Spatial Pattern Evolution and Industrial Characteristics of Economic and Technological Development Zones and High-Tech Industrial Zones in China

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Keywords: economic and technological development zone, high-tech industrial zone, spatial pattern.

Abstract: Economic and technological development zones (ETDZ) and high-tech industrial zones (HTIZ) are important types of development zones(DZ) in China, but there are differences and similarities in connotation and function between the two. This article collects basic data about ETDZ and HTIZ at the national level and the provincial level, and it analyzes the spatial pattern of their evolution from 2006 to 2018 using GIS spatial analysis techniques. First, the intensity of agglomeration is compared by measuring the degree of regional agglomeration and dispersion in 2006 and 2018. Second, the kernel density method is used to explore the evolution of the spatial layout and location of ETDZ and HTIZ and analyze their commonalities and differences. Finally, the trend and reasons for the spatial evolution of DZs are explored for three different industry groups. The research results show that: (1) the intensity of agglomeration of HTIZ layouts is stronger than that of ETDZ; (2) the distribution of labor-intensive, capital-intensive and technology-intensive DZs is concentrated at smaller scales and dispersed at larger ones; and (3) despite the differences between ETDZ and HTIZ in the establishment of goals, support, structural functions, and management systems, the spatial development of the zone shows a trend of convergence. In the future, while strengthening urban and rural planning and public management, the government should optimize the spatial layout of DZs by adjusting industrial structure, layout, transportation and land use in combination with the trend of industrial transformation and upgrading.

1. Introduction

The year 2019 marks the 41st anniversary of China's reform and opening up. During this period, China's GDP rose from ¥367.9 billion in 1978 to ¥90.03 trillion in 2018, a remarkable rate of growth. Such a huge development achievement reflects the success of the regional economic development strategy and policy implementation since the reform and opening up. Among the most successful development strategies is the planning and construction of the development zone which is seen as a uniquely "Chinese experience", brought to the attention of the international community especially other developing countries (Zhang J.K., 2010).

With the development of the commodity economy, international trade, science and technology as well as the international division of labor, DZs have gradually formed and expanded. Since the middle of the 20th century, there have been two new DZs in the world characterized

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by export processing zones and scientific industrial zones. In the past 20 years, driven by the reform and opening up policy and the wave of new technologies, China has successively created different types and levels of DZs, such as special economic zones, economic and technological development zones, high-tech industrial development zones, border economic cooperation zones, and bonded zones. Studying the evolution process of spatial layout and industrial characteristics, and adjusting the spatial organization and layout of DZs are conducive to realizing complementary advantages, resource conservation and high economic development efficiency of DZs, which is of great practical significance for promoting economic growth and an inevitable choice of development strategy for China. (Gao C., 2015).

Similar concepts in foreign countries include "enterprise zones" and "high-tech parks". Foreign scholars have long paid attention to the great impact of scientific industrial parks on urban development. Davelear (1991) realized that scientific industrial parks are not only the core of urban high-tech industries, but also stimulate local cities through re-industrialization, technology and industrial transfer and creation of synergies. Taubmann (1993) believes that the urbanization process induced by the construction of DZs in China will be the cause of another period of great urban development in China. Some scholars regard it as the product of a government system of space production. They believe that DZs with various titles can strive for additional construction land indicators, resulting in real estate speculation and the spread of urban inefficiency (Cartier, 2001; Walcott, 2002). In recent years, scholars have also studied cases of various countries and affirmed the role of DZs. They suggest that science parks effectively promote innovation and regional development in developed countries (Ratinho, 2010); In economically backward countries and regions, some export processing zones play a role in easing unemployment and promoting economic growth (Ham, 2011). With the rapid construction and development of all kinds of DZs in China, the research on them is also deepening gradually. The research on the early stage of the DZ mainly focused on the necessity of construction and location selection (Chen H.X., 1989), foreign experience (Zhao, 1989), etc., to cope with the lack of theoretical support at the beginning of the establishment of DZs in China. Later, the research focus shifted to new phenomena and problems (He, 1999; Long, 2000), DZ strategies (Liu, 2003), DZ and urban spatial structure evolution (Zhang X.P., 2003), etc. In recent years, research on DZs has presented a trend of multi-perspective diversification. Scholars pay attention to the harmonious development of DZs and regional economy, population, resources, environment and society (Zhang X.H., 2012) and spatial pattern evolution (Gao C., 2015; Wu, 2018; Cai, 2019), as well as research on the transformation and development of DZs (Zhou, 2017). In terms of research methods, due to the change of research topics and the progress of research technology, qualitative description has shifted to a combination of qualitative and quantitative methods.

