Spatial Distribution and Influencing Factors of the Specialized and Sophisticated "Little Giant" Enterprises within the Pearl River Delta Region in the Context of Regional Urbanization

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Abstract. Specialized and sophisticated "Little Giant" enterprises, as a practical form of German hidden champions in China, have emerged as pivotal forces driving industrial transformation and enhancing regional economic competitiveness. Against this backdrop, this work utilized geospatial big data and spatial analysis to investigate the spatial distribution characteristics of approximately 1409 national-level specialized and sophisticated "Little Giant" enterprises within the Pearl River Delta region from 2019 to 2023. In this foundation, this work further utilizes the multi-scale geographically weighted regression (MGWR) model to identify the factors influencing the spatial distribution of these enterprises. Overall, the research findings reveal the following inspirations. First, the specialized and sophisticated "Little Giant" enterprises within the Pearl River Delta region exhibit spatial agglomeration, with the degree of agglomeration showcasing an upward trend year by year. These enterprises, with an agglomeration scale of 80 km, present agglomeration distribution characteristics closely related to the development scale and regional synergy of the Pearl River Delta metropolitan area where they are located. Second, the spatial distribution of the specialized and sophisticated "Little Giant" enterprises within the Pearl River Delta region is primarily centered around Shenzhen, with northwest-southeast serving as its predominant distribution direction, which is consistent with the geographical relative positioning of the Guangzhou-Shenzhen corridor. Meanwhile, the spatial distribution of these enterprises shows a tendency to aggregate into the Guangzhou-Shenzhen corridor year by year, with the aggregation center shifting toward Shenzhen. Lastly, a multitude of factors concerning four dimensions, including physical geography and location, government, market, and society collectively influence the spatial distribution of the specialized and sophisticated "Little Giant" enterprises within the Pearl River Delta region. Among the significant global variables, such as slope, industrial structure, and industrial platform, they exert a positive influence on the spatial distribution of these enterprises, whereas altitude and land development degrees generate a negative effect. The industrial platform

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acts as the most significant positive influencing factor. Moreover, the influence of altitude, slope, distance from water, industrial structure, and land development degree extends to a global scale. By contrast, several local variables, encompassing government intervention, industrial platform, road network density, living convenience, and collaborative innovation environment, have a relatively limited influence on the spatial distribution of "Little Giant" enterprises.

Keywords: specialized and sophisticated "Little Giant" enterprises; spatial-temporal evolution; scale of impact; MGWR; pearl river delta region; regional urbanization

1 INTRODUCTION

In the context of global industrial chain reconstruction and digital economy, fostering the specialized transformation of small and medium-sized enterprises (SMEs) has progressively become a crucial strategy for advancing socioeconomic development worldwide. Accordingly, Germany initially proposed the concept of Hidden Champions (HCs), which refers to specific SMEs with leading advantages in lesser-known fields[1]. These HCs in Germany have successfully pioneered a novel approach to regional innovation. Thereafter, countries worldwide have developed corresponding incentive strategies. China also proposed the concept of "specialized and sophisticated" enterprises, akin to HCs, characterized by specialization, refinement, distinctiveness, and novelty to encourage SMEs with specialization and market differentiation to overcome their development bottlenecks and enhance their competitiveness. High-quality "specialized and sophisticated" enterprises can be recognised as "specialized and sophisticated" SMEs through a triennial assessment[2].In this context, the temporal and spatial distribution and the influencing factors of state-level specialized and sophisticated "Little Giant" enterprises must be investigated to supplement the empirical experience from China within the field of HC research in the world and to promote the growth of SMEs and the rational allocation of social resources under regional integration.

The business model of HCs emphasizes at least three core elements, namely, specific knowledge-intensive products, their decentralized organization, and a highly internationalized nature[3]. HCs require a unique set of complementary institutional variables, based on the niche strategy [4]. Consequently, the mechanisms driving the distribution of firms exhibit a distinctive degree of heterogeneity. Currently, research on HCs primarily focuses on internationalization strategies[5], research and development (R&D), and innovation models[6,7], with limited exploration into the geographical distribution of HCs. When examining the geographical distribution of HCs, scholars typically base their research on diverse driving factors, such as the historical origin of the system and culture[3], human capital, education system[4], social system, and market environment[8]. Schenkenhofer and Wilhelm[9] found that the hybrid human capital induced by the dual system of German higher education brought positive benefits to the development of SMEs regarded as HCs within specific regions. The distribution mechanism of HCs is not only influenced by the externalities of urban areas but also exerted a reverse decisive role on regional economic development[10].

"Specialized and sophisticated" enterprises have recently emerged as a focal point of concern within academic circles in China. Different scholars have conducted analyses on the influencing mechanisms of cultivating and developing “Specialized and sophisticated” enterprises. The results indicated that various factors, such as government policy support[11], knowledge spillover[12], and business environment[13], play a significant role in the growth and leap of “specialized and sophisticated” SMEs. In order to explore the environmental factors as critical external drivers in shaping the spatial distribution patterns of enterprises, domestic scholars have systematically discussed the distribution characteristics and influencing factors of state-level specialized and sophisticated “Little Giant” enterprises on three scales, namely, the entire country[14], the Yangtze River Delta[15], and the Yangtze River Economic Belt[16].

Based on the aforementioned research foundation, this study primarily focuses on three areas of innovative exploration:(1) Research Scale: From the perspective of research scale, the Pearl River Delta region, as an important breeding ground for “specialized and sophisticated” SMEs, the empirical research outcomes are still lacking. This research aims to enrich existing fingdings by focusing on the Pearl River Delta region as the sthdy scope. (2) Analysis of Spatial Distribution Patterns: Most literature has solely leveraged cross-sectional data, as the identification of such enterprises began in 2019. In contrast, this study adopts a spatiotemporal perspective to provide a deeper understanding of the spatial differentiation and evolutionary characteristics of enterprises' distribution patterns. (3) Identification of Distribution Mechanisms: In this study, a multi-scale geographically weighted regression (MGWR) model is employed to identify the influencing factors of enterprises. With regard to the selection of specific indexes, existing literature[17], which applies the MGWR model to identify the specific influencing factors of specialized and sophisticated “Little Giant” enterprises and investigate their functioning scale effects, adopts city-scale statistical data. At this point, the data limited to the macro level potentially results in insufficient accuracy of the measurement results. Therefore, this work comprehensively considers diverse influencing factors from four dimensions encompassing physical geography and location, government, market, and society, with city-scale statistical data and grid-accurate data serving as proxy indexes to enhance the scientific rigor of the research through indicator optimization. Through innovative exploration in these three areas, this work is expected to deepen the understanding of the formation of spatial distribution patterns of enterprises and provide valuable insights for promoting the development of SMEs and informing policy formulation related to regional enterprise planning.

