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Industrial Agglomeration of High Technology in Yangtze River Delta City Cluster Based on Knowledge Spillover Spatial Effect Study

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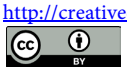


Abstract

The Yangtze River Delta (YRD) region has been a strong innovation capability and has a good economic development and innovation environment. This paper will focus on the spatial effects of high-tech industrial agglomeration in the Yangtze River Delta region based on the knowledge spillover theory, with the Yangtze River Delta regional city cluster as the research object. This paper begins with a review of relevant literature on knowledge spillover, high-tech industry agglomeration and the relationship between science and technology innovation and economic growth. On this basis, we measure the degree of industrial agglomeration in 27 urban areas of the Yangtze River Delta using the locational entropy research method and analyze the current situation of innovation and high-tech industry development in the Yangtze River Delta. It is found that most of the urban agglomerations are not randomly distributed in the first and third quadrants, indicating that they have considerable spatial correlation, and then relevant countermeasure suggestions are given.

Keywords

Knowledge Spillover, High-Tech Industry Clustering

1. Introduction

Over the past 40 years since the reform and opening up, China has seen a rapid increase in the level of industrial agglomeration. The clustering of high-tech industries has led to a large concentration of innovation resources. As a result, while improving the overall innovation capacity of the region, industrial agglomeration will form the corresponding enterprise clusters. Enterprise clusters strengthen the coordination and cooperation among enterprises, which can promote

regional employment and the concentration of scientific and technological talents while improving labor productivity, promoting the upgrading and optimization of industrial structure, and facilitating the coordinated development of regional industries, which is the driving force of high-quality economic growth.

With the rapid development of industrial clustering, high-tech industries have made significant contributions to the development of regional economies and innovative output. However, it should not be overlooked that there is still an uneven development between regions in China, both between eastern and western regions and between coastal cities and inland cities. The uneven allocation of resources in high-tech industry agglomeration can cause regional diseconomies, so much so that the agglomeration effect is reversed. In the context of "domestic circulation as the main theme and domestic and international circulation promoting each other", it is important to study the economic and spillover effects brought by the evolution of high-tech industrial agglomeration for the sustainable development of the region.

The rest of the paper is organized as follows: Part 2 is a review of the current status of research and related theories. Part 3 is the analysis of knowledge spillover and high-tech industry agglomeration in the Yangtze River Delta city cluster. Part 4 analyzes the spatial effects of knowledge spillover and high-tech industrial agglomeration in the Yangtze River Delta urban agglomeration. Part 5 gives the suggestions of relevant countermeasures and the conclusion and outlook. The paper concludes with some policy recommendations and directions for future research.

2. Literature Review

Marshall (1961) mentioned the theory of industrial agglomeration and externalities in his book Principles of Economics and summarized three reasons for agglomeration formation: labor concentration, specialized inputs of intermediate goods, and knowledge spillover. Anselin (2010) verified that the formation process of knowledge spillover effect generates agglomeration effect by using spatial measurement method. Glaeser et al. (1992) found in the study of knowledge spillover and industrial agglomeration that agglomeration effect promotes the development of regional innovation. Keller (2002) found that spatial distance affects the external knowledge spillover effect, and the farther the distance, the less favorable the knowledge spillover. Autant-Bernard et al. (2011) found that spatial agglomeration of firms affects their productivity levels and production efficiency. Wallsten (2001) empirically found that the higher the degree of cooperation of enterprise agglomeration, the more obvious the knowledge spillover effect.

Knowledge spillover also has an impact on industrial agglomeration. Simmie, (2002) found that agglomeration requires a combination of local and international knowledge spillover, which usually comes from both the supply and demand sides of the firm, from a study of SME agglomeration. Wang et al. (2006)

measured the spatial agglomeration of high-tech industries in China by two index methods, β index and industry concentration CR_n, and found that the industrial agglomeration and localization of high-tech industries in China showed a growing trend. Liang et al. (2007) found that there are significant global and local spatial dependence characteristics in the development of high-tech industries in China; Xi & Ji (2012) the factors affecting the agglomeration of high-tech industries are related to the investment in scientific and technological research and development, the scale of the regional economy to the level and foreign direct investment. Zhang (2014) found an inverted "U" curve relationship between industrial agglomeration and economic growth within urban clusters using dynamic panel generalized moments estimation method. Zhao (2016) used a dynamic panel data model to empirically study the effect of technological innovation capacity and industrial structure upgrading on economic growth and found that the intensity of innovation inputs had a non-linear relationship with economic growth; Ji & Zhu (2017) studied the impact of industrial agglomeration on resource mismatch, while other scholars investigated the impact of high-tech industrial agglomeration by empirically studying its impact with labor productivity, total factor productivity, and innovation R&D efficiency, Wang & Wang (2017) empirically found that specialized agglomeration in high-tech industries inhibits the increase of labor productivity. Tang et al. (2018) studied the influence of spatial characteristics of high-tech industries on R&D efficiency in Anhui Province, and found that the development of some key urban industries would drive the progressive development of neighboring cities thereby contributing to the industrial R&D efficiency in the province. Wan et al. (2018) studied the convergence of the innovation efficiency of provincial high-tech industries in China using the Cobb-Douglas SFA method with a spatial econometric model. Chen et al. (2019) measured Malmquist productivity index of Chinese high-tech industry based on panel data and used it to verify the effects of firm size, industrial agglomeration, and technological innovation on total factor productivity of high-tech industry found that total factor productivity of Chinese high-tech industry showed a decreasing trend due to the retreat of technological progress. Yang et al. (2019) argues that high-tech industry agglomeration triggers financial and technological externalities thus promoting high-quality economic development. Wang & Sun (2020) investigated whether co-located agglomeration of high-tech industries and productive services can effectively increase green total factor productivity through threshold regression and found that industry co-location agglomeration can increase green total factor productivity under appropriate conditions when a certain threshold is exceeded there is a suppressive effect.

