Study on the spatial distribution characteristics of urban innovation power in Yangtze River Delta urban agglomeration

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Abstract: Based on the evaluation index panel data of innovation capacity of 26 cities in the Yangtze River Delta urban agglomeration from 2013 to 2017, the global entropy method and exploratory spatial data analysis method (ESDA) were used to evaluate and analyze the spatial characteristics of urban innovation capacity. The results show that: (1) From 2013 to 2017, the innovation capacity of the Yangtze River Delta urban agglomeration has an obvious regional difference, showing a distribution pattern of "Strong In The East And Weak In The West" on the whole. (2) From 2013 to 2017, the innovation capacity of the Yangtze River Delta urban agglomeration shows significant positive agglomeration characteristics in space. (3) The spatial agglomeration evolution of the innovation capacity of each city has obvious spatial locking characteristics. Based on the research conclusion, this paper puts forward some suggestions on strengthening urban innovation connection, improving innovation structure, increasing innovation investment and strengthening scientific and technological strength.

1. Introduction
In the context of global regional cooperation and development, competition between urban agglomerations gradually replaces competition between cities [1]. As the most potential urban agglomerations for China's economic development, the Yangtze River Delta urban agglomeration is the core region of China's strategic development spatial structure, and the realization of innovative development of the Yangtze River Delta will promote higher quality regional development. According to the 19th CPC national congress, innovation is the primary driving force for urban development, and the government pays more attention to the construction of innovative cities and city clusters. To improve the city's innovation ability, it is necessary to understand the spatial agglomeration characteristics and evolution rules of innovation activities [2]. Therefore, it is of great significance to analyze the spatial agglomeration characteristics of innovation capacity of the Yangtze River Delta urban agglomeration for the realization of regional integration development of the Yangtze River Delta.

Based on the evaluation index panel data of innovation capacity of the Yangtze River Delta urban agglomeration from 2013 to 2017, this paper uses the global entropy method and exploratory spatial data analysis method (ESDA) to evaluate the innovation capacity of 26 cities and analyze the spatial characteristics, so as to provide suggestions for improving the innovation development of the Yangtze River Delta urban agglomeration.
2. Research data and methods

2.1. Research data
This paper selects 14 indicators[5-7] to evaluate the innovation ability of 26 cities in the Yangtze River Delta urban agglomeration, including education spending accounts for the proportion of financial expenditure, science and technology spending accounts for the proportion of financial expenditure, internal R&D spending as a share of GDP, patent applications per 10000 people, patent authorizations per 10000 people, students in institutions of higher learning per 10000 people, R&D practitioners per 10000 people, the proportion of the tertiary industry to GDP, actual utilization of foreign capital per capita, output value of new and high technology industries, road area per capita, green coverage rate of built-up area, the collection of public library per 100 people, and households with Internet broadband access per 10000 people.

The data of each indicator were obtained from Jiangsu Statistical Yearbook, Anhui Statistical Yearbook, Zhejiang Statistical Yearbook, Zhejiang Statistical Yearbook on Science and Technology, and statistical yearbooks of each city from 2014 to 2018.

2.2. Research methods

2.2.1. Global entropy method. Entropy method is an objective evaluation method to measure urban innovation capacity. The global entropy method [3] can be used to evaluate data from the perspectives of time and space. The calculation formula of the global entropy method is as follows:

\[ E_i = -k \sum_{j=1}^{n} P_{ij} \ln(P_{ij}) \quad W_i = \frac{g_i}{\sum_{m=1}^{m} g_i} \quad v_j = \sum_{i=1}^{m} W_i r_{ij} \quad (1) \]

Where, \( P_{ij} = \frac{r_{ij}}{\sum_{j=1}^{n} r_{ij}} \), \( k = \frac{1}{\ln(n^a)} \), \( g_i = 1 - E_i \), \( E_i \) and \( W_i \) are the entropy value and entropy weight of the evaluation index \( i \), and \( v_j \) is the comprehensive evaluation value of each city. In addition, \( n \) represents 26 cities in the Yangtze River Delta urban agglomeration. \( M \) represents 14 evaluation indicators. \( a \) represents the research years. Assuming that \( P_{ij} \) is equal to 0, \( P_{ij} \ln(P_{ij}) \) is equal to 0. In this paper, extreme value standardization is used to standardize each index.

