

## Research Article

# Spatial-Temporal Evolution Characteristics and Countermeasures of Urban Innovation Space Distribution: An Empirical Study Based on Data of Nanjing High-Tech Enterprises

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Since the financial crisis in 2008, innovation has gradually become the orientation of global economic development and the strategic choice for China's urban development. With the transformation of the urban development mode from factor-driven and capital-driven to innovation-driven, many innovation spaces have begun to emerge in cities, which attract academic attention. A large number of studies on the relation between innovation activities and geographic space mainly focus on the phenomena at the regional level, and the city is only regarded as a target of innovation activities agglomeration. The study on the distribution of innovation space within the city is insufficient. In particular, there is a lack of studies on the spatial-temporal evolution of urban innovation space distribution. However, the study on the spatial-temporal evolution characteristics of urban innovation space distribution can provide planning countermeasures for the construction of innovative cities in China. Taking Nanjing as an empirical area, the spatial-temporal evolution of urban innovation space distribution was studied through methods such as average nearest neighbor, standard deviational ellipse, kernel density estimation, and exploratory spatial data analysis based on the data of high-tech enterprises identified from 2008 to 2019. The results showed the following: (1) the distribution of urban innovation space has significant spatial agglomeration characteristics, and the degree of agglomeration continued to rise; (2) regardless of the macro- or microperspective, the distribution of urban innovation space has shown the characteristic of diffusion at the initial, but the trend of polarization in recent years is significant; and (3) the distribution of urban innovation space exhibited diverse agglomeration modes and evolution trends in different regions, and it can be divided into three categories: grouped, banded, and scattered.

## 1. Introduction

Currently, the world's economic structure is rapidly transforming from an industrial economy to a knowledge economy. Innovation has not only become a key factor for the growth of the global knowledge economy but also enhanced importance in local industrial development [1]. In particular, since the financial crisis in 2008, with the profound reorganization that has occurred in the world's political and economic pattern, all economic powers have paid high attention to innovation-driven development. At the same time, after more than 40 years of reform and opening-

up, China's economy has transformed from rapid development to a new stage of high-quality development, and the urban development mode began to transform from factor-driven and capital-driven to innovation-driven. For a city, new urban spaces are inevitably required for the innovation-driven urban development pattern [2]. The most significant spatial change is the growth of innovation spaces in the city. In this context, study on the urban innovation space and its planning practices has become an important topic.

The relation between innovation activities and geographic space has been long discussed in the academic field. Economists and geographers pay attention to the relation

between innovation clusters, innovative enterprises, innovative talents, and regional economic growth [3, 4] and explain why companies, organizations, and institutions in a few regions are more innovative than those in most cities [5]. In traditional theories, it is believed that agglomeration can enable enterprises to obtain external economies, and such a phenomenon can be explained by pools of common factors of production such as land, labor, energy, capital, and transportation [4, 6]. Subsequently, under the influence of Schumpeter [7], the phenomena of innovative activity leading to agglomeration economies were explained from different perspectives, such as agglomeration theory by Hoover [8], growth pole theory by Perroux [9], and product lifecycle theory by Vernon [10]. Since the 1970s, the process of global economic integration has been promoted by the development of science and technology, creating a “flat world” and inducing the debate about the agglomeration and spread of economic activities [11]. A large number of studies have shown that, contrary to the increasing globalization of ordinary production and trade, some knowledge-dependent innovation activities are more likely to agglomerate in specific regions [12]. Therefore, many scholars began to pay attention to the innovation network structure and innovation elements flow among regions and cities, trying to explore the distribution of innovation activities at the macrolevel [13–15].

In recent years, with the rise in open innovation and the lean startup [16, 17], the innovation activities have begun to return to urban areas because urban areas, especially metropolises, possess unique advantages such as convenient information exchange and proximity to the user market [5, 18], and the research on innovation space has been further extended on the urban scale. In this background, the analysis of the distribution and its mechanism of urban innovation activities have become important contents of discussion in urban innovation space and its planning practices. Among them, the spatial-temporal evolution characteristics of urban innovation space distribution are the spatial manifestation of innovation activities on the time scale, and its evolution trend has a profound impact on the sustainable development of the urban economy. Therefore, whether we can accurately grasp the spatial-temporal evolution characteristics of urban innovation space distribution and provide planning countermeasures will directly determine the core competitiveness and prospects of a city. Compared with studies focusing on the relation between innovation activities and geospatial at the regional level, the study on the distribution of innovation space within the city is insufficient. In particular, it is difficult to obtain diachronic data, so there is a lack of studies on the spatial-temporal evolution characteristics of urban innovation space distribution. At present, scholars mostly use innovation output data, such as paper publication, patent application, or authorization to characterize innovation activities and explore the distribution characteristics of innovation space in specific regions [19–21] or cities [22, 23]. A few Chinese scholars took industrial parks or emerging innovation carriers (such as maker space) as the objects of study and explored their spatial distribution characteristics and influencing factors in

cities [24, 25]. It can be seen that these studies paid far less attention to the innovation activities dominated by innovative enterprises, and it is difficult to directly describe the distribution characteristics of urban innovation space.

