Research on the Spatial Effect of China's High-tech Industry Agglomeration on Regional Innovation Efficiency

Bowei Wu, Yanyan Jiang*, Hanzhi Liu

* Corresponding author: Yanyan Jiang (SKwbw491@163.com)

School of Maritime Economics and Management, Dalian Maritime University, Dalian 116026, China

Abstract: This article analyzes the impact of high-tech industrial agglomeration on regional innovation efficiency using the spatial Durbin model. The results of China's provincial panel data from 2006 to 2019 indicate that specialized agglomeration and diversified agglomeration of high-tech industries have a positive impact on comprehensive technical efficiency and scale efficiency, and the promotion effect of specialized agglomeration is more significant. Meanwhile, the specialized agglomeration of high-tech industries can produce a positive spatial spillover effect on adjacent areas, but the spillover effect of diversified agglomeration is not significant. From regional perspective, the specialized agglomeration in the eastern will hinder the improvement of innovation efficiency within the region, but promote the improvement of innovation efficiency in neighboring regions, diversification has the opposite effect. The spatial spillover effect of high-tech industrial agglomeration in the central region on technological innovation efficiency can be realized through diversified agglomeration, while the western region conforms to the overall law.

Keywords: High-tech industry, Specialized agglomeration, Diversified agglomeration, Regional innovation efficiency

1 INTRODUCTION

It is widely recognized that China's economic and regional development is in a critical period of transformation from factor-driven to innovation-driven, so we need to pay attention to the transformation rate of innovation input and output. The development of high-tech industry is directly related to the transformation of China's economic development mode and the improvement of independent innovation ability, and then affects the realization of the strategic goal of an innovative country.

There are different views on the impact of high-tech industrial agglomeration on regional innovation in academic circles. The first view is that high-tech industrial agglomeration will significantly promote regional innovation, which is the current mainstream view. Volker (2019) found that the regulators in Germany's high-tech industrial clusters promote innovation by increasing the trust of members in the cluster and reducing information asymmetry[11]. Some domestic scholars believe that high-tech industrial agglomeration can promote regional technological innovation by promoting the emergence and diffusion of technological innovation, resulting in technological spillover effect, scale economy effect and labor

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productivity effect (Chengchao, L, 2016; Yang Haochang, 2016; Zhang Ke, 2019)[3,7,10]. The second view is that the agglomeration of high-tech industries has no significant impact on regional innovation, and even hinders regional innovation. Glaser et al., (1992) took American cities as the research object and found that Marshall externalities have negative effects on innovation[6]. When some scholars used the data of Britain, Italy and Sweden to study, they found that diversified agglomeration had no significant effect on innovation output, and even inhibited it (1998,1999)[1-2,12]. From the perspective of innovation value chain, some scholars believe that the inhibition of different agglomeration modes of high-tech industries on regional innovation only exists in some stages of innovation value chain (2017, 2019)[4-5,8]. The third view is that the impact of high-tech industrial agglomeration on regional innovation is not a simple linear relationship. Xie Ziyuan (2015) took the pharmaceutical manufacturing industry as an example to examine the relationship between the regional agglomeration level of high-tech industries and R&D efficiency, and found that the two were "inverted U-shaped"[14]. The empirical results of Xiong Pu et al., (2020) show that under the influence of various factors in the regional technological innovation system, the level of high-tech industrial agglomeration has a single threshold effect on regional technological innovation[13].

2 MODEL CONSTRUCTION

2.1 Preliminary construction of model

Considering that the agglomeration of high-tech industries will cause the flow of innovation elements among regions and the regional correlation with innovation activities, this article uses spatial econometric model to analyse the impact of China's high-tech industrial agglomeration on regional innovation efficiency. The tentative model is:

Therein, Eff_{it} represents the regional innovation efficiency of the i region at t time, Agg_{it} is the high-tech industry agglomeration level, which is originally measured by relative specialization agglomeration factor (*Mar*) and relative diversification agglomeration factor (*Jacobs*). α_i is the individual fixed effect, v_t is the time fixed effect, ε_{it} is the random error term, and ρ is the spatial autocorrelation coefficient. W stands for the spatial weight distance , and adopts the geographic distance matrix in this article. $W_{ij}=1/d_{ij}$, and d_{ij} is the European distance between regions i and j. X is the control variable that affects the regional innovation efficiency, including: innovation environment, industrial development level, financial development level and opening-up level.

$$Eff_{it} = a_0 + r\,WAgg_{it} + b_1 Agg_{it} + b_2 WAgg_{it} + b_3 X_{it} + b_4 WX_{it} + a_i + n_t + e_{it} \tag{1}$$