2.2.2. Global spatial autocorrelation analysis. Spatial autocorrelation analysis can be used to measure the spatial distribution characteristics of variables and their influence on the surrounding areas. The Moran's I index is an important indicator to describe spatial autocorrelation [4], which can reflect the overall trend of spatial correlation of urban innovation capacity in the Yangtze River Delta urban agglomeration. The calculation formula is as follows:

\[ Moran's \ I = \frac{\sum_{i=1}^{n} \sum_{j=1}^{n} W_{ij} (x_i - \bar{x})(x_j - \bar{x})}{\sum_{i=1}^{n} \sum_{j=1}^{n} W_{ij} / n} \]

(2)

In the formula, \( x_i \) and \( x_j \) respectively represent the value of urban innovation capacity of the city \( i \) and the city \( j \). \( N \) is the number of cities. \( W_{ij} \) is the spatial weight matrix. The Moran's I index is greater than or equal to minus 1 and less than or equal to 1. The Moran's I index is greater than 1, indicating that the urban innovation capacity has a positive spatial correlation. The Moran's I index is less than 1, indicating that urban innovation capacity has a negative spatial correlation. The Moran's I index is equal to 0, indicating that urban innovation capacity is randomly distributed in space.
2.2.3. **Local spatial autocorrelation analysis.** The local spatial autocorrelation coefficient can further reveal the spatial heterogeneity and instability of urban innovation capacity in the Yangtze River Delta urban agglomeration. The calculation formula is as follows:

$$I_i = Z_i \sum_{i=1}^{n} W_{ij} Z_j$$  \hspace{1cm} (3)

Where, $Z$ represents the deviation between the urban innovation capacity and the mean value, $Z_i = (x_i - \bar{x})$, $Z_j = (x_j - \bar{x})$. If $I_i$ is greater than 0, the cities with the same type of innovation capacity are adjacent to each other. If $I_i$ is less than 0, cities with different types of innovation capacity are adjacent to each other.

3. **Results and analysis**

3.1. **The distribution of innovation capacity in the Yangtze River Delta urban agglomeration**

In this study, the evaluation index system of innovation ability of the Yangtze River Delta urban agglomeration was established, and the global entropy value method was adopted to evaluate the innovation capacity of the Yangtze River Delta from 2013 to 2017. As the figure 1 shows.

From 2013 to 2017, the innovation capacity of the Yangtze River Delta urban agglomeration showed an increasing trend, but the regional differences were obvious, exhibiting an overall distribution pattern of "Strong In The East And Weak In The West". Suzhou and Shanghai have consistently ranked among the forefront of the Yangtze River Delta urban agglomeration in terms of innovation capacity, and the surrounding cities such as Wuxi and Jiaxing also have higher innovation capacity. Nanjing, having a quantity of universities, has been strengthening the introduction of science and innovation enterprises and R&D institutions in recent years, and the city’s innovation capacity has been significantly improved. In addition, the innovation capacity of Yancheng, Taizhou, Zhenjiang and Changzhou in Jiangsu province, as well as Hangzhou, Jinhua and Taizhou in Zhejiang province has been improving year by year. Then, the innovation capacity of each city in Anhui province is promoted at a slower speed, among which the innovation capacity of Tongling is decreased, which may be caused by its single industrial structure and the enterprises with heavy pollution and high energy consumption. Therefore, the city should strengthen the industrial transformation and upgrading.

![Figure 1. Spatial distribution of innovation capacity in the Yangtze River Delta in 2013 and 2017](image)

3.2. **Global autocorrelation and evolution of regional innovation activities**

The Moran’s I index of innovation capacity of 26 cities in the Yangtze River Delta urban agglomeration from 2013 to 2017 is calculated by ArcGIS software (as the Table 1 shows). According to the results, from 2013 to 2017, the Moran’s I index of innovation capacity of 26 cities in the Yangtze River Delta
urban agglomeration was all greater than 0, passing the significance level test of 5%, indicating that the urban innovation capacity of the Yangtze River Delta urban agglomeration has significantly positive agglomeration characteristics in space. From 2013 to 2017, Moran's I index's dropping from 0.378486 to 0.285426 showed that the spatial agglomeration of innovation capacity in 26 cities in the Yangtze River Delta urban agglomeration is weakened, but still high-level in spatial autocorrelation.

Table 1. Moran's I index of in the Yangtze River Delta’s innovation capacity from 2013 to 2017

| Years | 2013   | 2014   | 2015   | 2016   | 2017   |
|-------|--------|--------|--------|--------|--------|
| Moran's I | 0.378486 | 0.339966 | 0.307262 | 0.314035 | 0.285426 |
| Sig.   | 0.0018 *** | 0.0046 *** | 0.0099 *** | 0.0089 *** | 0.0157 ** |

*a *** and ** indicate that the coefficient of variables is significant at the significance level of 1% and 5%.