There is no unified definition for the concept of “urban innovation space” in existing studies. It is often referred to as knowledge areas, new economic spaces, technological innovation spaces, and innovation clusters or regions in previous literature [1, 26, 27]. Despite different names, the key role of innovation activities is invariably emphasized in related definitions, leading to a significant agglomeration of knowledge talents and innovative enterprises within a certain geographical space [28]. Therefore, analyzing the spatial distribution characteristics of innovative enterprises in a typical city within a certain period can help us understand the spatial-temporal evolution characteristics of urban innovation space distribution. High-tech enterprises have research and innovation capabilities identified by the government. As representatives of innovative enterprises, characterizing the distribution of urban innovation space through the distribution of high-tech enterprises can become an important technological path for study. To reveal the spatial-temporal evolution characteristics of urban innovation distribution, this study taking Nanjing as an empirical area through methods such as average nearest neighbor, standard deviational ellipse, kernel density estimation, and exploratory spatial data analysis analyzes the distribution of high-tech enterprises from 2008 to 2019. The study results are helpful to enrich the urban innovation space analysis and planning theory in the context of innovation-driven development and can provide empirical evidence for the construction of innovative cities in China.

## 2. Study Area, Data, and Methods

**2.1. Study Area.** Nanjing, located at the north Yangtze River Delta, is one of the central cities of East China. As the capital of Jiangsu Province, Nanjing has a strong industrial foundation and abundant education resources. In recent years, it has gradually grown into an important innovative city in China. According to the *2019 Innovative Cities Index* released by the advisory organization named 2thinknow, Nanjing ranked 269<sup>th</sup> among the top 500 global innovative cities, as well as 11<sup>th</sup> among 42 qualifier cities in China. At the same time, innovation has always been the focus of Nanjing’ urban construction. Since the goal of “Construction of Innovative City” was put forward, the high-tech enterprises have developed rapidly in Nanjing, and notable effects have been achieved in the construction of innovation space. Based on this, Nanjing was selected as an empirical area. The specific scope of the study includes 11 municipal districts (Gulou, Xuanwu, Qinhuai, Yuhuatai, Jianye, Qixia, Jiangning, Lishui, Gaochun, Liuhe, and Pukou) and Jiangbei New Area (see Figure 1).

**2.2. Data Sources.** The research data come from the high-tech enterprise information published by the China High-Tech Enterprise Identification Center. According to the

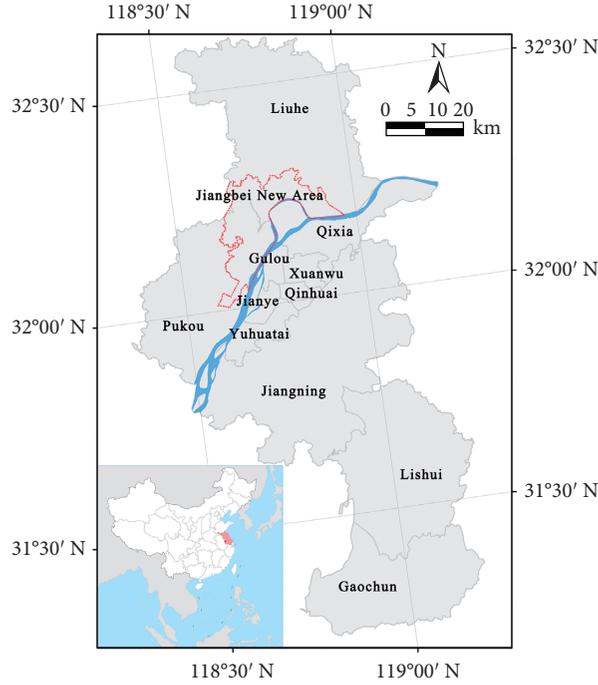


FIGURE 1: Study area range.

identification list of high-tech enterprises, 50 batches of high-tech enterprises have been identified in Jiangsu Province from 2008 to 2019. Among them, 7,692 items of high-tech enterprises in Nanjing were available (see Table 1). Then, the Baidu Map was used to analyze the geographic location of the high-tech enterprise and visualize it on the digital map. Since the validity period of the high-tech enterprise is three years, it needs to be reidentified after expiration, and the high-tech enterprises identified for three consecutive years are selected, to investigate the distribution characteristics of urban innovation space in Nanjing. Therefore, the data of high-tech enterprises identified in Nanjing are divided into four time periods: 2008–2010, 2011–2013, 2014–2016, and 2017–2019.

**2.3. Methods.** To explore the spatial-temporal evolution characteristics of the urban innovation space distribution in Nanjing more comprehensively, the high-tech enterprises identified in Nanjing from 2008 to 2019 were analyzed through methods such as average nearest neighbor, standard deviational ellipse, kernel density estimation, and exploratory spatial data analysis:

- (1) Average nearest neighbor (ANN). By measuring the average distance between each point and its nearest neighbor point and comparing it with the average distance between the points under even distribution, the distribution type of points can be determined [29]. The formula is shown as follows:

$$\text{NNI} = \frac{\overline{D_O}}{\overline{D_E}},$$

$$\text{among them, } \overline{D_O} = \frac{\sum_{i=1}^n d_i}{n}, \quad (1)$$

$$\overline{D_E} = \frac{0.5}{\sqrt{n/A}},$$

where NNI indicates the nearest neighbor index,  $\overline{D_O}$  indicates the average of the nearest neighbor distance of all the high-tech enterprise,  $\overline{D_E}$  indicates the average distance of the high-tech enterprise under even distribution,  $d_i$  refers to the distance between the  $i$ -th high-tech enterprise and its nearest neighbor,  $n$  refers to the number of high-tech enterprises, and  $A$  refers to the area of the survey region.

The value range of NNI is  $-1$  to  $1$ . If  $\text{NNI} < 1$ , the spatial distribution of high-tech enterprises is agglomeration, and the smaller index corresponds to the higher degree of agglomeration. On the contrary, if  $\text{NNI} > 1$ , the spatial distribution of high-tech enterprises is discrete, and the larger index corresponds to the higher degree of dispersion. Besides, if  $\text{NNI} = 1$ , high-tech enterprises are evenly distributed in the survey region.