In general, rich achievements have been made in the research on DZs, but most of them are economic DZs, lacking comparison and quantitative analysis of different types of DZs. At the same time, the research areas are more concentrated in the developed coastal areas, and the research on the spatial pattern and industrial evolution at the macro scale is insufficient, which makes it difficult to solve problems such as the optimization and integration of the spatial structure of DZs. In view of this, this paper takes national and provincial ETDZ and HTIZ as research objects and adopts GIS spatial analysis and other methods to analyze the spatial and temporal distribution and industrial characteristics of China's DZs from 2006 to 2018, to provide a benchmark for the future development of DZs.

2. Methodology

2.1. *Research objects and data sources*

Since the 1990s, there have been three peaks of "development zones fever (kai fa qu re)" in China. The first clean-up was after the DZ boom of 1992-1993, when the scale of construction was far beyond the actual needs and economic capacity. The second occurred in 1997, when most of the DZs were set-up by local governments in violation of regulations. In 2003-2006, the state council rationalized the DZ regulations and cut the number of national DZs from 6,866 to 1,568 and the planning area of 386,000 square kilometers was reduced to 9,949 square kilometers. By publishing *List of China development zone audit notice (2006 edition)*, the national DZ land use scale was brought within a reasonable limit (Zhang Pu, 2007). In 2017, the general office of the state council issued *several opinions on promoting the reform and innovative development of development zones*, which was China's first overall guidance document on various types of DZs. In 2018, the Ministry of Natural Resources issued *List of China development zone audit notice (2018 edition)*. This article selects 2006 and 2018 as the two points in time to represent the temporal development of ETDZs and HTIZs. Each DZ is represented as a point on the map, with the help of BMap software to query the geographical coordinate data for all types of DZs, using Arc-GIS10.2 software to establish "China DZ geospatial database".

2.2. *Research methods*

Three models were used for the spatial analysis of the DZs represented in the China DZ geospatial database: nearest neighbour analysis, kernel density and the standard deviational ellipse.

2.2.1. *Average nearest neighbor(ANN) analysis*

This method was first proposed by Clark and Evans (Clark P.J., 1954) and later introduced into the spatial analysis of urban settlements. The ANN analysis method compares the average distance between the observed nearest neighboring elements and the average distance between the random distribution patterns to judge the scale of their spatial agglomeration. The corresponding calculation formula is as follows:

$$\mathrm{ANN} = \frac{\bar{D}_0}{\bar{D}_E} \qquad (2.1)$$

Where, Do is the average distance between a spatial point and its nearest neighbor:

$$\bar{D}_0 = \frac{\sum_{i=1}^{n} d_i}{n} \qquad (2.2)$$

DE is the average distance of the random distribution of points:

$$\bar{D}_E = \frac{0.5}{\sqrt{\frac{n}{A}}} \qquad (2.3)$$

where di is the distance between point i and its nearest neighbors, n is the total number of regional points, and A is the area of the region where the points are located. If the average ANN is less than 1, a clustered pattern is indicated. If ANN is greater than 1, it shows a tendency towards dispersion.

2.2.2. *Kernel density estimation method*

The kernel density estimation method is to estimate the density of a point pattern by means of a moving cell, which is one of the most commonly used and effective methods in point pattern analysis (Wu, 2018). This method has been widely used in the study of spatial distribution characteristics of geographical elements, which can directly and succinctly reflect the spatial agglomeration area.

Assuming the density at p is, and the estimated value is the specific form of the kernel density model is shown below:

$$\widehat{\lambda_h}(p) = \sum_{i=1}^{n} \frac{3}{\pi h^4}\left(1 - \frac{(\mathrm{p}-\mathrm{p}_i)^{\ 2}}{h^2}\right)^2 \quad (2.4)$$

2.2.3. *Standard deviational ellipse (SDE)*

This is an analytical tool for measuring spatial differentiation of regional geographical elements. The main parameters of SDE analysis include gravity center, azimuth, long axis and short axis. The center of gravity reflects the relative position of the whole spatial distribution of each point. The azimuth reflects the main trend direction of its spatial distribution. The long axis is the direction with the most spatial distribution, while the short axis is the direction with the least spatial distribution. The ratio of long axis to short axis reflects the spatial distribution pattern of elements. Arc-GIS10.2 is used to calculate the SDE and then to analyze the overall development space of the DZ.

