Industrial Engineering and Innovation Management (2022)
Clausius Scientific Press, Canada

DOI: 10.23977/ieim.2022.050406
ISSN 2522-6924 Vol. 5 Num. 4

Study on the spatial and temporal evolution of technological innovation capability of industrial enterprises above the scale in Yangtze River Economic Zone

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Keywords: Yangtze River Economic Belt; Industrial Enterprises Above Scale; Technological Innovation; ESDA

Abstract: This paper employs exploratory spatial data analysis to examine the global and local autocorrelation of the spatial clustering of technological innovation capabilities of industrial enterprises above the scale in 11 provinces and cities in the Yangtze River Economic Belt, and to investigate its spatio-temporal evolution characteristics. It is found that (1) the technological innovation capability of industrial enterprises above the scale in the Yangtze River Economic Belt is not randomly distributed, but shows a significant clustering trend; (2) the positive spatial correlation becomes gradually weaker from 2011 and 2020 Moran's I index scatter plots, most of the cities in this 10-year time change are located in the first and third quadrants, indicating that the technological innovation capacity of enterprises in these cities has a high positive correlation in geographic space, so it is a general trend to strengthen the inter-regional cooperation capacity.

1. Introduction

The Yangtze River Economic Belt traverses the east, middle and west of China, covering 11 provinces and cities, carrying 40% of the country's population and 45% of the total economic output with a regional area of 21% of the country, and has a pivotal position in the overall development pattern of China. In the Outline of Yangtze River Economic Belt Development Plan, it is emphasized that the core of high-quality development lies in high-quality science and technology supply, playing the core driving role of enterprise-based independent innovation, continuously improving total factor productivity, and shaping new advantages of innovation-driven development. Industrial enterprises are the direct realizers of transforming science and technology into real productivity, the output of major scientific and technological innovation results, and bear the responsibility of local scientific and technological innovation development, especially the development of industrial enterprises above the scale is the core support force of the economic development of the Yangtze River Economic Zone, and their technological innovation capability plays an important role in the regional high-quality development. In this context, it is of practical significance to study the spatial and temporal evolution

characteristics of the technological innovation capacity of industrial enterprises above the scale of the Yangtze River Economic Belt to promote the high-quality development of the Yangtze River Economic Belt.

2. Literature Review

Relevant studies on the technological innovation capability of enterprises have focused on three perspectives. Di and Yao used stochastic frontier analysis model to study the impact of reverse outsourcing behavior on innovation efficiency of listed A-share semiconductor industry enterprises in China[1]; Gao and Xiao used SBM-DEA model to measure green technology innovation efficiency of industrial enterprises in 30 Chinese provinces [2]; Chen et al., used DEA-Malmquist model to measure and dynamically analyze the technological innovation efficiency of seed industry enterprises, and use Tobit model and threshold regression model to analyze the influence of government subsidies and market concentration on the technological innovation efficiency of enterprises [3]. Second, the study of technological innovation of enterprises in different industries. Yu and Wang used a case study approach in this paper to explore the path of digital technology-enabled technological innovation in China's manufacturing enterprises [4]; Wen studied the impact of employee shareholding and internal control quality on binary innovation in high-tech enterprises in the context of hybrid reform [5]; Ma et al. took automotive enterprises as the research object and explored the relationship between collaborative R&D and breakthrough technological innovation in incumbent enterprises and the mediating role of intergenerational knowledge bridges [6]; thirdly, a study on the spatial distribution of innovation capabilities. Cheng evaluated the innovation capability and explored the spatial and temporal evolution and future development direction of urban innovation development in Sichuan Province through 21 regions and cities in Sichuan Province [7]; Zhao constructed a spatial econometric model and a nonlinear threshold regression model to empirically analyze the spatial characteristics of FDI and regional innovation capability in cities in the Guangdong-Hong Kong-Macao Greater Bay Area [8]; Xu and Liu used kernel density estimation and center of gravity-standard deviation ellipses to analyze the spatial evolution pattern of green innovation efficiency in the Yellow River Basin and explored its influencing factors using spatial econometric models [9]. This paper combines geospatial factors with enterprise technological innovation capability and uses exploratory analysis to specifically study the spatial and temporal evolution characteristics of technological innovation capability of industrial enterprises above the scale in 11 provinces and cities in the Yangtze River Economic Belt.