This paper focuses the research perspective on the link between high-tech industrial agglomeration and knowledge innovation output in the Yangtze River Delta region, which involves including the effect of knowledge spillover from high-tech industrial agglomeration to the region. Most of the current studies are

limited to the macroscopic studies on the national provincial panels and relatively single study on the role of high-tech industrial agglomeration on economic growth, while this paper will focus on the study of the effect of urban agglomeration in the Yangtze River Delta region, which will explore the relationship between innovation output and industrial agglomeration, and then can enrich the theoretical study of related industrial agglomeration.

3. Status of Knowledge Spillover and High-Tech Industry Clustering in the Yangtze River Delta City Cluster

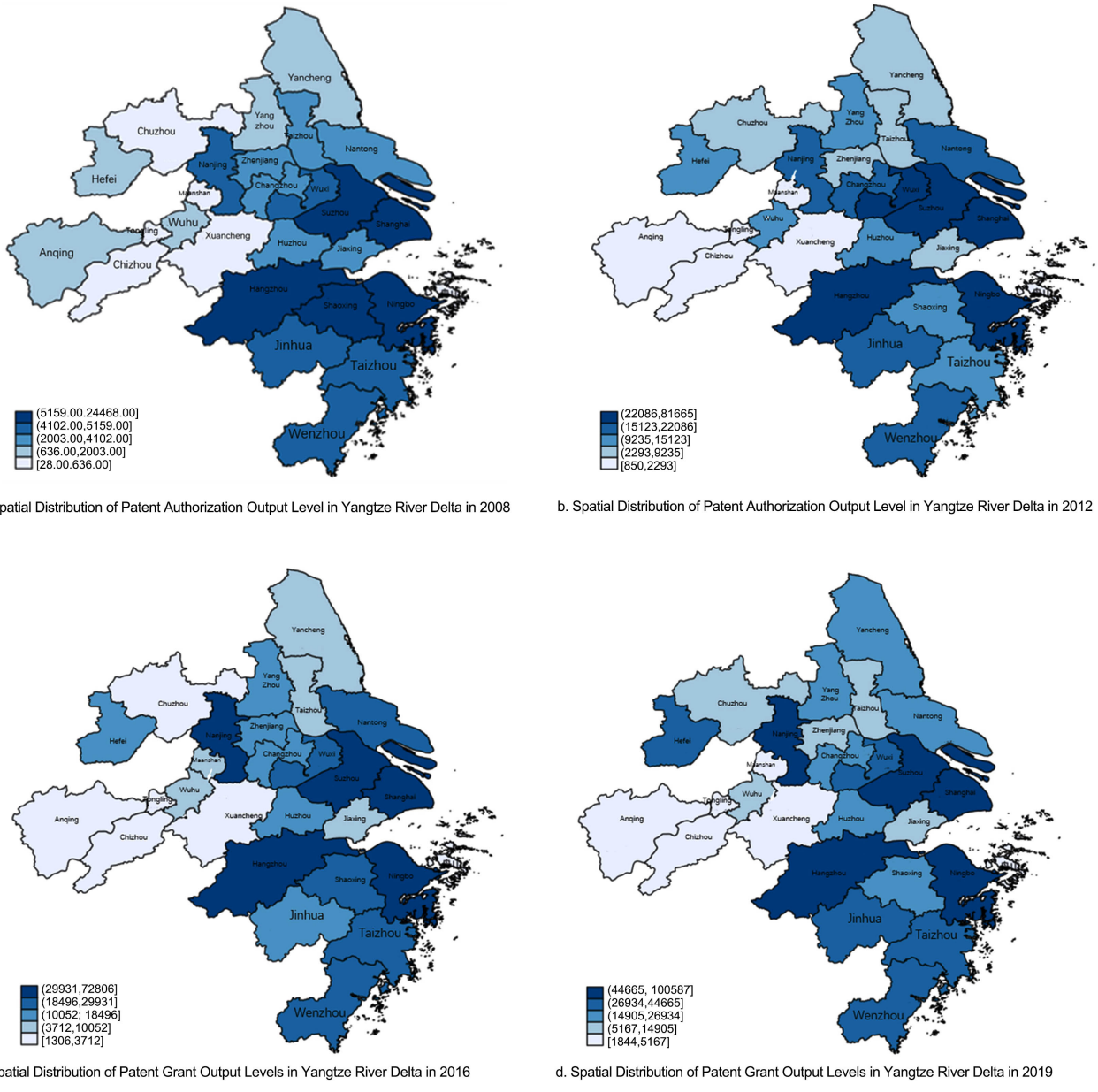
3.1. Current Status of Knowledge Spillover in the Yangtze River Delta City Cluster

In order to more clearly reflect the changing trend of knowledge spillover in the Yangtze River Delta region, this paper uses stata15.1 to divide the number of patents granted from 2008 to 2019 in 27 cities in the Yangtze River Delta into five gradients from high to low, and the results are shown in Table 1 and Figure 1, The data in this section are obtained from the 2009-2020 Statistical Yearbook of each municipality and the 2009-2020 Statistical Bulletin of National Economic and Social Development of each municipality.

In terms of the distribution of annual patent grants: cities with high levels of knowledge innovation output are distributed in a Z-shaped pattern with Shanghai as the core along the traffic route centered on Hefei, Nanjing, Hangzhou and Ningbo. The knowledge innovation output levels of four cities, namely Shanghai, Suzhou, Hangzhou and Ningbo, always remain in the first gradient, and Hefei rises from the fourth gradient in 2008 to the second gradient in 2019. The knowledge innovation output levels of most cities in Jiangsu as well as Hangzhou are basically stable and concentrated in the second and third gradients, with Wuxi and Nantong dropping from the first and second gradients to the second and third gradients, respectively, indicating a certain spatial spillover phenomenon. Most cities in Anhui, except Hefei, Wuhu and Maanshan, are in the fifth gradient, and the output level is low compared with other cities. In terms of spatial distribution, the cities in Anhui Province with low patent grant volume are mainly located in the western part of it, and the cities in Jiangsu Province with low output level of patent grant are mainly located in the northern part of it. The number of patents granted in Hefei has grown well in these 12 years, from only 1665 in 2008, which was located in the fourth tier of the Yangtze River Delta city group, to 44,665 in 2019, becoming a member of the second tier, which has led to the progress and development of neighboring cities, such as Chuzhou and Wuhu.