TABLE 1: Number of high-tech enterprises identified in Nanjing from 2008 to 2019.

Variables	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
	232	182	95	332	309	232	488	558	659	631	1844	2130

(2) Standard deviational ellipse (SDE). As a spatial statistical technique measuring the directional characteristics of geographical elements distribution [30], the standard deviational ellipse can be used to analyze the location characteristics of urban

innovation space distribution at the macrolevel. It usually includes the center of spatial distribution,  $X$ -axis standard deviation,  $Y$ -axis standard deviation, and azimuth angle. The formula is shown in the following equations:

$$\bar{x} = \frac{\sum_{i=1}^n x_i}{n}; \quad (2)$$

$$\bar{y} = \frac{\sum_{i=1}^n y_i}{n},$$

$$\sigma_x = \sqrt{\frac{\sum_{i=1}^n [(x_i - \bar{x})\cos \theta - (y_i - \bar{y})\sin \theta]^2}{n}}, \quad (3)$$

$$\sigma_y = \sqrt{\frac{\sum_{i=1}^n [(x_i - \bar{x})\sin \theta - (y_i - \bar{y})\cos \theta]^2}{n}}, \quad (4)$$

$$\tan \theta = \frac{\sum_{i=1}^n (x_i - \bar{x})^2 - \sum_{i=1}^n (y_i - \bar{y})^2 + \sqrt{[\sum_{i=1}^n (x_i - \bar{x})^2 - \sum_{i=1}^n (y_i - \bar{y})^2]^2 + 4 \sum_{i=1}^n (x_i - \bar{x})^2 (y_i - \bar{y})^2}}{2 \sum_{i=1}^n (x_i - \bar{x})^2 (y_i - \bar{y})^2}, \quad (5)$$

where  $(x_i, y_i)$  is the coordinate of the  $i$ -th high-tech enterprise,  $\bar{x}$  and  $\bar{y}$  indicate the average of the  $x$ -coordinate and  $y$ -coordinate of all the high-tech enterprise, namely, the coordinate of the spatial distribution center,  $\theta$  refers to the azimuth angle of the standard deviational ellipse, namely, the angle between the due north and the long axis of the standard deviational ellipse when rotating clockwise, and  $\sigma_x$  and  $\sigma_y$  refer to the  $X$ -axis standard deviation and  $Y$ -axis standard deviation.

(3) Kernel density estimation (KDE). Kernel density estimation is a nonparametric method used to estimate the density of points in the surrounding neighborhood [31]. In this study, the location characteristics of urban innovation space distribution at the microlevel were described via kernel density estimation. Assuming that  $x_1, x_2, \dots, x_n$  is the independently distributed high-tech enterprise, the formula is shown as

$$f(x) = \frac{1}{nh} \sum_{i=1}^n K\left(\frac{x - x_i}{h}\right), \quad (6)$$

where  $n$  refers to the number of high-tech enterprises;  $K$  is the spatial weight function, generally the range attenuation function;  $h$  refers to the

bandwidth; and  $x - x_i$  represents the distance from the estimation point  $x$  to the sample  $x_i$ .

(4) Exploratory spatial data analysis (ESDA). This study adopts spatial autocorrelation analysis, including global spatial autocorrelation and local spatial autocorrelation. According to the existing urban road density requirements in China, the mesh scale of 1000 m  $\times$  1000 m was selected to calculate the global spatial autocorrelation and local spatial autocorrelation.

Global spatial autocorrelation: Moran's  $I$  was used to estimate the similarity of the attribute value in neighboring spatial units, to detect the agglomeration degree of high-tech enterprises. The formula is shown as

$$I = \frac{n \sum_{i=1}^n \sum_{j=1}^n w_{ij} (y_i - \bar{y})(y_j - \bar{y})}{\sum_{i=1}^n \sum_{j=1}^n w_{ij} \sum_{i=1}^n (y_i - \bar{y})^2}, \quad (7)$$

where  $n$  is the number of spatial units,  $y_i$  and  $y_j$  represent the number of high-tech enterprises in units  $i$  and  $j$ ,  $\bar{y}$  is the average number of high-tech enterprises in each spatial unit, and  $w_{ij}$  indicates the spatial weight matrix of units  $i$  and  $j$ . In this study, Queen matrix was used to construct the neighbor weight matrix. That is, when units  $i$  and  $j$  have a common boundary or common vertex,  $w_{ij}$  is taken as 1; otherwise, it is taken as 0.

The value range of  $I$  is  $-1$  to  $1$  [32].  $I > 0$  indicates a positive correlation; that is, the spatial distribution of high-tech enterprises is agglomeration, and when the value tends to  $1$ , the agglomeration characteristics are more significant. On the contrary,  $I < 0$  indicates a negative correlation; that is, the spatial distribution of high-tech enterprises is discrete; when the value tends to  $-1$ , the discrete characteristics are more significant. Besides, if  $I = 0$ , it suggests no spatial autocorrelation is observed.

Local spatial autocorrelation: based on the measurement of Moran's  $I$ , the LISA model was further used to inspect the spatial agglomeration mode of high-tech enterprise distribution. The formula is shown as

$$I_i = \frac{n(z_i - \bar{z}) \sum_{j=1}^n w_{ij}(z_j - \bar{z})}{\sum_{j=1}^n (z_j - \bar{z})^2}, \quad (8)$$

where  $n$  is the number of spatial units,  $z_i$  and  $z_j$  represent the number of high-tech enterprises in units  $i$  and  $j$ ,  $\bar{z}$  is the average number of high-tech enterprises in each spatial unit, and  $w_{ij}$  indicates the spatial weight matrix of units  $i$  and  $j$ .

