funding can effectively enhance the level of technological innovation in the location and promote local economic development, but it has a negative spillover effect on the technological innovation capability of the surrounding areas. The positive inter-regional spillover effect of R&D personnel investment is the positive spillover effect of R&D personnel investment is greater between regions. The level of urbanization has a negative spillover effect on technological innovation capacity. The level of government support has a positive spillover effect on inter-regional technological innovation capabilities.

5.2. Insights

The following recommendations are made for the development of high-tech industries and technological innovation in the Yangtze River Economic Zone in response to the findings of the article:

First, strengthen the level of concentration of high-tech industries in each region. Local governments should actively promote mutual cooperation and collaborative innovation among local high-tech enterprises, create high-tech industrial parks, improve high-tech industrial chains, promote the conversion rate of resources, attract more high-tech enterprises to settle in and accelerate the degree of high-tech industrial agglomeration. Chongqing, for example, has seen leaps and bounds in the concentration of high-tech industries in recent years, and has now become a region where high-tech industries are concentrated. At the same time, it is also necessary to give full play to the spatial spillover effect of high-tech industrial agglomeration, strengthen the radiation-driven role of high agglomeration areas and promote the integrated development of high-tech industries in the Yangtze River Economic

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Secondly, attach importance to the cultivation of technological innovation capabilities. Technological innovation is inseparable from human and financial support, so governments and enterprises should pay attention to the talent training system, stimulate the innovation spirit of researchers, and increase the financial investment in research and development, strengthen the construction of research and development teams, actively encourage technological innovation and improve the incentive mechanism for research and development, so as to provide technology and innovation guarantee for the development of the region and enterprises. Especially in the south-western region, where the investment in R&D personnel and funds is relatively low, it is necessary to strengthen the policy of introducing talents, attracting high-quality professionals, building channels for talent exchange and creating a pool of information exchange, so as to enhance the regional technology and talent reserves.

Thirdly, focus on various factors and adapt to local conditions. As provinces and cities in the Yangtze River Economic Belt are located in different regions of China, with differences in various aspects such as economy, environment and talents, each region can make differentiated development, and local governments should formulate or adopt corresponding laws and regulations according to the actual regional situation, aiming to promote the long-term development of high-tech industries or high-tech enterprises in the Yangtze River Economic Belt. In addition, the eastern and western regions should also pay attention to inter-regional cooperation and exchanges, with the eastern regions making full use of existing resources to strengthen technological innovation and the central and western regions making full use of the spillover effect of scientific research talent and other elements to promote the further development of high-tech industries.

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