3. Analysis/Results

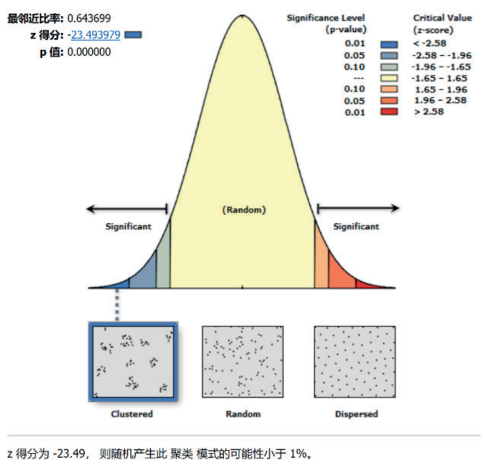
3.1. *General situation of ETDZ and HTIZ*

As the two main forms of DZs in China, ETDZs and HTIZs have both similarities and differences in strategic objectives, development models, management structure, and overall functions. ETDZs are important components of China's opening to the outside world strategy. Their purpose is to attract foreign investment, create an environment with a strong attraction to foreign capital to introduce technology and management, promote scientific and technological progress, expand exports, and provide a window on the world for host cities and regions. In order to reduce the cost of investment, ETDZs focus on the advantages of geographical resources, and are mainly located in urban or suburban areas of coastal port cities with superior access to inland transportation hubs. The main task of HTIZs is to promote the transformation of traditional industries and the development of local economies by relying on China's scientific and technological strength and industrial foundation, and to accelerate the commercialization, industrialization and internationalization of China's high-tech achievements. Therefore, their layouts rely mainly on access to intellectual resources, and the location selection is based mainly on the concentration of universities, scientific research institutions and large enterprises with strong scientific research strength

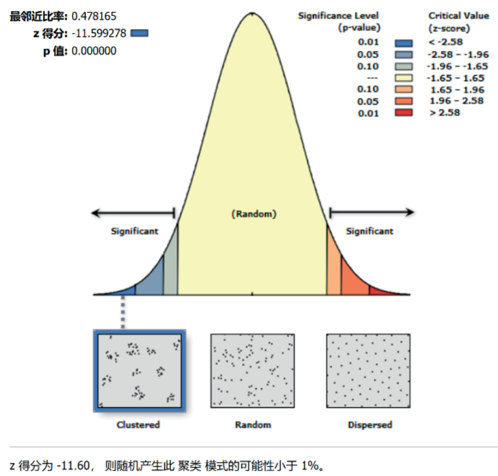
(Chen, Y. S, 2002). In 2006, after reorganizing the DZs, the state published *List of China development zone audit notice*, cataloging 1,395 economic and technological DZs and 118 high-tech industrial DZs. In 2018, Ministry of Natural Resources reissued the list, which included 2,210 economic and technological DZs and 339 high-tech industrial DZs.

3.2. *Spatial Analysis: Clustering and Dispersion*

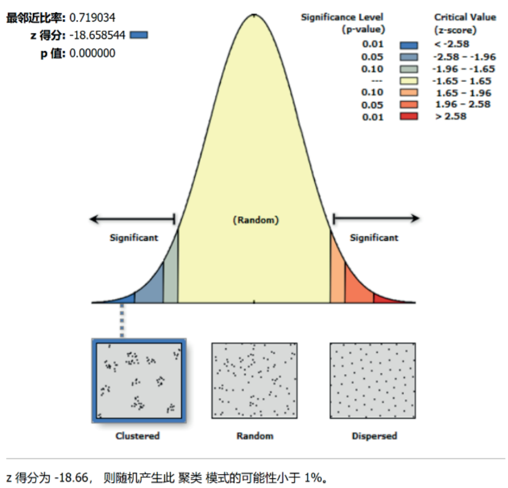
In this paper, Euclidean distance is the measurement method used in the ANN analysis which is adopted to quantify the spatial distribution of ETDZ and HTIZ in 2006 and 2018 respectively, and the calculation results are shown in Figure3.1. Figure 3.1 (a) shows the results of the ANN calculation in ETDZ in 2006. The ANN ratio is 0.64, indicating that the spatial layout of the economic zone in 2006 presents a clustered state. Figure 3.1 (b) shows the calculation results of the ANN of HTIZ in 2006. The ANN ratio is 0.48, indicating that the spatial layout of the high-tech zone in 2006 also presents a clustered state, and the degree of clustering is higher than that of the economic zone. In 2018, the ANN ratio of the economic DZ is 0.72, and the ANN ratio of the high-tech DZ is 0.64, which is higher than the ANN ratio of 2006, respectively. This indicates that the spatial layout of DZs the two regions is clustered, and the difference in intensity of agglomeration is gradually decreasing. However, the HTIZ is still more clustered than the ETDZ.