In terms of the distribution of the gradient at different times, the cross-sectional data of patent grants in four years are selected in this paper, and it can be seen from Table 1 and Figure 1 that the spatial distribution of knowledge innovation output in the Yangtze River Delta city cluster is relatively stable and the spatial clustering distribution is obvious. From 2008 to 2019, the pattern of knowledge

innovation output in the Yangtze River Delta basically remains on the pattern of "5 + 5 + X", which represents the first and second gradients of "5 + 5" high-output cities and the distribution pattern of X cities in the remaining gradient. With the rapid development of Nanjing and Hefei, the knowledge innovation output level has reached the first and second gradient level one after another. With Shanghai as the core along the cities of Hefei, Hangzhou, Nanjing, and Ningbo as the center, the Z-shaped regional output aggregation is high, and the output level capability is dispersed outward to build the pattern of multi-city synergistic development in the Yangtze River Delta.



a. Spatial Distribution of Patent Authorization Output Level in Yangtze River Delta in 2008

b. Spatial Distribution of Patent Authorization Output Level in Yangtze River Delta in 2012

c. Spatial Distribution of Patent Grant Output Levels in Yangtze River Delta in 2016

d. Spatial Distribution of Patent Grant Output Levels in Yangtze River Delta in 2019

Figure 1. Spatial distribution of knowledge innovation output levels in yangtze river delta in 2008, 2012, 2016 and 2019. Source: Spatial distribution of knowledge innovation output levels in the Yangtze River Delta in 2008, 2012, 2016 and 2019 produced by ArcGIS.

Table 1. Knowledge innovation output gradient in yangtze river delta 2008, 2012, 2016, 2019.

	2008	2012	2016	2019
First gradient	Shanghai, Suzhou, Hangzhou, Shaoxing, Ningbo	Shanghai, Suzhou, Wuxi, Hangzhou, Ningbo	Shanghai, Suzhou, Hangzhou, Ningbo, Nanjing	Shanghai, Suzhou, Hangzhou, Ningbo, Nanjing
Second gradient	Wuxi, Nanjing, Wenzhou, Jinhua, Taizhou	Nanjing, Changzhou, Nantong, Jinhua, Wenzhou	Nantong, Wuxi, Shaoxing, Wenzhou, Taizhou	Hefei, Wuxi, Jinhua, Taizhou, Wenzhou
Third gradient	Nantong, Taizhou, Yangzhou, Zhenjiang, Changzhou, Huzhou, Jiaxing	Shaoxing, Taizhou, Huzhou, Wuhu, Hefei, Yangzhou, Zhenjiang	Yangzhou, Changzhou, Hefei, Huzhou, Jinhua, Zhenjiang,	Yancheng, Nantong, Yangzhou, Changzhou, Huzhou, Shaoxing
Fourth gradient	Yancheng, Hefei, Ma'anshan, Wuhu, Anqing	Jiaxing, Ma'anshan, Chuzhou, Taizhou, Yancheng	Yancheng, Taizhou, Ma'anshan, Jiaxing, Wuhu	Chuzhou, Wuhu, Taizhou, Zhenjiang, Jiaxing
Fifth gradient	Chuzhou, Tongling, Chizhou, Xuancheng, Zhoushan	Anqing, Chizhou, Xuancheng, Tongling, Zhoushan	Chuzhou, Xuancheng, Tongling, Chizhou, Zhoushan, Anqing	Ma'anshan, Tongling, Xuancheng, Chizhou, Zhoushan, Anqing

Source: Statistical yearbook of cities 2009-2020, statistical bulletin of national economic and social development of cities 2009-2020.

3.2. The Current Situation of High-Tech Industry Clustering in the Yangtze River Delta City Cluster

This paper adopts the method in (Wang & Sun, 2020) to select location entropy as the evaluation index of industrial agglomeration. This index is mainly calculated by the output value of high-tech industries as shown in Equation (1):

$$LQ_{it} = \frac{Y_{it}}{Q_t} \tag{1}$$

In Equation (1), LQ_{it}, Q_{it} and Y_{it} denote the location entropy, output value of high-tech industries and output value of all industries in region i in year t, respectively, and Q_t and Y_t are the output value of high-tech industries and output value of all industries in the country in year t, respectively. The data in this section comes from the 2009-2020 China Torch Statistical Yearbook and the China City Yearbook.

The method was used to measure the degree of high-tech industry agglomeration of 27 cities in Yangtze River Delta, and then ArcGIS software was used to draw the spatial distribution of high-tech industry agglomeration level of 27 cities in Yangtze River Delta as shown in Figure 2.

The industrial agglomeration degree of each region in the Yangtze River Delta region since 2008 is mostly greater than 1, which is higher than the national average level of the industry. Among them, the cities with strong concentration of high-tech industries are mainly concentrated in Shanghai, Nanjing, Wuxi, Suzhou, Yangzhou and Nantong in Jiangsu, and Hangzhou in Zhejiang, while most of the cities in Anhui Province, except Hefei, Maanshan and Wuhu, have weaker concentration than other cities.