2 RESEARCH REGIONS AND DATA PROCESSING

2.1 Research Regions

The Pearl River Delta is located in the south-central portion of Guangdong Province, China. This region consists of nine cities, namely, Guangzhou, Foshan, Zhaoqing, Shenzhen, Dongguan, Huizhou, Zhuhai, Zhongshan, and Jiangmen. Meanwhile, the Pearl River Delta serves a major part of the Guangdong-Hong Kong-Macao Greater Bay Area (hereinafter referred to as the Greater Bay Area), one of the four Greater Bay Areas in the world. Moreover, the Pearl River Delta is not only a frontier of China’s opening to the outside world but also a pivotal platform for global scientific and technological innovation. After more than 40 years of development since the reform and opening up, the urban agglomeration of the Pearl River Delta has established a solid manufacturing foundation due to its resource endowment advantages. For example, in 2021, approximately 57,000 high-tech enterprises can be found in nine cities within the Pearl River Delta region. Furthermore, the Greater Bay Area consistently insists on increasing investment in basic research to bolster its capabilities for original, independent, and cutting-edge innovation. In this regard, nine cities within the Pearl River Delta region of the Greater Bay Area granted a total of 111,200 invention patents in 2022, accounting for 13.9% of the national invention patents granted. In 2020, enterprises in these cities submitted a total of 28,000 *Patent Cooperation Treaty* (PCT) international patent applications, accounting for 40.6% of such patent applications in China.

The distribution of five batches of "Little Giant" enterprises identified within the Pearl River Delta Region from 2019 to 2023 is shown in Figure 1. In the Pearl River Delta region, often referred to the "world factory", SMEs have constantly been the key to its industrial development. In the face of a new wave of technological and industrial changes, the transformation and upgrading of SMEs within the Pearl River Delta region has fostered in new opportunities and challenges. By the end of 2023, the Pearl River Delta has cultivated a total of 1,409 specialized and sophisticated "Little Giant" enterprises, including 754 enterprises in Shenzhen, accounting for 53.5% of the total. By 2023, the number of specialized and sophisticated "Little Giant" enterprises in Guangdong Province, predominantly situated in the Pearl River Delta region, has risen to the top spot among all provinces in China. Overall, strong economic strength, coupled with a favorable industrial base and a dense R&D innovation atmosphere, provide advantageous conditions for the cultivation of specialized and sophisticated enterprises, enabling the Pearl River Delta region to evolve into an important gathering place for state-level specialized and sophisticated "Little Giant" enterprises.

2.2 Data Sources and Index System Construction

Data Sources of the Specialized and Sophisticated "Little Giant" Enterprises within the Pearl River Delta Region.

The list of the specialized and sophisticated "Little Giant" enterprises within the Pearl River Delta region stems from the Department of Industry and Information Technology of Guangdong Province and the SME Service Bureau of Shenzhen Municipality. Since 2019, the Department of Industry and Information Technology of Guangdong Province began to select "Little Giant" enterprises according to a series of criteria such as whether the target enterprises are the focus of niche markets, whether they possess high innovation efficiency and market share, and whether they belong to advanced manufacturing industries. The relevant review is implemented once every 3 years, provided that those who fail the review will be disqualified. As of 2023, five batches of 1,409 "Little Giant" enterprises have been identified in nine cities within the Pearl River Delta region, except those that failed the review. The list of enterprises in the past years utilized in this work comprises those that have either successfully passed the initial evaluation or have passed the review in previous years.

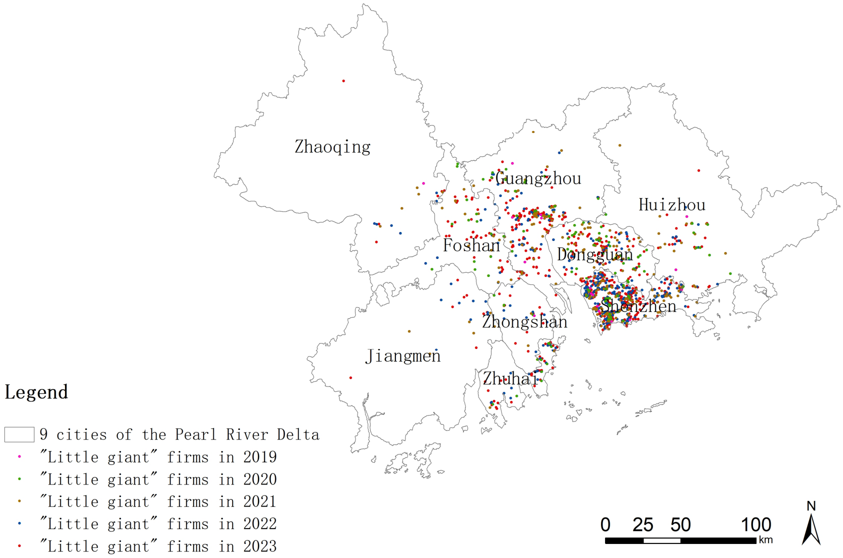

Fig. 1. Five Batches of "Little Giant" Enterprises Identified within the Pearl River Delta Region from 2019 to 2023.

The statistics of the number of local government enterprises within various industries are outlined in Figure 2 in accordance with the *Industrial Classification for National Economic Activities (GB/T 4754-2017)*.

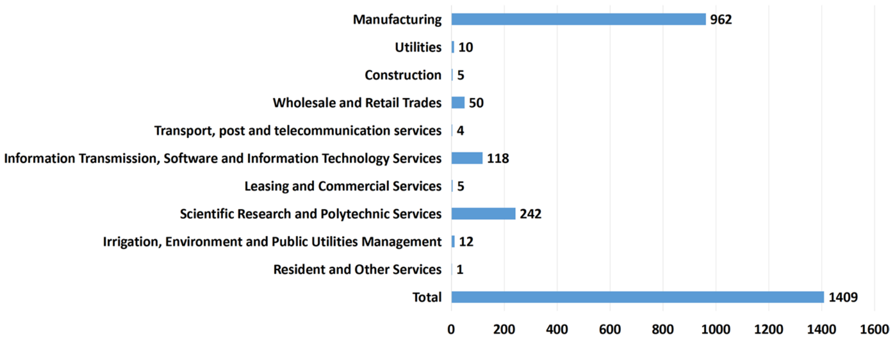

Fig. 2. Number of "Little Giant" Enterprises within the Pearl River Delta Region by Industry.