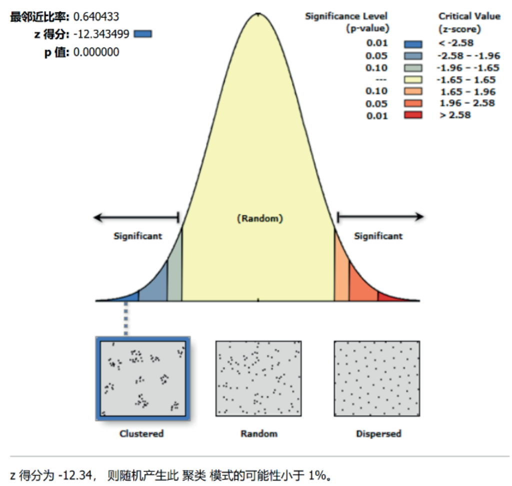
(a) *ETDZ in 2006*



(b) *HTIZ in 2006*



(c) *ETDZ in 2006*



(d) *HTIZ in 2018*

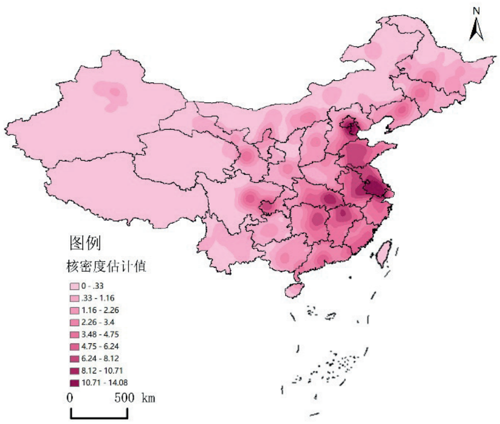
Figure 1. *ANN analysis of ETDZ and HTIZ, 2006 and 2018.*

3.3. *Agglomeration of ETDZ and HTIZ*

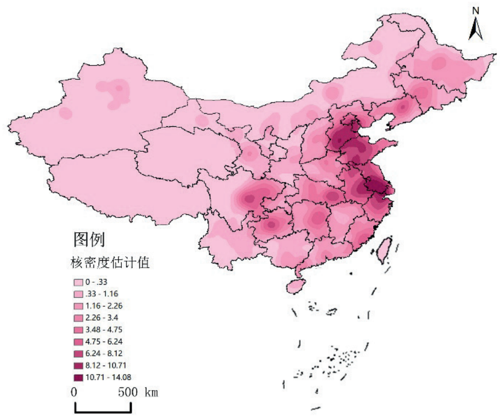
The spatial distribution and agglomeration of ETDZ and HTIZ in 2006 and 2018 were analyzed. The research adopted the kernel density analysis method to obtain four spatial agglomeration distribution maps, as shown in Figure 3.2. On the whole, the distribution of DZs in China has obvious regional distribution characteristics that differentiate between the dense eastern region and the sparse western region. Its distribution is highly consistent with the distribution of urban agglomerations. However, some regions show a significant spatial transfer trend.

In 2006, ETDZ in the eastern region formed a continuous cluster of DZs based on the Beijing-Tianjin-Hebei and Yangtze river delta city clusters, the central region formed a cluster of DZs based on the central Yangtze river central plains city clusters, and the western region formed a cluster of DZs based on the Chengdu-Chongqing city clusters. In 2018, the continuous agglomeration trend of the Beijing-Tianjin-Hebei, Shandong peninsula and Yangtze river delta regions gradually expanded, and the Chengdu-Chongqing-Guizhou city cluster also gained new agglomeration points, while the agglomeration trend of the central Yangtze river city cluster weakened.