2.2 Variable declaration

Based on the research of Li Jinyan and Song Deyong (2008), this study adopts the relatively specialized and diversified agglomeration index to evaluate the specialized agglomeration and diversified agglomeration of high-tech industries[9]. The calculation formulas are as follows:

$$Mar_i = \max_j \left(S_{ij} / S_i \right) \tag{2}$$

$$Jacobs_i = 1/\sum_j \left|S_{ij} - S_i\right| \tag{3}$$

S_{ij} represents the proportion of the main business income of industry j among the high-tech industries in i province to the main business income of industrial enterprises above designated size in this province, and S_i represents the proportion of the main business income of industry i in all provinces to the main business income of industrial enterprises above designated size in China. Considering the data integrity and research representativeness, this article calculates the agglomeration degree of high-tech industries based on the main business income, and evaluates the specialization and diversification agglomeration level of high-tech industries represented by four high-tech industries: medical equipment and instrument manufacturing, computer and office equipment manufacturing, electronic and communication equipment manufacturing and pharmaceutical manufacturing.

The three-stage data envelopment analysis (*DEA*) model put forward by Fried et al.(2008) not only includes the influence of external environment on regional innovation efficiency, but also covers the influence of random error on regional innovation efficiency[9]. The specific calculation steps are as follows:

The first stage: determine the input-output index to evaluate the regional innovation efficiency, evaluate the initial comprehensive technical efficiency (*TE*) of each province by *DEA-BCC* model based on the variable return on scale hypothesis, and decompose it into pure technical efficiency (*PTE*) and scale efficiency (*SE*):

$$TE = PTE * SE \tag{4}$$

The second stage: taking the selected environmental variables as independent variables and the input slack obtained in the first stage as dependent variables to construct a stochastic frontier model (*SFA*) with the following formula:

$$S_{ni} = f(Z_i, \beta_n) + \nu_{ni} + \mu_{ni}; i = 1, 2, \ldots N; n = 1, 2, \ldots N \tag{5}$$

Therein, S_{ni} is input slack, Z_i is environmental variable, β_n is environmental variable coefficient, ν_{ni} representing random disturbance term and management inefficiency term.

The adjustment formula becomes:

$$X_{ni}^A = X_{ni} + \left[\max\left(f\left(Z_i; \overline{\beta_n}\right)\right) - f\left(Z_i; \beta_n\right)\right] + \left[\max\left(\nu_{ni}\right) - \nu_{ni}\right]; \quad i = 1, 2, \ldots I; n = 1, 2, \ldots N \tag{6}$$

Which X_{ni}^A represents the adjusted input; X_{ni} is the input before adjustment; $\max\left(f\left(Z_i; \hat{\beta}_n\right)\right) - f\left(Z_i; \beta_n\right)$ stands for an external environmental factor item; $\max(\nu_{ni}) - \nu_{ni}$ is a random noise adjustment term.

The third stage: adopting the adjusted innovation input data and the first stage innovation output data, then used the *DEA-BCC* model of the first stage again to evaluate the regional innovation efficiency of each province. In conclusion, this study determines two input variables, one output variable and three environmental variables, as shown in Table 1.

Table 1: SDM and evaluation system of regional innovation efficiency index

Variable		Calculation method
Specialization agglomeration (*Mar*)		Relative specialization agglomeration factor
Diversification (*Jacobs*)		Relative diversification agglomeration factor
Innovative environment (*Invir*)		Share of technology market turnover in GDP
Industrial development level (*Indus*)		Tertiary industry added value as a proportion of GDP
Financial development level (*Finan*)		Financial institutions' year-end loan balance as a proportion of GDP
Opening level (*Open*)		Total import and export as a percentage of GDP
Evaluation of regional innovation efficiency	R&D investment	Internal expenditure stock of R&D funds
	R&D personnel investment	Full-time equivalent of R&D personnel
	Innovation output	Number of patents granted
	Number of innovative institutions	The sum of the number of scientific research institutions and universities
	Infrastructure	Post and telecommunications business as a proportion of GDP
	Government support	Proportion of government funds in internal R&D expenditure

The data of this study mainly comes from various statistical yearbooks, and the missing data is completed by interpolation. The subjects are 30 provinces and cities except Tibet, Taiwan Province, Hongkong and Macau.