Zhu et al. [18] classified the "Little Giant" enterprises as those in the manufacturing industry, producer services that provide intermediate services for the manufacturing industry, and related enterprises in other industries. Relevant statistics indicated that the proportion of manufacturing enterprises in the "Little Giant" enterprises within the Pearl River Delta region is 68.3%, which is slightly higher than its overall proportion in the country. The proportion of enterprises in producer services is second only to manufacturing, accounting for 98%.

This work further utilizes the website "TianYanCha.com" (URL: https://www.tianyancha.com/) to obtain information about these enterprises, such as the registration time and the number of participants insured, based on the list of enterprises. In addition, the social and economic development data of the areas where these enterprises are located originate from the National Bureau of Statistics and the official websites of local governments. Meanwhile, various natural geographic data, such as altitude and topography, stem from the Geospatial Data Cloud platform, Resource and Environment Science and Data Center of the Chinese Academy of Sciences, and so on. Moreover, the data of a series of facility service points, such as life services, public services, and innovative services, come from point-of-interest (POI) data crawled through the application programming interface (API) (URL: https://lbs.amap.com/) of Amap.com.

Influencing Factors of Spatial Distribution of Enterprises and the Selection of Proxy Indexes.

Spatial agglomeration and distribution of enterprises are influenced by numerous factors. Given the specific natural and geographical background, the joint efforts of various forces from the government, market, and society can create a better environment for the cultivation and development of specialized and sophisticated "Little Giant" enterprises. In particular, a favorable natural geographical environment can provide suitable climatic conditions and abundant and high-quality natural resources for the distribution and agglomeration of enterprises[17]. Meanwhile, superior location conditions facilitate enterprises in more readily benefiting from the spillover effect brought by urban development more easily. Both factors serve as the fundamental conditions for "Little Giant" enterprises to achieve agglomeration and comparative advantages. During the collaborative efforts of multi-agents cooperating to establish software and hardware infrastructure that supports the sustainable development of enterprises, the enactment of relevant government policies, coupled with the investment of capital subsidies, is of great significance to promoting the transformation of enterprises and alleviating the development problems of enterprises[18]. Meanwhile, the government's emphasis on fiscal expenditure on science and technology is beneficial to providing effective resource support for enterprise innovation[19]. From the market perspective, a reasonable industrial structure and a perfect industrial platform can enable enterprises to obtain corresponding industrial support from their industries[15], which is closely related to the development prospects of enterprises. On the one hand, better availability of credit resources will help in alleviating the financing difficulties of SMEs[20], while opening-up trade can exert a regulatory effect on the transformation and upgrading of enterprises[21]. On the other hand, from the perspective of society dimension, the construction of perfect transportation facilities is conducive to reducing the transportation cost of enterprises, thereby attracting the agglomeration of enterprises[16]. Distribution of residential areas is related to the commuting cost of the labor force, which in turn affects the classification and agglomeration of enterprises by affecting the labor cost of enterprises[22]. A regional collaborative innovation environment is a core condition for upgrading and developing enterprises. For instance, the cooperation between enterprises, universities, and research institutes, for instance, helps in strengthening technical exchanges to ensure that enterprises can master more market information and technical elements[23]. The degree of land development affects the distribution and agglomeration of enterprises by affecting the factors represented by the spillover of public service facilities[14].

This work selects a total of 16 factors that affect the spatial distribution of enterprises in four dimensions, namely, physical geography and location, government, market, and society, with reference to relevant research results. The specific information is illustrated in Table 1. Furthermore, the specific values of each index are determined through data cleaning, regional gridding, spatial join, and divisional statistics, with dimensionless index processing being implemented.

Table 1. Selection of Influencing Factors on the Distribution of Specialized and Sophisticated "Little Giant" Enterprises within the Pearl River Delta Region.

Influence dimensions	Influencing factors	Specific indexes	Data sources
Physical geography and location	Altitude	Average altitude within the grid	DEM altitude data with an accuracy of 30m from Geospatial Data Cloud platform (URL: https://www.gscloud.cn/)
	Slope	Average slope within the grid	DEM altitude data with an accuracy of 30m from Geospatial Data Cloud platform (URL: https://www.gscloud.cn/)
	Distance from water	Distance between grid center point and nearest water body	Water vector data from OpenStreetMap (URL: https://www.openstreetmap.org/)
	Central region	Distance between grid center point and urban built-up area	Dataset of urban built-up area in China in 2020[24]
Government	Degree of government intervention	Proportion of general public budget expenditure to regional GDP	Statistical yearbooks of various cities
	Financial expenditure on science and technology	Proportion of science and technology expenditure to total fiscal expenditure	Statistical yearbooks of various cities
Market	Industrial structure	Proportion of added value of secondary and tertiary industries to regional GDP	Statistical yearbooks of various cities
	Industrial platforms	Number of industrial parks within the grid	POI data of the Pearl River Delta region from Amap.com
	Availability of credit resources	Number of banks within the grid	POI data of the Pearl River Delta region from Amap.com
	Degree of dependence upon foreign trade	Proportion of the sum of goods imports and exports to regional GDP	Statistical yearbooks of various cities
Society	Accessibility	Sum of the	POI data of the Pearl River Delta region from

	for short-distance transportation	number of bus stations and subway stations in the grid	Amap.com
	Accessibility for medium-long distance transportation	Distance between grid center point and nearest high-speed toll station	POI data of the Pearl River Delta region from Amap.com
	Road network density	Total length of the road network within the grid	Vector data of road network from OpenStreetMap (URL: https://www.openstreetmap.org/)
	Living convenience	Number of residential communities within the grid	POI data of the Pearl River Delta region from Amap.com
	Collaborative innovation environment	Sum of the number of universities and scientific research institutions within the grid	POI data of the Pearl River Delta region from Amap.com
	Degree of land development	Area proportion of urban construction land within the grid	Land development data from Resource and Environment Science and Data Center of Chinese Academy of Sciences (URL: https://www.resdc.cn)

3 RESEARCH METHODOLOGY

First, this work utilizes employs global spatial autocorrelation analysis to determine whether the "Little Giant" enterprises present spatial agglomeration from 2019 to 2023. This work further utilizes multi-distance spatial clustering analysis (Ripley's K-function) to explore the spatial agglomeration phenomenon of "Little Giant" enterprises across different distance scales over the years, with the calculated distance peak value serving as the research radius. Moreover, the kernel density analysis is carried out to derive the annual agglomeration center area of "Little Giant" enterprises. Meanwhile, the standard deviational ellipse is utilized to analyze the evolution of the spatial distribution of "Little Giant" enterprises with time. Lastly, this work divides the Pearl River Delta region into a grid with a size of 10 km × 10 km to investigate the influence of different factors on the spatial distribution of "Little Giant" enterprises, leveraging the MGWR to analyze diverse factors.