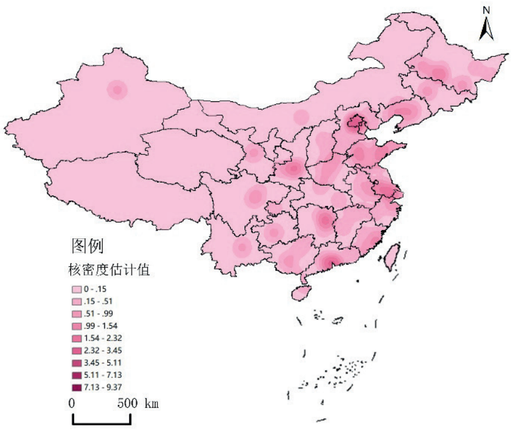
In 2006, the distribution of HTIZ was mainly concentrated in the Beijing-Tianjin-Hebei region, the Yangtze river delta, Henan province, the central plains of the Yangtze river and the pearl river delta city clusters; in 2018, the agglomeration trend has been greatly strengthened,



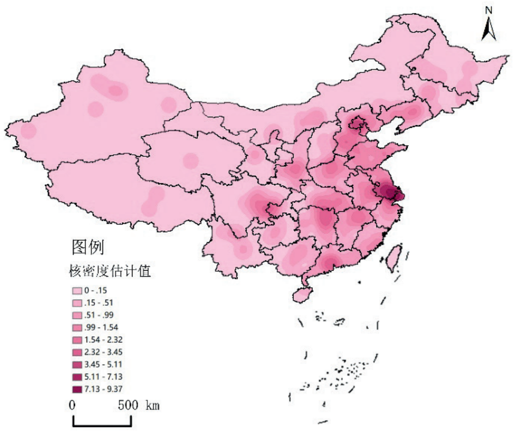
(a) ETDZ in 2006



(b) ETDZ in 2018



(c) HTIZ in 2006



(d) HTIZ in 2018

Figure 2. *K density analysis of ETDZ and HTIZ, 2006 and 2018.*

with the formation of agglomeration peaks in the city clusters of the Yangtze river delta, and significant agglomeration trends in the central plains and east of Liaoning province peninsula.

3.4. *Industrial agglomeration status of ETDZ and HTIZ*

According to the leading industries assessed by *List of China development zone audit notice*, this paper classifies the industries into technology-intensive, capital-intensive and labor-intensive industries according to the importance of the use of input factors in the process of industrial development. The food industry, shoes and clothing manufacturing, wood furniture, and paper making and printing are classified as labor-intensive industries; petrochemical industry, ceramic building materials, non-metallic products, metal smelting, and plastic manufacturing are classified as capital-intensive industries; and communications, electronics, automobile manufacturing, and biomedicine and equipment manufacturing are classified as technology-intensive industries. The ANN method was adopted to calculate the agglomeration degree of the three types of industries in 2006 and 2018. The results passed the significance test, and the ANN ratio is shown in Table 3.1. It can be seen that the distribution of the three types of industries has grown more dispersed from 2006 to 2018.The technology-intensive industries are more concentrated than either of the other two, and the newly established capital-intensive industries are more dispersed.

To further analyze the spatial characteristics of three types of industrial development, this paper uses ArcGIS10.2 to conduct the SDE analysis, and obtains the spatial pattern of the development level of three types of industries and the relevant parameters of the SDE (Tables 3.2, 3.3 and Figure 3.3). On the whole, the SDE spindle of the three types of industries in 2006 and 2018 generally shows the direction of "northeast – southwest", and the direction of the spindle moves to the northwest. The SDE covers most areas in the southeast, and its distribution range shows an increasing trend over time. Capital-intensive industries have the most obvious development trend to the west and north, followed by labor-intensive industries, which show a gradual diffusion trend to the western inland areas. From the shape of the SDE, the ratio of the short axis to the long axis has decreased from 2006 to 2018. It can be seen that the spatial distribution of the DZ is increasingly extending to the northeast and southwest, indicating

Table 1. *The ANN ratio for three industry types, 2006 and 2018.*

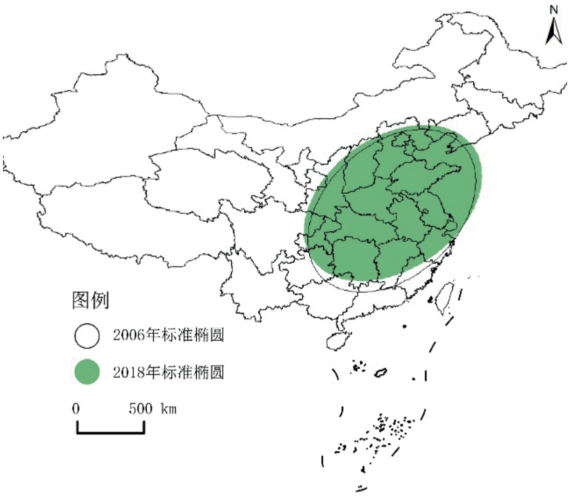
2006年		2018年	
Industry types	ANN ratio	Industry types	ANN ratio
Technology-intensive	0.561684	Technology-intensive	0.612738
Capital-intensive	0.612888	Capital-intensive	0.713115
Labor-intensive	0.633458	Labor-intensive	0.708602