3 EMPIRICAL ANALYSIS

3.1 Spatial autocorrelation test

Based on the above research, this section will make a spatial empirical analysis. Firstly, Moran index is used to measure the spatial correlation among technological innovation efficiency, pure technical efficiency and scale efficiency. The value range of the global Moran index is [-1,1]. Moran's I index is calculated as follows:

$$\text{Moran's I} = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}\left(x_i - \bar{x}\right)\left(x_j - \bar{x}\right)}{s^2 \sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}} \quad (7)$$

Where s^2 is the sample variance, the (i, j) element of the spatial weight matrix ω_{ij}, that is, the distance between two provinces, and $\sum_{i=1}^{n}\sum_{j=1}^{n}\omega_{ij}$ is the sum of all spatial weights. The global Moran's I index of comprehensive technical efficiency and scale efficiency in each stage is positive and passed the significance test, but the global Moran's I index of pure technical efficiency is not significant, indicating that there is spatial correlation between comprehensive technical efficiency and scale efficiency among regions, but there is no spatial correlation between pure technical efficiency, so the following spatial effect analysis takes comprehensive technical efficiency and scale efficiency as the explained variables.

3.2 Selection and estimation of panel model

Before the spatial panel model regression, the Lagrange multiplier test of ordinary least squares regression is given to judge whether the explained variables and residual terms have spatial effects. From the LM test results in Table 2 and its significance, the model with spatial effect should be considered in studying the influence of high-tech industrial agglomeration on regional innovation efficiency.

Table 2: Test results of spatial panel model

Test	Model 1	Model 2	Model 3	Model 4
LM error	8.965***	29.489***	1.165	9.016***
Robust LM error	12.224***	4.944**	16.230***	8.548***
LM lag	37.198***	79.677***	19.797***	45.744***
Robust LM lag	40.457***	55.131***	34.862***	45.276***
LR error	40.970***	69.880***	21.240***	33.800***
Wald error	28.990***	60.220***	26.740***	33.150***
LR lag	36.310***	70.200***	35.900***	62.170***
Wald lag	36.440***	71.010***	21.240***	53.850***
Hausman	34.670***	34.100***	32.550**	55.480***
Spatial fixation effect	50.000***	22.070**	56.230***	53.150***
Time fixation effect	53.200***	51.490***	50.320***	51.030***

Table 3 shows that it is reasonable to use spatial Dobbin model to demonstrate the influence of high-tech industrial agglomeration on regional innovation efficiency. Hausman test is significant, so fixed effect model should be selected for parameter estimation. The spatial correlation coefficient ρ of the explained variables is positive and significant, so it can show that economic growth has regional liquidity, that is, it has a driving spatial spillover effect, and it also confirms the necessity of considering spatial effect in model application.

Table 3: Estimation results of SDM of geographical distance matrix

Var	Integrated technical efficiency		Scale efficiency	
Mar	0.009** (0.01)		0.006* (0.01)	
Jacobs		0.006*** (0.01)		0.007*** (0.01)
Invir	3.274*** (0.69)	2.403*** (0.66)	1.449** (0.66)	2.974*** (0.61)
Indus	-0.442*** (0.18)	-0.405*** (0.17)	-0.278** (0.16)	-0.223** (0.15)

Var	Integrated technical efficiency		Scale efficiency	
Finan	0.015 (0.03)	0.036 (0.03)	-0.011 (0.03)	0.039 (0.03)
Open	0.190*** (0.05)	0.259*** (0.05)	0.310*** (0.04)	0.387*** (0.04)
W*Mar	0.128*** (0.043)		0.129*** (0.03)	
W*Jacobs		0.001 (0.01)		0.006*** (0.01)
W*Invir	-0.779 (1.46)	-3.617*** (1.27)	2.535** (1.34)	-0.66 (1.1)
W*Indus	0.759*** (0.27)	1.188*** (0.25)	0.452** (0.25)	1.048*** (0.24)
W*Finan	0.013 (0.08)	-0.003 (0.04)	0.005 (0.03)	-0.022 (0.08)
W*Open	-0.438** (0.12)	-0.150 (0.13)	-0.537*** (0.11)	-0.079 (0.12)
Spatial	0.394*** (0.08)	0.383*** (0.08)	0.524*** (0.06)	0.493*** (0.06)
R^2	0.47	0.49	0.64	0.69

Note: * * * * and * * * are significant at the statistical level of 10%, 5% and 1% respectively. The Z values in brackets are the same below.

3.3 Direct effect and indirect effect

Due to the obvious differences in the level of high-tech industrial agglomeration and innovation efficiency among regions in China, in order to study the spatial effects of high-tech industrial agglomeration patterns in different regions on innovation efficiency, this study continues to divide the samples into three regions: the east, the middle and the west, and the results are shown in Table 4.