3.1 Global Moran's Index

Global autocorrelation analysis typically uses Moran's I as the measure[25]. Global Moran's I can be utilized to assess whether the spatial distribution of "Little Giant" enterprises is statistically aggregated or dispersed, thereby revealing the overall spatial pattern of LGE. The specific calculation equation is expressed as follows:

$$I = \frac{\sum_{i=1}^{n}\sum_{j\neq i}^{n} W_{ij}\left(X_i - \bar{X}\right)\left(X_j - \bar{X}\right)}{\frac{1}{n}\sum_{i}^{n}\left(X_i - \bar{X}\right)^2 \sum_{i=1}^{n}\sum_{j\neq i}^{n} W_{ij}} \tag{1}$$

where X_i represents the number of enterprises in the *i*-th space unit, X_j denotes the number of enterprises in the *j*-th space unit, and W_{ij} indicates the weight parameter between the *i*-th space unit and the *j*-th space unit, indicating the proximity between them.

3.2 Ripley's K-function

Multi-distance spatial clustering analysis typically utilizes Ripley's K-function to determine the distribution pattern of point events with the change in spatial research scale(i.e., distance)[26]. This method is used for multi-distance clustering analysis of point data, thereby exploring whether there is a spatial clustering phenomenon of "Little Giant" enterprises occurs across diverse distance scales. The specific calculation equation is expressed as follows:

$$K(d) = A\sum_{i=1}^{n}\sum_{j=1}^{n}\frac{\delta_{ij}(d)}{n^2} \tag{2}$$

$$i,j = 1,2,...n; i \neq j, dij \leq d, \delta_{ij}(d) = \begin{cases} 1(d_{ij} \leq d) \\ 0(d_{ij} > d) \end{cases}, \; L(d) = \sqrt{\frac{K(d)}{\pi}} - d \tag{3}$$

where *A* represents the area of the research region, *n* denotes the number of enterprises within the research region, *d* stands for distance scale, and d_{ij} indicates the distance between enterprise *i* and enterprise *j*.

3.3 Kernel Density Analysis

Kernel density analysis is capable of presenting its spatial distribution characteristics according to the data of known sample points within regular areas[27]. The specific calculation equation is expressed as follows:

$$f(x) = \frac{1}{nh}\sum_{i=1}^{n} K(\frac{x - x_i}{h}) \tag{4}$$

In equation (4), K represents the weight function of the kernel; d denotes the bandwidth, which is the width of the surface extending in space around the location of the enterprise as the origin; n represents the number of enterprises; and $x - x_i$ represents the distance from the estimation point x to the sample x_i.

Therefore, this study leverages kernel density analysis to visualize the geographical distribution pattern of "Little Giant" enterprises.

3.4 Standard Deviational Ellipse

The standard deviational ellipse can be utilized to analyze the distribution center of gravity, direction, and coverage of spatial elements. Calculating the elliptic parameters distributed within the element space aids in quantitatively analyzing the geographical spatial distribution characteristics of the research object on a global scale[26].

Assuming there are n enterprise samples, and the coordinates of sample i are (x_i, y_i) . The specific calculation equation is expressed as follows:

$$C = \begin{pmatrix} \mathrm{var}(x) & \mathrm{cov}(x,y) \\ \mathrm{cov}(y,x) & \mathrm{var}(y) \end{pmatrix} = \frac{1}{n}\begin{pmatrix} \sum_{i=1}^{n}\tilde{x}_i^2 & \sum_{i=1}^{n}\tilde{x}_i\tilde{y}_i \\ \sum_{i=1}^{n}\tilde{x}_i\tilde{y}_i & \sum_{i=1}^{n}\tilde{y}_i^2 \end{pmatrix} \tag{5}$$

Whereas:

$$\mathrm{var}(x) = \frac{1}{n}\sum_{i=1}^{n}(x_i - \overline{x})^2 = \frac{1}{n}\sum_{i=1}^{n}\tilde{x}^2 \tag{6}$$

$$\mathrm{cov}(x,y) = \frac{1}{n}\sum_{i=1}^{n}(x_i - \overline{x})(y_i - \overline{y}) = \frac{1}{n}\sum_{i=1}^{n}\tilde{x}_i\tilde{y}_i \tag{7}$$

$$\mathrm{var}(y) = \frac{1}{n}\sum_{i=1}^{n}(y_i - \overline{y})^2 = \frac{1}{n}\sum_{i=1}^{n}\tilde{y}^2 \tag{8}$$

The major axis represents the predominant direction of the distribution pattern, while the minor axis represents the extent of the distribution. The larger the disparity between the lengths of the major and minor axes, the more significant the directional bias of the distribution becomes. On this basis, this work uses the standard deviational ellipse and the shift of the center of gravity to reflect the spatial evolution of "Little Giant" enterprises in the time dimension.

3.5 MGWR

In comparison with the classical GWR, MGWR possesses the following advantages. Specifically, MGWR initially allows each variable to present a different level of spatial smoothness, thus addressing the defects of classical GWR. Second, the specific bandwidth of each variable in MGWR can be used as a scale index for each spatial process. Finally, the multi-bandwidth method forms a spatial process model closer to the real situation, which is more conducive to revealing the scale effect of spatial distribution influencing factors[17]. The equation utilized to describe the MGWR model is determined as follows:

$$Y_i = \sum_{j=1}^{k} \beta_{bw_j} \left(u_i, v_i\right) X_{ij} + \varepsilon_i \tag{9}$$

where Y_i denotes the number of "Little Giant" enterprises within the grid; X_{ij} indicates the factors that affect the spatial distribution of "Little Giant" enterprises; β_{bw_j} represents the regression coefficient of the *j*-th influencing factor, bw_j is the bandwidth applicable to the regression coefficient of the *j*-th influencing factor; and $\left(u_i, v_i\right)$ signifies the coordinate of the grid centroid. The MGWR model is typically based on the GWR model setting. Nevertheless, each regression coefficient β_{bw_j} in the MGWR model is obtained based on local regression, with their bandwidth exhibiting specificity. The kernel function and bandwidth selection criteria of MGWR continue those of classical GWR. Hence, this work utilizes the most commonly used quadratic function and AICc criterion, with the backward fitting algorithm as the estimation method and the classical GWR estimation as the initial estimation[28].