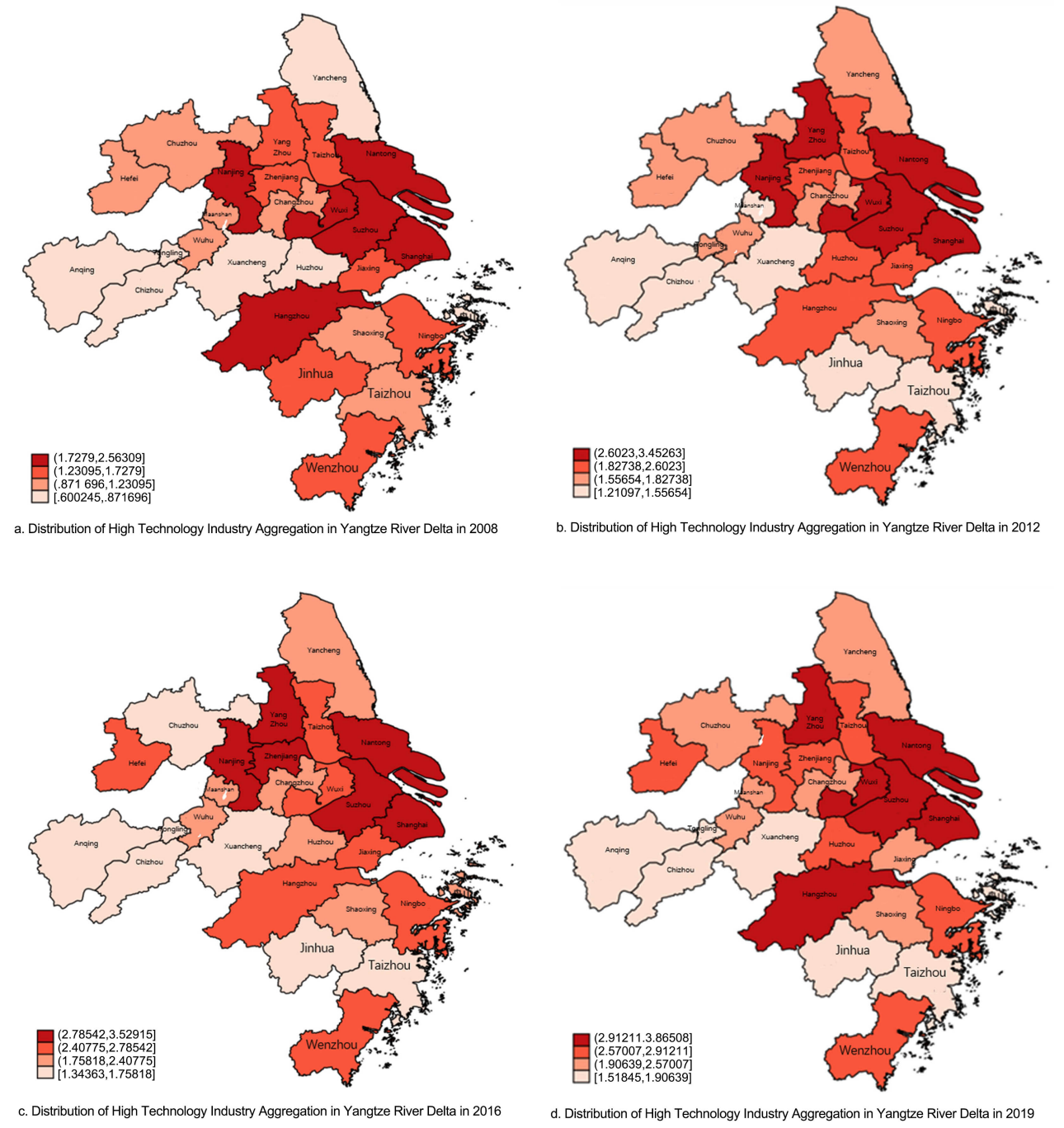


Figure 2. Spatial distribution of agglomeration levels of high-tech industries in Yangtze river delta in 2008, 2012, 2016 and 2019. Source: Spatial Distribution of Agglomeration Levels of High-Tech Industries in Yangtze River Delta in 2008, 2012, 2016 and 2019 produced by ArcGIS.

The level of high-tech industry agglomeration in the Yangtze River Delta region mainly spreads outward with Shanghai as the center, and the overall high-tech industry agglomeration in Jiangsu Province is better than other cities and belongs to the high agglomeration zone. In recent years, the agglomeration of high-tech industry in Anhui Province has increased, mainly because the northern Yangtze River Delta with Nanjing and Yangzhou as the center has driven the

industrial development of neighboring cities such as Hefei, Maanshan, Wuhu, Chuzhou and Yancheng in northern Jiangsu Province in recent years, and the central Yangtze River Delta with Suzhou as the center has driven the industrial development of Zhejiang Province such as Huzhou City, whose development has reached the second gradient in recent years.

The overall industrial agglomeration in Zhejiang Province is relatively stable, and Hangzhou, Ningbo and Wenzhou continue to play a leading role in development. The overall industrial agglomeration level of the Yangtze River Delta is greater than 1, which means that the agglomeration of high-tech industries is higher than the national average, and the agglomeration of high-tech industries will be reflected by high innovation level, which provides a solid foundation for the integration of the regional economy of the Yangtze River Delta. In addition, in the era of knowledge-based economy and the background of national policy guidance and support, vigorous development of high-tech industries in the Yangtze River Delta is not only conducive to the enhancement of its regional competitiveness and comprehensive strength, but also can play a leading role in innovative development for the neighboring regions.

4. Spatial Effects of High-Tech Industry Agglomeration in Yangtze River Delta City Cluster Based on Knowledge Spillover

This paper conducts a spatial analysis of knowledge spillover and high-tech industrial agglomeration in the Yangtze River Delta (YRD) by combining innovation output (patent grants) and high-tech main business income of the YRD city cluster from 2008 to 2019.

4.1. Global Moran Analysis

Moran index, as a common index for spatial econometric analysis, is intended to be used for spatial correlation testing, which can reflect the degree of spatial correlation between the region under study, such as the Yangtze River Delta, and neighboring cities. The index range of MoranI is [−1, 1], and an index greater than 0 indicates positive spatial correlation, and less than 0 indicates negative spatial correlation. The larger the absolute value, the stronger the correlation; the smaller the absolute value, the weaker the correlation. Before the empirical analysis, the existence of spatial correlation is usually judged by Moran's I. Only with spatial correlation can the subsequent spatial measurement study be carried out, and Moran's I can be divided into global Moran's I and local Moran's I.