Table 2. *The spatial pattern of three industrial types in 2006 according to the SDE method.*

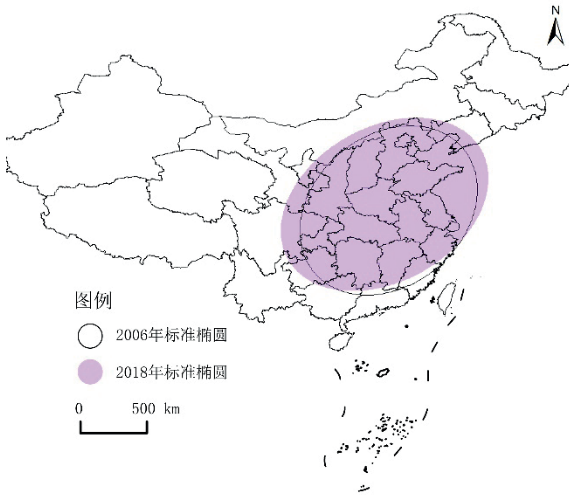
Types of ellipse	Gravity center	Azimuth	Shape exponent
technology-intensive	115.44°E, 32.78°N	47.35	0.683014277
capital-intensive	114.83°E, 32.90°N	50.32	0.775503017
labor-intensive	115.48°E, 32.82°N	48.15	0.669838471

Table 3. *The spatial pattern of three industrial types in 2018 according to the SDE method.*

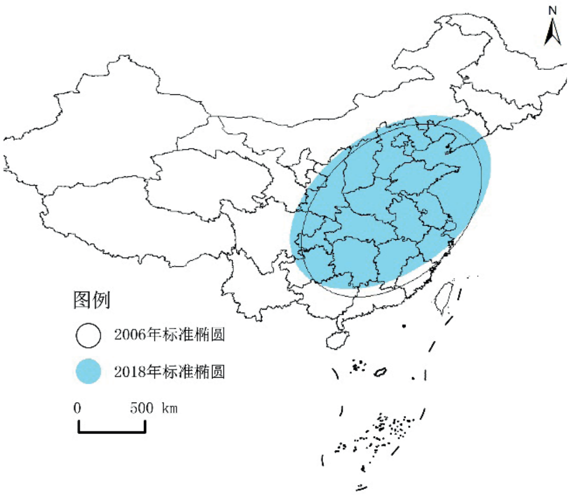
Types of ellipse	Gravity center	Azimuth	Shape exponent
Technology-intensive	115.58°E, 33.57°N	55.03	0.675380754
Capital-intensive	114.43°E, 33.53°N	60.36	0.694571416
Labor-intensive	115.39°E, 33.67°N	54.51	0.618682398



(a) Spatial pattern of technology-intensive industries



(b) Spatial pattern of capital-intensive industries



(c) Spatial pattern of labor-intensive industries

Figure 3. *Standard deviation ellipse of the three industry types.*

that the centripetal force is gradually decreasing and the dispersion degree of the distribution is increasing.

The three types of industries were analyzed for their kernel density, and their spatial distribution patterns were obtained (Figure 3.4). It can be seen that there is a distribution pattern which is concentrated at small scales and dispersed at large ones. In 2006, there were 1,173 technology-intensive industries, accounting for 77.53%, and 1,969 in 2018, accounting for 77.25%. These industries are mainly distributed in the Beijing-Tianjin-Hebei region, Yangtze river delta region, and the central plain city cluster of the Yangtze river. The agglomeration scale of Beijing-Tianjin-Hebei region is expanding, and it forms a contiguous pattern with central Shandong province and the Yangtze river delta region in the south. In 2006, there were 705 capital-intensive industries, accounting for 46.60%, and 1,219 in 2018, accounting for 47.82%. These industries were mainly distributed in the Beijing-Tianjin-Hebei region, the Yangtze river delta, and the central plains of the Yangtze river. In 2006, there were 908 labor-intensive industries, accounting for 60.01%, and 1370 in 2018, accounting for 53.75%. The distribution of labor-intensive industries is more concentrated: the central area of the Yangtze river shows a weakening trend while the agglomeration trend of Chengdu-Chongqing area is strengthening.