The results in the LISA agglomeration map are classified into five categories [33].  $I_i > 0$  indicates a positive correlation; that is, the high value is surrounded by the high value, or the low value is surrounded by the low value.  $I_i < 0$  indicates a negative correlation; that is, the high value is surrounded by the low value, or the low value is surrounded by the high value. Nonsignificant suggests no spatial autocorrelation is observed.

### 3. Results

**3.1. Agglomeration Degree and Evolution Trend.** In this study, the average nearest neighbor and the global spatial autocorrelation were used to explore the agglomeration degree and evolution trend of urban innovation space distribution in Nanjing. According to the results of the nearest neighbor index (see Table 2), the agglomeration degree of high-tech enterprises identified in Nanjing is gradually enhanced. Especially, in recent years, with increasing policy support for innovative enterprises, the number of high-tech enterprises identified in Nanjing had risen rapidly, and the nearest neighbor index declined from 0.3 to about 0.2, further realizing agglomeration.

Furthermore, it can be seen that, from the Global Moran's  $I$  of high-tech enterprises identified in Nanjing (see Table 3), the Global Moran's  $I$  was all greater than 0 in four time periods, and all significant values were at the level of 1%. It means that the distribution of urban innovation space has a significant spatial agglomeration characteristic. Meanwhile, although the Global Moran's  $I$  declined slightly in recent years, it continued to rise from 0.129 to 0.190, indicating that the agglomeration degree of urban innovation space distribution in Nanjing is gradually enhanced.

**3.2. Location Characteristic and Evolution Trend.** To display the location characteristic and evolution trend of urban innovation space distribution more intuitively, the data of

TABLE 2: Nearest neighbor index of high-tech enterprises identified in Nanjing.

Variables	2008–2010	2011–2013	2014–2016	2017–2019
NNI	0.358***	0.329***	0.304**	0.215***

The NNI is significant at the level of 10%\*, 5%\*\*, and 1%\*\*\*.

TABLE 3: Global Moran's  $I$  of high-tech enterprises identified in Nanjing.

Variables	2008–2010	2011–2013	2014–2016	2017–2019
Global Moran's $I$	0.129***	0.174***	0.198***	0.190***

The Global Moran's  $I$  is significant at the level of 10%\*, 5%\*\*, and 1%\*\*\*, respectively.

Nanjing high-tech enterprises were analyzed using standard deviational ellipse and kernel density estimation. The results of the standard deviational ellipse reflected the distribution center and distribution direction of urban innovation space in Nanjing at the macrolevel, and the results of kernel density estimation reflected the specific areas of urban innovation space distribution in Nanjing at the microlevel.

**3.2.1. Macroscopic Location Characteristic and Evolution Trend.** According to the results of the standard deviational ellipse, the semimajor axis length, semiminor axis length, and area of the ellipse all show a trend of increasing at the initial and began to decrease in recent years (see Table 4), and the position of the spatial distribution center also shows a trend of reverse movement after moving outward, indicating that the distribution of urban innovation space in Nanjing at the macrolevel has shown the characteristic of diffusion at the initial, but the trend of polarization in recent years is significant (see Figure 2). Nevertheless, the main urban area was always within the ellipse, indicating that the main urban area is the most intensive area of urban innovation space. The conclusion is not conflicted with the gradually enhanced agglomeration degree of urban innovation space distribution in Nanjing; that is, the expansion of the distribution range of urban innovation space does not necessarily lead to the decline in its spatial agglomeration degree. If the distribution of urban innovation space in the agglomeration area is more concentrated in this process, it may induce such a phenomenon of weakened agglomeration degree at the macrolevel (shown as an expansion of the standard deviational ellipse) but enhanced agglomeration degree at the specific areas. It means that although the number of urban innovation spaces in Nanjing continues to rise, the urban innovation space tends to be concentrated in specific areas.

Besides, the flattening of the ellipse also shows a trend of increasing at the initial and began to decrease in recent years, indicating that the diffusion trend in the semimajor axis direction is stronger than the semiminor axis direction at the initial, and then, the urban innovation space tends to be evenly distributed in the intensive area. And the azimuth angle of the ellipse generally showed a decreasing trend,

TABLE 4: Results of standard deviational ellipse.

Variables	2008–2010	2011–2013	2014–2016	2017–2019
Semimajor axis (km)	27.977	29.528	32.294	31.586
Semiminor axis (km)	13.720	13.713	14.349	14.334
Flattening	0.510	0.536	0.556	0.546
Area (km <sup>2</sup> )	1205.786	1271.920	1455.560	1422.213
Center coordinates	118.798°N, 32.009°E	118.807°N, 31.998°E	118.809°N, 31.979°E	118.805°N, 31.987°E
Azimuth angle (°)	167.485	166.396	164.033	163.555

Flattening refers to the ratio of the difference value between the semimajor and semiminor axis length to the semimajor axis length of the ellipse, reflecting the flattening degree of the ellipse.