3. Empirical Analysis

3.1 Study on the spatial and temporal evolution of technological innovation capability of industrial enterprises above the scale in Yangtze River Economic Zone based on ESDA

3.1.1 Spatial autocorrelation analysis

Moran's index is generally an important metric used to measure spatial correlation. Generally speaking, the Moran index is divided into the global Moran index and the Anselm local Moran index [10, 11]. The spatial correlation of industrial enterprises' technological innovation capability is mainly manifested by the existence of spatial spillover effects of regional enterprises' technological innovation behavior, which has an important impact on the innovation activities of the surrounding related regions. Meanwhile, another manifestation of spatial correlation is spatial heterogeneity, which in turn is based on spatial non-homogeneity, thus leading to spatial variability in regional technological innovation efficiency.The global Moran index is calculated as follows:

$$I = \frac{n}{S_0} \frac{\sum_{i=1}^{n} \sum_{j=1}^{n} w_{i,j} z_i z_j}{\sum_{i=0}^{n} z_i^2}$$

$$S_0 = \sum_{i=1}^{n} \sum_{j=1}^{n} w_{i,j}$$

$$Z_i = \frac{I - E[I]}{\sqrt{V[I]}}$$

$$E[I] = -\frac{1}{n-1}$$

$$V[I] = E[I^2] - E[I]^2$$

Typically, the Global Moran's I index ranges from -1.0 to 1.0. Moran's I > 0 indicates positive spatial correlation, with higher values indicating more pronounced spatial correlation; Moran's I < 0 indicates negative spatial correlation, with smaller values indicating greater spatial variation. The Moran's I index reveals the global spatial correlation of observations, while the Moran's I scatter plot depicts the local spatial correlation, thus indicating the spatial aggregation of high (or low) observations of innovation activities.

3.1.2 The actual measurement of spatial distribution of technological innovation capability of industrial enterprises above the scale in Yangtze River Economic Zone

3.1.2.1 Selection of indicators

Drawing on previous research results [12-20], this paper selects the number of patent applications of industrial enterprises above the scale as a measure of the output of enterprise technological innovation capability.

3.1.2.2 Global spatial interdependence test of technological innovation capability of industrial enterprises above the scale in Yangtze River Economic Zone

The spatial interdependence of technological innovation capability of industrial enterprises above the scale in Yangtze River Economic Belt from 2011 to 2020 was examined based on the number of patent applications using the global Moran's I index, and the results are shown in Table 1.

Table 1: Global Moran index of technological innovation capability of industrial enterprises above the scale of Yangtze River Economic Zone and its test, 2011-2020

year	I	E(I)	sd(I)	z	P-value*
2011	0.134	-0.100	0.168	1.394	0.082
2012	0.138	-0.100	0.175	1.361	0.087
2013	0.133	-0.100	0.176	1.321	0.093
2014	0.141	-0.100	0.165	1.462	0.072
2015	0.091	-0.100	0.166	1.149	0.125
2016	0.126	-0.100	0.158	1.433	0.076
2017	0.158	-0.100	0.169	1.530	0.063
2018	0.112	-0.100	0.155	1.361	0.087
2019	0.100	-0.100	0.159	1.253	0.105
2020	0.102	-0.100	0.166	1.214	0.112

The results in Table 1 show that Moran's I indexes are all greater than zero, indicating that the technological innovation capability of industrial enterprises above the scale in the Yangtze River

Economic Zone is not randomly distributed, but shows a significant clustering trend. However, the p-values of 2015, 2019 and 2020 are greater than 0.1, Moran's I index does not pass the 10% significance test, and both 2011-2014 and 2016-2018 are significant at the 10% level, which indicates that both neighboring provinces and cities have a higher number of patent applications or a lower number of patent applications, and patent applications have spatial spillover effects. Overall, in the first stage 2011-2018, the Moran index is greater than 0 and highly significant except for 2015, which indicates that there is an obvious positive regional correlation in this stage, that is, there is significant spatial dependence between neighboring provinces and regions, and the spatial spillover diffusion effect of innovation is obvious. The Moran indexes of the second stage 2019-2020 are all insignificant, indicating that there is no significant regional correlation in these two stages, i.e., there is no geographic spatial dependence or spillover diffusion effect between neighboring provinces and regions.