In this paper, we can examine the robustness of the results through the combination of different spatial weight matrices (all normalized), and the global Moran's I is calculated as shown in Equation (2).

$$I = \frac{\sum_i^n \sum_{j=1}^n w_{ij}\left(y_i - \overline{y}\right)}{S^2 \sum_i^n \sum_{j=1}^n w_{ij}}$$

$$S^2 = \frac{1}{n}\sum_{i=1}^{n}\left(y_i - \bar{y}\right)^2,\ \ \bar{y} = \frac{1}{n}\sum_{i=1}^{n} y_i \tag{2}$$

In Equation (2): y_i is the observed value of region i; n is the number of regions. w_{ij} is the constituent element of the spatial weight matrix W. The significance of the spatial correlation is judged by constructing the standard statistic Z under the assumption of random distribution according to the results of Moran's I calculation, as shown in Equation (3).

$$Z(I) = \frac{I - E(I)}{\sqrt{Var(I)}} \tag{3}$$

In Equation (3): $E(I)$ denotes the expectation of Moran's I; $Var(I)$ is the variance of Moran's I.

The results of the global Moran's I measures of innovation output and high-tech industry agglomeration for the Yangtze River Delta city cluster from 2008 to 2019 are shown in Table 2 and Table 3.

As can be seen from Table 2 and Table 3, the global Moran's I of patent grant and high-tech industry agglomeration in China's Yangtze River Delta region from 2008 to 2019 are all greater than 0. Except for the spatial adjacency weight matrix of patent grant which fails the test in some years (we will exclude this weight matrix for study in the subsequent empirical evidence), the rest of the spatial weight matrices pass the test at least at the 5% significance level, which indicates that there is indeed a significant positive autocorrelation between high-tech industry agglomeration in China's Yangtze River Delta region and the knowledge innovation output of the region. In other words, the spatial distribution of innovation output and high-tech industry agglomeration in China's Yangtze River Delta is not in a completely random state, but shows a spatial concentration of cities with similar agglomeration levels.

Table 2. Global Moran's I index of innovation output in the Yangtze River delta, 2010-2019.

year	2008	2009	2010	2011	2012	2013
0 - 1 weight	0.225**	0.269***	0.257***	0.186**	0.109	0.043
Geographic weights	0.158***	0.179***	0.226***	0.184***	0.166***	0.132**
Economic weights	0.207**	0.255***	0.332***	0.416***	0.535***	0.585***
Economic geographic weights	0.18*	0.221**	0.293***	0.345***	0.422***	0.446***
year	2014	2015	2016	2017	2018	2019
0 - 1 weight	0.065	0.141*	0.124*	0.082	0.11	0.01
Geographic weights	0.132**	0.194**	0.158**	0.123**	0.134**	0.074*
Economic weights	0.538***	0.464***	0.419***	0.405***	0.402***	0.418***
Economic geographic weights	0.413***	0.374***	0.332***	0.316***	0.318***	0.313***

Note: ***, **, * indicate significant at 1%, 5%, and 10% significance levels, respectively, as in the following table. Source: 2009-2020 Statistical Yearbook of each city, China High Technology Yearbook, China Statistical Yearbook, Statistical Bulletin of National Economic and Social Development of each city.

Table 3. Global Moran's I index of high technology industry aggregation in Yangtze River delta, 2008-2019

year	2008	2009	2010	2011	2012	2013
0 - 1 weight	0.142*	0.287***	0.186**	0.253**	0.355***	0.287***
Geographic weights	0.159**	0.26***	0.158**	0.164**	0.232***	0.207***
Economic weights	0.329***	0.25**	0.238***	0.312***	0.305***	0.32***
Economic geographic weights	0.267***	0.239***	0.202**	0.265**	0.278***	0.281***
year	2014	2015	2016	2017	2018	2019
0 - 1 weight	0.258**	0.252**	0.229**	0.345***	0.329***	0.305***
Geographic weights	0.176***	0.21***	0.18***	0.275***	0.292***	0.314***
Economic weights	0.333***	0.303***	0.267**	0.245**	0.269***	0.288***
Economic geographic weights	0.283***	0.27***	0.233***	0.246***	0.271***	0.289***

Source: 2009-2020 statistical yearbook of each city, china high technology yearbook, China statistical yearbook, statistical bulletin of national economic and social development of each city.

In order to clearly analyze the changes of knowledge innovation as well as high-tech industry agglomeration variables, **Figure 3** and **Figure 4** plot the line graphs of their Moran's I indices under different spatial weight dimensions, taking the economic-geographic nested dimension as an example, it is obvious from the graphs that the Moran's I indices of knowledge innovation output all start to increase year by year after 2009, but although the growth rate becomes slower after 2013, and to 2018 it has a decreasing trend but seems to have an increasing trend since 2019, which may be due to the active implementation of China's innovation-driven development strategy, technological innovation is getting more and more attention related to it.

For high-tech industry agglomeration since 2008, China adjusted its high-tech enterprise recognition and management policy for the third time, which accelerated the change of economic development mode and the new stage of relying on innovation to promote economic and social development, the state and government began to pay more attention to guiding the development of high technology and increased the investment in the real economy such as the field of technological innovation; after 2009, the Moran's I index of high-tech industry agglomeration gradually increased, indicating the rapid development and agglomeration of high-tech industry, and after 2014 the agglomeration area began to show the phenomenon of congestion, so the agglomeration effect was weakened. In addition, the statistical results of Moran's I index further point out that the spatial effects of high-tech industrial agglomeration and knowledge innovation cannot be ignored when studying the effects of high-tech industrial agglomeration on knowledge innovation in China, so it is more appropriate to choose the relevant spatial model for the analysis.