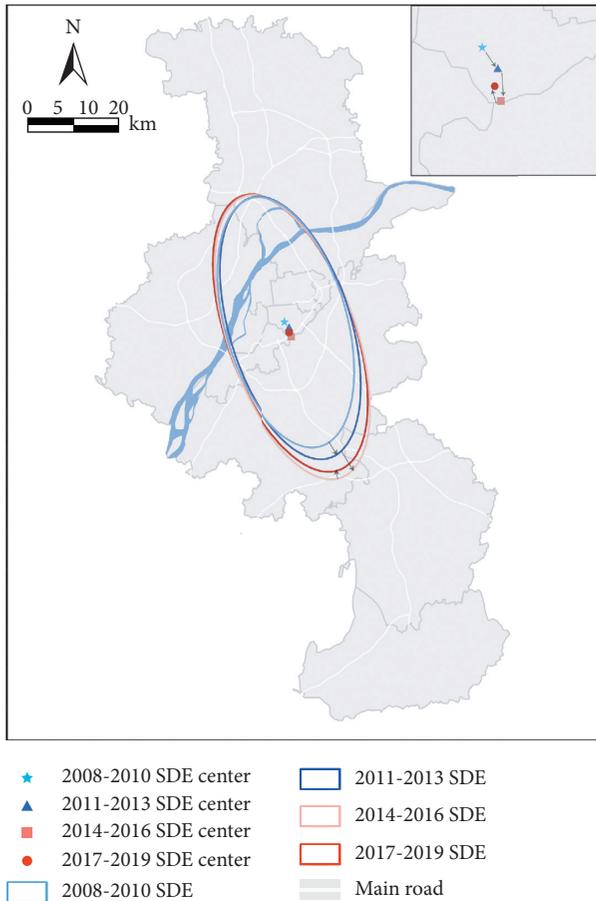


FIGURE 2: Standard deviational ellipse of high-tech enterprises identified in Nanjing.

indicating that the growth rate of urban innovation space in the “northwest-southeast” region is faster than that of the “northeast-southwest” region.

**3.2.2. Microscopic Location Characteristic and Evolution Trend.** To find out the hot spot regions and evolution trend of urban innovation space distribution in Nanjing at the microlevel, the kernel density estimation is used to analyze the distribution of high-tech enterprises in Nanjing, and the search radius is set to 3 km. The results manifested that the distribution of urban innovation space in Nanjing at the microlevel also presents a trend of polarization in recent

years after diffusion. On the whole, it can be divided into the following two phases:

- (1) In the first phase (2008–2013), the spatial units involved in innovation activities constantly increased, which was the diffusion phase of urban innovation space distribution (see Figures 3(a) and 3(b)). With the overflow of urban functions and the development of peripheral areas, the number of hot spot regions of urban innovation space distribution continued to be increased and the scope continued to be expanded. The aggregation intensity of urban innovation space in the main urban area was greatly enhanced, and some warm spot regions evolved into hot spot regions. Meanwhile, the urban innovation space in the peripheral areas began to appear sporadically, which is driving the core-periphery structure of urban innovation space distribution gradually formed.
- (2) In the second phase (2014–2019), the hot spot regions of urban innovation space distribution began to shrink, which was the polarization phase of urban innovation space distribution (see Figures 3(c) and 3(d)). Although the spatial units involved in innovation activities still increased, the distribution of urban innovation space in the main urban area and the peripheral areas all displayed a trend of polarization. In particular, the spatial polarization was significant in the main urban area. Most of the high-density regions of urban innovation space distribution have shrunk significantly, and some have turned from hot spot region to warm spot region. In terms of urban innovation space distribution in the peripheral areas, its hot spot regions and warm spot regions were gradually weakened. It means that the main urban area is more attractive to innovative activities than the peripheral areas. In addition, with the construction of Jiangbei New Area, new clusters of innovative activities have begun to form in the new area. During this period, the distribution of urban innovation space in Nanjing still maintains the core-periphery structure.

**3.3. Agglomeration Mode and Evolution Trend.** It can be seen from the nearest neighbor index and Global Moran’s  $I$  that the distribution of urban innovation space in Nanjing exhibited significant agglomeration characteristics. To further reveal the agglomeration mode and evolution trend of