4 RESULT ANALYSIS

4.1 Analysis of the Temporal and Spatial Distribution Characteristics of Enterprises

Coupling of Agglomeration Scale and Regional Co-evolution of the Pearl River Delta Metropolitan Area.

This work conducts global autocorrelation analysis on five batches of specialized and sophisticated "Little Giant" enterprises within the Pearl River Delta region from 2019 to 2023 using the global Moran's I, a key index to measure the degree of spatial autocorrelation. The aforementioned analysis is performed using the inverse distance spatial weight matrix and the shared boundary spatial weight matrix, thereby realizing the preliminary assessment on the spatial agglomeration of specialized and sophisticated "Little Giant" enterprises. The relative results are depicted in Table 2. As can be seen from Table 2. The values of Moran's I in the results of the two weight matrices are both greater than zero, while the P value presents a high degree of confidence. This result indicates that the "Little Giant" enterprises within the Pearl River Delta region have exhibited autocorrelation in spatial distribution since 2019. In addition, the year-on-year increase of positive significance indicates that the agglomeration degree of "Little Giant" enterprises within the Pearl River Delta region is on the rise with each passing year.

Table 2. Moran's I Analysis Results for the Specialized and Sophisticated "Little Giant" Enterprises within the Pearl River Delta Region.

Years	Inverse distance spatial weight			Shared boundary spatial weight		
	Moran's I	Z-scores	P values	Moran's I	Z-scores	P values
2019	0.082	3.072	0.002	0.121	5.67	0.000
2020	0.419	15.059	0.000	0.368	16.55	0.000
2021	0.576	21.005	0.000	0.566	25.83	0.000
2022	0.642	23.853	0.000	0.629	29.24	0.000
2023	0.669	24.754	0.000	0.642	29.67	0.000

In this foundation, this work further explores the characteristics of the agglomeration space, namely, the distance scale difference of the agglomeration space. Specifically, the calculation of Ripley's K-function by Crimestat software reveals the change in agglomeration characteristics of the specialized and sophisticated "Little Giant" enterprises within the Pearl River Delta urban agglomeration with distance. The L(d) value in Ripley's K-function is used to indicate the clustering strength, with the d value utilized to measure the clustering scale. Furthermore, the upper and lower bounds of the actual confidence interval of Ripley's K-function are obtained by simulation, which is also referred to as the envelope. The value of L(d) above the envelope indicates that enterprises present significant spatial agglomeration characteristics. Meanwhile, the value of L(d) below the envelope indicates that enterprises present significant spatial dispersion characteristics. The value of L(d) within the envelope represents the random distribution of enterprises in space. A larger L(d) value indicates a more significant degree of enterprise spatial agglomeration and a weaker degree of enterprise dispersion. The result of Ripley's K-function analysis of the specialized and sophisticated "Little Giant" enterprises within the Pearl River Delta region from 2019 to 2023 indicates that the L(d) values in all the years except 2019 are higher than the maximum value in random distribution, demonstrating that the spatial distribution of "Little Giant" enterprises within the Pearl River Delta region presents significant agglomeration characteristics across diverse distance scales. This finding is consistent with the calculation result of global Moran's I. Ripley's K-function analysis of "Little Giant" enterprises from 2020 to 2023 is illustrated in Figure 3. In addition, the L(d) curve corresponding to 2019 is located above the envelope within a radius of 4-7 km, indicating that the first batch of "Little Giant" enterprises failed to form agglomeration in different distance ranges due to a limited number. In the case of enterprise agglomeration reaching the peak distance, enterprises present the greatest degree of agglomeration. From the perspective of different spatial distance scales, the corresponding L(d) curves from 2020 to 2021 exhibit a "double-peak" feature. Specifically, the L(d) curve corresponding to 2020 showcases agglomeration peaks at the distances of 18 and 33 km, while the L(d) curve corresponding to 2021 showcases agglomeration peaks at the distances of 31 km and 43 km. The L(d) curves from 2020 to 2021 progressively show a double-peak feature, whereas the L(d) curves from 2022 demonstrate a single-peak feature (Figure 3). In this regard, the L(d) curves corresponding to 2022 and 2023 reach the peak at 64 km and 69 km, respectively. From Ripley's K-function curve in 2023, it can be seen that the agglomeration scale of specialized and sophisticated “Little Giant” enterprises within the Pearl River Delta region is primarily concentrated in the distance of 80 km.

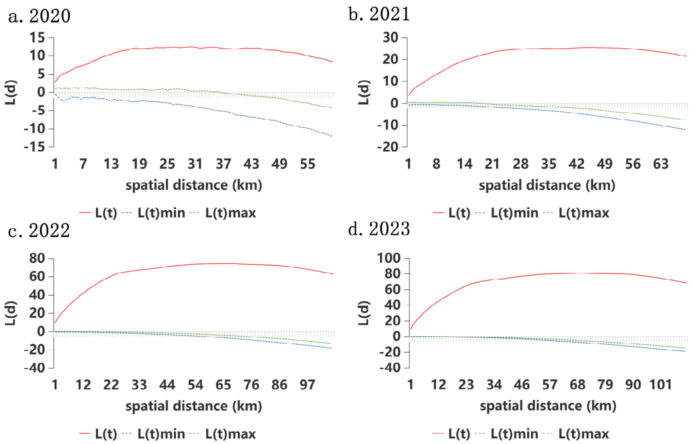

Fig. 3. Analysis of Ripley’s L(d) Function of “Little Giant” Enterprises from 2020 to 2023.

A study on the spatial aggregation scale of the specialized and sophisticated “Little Giant” enterprises within the Yangtze River Delta region through a comparison of the peak value of the L(d) curves with the scale of the metropolitan area indicates that the spatial distribution of enterprises in 2021 presents a “double-peak” feature at the distances of 70 and 170 km, which conforms to the 1 h commuting radius in the metropolitan area and between cities in the metropolitan area[16]. In comparison with the Yangtze River Delta region, the L(d) curves of the “Little Giant” enterprises within the Pearl River Delta region peaked at 69 km in 2023, with the agglomeration scale reaching the first peak in the Yangtze River Delta region. Concurrently, no second agglomeration peak occurred in a larger distance range, indicating that the agglomeration effect of “Little Giant” enterprises within the Pearl River Delta region is weaker than that in the Yangtze River Delta region. Notably, this finding is related to the volume difference between the two urban agglomerations. Nevertheless, it has been suggested that the Pearl River Delta urban agglomeration exhibits a more significant “siphonic effect” and the risk of negative spillover than the Yangtze River Delta urban agglomeration[29]. In addition, the comparison of the agglomeration scale of “Little Giant” enterprises demonstrates that the Pearl River Delta should not only improve the degree of regional coordinated development among multi-cities but also speed up the construction of Greater Bay Area’s one-hour living circle, so that enterprises can realize the efficient exchange and transformation of inter-regional elements in the metropolitan area as well as enjoy the scale effect brought by spatial agglomeration, thereby seeking accelerated growth in the context of metropolitan integration.