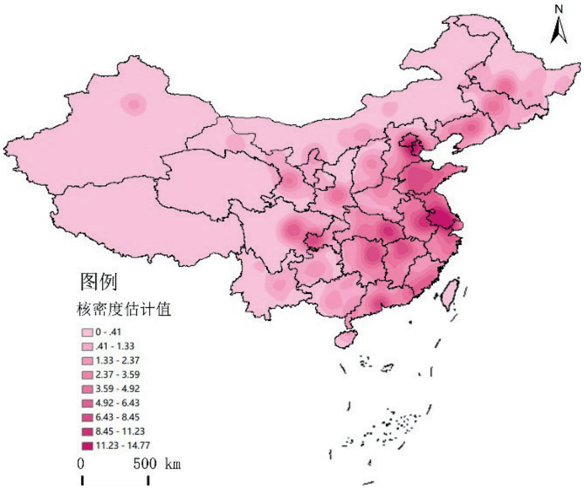
4. Conclusion

This study uses three modern geoscience analysis methods: nearest neighbor index, kernel density estimation, and the SDE to understand the overall spatial distribution of three industrial types in China's economic and high-tech zones in 2006 and 2018. Three conclusions may be drawn from the analysis.

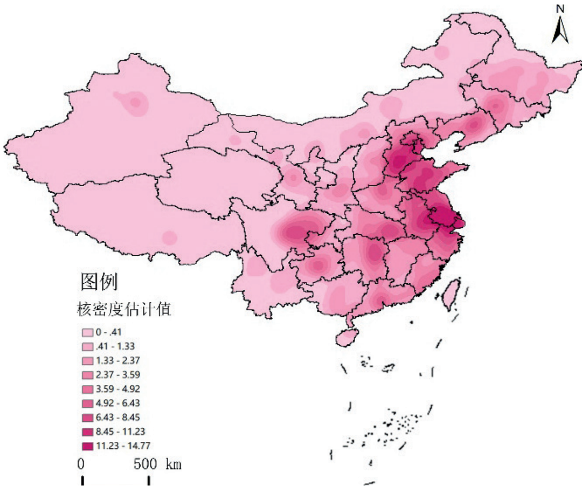
4.1 Both the ETDZs and HTIZs show an agglomerated spatial distribution. The HTIZs are more agglomerated than the ETDZs, but the difference in intensity of agglomeration is gradually shrinking. In terms of the overall distribution density characteristics, the two kinds of DZs are densely distributed in the east and sparsely distributed in the west. At a large scale, the ETDZ in the Beijing-Tianjin-Hebei region, Shandong province and the Yangtze river delta region show a trend towards concentrated contiguous development. With the continuous strengthening of infrastructure, these regions have made great achievements in attracting foreign investment. The trend of the HTIZs is more obvious in the Chengdu-Chongqing city clusters, the central plains of the Yangtze river, the Yangtze river delta and the pearl river delta. The open external environment encourages the clustering of a large number of high-tech talented workers, laying the foundation for the development of more HTIZs.

4.2 The distribution of labor-intensive, capital-intensive and technology-intensive DZs presents a distribution pattern which is concentrated at smaller scales and dispersed at larger ones. The distribution of technology-intensive industries is more concentrated than the capital and labor intensive industries, mainly in the Beijing-Tianjin-Hebei region, the Yangtze river delta and the central plains urban agglomeration of the Yangtze river. Capital-intensive industries are more dispersed and mainly distributed in the Beijing-Tianjin-Hebei region, the Yangtze river delta and the central plains of the Yangtze river. Labor-intensive industries in the central plains of the Yangtze river showed a weakening trend, and the agglomeration trend in Chengdu-Chongqing area was strengthened.

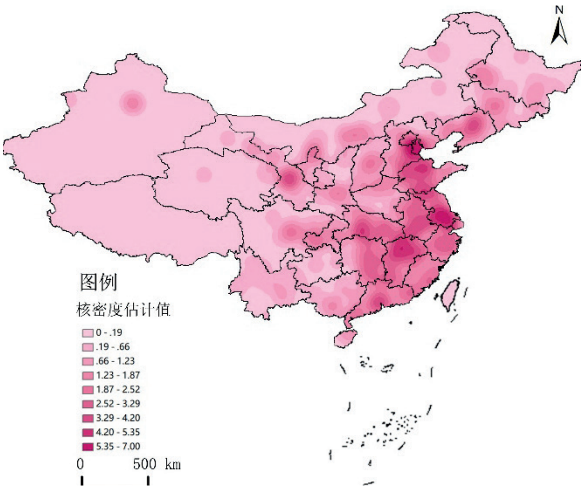
4.3 Although there are differences between the ETDZ and HTIZ in the establishment of goals, support, structural functions, management system and other aspects, their spatial development shows a trend of convergence. Due to the strategic adjustment of their macro-eco-