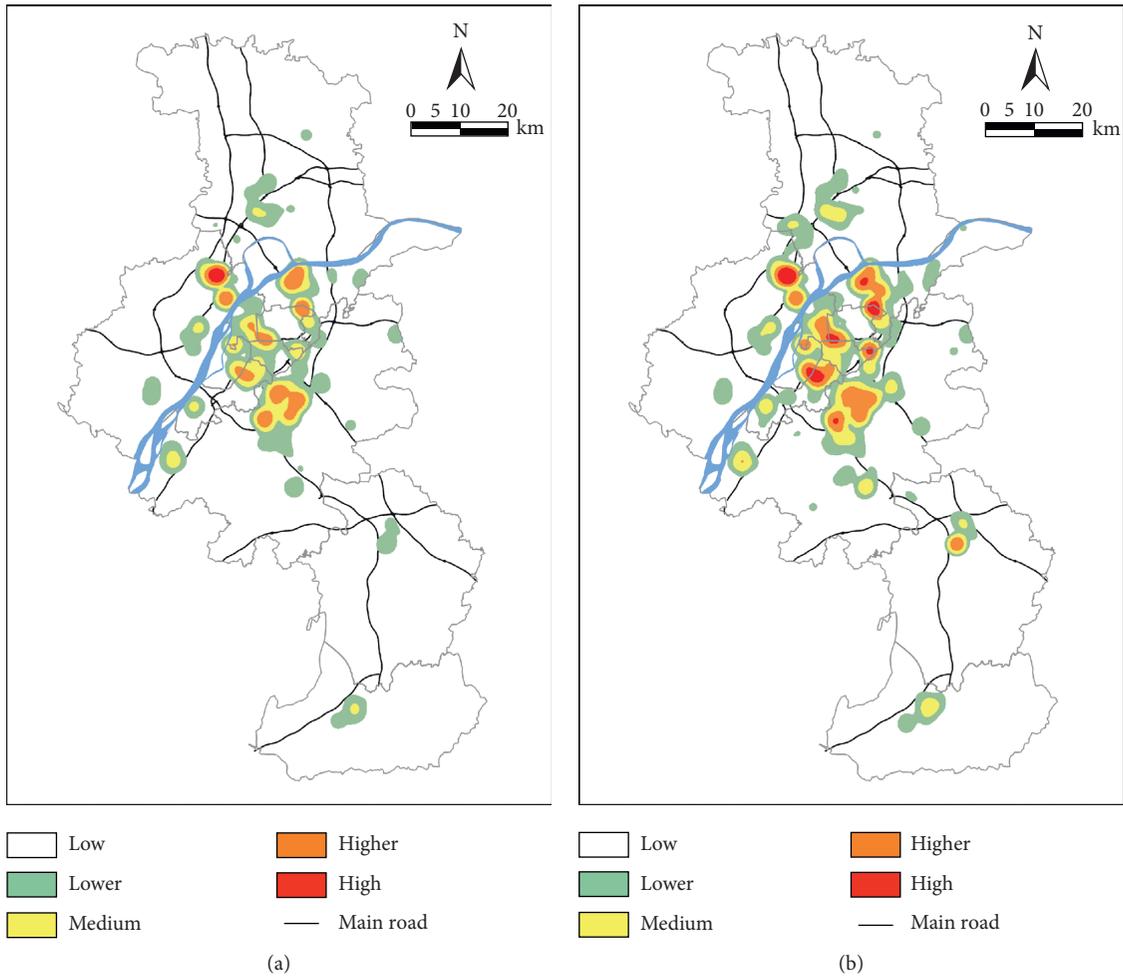


FIGURE 3: Continued.

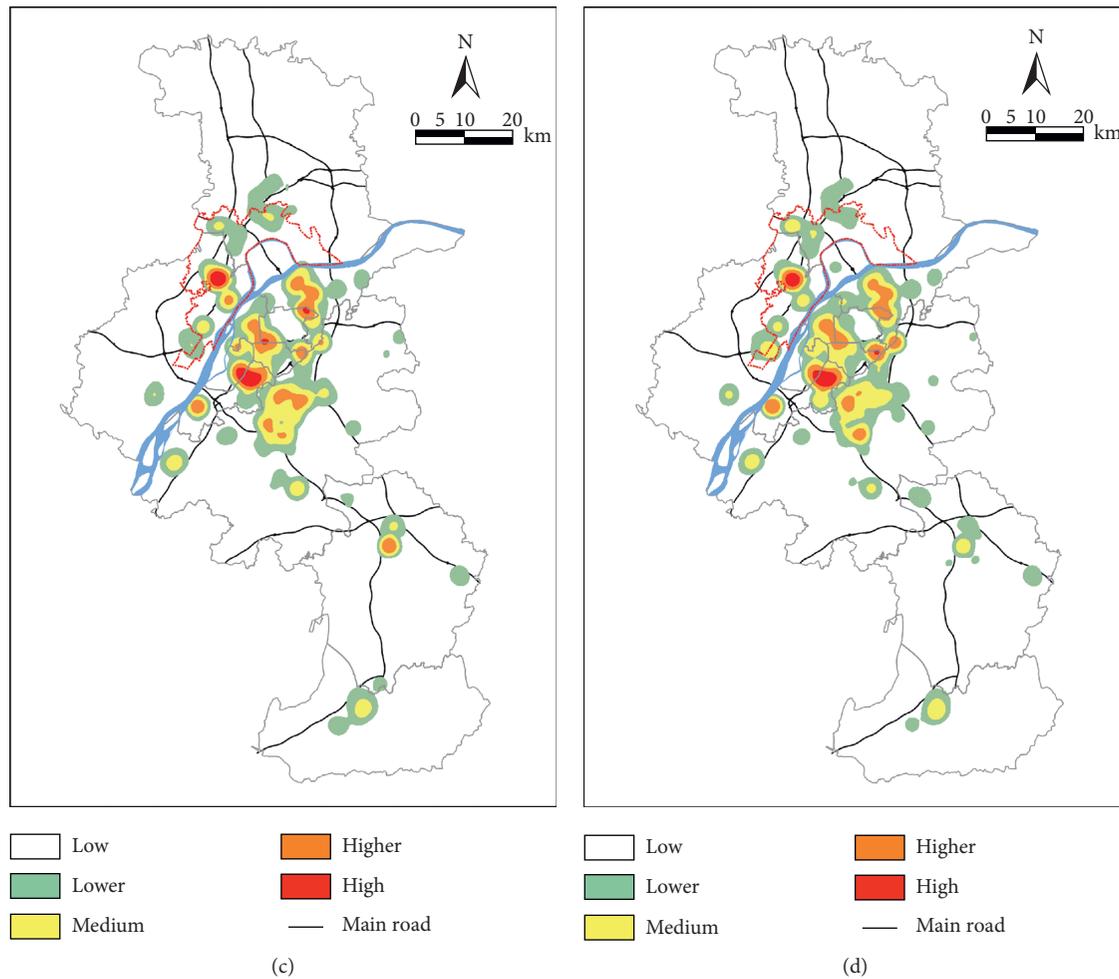


FIGURE 3: Results of kernel density estimation: (a) 2008–2010; (b) 2011–2013; (c) 2014–2016; (d) 2017–2019.

urban innovation space distribution in Nanjing, local spatial autocorrelation analysis was conducted in this study.