Spatial Characteristics of the Geographical Distribution Pattern of Enterprises.

The research results of spatial autocorrelation and spatial agglomeration intensity of specialized and sophisticated “Little Giant” enterprises within the Pearl River Delta region indicated that the spatial distribution of enterprises presents a trend of annual agglomeration within a certain scale from 2019 to 2023. This work utilizes kernel density analysis and standard deviational ellipse for further analysis to explore the evolution of the spatial distribution of these enterprises over time.

In combination with the L(d) curves, this work excludes the data from 2019 with an insignificant agglomeration effect. Taking the peaks in 2020 (18 and 33 km), 2021 (31 and 43 km), 2022 (64 km), and 2023 (69 km) as the radius, this work analyzes the local agglomeration characteristics of the point distribution of the specialized and sophisticated “Little Giant” enterprises within the Pearl River Delta region by using the kernel density method. The relevant results are outlined in Figure 4.

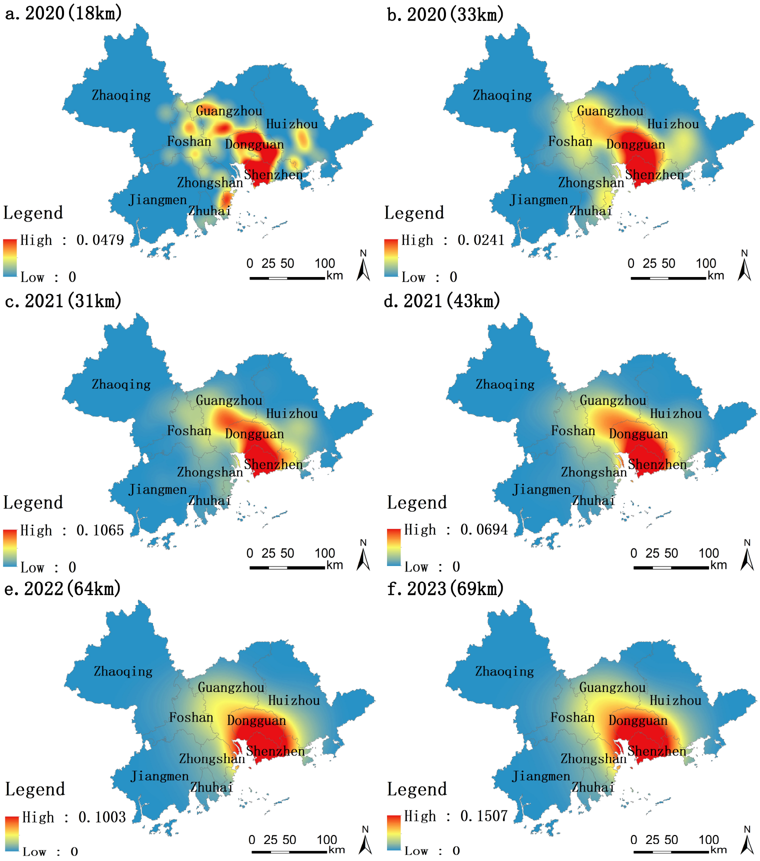

Fig. 4. Kernel Density Analysis of “Little Giant” Enterprises from 2020 to 2023.

The results of the kernel density analysis indicated that the specialized and sophisticated “Little Giant” enterprises within the Pearl River Delta region demonstrate a remarkable concentric spatial agglomeration feature with Shenzhen as the core, extending outward in a bay-shaped pattern across various scales over the years. Meanwhile, these enterprises exhibit a strong agglomeration effect in Shenzhen, Dongguan, and Guangzhou, with the agglomeration degree annually increasing. Moreover, the "Little Giant" enterprises in other cities not only experience a rapid decline in density beyond the peak radius but also display increasingly scattered and random spatial distributions.

The standard deviational ellipse is utilized to analyze the directional characteristics and evolution of the spatial distribution of the specialized and sophisticated "Little Giant" enterprises within the Pearl River Delta region from 2019 to 2023. The relevant results are depicted in Figure 5. The results of the standard deviational ellipse analysis demonstrate that the specialized and sophisticated "Little Giant" enterprises within the Pearl River Delta region are primarily distributed in northwest-southeast, which is consistent with the geographical relative positioning from Guangzhou to Shenzhen. During the period from 2019 to 2023, the distribution of enterprises gradually gathered in Guangzhou-Shenzhen, indicating that the "Little Giant" enterprises gathered in Guangzhou-Shenzhen each passing year in spatial distribution. The change in the center of gravity of the ellipse indicates that the spatial agglomeration center of the "Little Giant" enterprises progressively shifted toward Shenzhen after 2021.

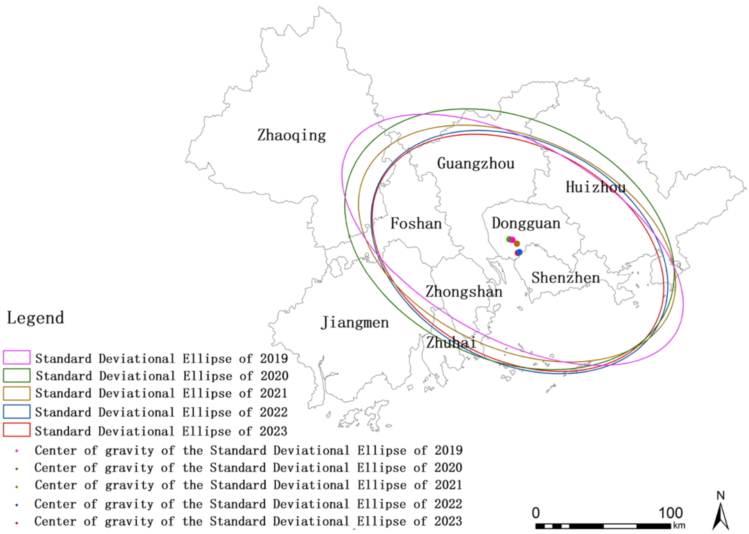

Fig. 5. Standard Deviational Ellipses and Their Central Changes of "Little Giant" Enterprises from 2019 to 2023.