3.3. LISA analysis of regional innovation activity based on Moran scatter plots

The Moran's I index only presents the spatial agglomeration characteristics of the overall innovation capacity of the Yangtze River Delta urban agglomeration. In order to further explore the spatial agglomeration of each city's innovation capacity, this paper continued to calculate the local spatial autocorrelation coefficient, drawing Moran scatter plots and LISA agglomeration maps to reflect the innovative correlation characteristics of the city and surrounding areas (as the Figure 2 shows). In general, cities with high innovation capacity in the Yangtze River Delta urban agglomeration are concentrated in the eastern part of the Yangtze River Delta, while cities with low innovation capacity are concentrated in the western part of it. According to the Moran scatter plots, the spatial agglomeration evolution of urban innovation capacity in the Yangtze River Delta urban agglomeration has obvious spatial locking characteristics from 2013 to 2017. Except for Huzhou and Shaoxing, achieving the quadrantal transition, each city is stably distributed in its own quadrant.

Figure 2. LISA agglomeration maps of the Yangtze River Delta’s innovation capacity in 2013 and 2017

**High-High cluster’s quadrant:** Cities in this quadrant have higher innovation capacity and show strong innovation spillover effect on neighboring cities. From 2013 to 2017, Nantong, Jiaxing, Changzhou, Wuxi, Zhenjiang, Maanshan, Wuhu, Suzhou, Shanghai and Nanjing are steadily distributed in the first quadrant. Under the influence of Suzhou and Shanghai, Huzhou's innovation capacity jumps from L-H quadrant to H-H quadrant. Lisa agglomeration maps show that Suzhou and Shanghai maintain a high level of innovation capacity with their strong economic strength and abundant talent reserve, forming a highly significant and concentrated innovation region of the Yangtze River Delta.

**Low-High outlier’s quadrant:** Cities in this quadrant have weaker innovation capacity than surrounding cities. From 2013 to 2017, Chuzhou, Xuancheng, Jinhua, Zhoushan, Taizhou and Yangzhou are steadily distributed in the second quadrant. Chuzhou shows a significant L-H aggregation effect in 2017, which may be attributed to its weaker technology and talent resources, slower growth of its innovation capacity, and less influence from cities with rapid improvement of innovation capacity, such
as Nanjing and Hefei. Therefore, innovation cooperation with surrounding cities should be strengthened.

**Low-Low cluster’s quadrant:** Cities in this quadrant and adjacent cities have weaker innovation capacity. From 2013 to 2017, Yancheng, Taizhou, Chizhou, Anqing, and Tongling are steadily distributed in the third quadrant. Shaoxing’s innovation capacity is significantly improved, jumping from L-L quadrant to H-L quadrant. The Moran scatter point of Chizhou and Anqing has spread outward obviously, indicating that the deeper gap between cities and surrounding cities in innovation capacity has appeared. Anqing and Chizhou are short of innovative talents and technologies, and their innovation capacity improves slowly, showing a significant L-L concentration.

**High-Low outlier’s quadrant:** Cities in this quadrant have high innovation capacity while the innovation ability of neighboring cities is low. From 2013 to 2017, Hangzhou, Hefei, and Ningbo are steadily distributed in the fourth quadrant. These three cities have implemented active policies and strategies of talent attraction and innovative development to promote the concentration of innovative technologies and talents, leading to the constantly improving of the cities’ innovation capacity. At the same time, the innovation capacity of neighboring cities has not been improved, indicating that the polarization effect of innovation capacity in this region has been enhanced.

4. Conclusions and suggestions
According to the calculation and analysis, the urban innovation capacity of the Yangtze River Delta urban agglomeration from 2013 to 2017 is increasing, with great regional differences and significantly positive agglomeration characteristics in space. Each city has an obvious spatial locking characteristic in the spatial agglomeration evolution of the innovation ability. LISA agglomeration maps show that Suzhou and Shanghai have formed an obvious High-Hight cluster area with their strong economic strength and abundant talent reserve, and Anqing and Chizhou have formed an obvious Low-Low cluster area due to the lack of innovative talents and technology. Meanwhile the Low-High outlier effect of Chuzhou tends to be obvious within five years.

Based on the research conclusions, the following suggestions are proposed:
Cities should actively strengthen the urban innovation connection, give full play to the leading role of cities with higher innovation capacity, improve and perfect the urban innovation structure, build a highly shared and cooperative innovation network, improve the utilization efficiency of regional innovation resources, and promote the integrated development of the Yangtze River Delta. In addition, the local governments should increase the investment in innovation, attract innovative talents to gather, constantly improve the innovation incentive mechanism, support the development of scientific research projects, rely on scientific and technological progress to promote the improvement of regional innovation capacity, and promote the high-quality development of the Yangtze River Delta urban agglomeration.

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