As shown in the LISA agglomeration map (see Figure 4), there are five categories of units in Nanjing. Among them, high-high and high-low units have a high agglomeration degree of high-tech enterprises, so they are the key areas of innovation activities. Based on this, it can be seen that the distribution of urban innovation space exhibited diverse agglomeration modes and evolution trends in different regions. Besides, low-high units indicate the spatial units have a low agglomeration degree of high-tech enterprises that are surrounded by spatial units having a high agglomeration degree of high-tech enterprises. Because of the spillover effect of innovation activities, when there are low-high units around the dense regions of high-high and high-low units, these low-high units will become the potential spaces of innovative activities [23]. During the evolution of urban innovation space distribution, the low-high units around the dense regions of high-high and high-low units also exhibited a trend to high-high or high-low units. Specifically, the agglomeration mode of urban innovation space distribution in Nanjing can be divided into three categories: grouped, banded, and scattered:

- (1) The main urban area is a highly concentrated area of urban innovation space, showing a grouped agglomeration mode. The high-high and high-low units generally show a trend moving towards the main urban area, and three dense regions of urban innovation space were gradually formed over time in the main urban area. This conclusion also verifies the phenomenon that the new geography of innovation is transforming from suburbs to urban areas proposed by the Brookings Institution [34]. Besides, according to the results, the distribution of urban innovation space within the main urban area of Nanjing displays a trend of inward filling and outward expansion. Three dense regions of urban innovation space in the main urban area have a trend of contiguous expansion, and the surrounding area mainly shows an eastward and southward growth trend.
- (2) Jiangbei New Area has developed into a new leading area for urban innovation activities in recent years, and the distribution of urban innovation space has shown a banded agglomeration mode. Since the Jiangbei New Area was approved as a national new

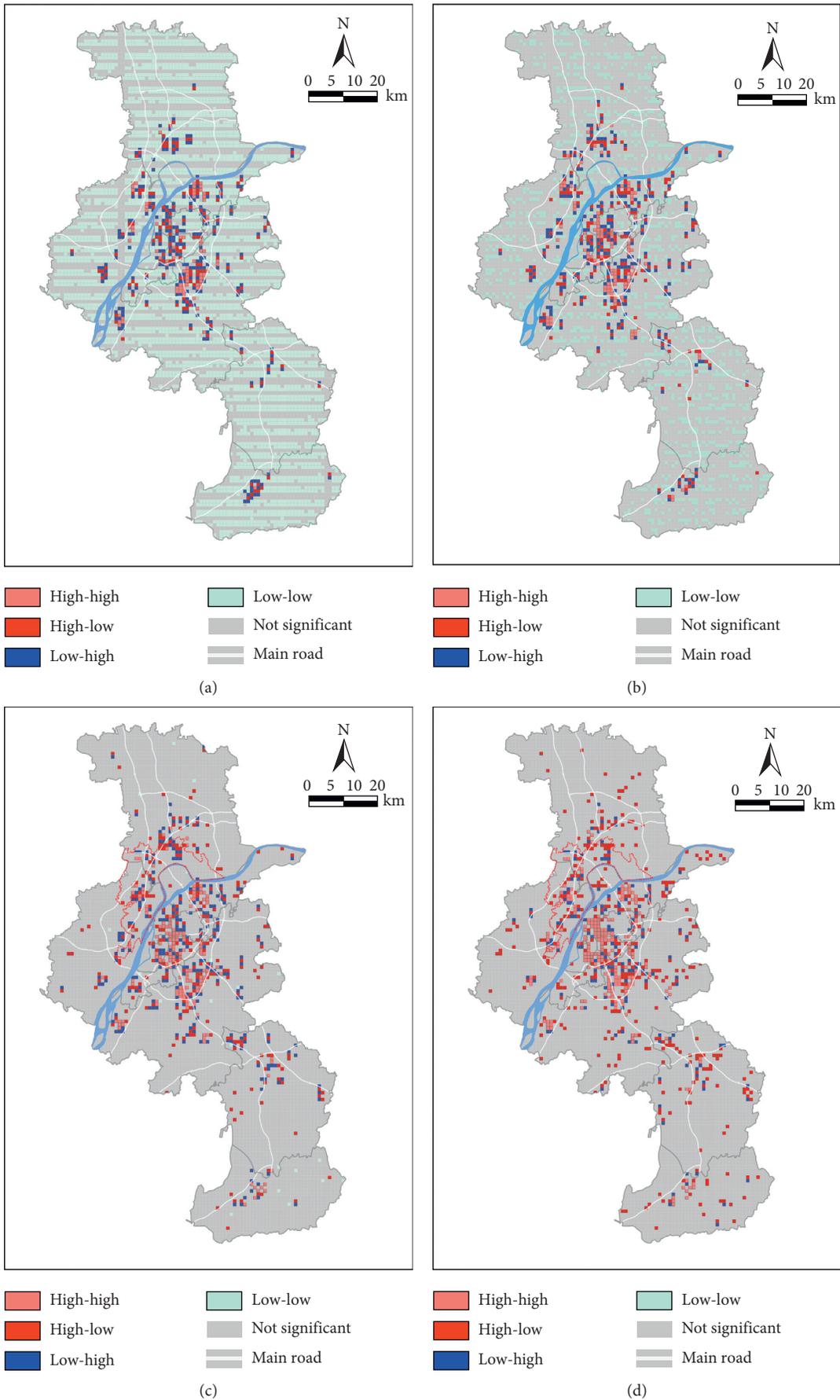


FIGURE 4: LISA agglomeration map of urban innovation space in Nanjing: (a) 2008–2010; (b) 2011–2013; (c) 2014–2016; (d) 2017–2019.

area in 2015, a series of supportive policies for innovation has been implemented. The ever-expanding policy advantages greatly enhance its innovation radiation effect, and the urban innovation space rises rapidly, showing a trend of spreading and linking within the Jiangbei New Area, and the agglomeration belt of innovation space has been initially formed. In addition, high-density block nodes of urban innovation space have gradually formed within some new functional blocks.