The kernel density analysis and the overall geographical spatial pattern presented by the standard deviational ellipse indicated that Shenzhen, serving as the science and technology center of the Greater Bay Area, has progressively evolved into a powerful engine to promote the industrial transformation of SMEs within the Pearl River Delta urban agglomeration. Meanwhile, it can be inferred that the evolution of Ripley's K-function curves in Section 4.1 from bimodal to unimodal is induced by the spatial pattern with Shenzhen as the center gradually becomes significant over time. Building upon the deep accumulation of manufacturing industry and private economy, Shenzhen is driven by its objective of being an international innovation capital. Accordingly, the government provides them with perfect innovation services around the innovation demands of enterprises, urging enterprises to accelerate their self-upgrading. In Shenzhen, a municipality with independent planning status, the specialized and sophisticated enterprises that have been declared since 2022 do not need to be declared to join the list of specialized and sophisticated enterprises in Guangdong Province. Moreover, Shenzhen has introduced more diversified policy dividends to innovative SMEs[30], which is coupled with the phenomenon that the agglomeration center of "Little Giant" enterprises has shifted to Shenzhen since 2021. Specifically, the favorable industrial innovation environment on the government and market sides furnishes beneficial nutrients for the development of specialized and sophisticated enterprises, acting as a key to the industry upgrading of specialized and sophisticated enterprises in Shenzhen.

The measurement results of the Guangzhou–Shenzhen metropolitan area indicated that the current physical area of Guangzhou metropolitan area ranges from 35 km to 55 km, whereas the physical area of Shenzhen metropolitan area ranges from 35 km to 40 km[31]. The Guangzhou-Shenzhen metropolitan area is the most mature metropolitan area in China. Given the geographical proximity of Guangzhou and Shenzhen, two first-tier cities, the 14th Five-Year Plan of Guangdong Province in the Pearl River Delta region proposed a brand-new objective of promoting Guangzhou and Shenzhen to plan their territorial spatial layout based on the overall situation of "dual-region" construction, thereby jointly building Greater Bay Area's "twin cities" with global influence. The evolution of Ripley's K-function curves from bimodal to unimodal demonstrates to some extent that the inter-city stitching of Guangzhou, Dongguan, and Shenzhen is progressively accelerating to a certain extent, which coincides with the development theme of Guangzhou-Shenzhen integration. Currently, the spatial agglomeration scale of the specialized and sophisticated "Little Giant" enterprises within the Pearl River Delta region is primarily within an 80 km distance. The physical geographical radius of the metropolitan area formed by Guangzhou and Shenzhen is within a range from 70 km to 90 km. Over time, the scale of enterprise agglomeration gradually aligns with this phenomenon. This notion indicates that the agglomeration situation of "Little Giant" enterprises presents the phenomenon that the agglomeration intensity in the urban fringe is progressively increasing. Thus, the boundaries of enterprise layout and between urban agglomerations are fuzzy with regional development.

4.2 Analysis of Factors Influencing the Spatial Distribution of Enterprises

Overall Regression Result Analysis.

This work mainly utilizes MGWR to explore the factors influencing spatial distribution and the agglomeration of enterprises. Specifically, first and foremost, to reduce the influence of multicollinearity and heteroscedasticity, three variables with VIF values greater than 10, including financial expenditure on science and technology, availability of credit resources, and accessibility for short-distance transportation, are excluded to minimize the influence of multicollinearity and heteroscedasticity. The robust standard error is utilized for parameter estimation. Furthermore, this work discovered through testing Moran's I of influencing factors that the explanatory variables all present spatial heterogeneity and fulfill the utilization conditions of the GWR model. The regression of GWR and MGWR is simultaneously implemented for the convenience of comparison. Table 3 illustrates the adjusted goodness of fit R^2 of the MGWR model is 0.840, which is higher than 0.541 of the GWR model, exhibiting a lower AICc value of 805.952. This result indicates that the regression result of MGWR is superior to that of the GWR model. Hence, this research adopts the MGWR model to implement regression analysis.

Table 3. Indexes of Classical GWR and MGWR Models.

Explained variables	Models	Sample size	Residual sum of squares	AICc	R^2	Adjusted R^2
Number of enterprises within the grid	GWR	693	311.800	1443.880	0.550	0.541
Number of enterprises within the grid	MGWR	693	96.984	805.952	0.860	0.840

Table 4 illustrates the regression results of the MGWR model. In this connection, P was selected to examine whether each variable passed the 10% significance level test. Specifically, all the sample points of the five variables, encompassing altitude, slope, industrial structure, industrial platform, and the degree of land development, passed the 10% significance level test. Slope, industrial structure, and industrial platform exert positive influence. By contrast, altitude and the degree of land development exert a negative influence. Furthermore, five variables, including distance from water, government intervention, road network density, living convenience, and collaborative innovation environment, are locally significant. Approximately 8.8% of the samples related to the distance from water passed the test. Meanwhile, 18.3% of the samples related to government intervention passed the test. Furthermore, 74.7% of the samples related to road network density, coupled with 34.1% of the samples related to living convenience and 39.0% of the samples related to collaborative innovation environment, passed the test. By contrast, all the sample points related to the central region, degree of dependence upon foreign trade, and accessibility for medium-long distance transportation are insignificant. The statistical description of the variable regression coefficient is depicted in Table 5. In terms of the global significant variables, the influence intensity exerted by the average coefficient on variables (i.e., their absolute values) from large to small can be summarized as an industrial platform (0.425), the degree of land development (|-0.090|), industrial structure (0.085), slope (0.078), and altitude (|-0.068|). Consequently, the industrial platform serves as a core factor that affect the spatial distribution of "Little Giant" enterprises, with its influence degree far greater than other factors.

Table 4. Regression Results of MGWR Model.

Variables	Bandwidth		Samples with significant coefficients	
	MGWR	GWR	Sample size	Proportion of variables to all samples/%
Altitude	692.000	135.000	693	100
Slope	692.000	135.000	693	100

Distance from water	692.000	135.000	61	8.8
Central region	692.000	135.000	0	0
Degree of government intervention	43.000	135.000	127	18.3
Industrial structure	692.000	135.000	693	100
Industrial platforms	196.000	135.000	693	100
Degree of dependence upon foreign trade	692.000	135.000	0	0
Accessibility for medium-long distance transportation	692.000	135.000	0	0
Road network density	88.000	135.000	518	74.7
Living convenience	43.000	135.000	236	34.1
Collaborative innovation environment	141.000	135.000	270	39.0
Degree of land development	692.000	135.000	693	100

Table 5. Descriptive Statistics of MGWR Coefficients.