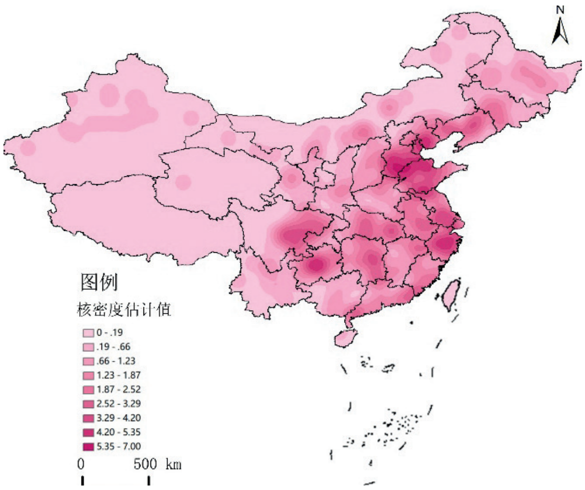
(a)Density analysis of technology-intensive industries in 2006



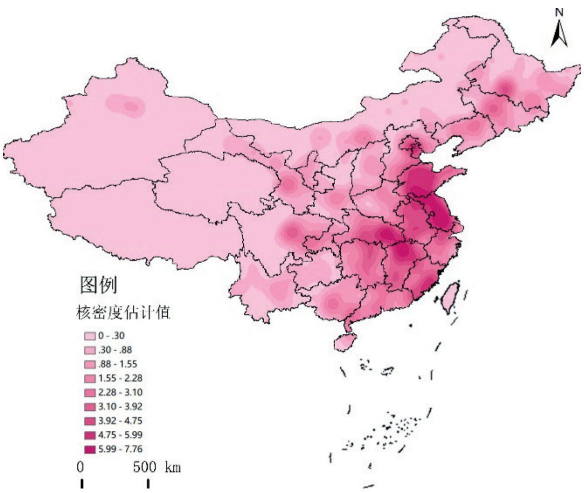
(b) Density analysis of technology-intensive industries in 2018



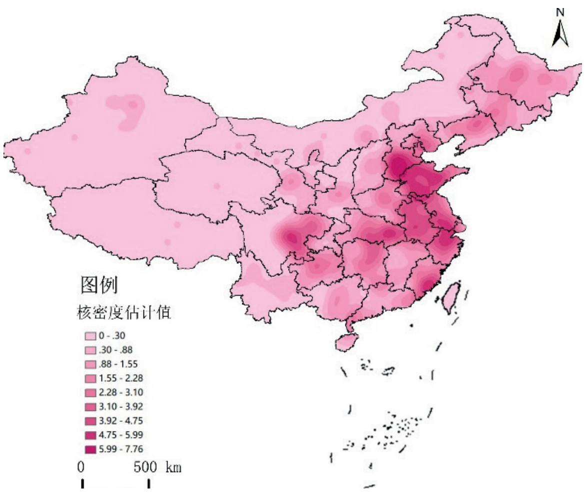
(a) density analysis of capital -intensive industries in 2006



(b) density analysis of capital -intensive industries in 2018



(a) density analysis of labor-intensive industries in 2006



(b)density analysis of labor-intensive industries in 2018

Figure 4. *Kernel density analysis of three industrial types in 2006 and 2018.*

nomic structure, the ETDZs are actively committed to the development of high-tech industry while vigorously developing modern industry. Due to the poor foundation of some high-tech industrial DZs, their development does not reflect the distinctive characteristics of high-tech industries, especially since the Ministry of Foreign Trade and Economic Cooperation and the Ministry of Science and Technology began to implement the strategy and action plan of promoting trade through science and technology. Therefore, the high-tech industrial DZs are also actively choosing an export orientation (Chen, Y. S., 2002).

From the development of ETDZs and HTIZs in China over the years, we can see the same growth trajectory of the two types of DZs: starting from policy support, through various infrastructure construction, moving towards comprehensive innovation and sustainable development. As a test of reform and opening up policy and as new spatially grounded instruments for economic development, the two types of DZs are facing new opportunities and more severe challenges in the new millenium. The two types of DZs need to continue to advance from mainly relying on policy support and infrastructure construction to focus on management and industrial innovation while constantly enhancing their capacity for sustainable development and continuous organic innovation. The findings of this paper inspire the need for future research on the mechanisms that drive the knowledge economy and the factors that encourage the clustering or dispersion of ETDZs and the HTIZs in China's space economy.

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