4.2. Local Moran Analysis

The local Moran's I can more accurately reflect the spatial dependence among

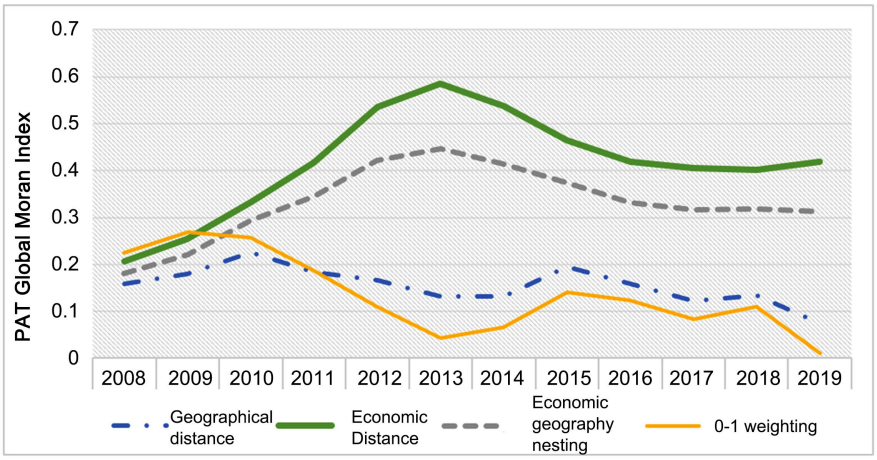


Figure 3. Trends in Yangtze river delta innovation output global moran index from 2008-2019 (Researcher's own construct). Data source: 2009-2020 Statistical Yearbook of each city, 2009-2020 Statistical Bulletin of National Economic and Social Development of each city.

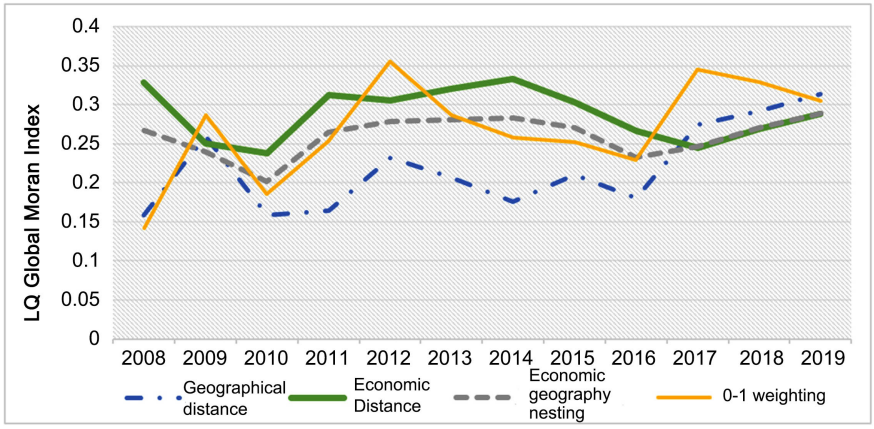


Figure 4. The trend of the global Moran index of the Yangtze River Delta locational entropy from 2008-2019. Data source: 2009-2020 Statistical Yearbook of each city, 2009-2020 Statistical Bulletin of National Economic and Social Development of each city.

the cities in the Yangtze River Delta region. To this end, this indicator is used in this section to further test and analyze the local spatial correlation of knowledge innovation output and high-tech industry agglomeration in the Yangtze River Delta city cluster in China. The local Moran's I is calculated as shown in Equation (4).

$$I_i = \frac{n\left(y_i - \bar{y}\right)\sum_{j=1}^{n} w_{ij}\left(y_i - \bar{y}\right)}{\sum_{j=1}^{n} w_{ij}\left(y_i - \bar{y}\right)^2} \tag{4}$$

By measuring the results of local Moran's I, it is usually possible to classify industrial agglomeration into four spatially relevant types: 1) High-High type (HH), i.e. the first quadrant, represents cities with high industrial agglomeration in the Yangtze River Delta city cluster surrounded by cities with the same high agglomeration. 2) Low-High (LH), the second quadrant, indicates that cities in

the Yangtze River Delta urban agglomeration with low industrial agglomeration are nevertheless surrounded by neighboring cities with high agglomeration. 3) Low-Low (LL), the third quadrant, represents the case where the cities in the Yangtze River Delta urban agglomeration have low agglomeration in themselves and their surroundings. 4) High-Low (HL), the fourth quadrant, indicates that the cities in the Yangtze River Delta urban agglomeration are surrounded by low agglomeration cities despite their high industrial agglomeration. The first and third quadrant clusters imply positive spatial correlation among cities in the Yangtze River Delta urban agglomeration; while the second and fourth quadrants indicate negative spatial correlation among cities.

In this section, the cross-sectional data of 2019 are selected for analysis, and the scatter plot of local Moran's I is drawn using stata15.1. The horizontal coordinate (z) represents the statistics of the city's knowledge innovation output, and the vertical coordinate (Wz) represents the statistics under the weighting of the neighboring cities' knowledge innovation output, as shown in **Figure 5** to give the local Moran's I scatter plot of 27 cities in the Yangtze River Delta region of China in 2019 The local Moran's I scatter plot of knowledge innovation output of 27 cities in the Yangtze River Delta region of China in 2019 is shown in **Figure 5** based on the geographic-economic dual dimension.