Table 4: Decomposition results of regional high-tech industrial agglomeration's effect on regional innovation efficiency

Var	Direct effect						Indirect effect					
	TE			SE			TE			SE		
	East	Middle	West	East	Middle	West	East	Middle	West	East	Middle	West
Mar	-0.008 (0.04)	0.102 (0.05)	0.059*** (0.01)	-0.044** (0.03)	0.014 (0.02)	0.076*** (0.01)	0.129** (0.08)	0.191 (0.03)	0.217*** (0.04)	0.049* (0.07)	0.358 (0.04)	0.205*** (0.05)
Jacobs	0.001* (0.01)	0.013*** (0.01)	0.004* (0.011)	0.005** (0.01)	0.014*** (0.01)	0.003* (0.01)	-0.002* (0.01)	0.006*** (0.01)	0.016*** (0.05)	-0.005* (0.01)	0.011** (0.01)	0.019*** (0.06)
Invi	5.788	1.324	0.171	1.735	1.511	1.821	0.318	-	-	4.668	-	-

Var	Direct effect						Indirect effect					
		TE			SE			TE			SE	
r	*** (1.30)	*** (2.08)	* (-1.06)	*** (0.87)	*** (2.463)	* (1.11)	* (1.74)	1.145 (6.78)	10.94* (6.01)	*** (1.39)	1.371* (9.69)	7.208 (6.07)
Indus	-1.906*** (0.49)	-1.166*** (0.32)	-0.265 (0.25)	-1.144*** (0.38)	-1.053*** (0.35)	-0.388 (0.26)	2.572*** (0.81)	2.221** (0.44)	0.295 (0.94)	2.825*** (0.62)	2.091 (1.04)	0.19 (0.99)
Finan	0.182** (0.08)	0.579*** (0.12)	-0.0451 (0.04)	0.102* (0.06)	0.422*** (0.12)	-0.057 (0.04)	-0.289 (0.12)	-0.797* (0.24)	0.570*** (0.13)	-0.262 (0.1)	-0.142 (0.31)	0.605*** (0.13)
Open	0.173** (0.1)	0.114** (0.46)	0.727 (0.14)	0.062* (0.07)	0.505*** (0.51)	0.961* (0.15)	0.0815 (0.18)	-0.446 (0.75)	1.355* (0.74)	0.152 (0.14)	0.0287 (0.96)	1.741** (0.77)
ρ	0.23** (0.12)	0.27** (0.11)	0.57*** (0.07)	0.25** (0.11)	0.47*** (0.08)	0.57*** (0.07)						
R^2	0.42	0.82	0.77	0.61	0.86	0.82						

High-tech industry specialization agglomeration: the direct effect coefficient of the eastern region on comprehensive technical efficiency is -0.008, which is not significant. The coefficient of direct effect on scale efficiency is -0.044, and the coefficient of indirect effect is 0.129 and 0.049, respectively, which all pass the significance test. This shows that the spatial spillover effect of high-tech manufacturing agglomeration in the eastern region on the overall regional technical efficiency is not significant, and even hinders the improvement of technological innovation efficiency in the region, but the spatial spillover effect on technological innovation in neighboring regions is more obvious. The direct effect coefficient and indirect effect coefficient of comprehensive efficiency and scale efficiency in central China are not significant, which shows that the specialization of high-tech manufacturing industry in central China has no obvious effect on regional innovation efficiency. The direct effect coefficients in the western region are 0.059 and 0.076 respectively, and the indirect effect coefficients are 0.217 and 0.205 respectively, which are all positive numbers. This result shows that specialized agglomeration can produce positive spillover effects in the western region.

In terms of diversification and agglomeration of high-tech industries, the direct effect coefficients of the eastern region on comprehensive efficiency and scale efficiency are significant, with values of 0.001 and 0.005 respectively. The coefficients of indirect effects are -0.002 and -0.005, respectively, and both pass the 10% significance test, which shows that the diversified agglomeration of high-tech manufacturing industry in the east has a positive spatial spillover effect on its technological innovation efficiency, while it inhibits the technological innovation efficiency in neighboring areas. The coefficients of direct effect on comprehensive efficiency and scale efficiency in the central region are 0.013 and 0.014 respectively, and the coefficients of indirect effect are 0.006 and 0.011 respectively, and they all pass the significance test, which shows that diversified agglomeration can have a positive impact on technological innovation. The direct effect coefficients of comprehensive efficiency and scale efficiency in the western region are 0.004 and 0.003, and the indirect effect coefficients are 0.016 and 0.019, which are all positive numbers, indicating that diversified agglomeration can also promote the technological innovation efficiency in the western regions. On the whole, the effect of technological innovation in western China is basically consistent with the national level. High-tech industry agglomeration can promote the efficiency of regional technological innovation from two aspects: specialization and diversification, but the effect of specialization is more significant.