- (3) The distribution of urban innovation space in the peripheral areas always remains a scattered agglomeration mode. In 2008–2019, scattered agglomeration was dominated in the distribution of urban innovation space in the peripheral areas, and independent scattered agglomeration characteristics were displayed relying on suburban urban areas with complete urban functions and industrial parks with better industrial foundation. Moreover, some new agglomeration areas of urban innovation space also begin to emerge in villages near scenic areas and those with special cultural or ecological advantages, which reflect the new development trend of “where there is landscape, there is the new economy.” In this context, some key peripheral areas may also become new scattered growth poles of urban innovation space in the future.

#### 4. Conclusion

At present, a large number of researches regard the government as one of the important behavioral subjects in innovation activities [35], and the key role of the government in the development of an innovative economy is recognized [36, 37]. Among them, creating spaces suitable for innovation activities through policy adjustment has always been an important intervention means for the government to support the innovative economy [38]. This study explores the spatial-temporal evolution characteristics of urban innovation space distribution in a data-driven manner through methods such as average nearest neighbor, standard deviational ellipse, kernel density estimation, and exploratory spatial data analysis based on the data of high-tech enterprises identified in 2008–2019. The main conclusions and corresponding countermeasures are as follows:

- (1) The distribution of urban innovation space has significant spatial agglomeration characteristics, and the degree of agglomeration continued to rise. The agglomerate of urban innovation space is the major characteristic of innovation activity, which is supported by the external economies, urban amenity, and other theories [39, 40]. Based on this, it is needed to reasonably guide the distribution of urban innovation space at the city territory while focusing on improving the innovation vitality in the agglomeration areas. On the one hand, innovation supportive policies should be improved for these dense regions of innovation activities, to create growth poles of

innovation. On the other hand, the excessive agglomeration of urban innovation space may also lead to the unbalanced development of urban space. Therefore, it should appropriately strengthen the guidance of urban innovation space distribution through the land, fiscal, and tax preferential policies, thereby facilitating the optimization of urban innovation space distribution.

- (2) Regardless of the macro- or micro-perspective, the distribution of the urban innovation space has shown the characteristic of diffusion at the initial, but the trend of polarization in recent years is significant. Although the distribution of urban innovation space has significant spatial agglomeration characteristics, there are differences in agglomeration trends at different evolution phases. Based on this, differentiated planning countermeasures should be adopted for the urban innovation space with different evolution phases. In the initial innovation activities, the growth of innovation space in “periphery areas” is generally faster than “central areas.” In this stage, it is needed to pay attention to the key peripheral areas with innovative growth vitality and enhance the synergy of the innovation capabilities at the city territory. With the development of the urban economy, innovation activities will be more agglomerated in the main urban area. Therefore, it is necessary to implement inclusive innovation supportive policies in the main urban area and combine innovative urban construction and urban renewal activities, to guide the innovation elements flow to the main urban area.
- (3) The distribution of urban innovation space exhibited diverse agglomeration modes and evolution trends in different regions, and it can be divided into three categories: grouped, banded, and scattered. The occurrence of innovation activities is a complex process of interactions between multiple subjects, and the evolution of the urban innovation space distribution is also the result of various factors [41]. Due to different mechanisms, the distribution of urban innovation space often displays diverse agglomeration modes in different regions. Based on this, it is needed to focus on the potential spaces for innovation activities and through an in-depth analysis of agglomeration mechanism, provide precise policy supply for urban innovation spaces of different agglomeration modes to promote the transformation of potential spaces into urban innovation spaces, and realize the sustainable development of innovative activities.

#### 5. Discussion

Undoubtedly, with the transformation of China’s economy to high-quality development after the financial crisis, the era of innovation-driven urban economic has arrived. A large number of innovation spaces have emerged in some

economically developed cities such as Shanghai, Hangzhou, and Nanjing. Therefore, it is an important research topic to grasp the evolution characteristics of urban innovation space distribution, identify the potential spaces for innovation activities in the city, and take corresponding countermeasures to facilitate the high-quality development of the urban economy. This study has changed the static descriptions that emphasize a single spatial dimension in the study of urban innovation space distribution. From the perspective of spatial-temporal, the research conclusions reflect the evolution characteristics of urban innovation space distribution more accurately.

However, what calls for attention is that although the data of high-tech enterprises can characterize the urban innovation space distribution to a certain extent, it is still not enough to fully explain the evolution characteristics of urban innovation space distribution. On the one hand, some high-tech enterprises tend to register in areas where more preferential policies can be obtained, making the registered addresses of some high-tech enterprises inconsistent with their location addresses. And it is difficult for many start-up innovative enterprises to be identified as high-tech enterprises in a short time. These objective factors will have a certain impact on the data analysis results. On the other hand, high-tech enterprises contain multiple industry categories and have a different lifecycle. Whether these different innovative enterprises have varying distribution characteristics is not discussed in this study. Besides, this study focuses on the distribution characteristics of urban innovation space, and the mechanism analysis has not been discussed. In future research, multiple source spatial data and other spatial econometric analysis methods can be used to quantitatively analyze the mechanism of urban innovation distribution. We need to grasp the space needs of innovative activities by taking advantage of the enormous potential offered by data-driven analysis and provide planning countermeasures for the construction of innovative cities.

### Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

### Disclosure

The funding sources had no role in the study design, data collection, analysis or interpretation, or the writing of this manuscript.

### Conflicts of Interest

The authors declare there are no conflicts of interest.

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