The adjacency matrix takes into account both spatial geography and different economic levels in the Yangtze River Delta city cluster, and can better synthesize the spatial correlation among cities. The six cities located in the HH quadrant are still Shanghai, Suzhou, Nanjing, Hangzhou, Wuxi and Ningbo, indicating high spatial agglomeration and high knowledge innovation output, showing positive spatial correlation. The fact that Wenzhou, Hefei and Jinhua are located in the HL quadrant indicates that the region has a negative spatial correlation with neighboring cities in terms of knowledge innovation output levels, indicating that these cities have high knowledge innovation capabilities but the neighboring cities with similar levels of economic development do not have sufficient knowledge innovation capabilities and thus do not progress and develop. Most cities in Anhui, Zhoushan, Huzhou, Taizhou, and Shaoxing in Zhejiang, and Yancheng, Nantong, and Zhenjiang in Jiangsu are located in the LL quadrant, indicating that these regions have low knowledge innovation output and the neighboring economic areas also have low knowledge innovation output levels, while three cities, Taizhou, Changzhou, and Yangzhou, are located in the LH quadrant, indicating that the neighboring cities have high knowledge spillover levels, but their own innovation output is insufficient, as shown in **Figure 5** and **Table 4**.

Given that the local Moran's I scatter plot of high-technology industry agglomeration is similar to the method of knowledge innovation output analysis, this paper therefore only shows the spatial correlation of high-technology industry agglomeration in 2019 using the economic-geographic nested adjacency matrix.

As shown in **Figure 6** and **Table 5**, overall it seems that the 27 cities in the Yangtze River Delta are mainly concentrated in the first and third quadrants,

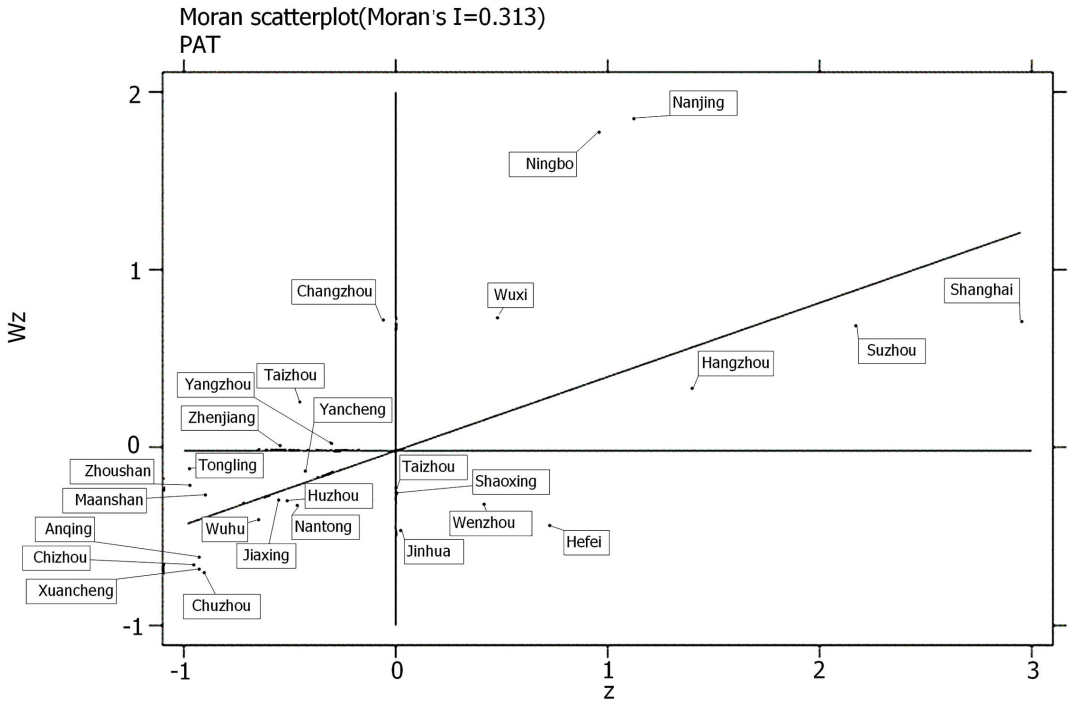


Figure 5. 2019 Yangtze river delta patent grant number local Moran's I scatter plot-economic geography proximity. Source: 2019 Yangtze River Delta Patent Grant Number Local Moran's I Scatter Plot-Economic Geography Proximity plotted by stata15.1.