3.1.2.3 Local spatial correlation test of technological innovation capability of industrial enterprises above the scale in Yangtze River Economic Zone

The global Moran index gives the overall spatial correlation, and in order to more clearly illustrate the relationship between the technological innovation capacity of industrial enterprises in each city and the surrounding cities, this feature is revealed by drawing a Moran scatter plot. The cities falling into the first quadrant (High-High) indicate that the technological innovation capability of both the city and the surrounding cities is high and the differences are small; the cities falling into the second quadrant (Low-High) indicate that the technological innovation capability of the city is low, while the technological innovation capability of the surrounding cities is high and there are large The cities falling into the third quadrant (Low-Low) indicate that the technological innovation ability of enterprises in this city and the surrounding cities are both low and the difference is small; the cities falling into the fourth quadrant (High-Low) indicate that the technological innovation ability of enterprises in this city is high, but the technological innovation ability of enterprises in the surrounding cities is low and the difference is large. The details are shown in Figure 1.

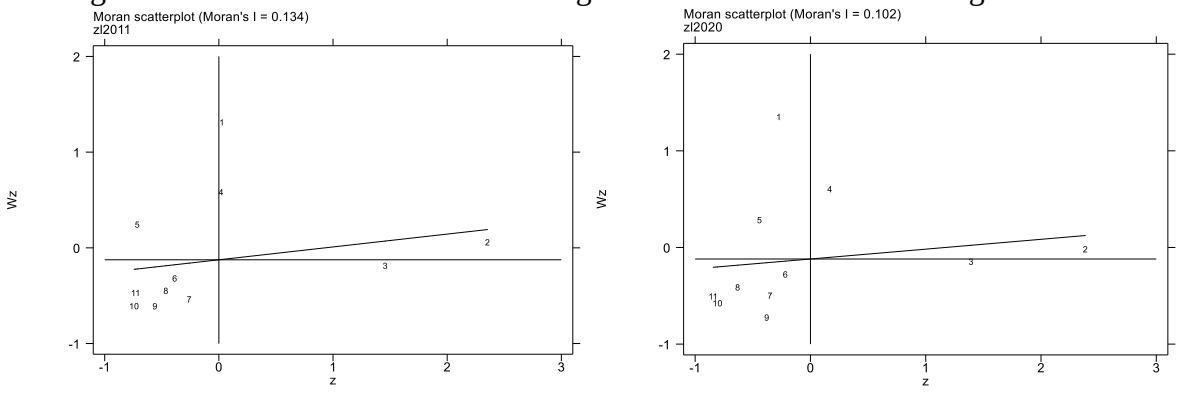

Figure 1: Scatterplot of Moran's I index of technological innovation capability of industrial enterprises above the scale in 11 provinces and cities in Yangtze River Economic Zone in 2011 and 2020

Figures 1 show the scatter plots of Moran's I index for the technological innovation capacity of industrial enterprises above the scale in 11 provinces and cities in the Yangtze River Economic Belt in 2011 and 2020, respectively, where the numbers 1-11 indicate Shanghai, Jiangsu, Zhejiang, Anhui, Jiangxi, Hubei, Hunan, Chongqing, Sichuan, Yunnan and Guizhou, respectively. As can be seen from Figure 1, in 2011, three cities in the first quadrant are Shanghai, Jiangsu and Anhui; only one city in the second quadrant is Jiangxi; six cities in the third quadrant are Hubei, Hunan, Chongqing, Sichuan,

Yunnan and Guizhou; and only one city in the fourth quadrant is Zhejiang. By 2020, there will be 2 cities in the first quadrant (Jiangsu and Anhui), 2 cities in the second quadrant (Shanghai and Jiangsu), 6 cities in the third quadrant (Hubei, Hunan, Chongqing, Sichuan, Yunnan and Guizhou), and 4 cities in the fourth quadrant (Zhejiang), which will remain unchanged. From the above descriptive analysis, most of the cities in this 10-year time change are located in the first and third quadrants, indicating that there is a high positive correlation in geographic space between the technological innovation capability of enterprises in these cities.

4. Conclusions and Implications

This paper analyzes the spatial and temporal evolution characteristics and key influencing factors of technological innovation capability of industrial enterprises above the scale in Yangtze River Economic Zone from 2011 to 2020, and the main conclusions and insights are.

First, the technological innovation capability of industrial enterprises above the scale in Yangtze River Economic Zone is not randomly distributed, but shows a significant clustering trend. Second, from the scatter plot of Moran's I index in 2011 and 2020, most of the cities in this 10-year time change are located in the first and third quadrants, which indicates that there is a high positive correlation between the technological innovation capacity of enterprises in these cities in geographic space. Therefore, there is a general trend to strengthen the inter-regional cooperation capacity.

Acknowledgement

This research was supported by the Graduate Research Innovation Fund project (Project number: 3192022078).

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