3.4 Robustness test

In order to test the reliability of the impact of high-tech industrial agglomeration on regional innovation efficiency, this study adds economic characteristic weights on the basis of geographical distance matrix, and forms a nested spatial weight matrix Wij = wd. Diag (x1/x, X2/X, X3/X…Xn/X), where diag (…) is a diagonal matrix, x represents real GDP, and Xi is the average value of economic variable x of real GDP in region I during the inspection period. X is the average GDP of all sections in the investigation period, and the nested space weight matrix is used for analysis. Table 5 show that the regression results of high-tech industrial agglomeration on regional innovation efficiency are basically consistent with the results of the geographical distance matrix adopted in the previous article, which indicates that the basic conclusion of high-tech industrial agglomeration on regional innovation efficiency is robust.

Table 5: Estimation results of SDM of economic distance matrix

Var	Direct effect				Indirect effect			
	TE		SE		TE		SE	
Mar	0.015*		0.023***		0.167***		0.331***	
	(0.01)		(0.01)		(0.05)		(0.05)	
Jacobs		0.025***		0.034***		0.029		0.07***
		(0.01)		(0.01)		(0.02)		(0.02)
Invir	2.96***	4.290***	1.164*	3.29***	-0.709	-0.62	4.441***	6.046***
	(0.7)	(0.66)	(0.61)	(0.56)	(1.67)	(2.13)	(1.56)	(2.13)
Indus	-0.51**	-0.59***	-0.23	-0.37**	2.01***	1.19**	2.67***	1.01**
	(0.19)	(0.18)	(0.17)	(0.15)	(0.41)	(0.53)	(0.36)	(0.50)
Finan	0.03*	0.02*	0.09**	0.019*	-0.141	0.033	-0.45***	-0.17
	(0.04)	(0.04)	(0.03)	(0.03)	(0.1)	(0.1)	(0.11)	(0.10)
Open	0.19***	0.17***	0.29***	0.25***	-0.23*	-0.186	-0.40***	-0.40***
	(0.06)	(0.06)	(0.05)	(0.05)	(0.13)	(0.14)	(0.12)	(0.14)
ρ	0.221**	0.290***	0.257***	0.378***				
	(0.08)	(0.08)	(0.08)	(0.07)				
R^2	0.504	0.5274	0.7044	0.7251				

4 CONCLUSIONS

This study uses data envelopment analysis (DEA) to measure and analyze the technological innovation efficiency, pure technical efficiency and scale efficiency of 30 provinces in China from 2006 to 2019, and uses spatial Durbin model to further investigate the spatial effects of two high-tech industrial agglomeration modes on comprehensive technical efficiency and scale efficiency. The results show that:

There are significant spatial differences in regional comprehensive technical efficiency in China, and the comprehensive technical efficiency of provinces and cities in the eastern region is much higher than that of provinces and cities in the central and western regions. The difference of comprehensive technical efficiency in different regions is mainly caused by the difference of scale efficiency, while the difference caused by pure technical efficiency is relatively small.

From the national point of view, spatial spillover, specialized agglomeration and diversified agglomeration of high-tech industries have a positive impact on comprehensive technical efficiency and scale efficiency, which can promote the efficiency of technological innovation in the region, and the spillover effect of specialized agglomeration is more obvious; As for the spatial spillover between adjacent regions, the professional agglomeration of high-tech industries has a positive spatial spillover effect on comprehensive technical efficiency and scale efficiency, and the spillover effect of diversified agglomeration is not obvious. Sub-regions show that specialized agglomeration in the eastern region will hinder the improvement of innovation efficiency in the region, but promote the improvement of innovation efficiency in neighboring regions; Diversified agglomeration will promote the improvement of innovation efficiency in the region, but hinder the improvement of innovation efficiency in neighboring regions. The spatial spillover effect of high-tech industrial agglomeration on technological innovation efficiency in central China can be realized through diversified agglomeration. The results in the western region are consistent with the national level. The spatial spillover effects of regional innovation environment, financial development level and opening-up level on regional comprehensive technical efficiency and scale efficiency are significantly positive; The spatial spillover effect of industrial development level on regional comprehensive technical efficiency and scale efficiency is negative. It shows that the better the innovation market environment in the region, the easier it is to raise funds, and the higher the level of opening to the outside world, the more conducive it is to improving the efficiency of regional technological innovation.

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