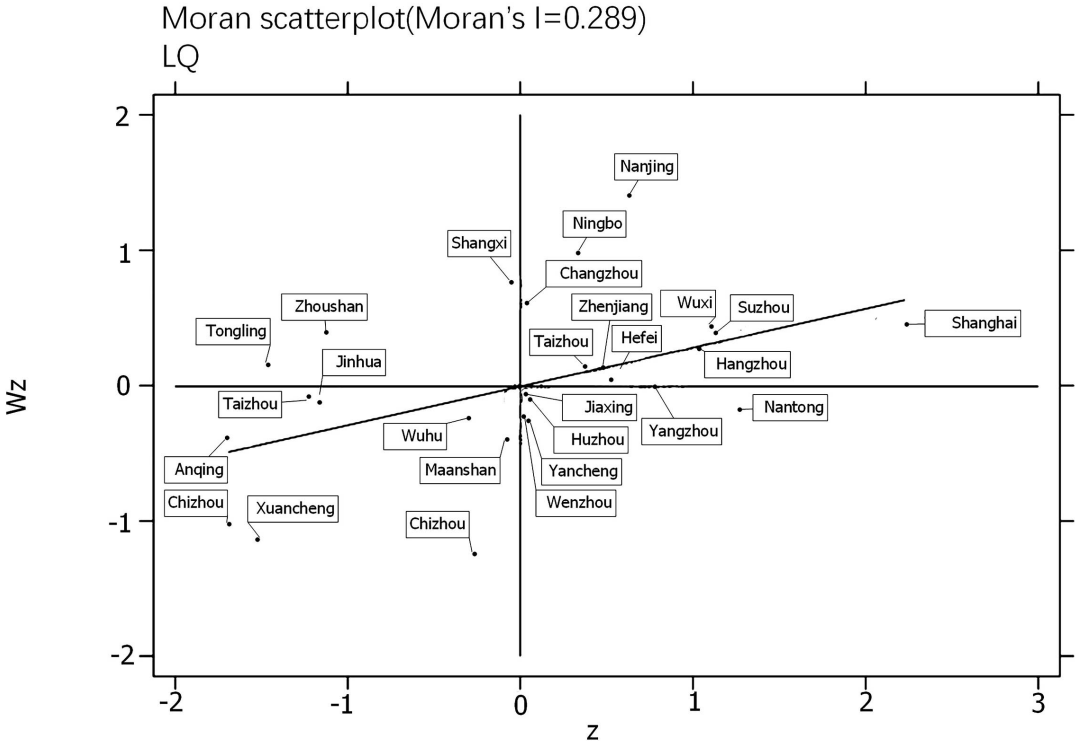


Figure 6. Local Moran's I scatter plot of high technology industry agglomeration in Yangtze River delta 2019—Economic Geography Neighborhood. Source: Local Moran's I Scatter Plot of High Technology Industry Agglomeration in Yangtze River Delta 2019 Economic Geography Neighborhood plotted by stata15.1.

Table 4. 2019 Yangtze river delta patent grant number local Moran's I distribution quadrant table—economic geography neighborhood.

city	Economically geographically close
HH quadrant	Shanghai, Suzhou, Hangzhou, Ningbo, Wuxi, Nanjing
LH quadrant	Changzhou, Taizhou, Yangzhou, Jiaxing
LL quadrant	Tongling, Zhoushan, Yancheng, Ma'anshan, Anqing, Chizhou, Chuzhou, Xuancheng, Wuhu, Huzhou, Nantong, Shaoxing, Taizhou, Zhenjiang
HL quadrant	Wenzhou, Hefei, Jinhua

Source: Statistical yearbooks of municipalities from 2009 to 2020.

Table 5. 2019 Yangtze river delta high-tech industry agglomeration local Moran's I distribution quadrant table—economic geography neighborhood.

city	Economically geographically close
HH quadrant	Shanghai, Suzhou, Hangzhou, Ningbo, Wuxi, Zhenjiang, Nanjing, Taizhou, Changzhou, Jiaxing, Huzhou, Hefei, Yangzhou
LH quadrant	Zhoushan, Shaoxing
LL quadrant	Tongling, Taizhou, Jinhua, Anqing, Wuhu, Ma'anshan, Xuancheng, Chizhou, Chuzhou
HL quadrant	Wenzhou, Yancheng, Nantong

Source: 2009-2020 Statistical Yearbook of each city, China High Technology Yearbook, China Statistical Yearbook, Statistical Bulletin of National Economic and Social Development of each city.

and a small number of cities are distributed in the second and fourth quadrants, which indicates that most of the high-tech industrial agglomeration in the Yangtze River Delta in China has obvious positive spatial correlation characteristics in 2019, and the majority of cities have similar industrial agglomeration levels with their neighboring provinces and cities, and a few cities show negative spatial autocorrelation.

The four quadrants in the figure correspond to the four spatially relevant types of high-tech industrial agglomeration, and the related explanations are similar to those of knowledge innovation output here. It can be seen that the regions located in the HH quadrant include about 13 cities such as Shanghai, Wuxi, Suzhou, Hangzhou, Ningbo, Nanjing and Hefei; the regions located in the LH quadrant, among which Zhoushan and Shaoxing belong to this type; most cities in Anhui are located in the LL quadrant, and all these regions are low in terms of the agglomeration of high-tech industries; while cities such as Wenzhou, Yancheng and Nantong belong to the high-low type and are located in the HL quadrant.

5. Conclusion and Future Research

This paper examines the spatial effects of knowledge spillover and high-tech in-

dustrial agglomeration in 27 cities of the Yangtze River Delta from 2008 to 2019, and draws the following conclusions and countermeasures.

1) The global Moran of the Yangtze River Delta region shows that both knowledge innovation output and high-tech industry agglomeration are significant at least at the 5% level of significance under different geographic proximity, economic proximity, and economic geographic proximity, which indicates that the Yangtze River Delta urban agglomeration has spatial correlation and positive spatial correlation, indicating that the Yangtze River Delta region is clustered together with high value. Knowledge innovation output tends to decline after 2013, and high-tech industrial agglomeration also tends to decline after 2014, probably because high-tech industrial agglomeration leads to a certain "crowding-out effect", resulting in a weakened agglomeration effect, which leads to a weakened knowledge innovation output.

2) The test of the 2019 local Moran index shows that Shanghai, Suzhou, Hangzhou and Wuxi are basically located in the high-high (HH) quadrant, indicating that they have a high level of agglomeration in themselves and their neighboring cities. The knowledge innovation output of most cities in Anhui Province in the Yangtze River Delta region is weaker than that of other cities, except for Hefei, which is basically located in the low-low (LL) quadrant, while most other cities have certain spatial correlation. Most of the other cities have some spatial correlation.

3) Collaborative innovation among high-tech clusters in the Yangtze River Delta is to promote entrepreneurial activities through the joint efforts of internal and external high-tech enterprises such as government, investment intermediaries, universities and research institutes, and the public, with the premise of resource sharing, benefit sharing, and division of labor. High-tech enterprises, as the core subjects in the innovation ecosystem, build innovation consortia with other innovation subjects to enhance the effectiveness of the Yangtze River Delta Science and Technology Innovation Community.

4) With the rapid development and progress of high-tech industries, the construction of the industrial innovation ecosystem is bound to keep pace with the times, and scholars nowadays have done relevant research in this area, and the model of combining the innovation ecosystem with the ecosystem is widely used. Thus, according to the conclusion of this paper, the next research can be conducted in the future innovation development path combining the path of industrial development and ecological development.

Limitations of the Study

Due to the influence of the new crown epidemic, the relevant data in the past 2 years fluctuate greatly and cannot effectively respond to the development status of high-tech industrial clusters in the Yangtze River Delta city cluster. Therefore, this paper is based on the data from 08 - 19 years, and the analysis of regional industrial clustering in the gradual formation of Yangtze River Delta Science and Technology Innovation Community (2019).

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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