Variables		Mean value	Standard deviation	Minimum value	Median	Maximum value
Global significant variables	Altitude	-0.07	0.006	-0.082	-0.07	-0.059
	Slope	0.078	0.006	0.069	0.077	0.088
	Industrial structure	0.085	0.003	0.079	0.085	0.093
	Industrial platforms	0.425	0.136	0.220	0.410	0.692
	Degree of land development	-0.09	0.004	-0.097	-0.09	-0.085
Local significant variables	Distance from water	0.027	0.009	0.013	0.027	0.037
	Degree of government intervention	-0.01	0.194	-0.819	0.036	0.565
	Road network density	0.363	0.190	0.070	0.299	0.999
	Living convenience	-0.18	0.266	-1.092	-0.12	0.342
	Collaborative innovation environment	0.332	0.532	-0.136	0.127	1.761

Scale Effect and Spatial Pattern Analysis of Coefficients.

The MGWR model is capable of reflecting the scale differences affected by different variables, with a smaller variable bandwidth revealing a more significant spatial specificity of the influencing factors. Table 4 indicates the bandwidths of the diverse variables in the MGWR model, reflecting that the spatial scales affected by variables exhibit significant differences. By contrast, the bandwidth of the regression results of the classical GWR model solely reflects the average level of the spatial scales. The results of Ripley's K-function and kernel density analysis indicated that the specialized and sophisticated "Little Giant" enterprises within the Pearl River Delta region present scale effects in terms of spatial distribution. Accordingly, the analysis of the spatial distribution of the variable regression coefficient can be leveraged to explore the spatial heterogeneity of the influencing factors of the distribution of "Little Giant" enterprises within the Pearl River Delta region. In this context, this work divides the influence intensity of each factor into five grades by using the natural breakpoint method, with their visualization depicted in Figure 6.

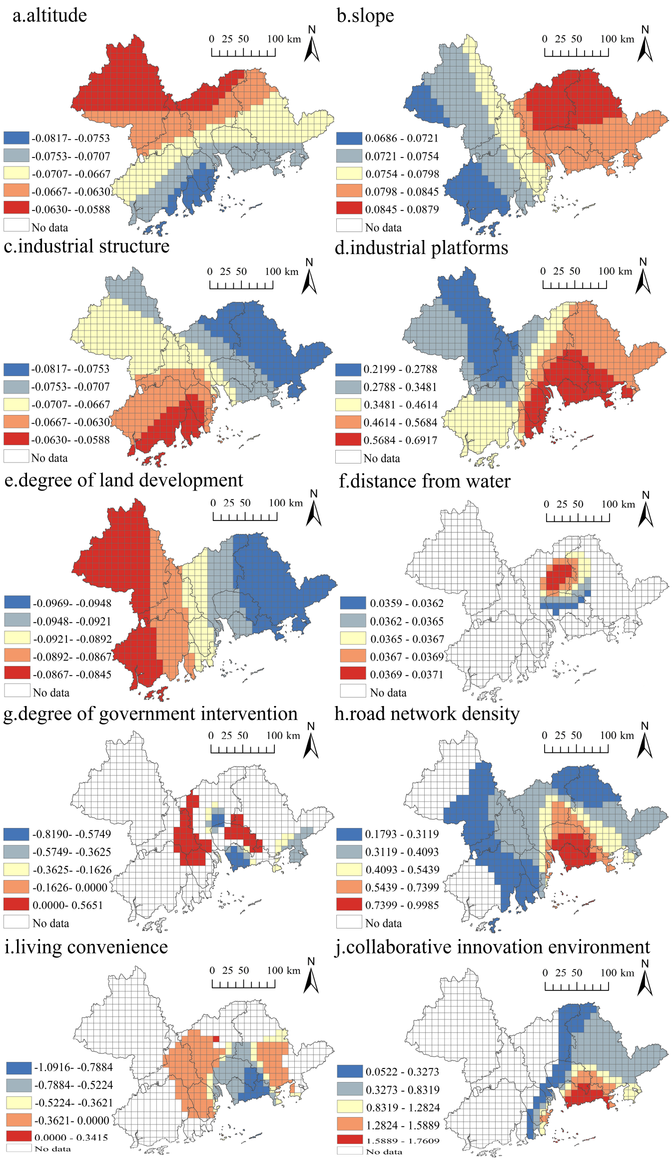

Fig. 6. Spatial Differentiation Pattern of Influencing Factors Concerning the Distribution of Specialized and Sophisticated "Little Giant" Enterprises within the Pearl River Delta Region.

The regression results of the global significant variables indicated that the bandwidths of altitude and slope in the MGWR model are both 692. Accordingly, these variables can be regarded as global variables, with their effects showing no significant spatial variation. The regression coefficient of altitude ranges from -0.082 to -0.059, with an average of -0.068. By contrast, the regression coefficient of slope ranges from 0.069 to 0.088, with an average value of 0.078. The negative influence of altitude on the spatial distribution of the "Little Giant" enterprises within the Pearl River Delta region shows a spatial differentiation pattern that gradually increases from northwest to southeast. Meanwhile, the positive influence of slope on the spatial distribution of these enterprises exhibits a spatial differentiation pattern that progressively increases from southwest to northeast. The topography of the Pearl River Delta region is dominated by plains and hills, with its west, east, and north being surrounded by hills and mountains. Accordingly, the "Little Giant" enterprises are located at low-altitude plains. In this regard, the Greater Bay Area, located in the southeast coastal plain, attracts a myriad of enterprises because of its superior natural and geographical conditions.

Industrial structure, as a global variable, shows a regression bandwidth of 692, with its influence presenting no significant spatial variation. In addition, the regression coefficient of this variable ranges from 0.079 to 0.093, with an average of 0.085. The positive influence exerted by industrial structure on the spatial distribution of the "Little Giant" enterprises within the Pearl River Delta region presents a spatial differentiation pattern with the south as the high-value area and gradually weakening to the northeast. At present, the Pearl River Delta region is in a critical period of deep integration into the Greater Bay Area's development, economic structure, and industrial upgrading and adjustment. Moreover, SMEs occupy an important share of the economy within the Pearl River Delta region. "Little Giant" enterprises, as the best among SMEs, are closely related to the regional industrial structure. Consequently, the industrial structure exerts a global influence involving a larger spatial scale. Given this situation, the development of the secondary and tertiary industries can provide additional supporting support for enterprises. Moreover, the improvement of industrial specialization and refinement is conducive to stimulating SMEs to achieve innovative breakthroughs in technology and products, thereby enhancing the market competitiveness of enterprises.

The regression bandwidth of the industrial platform, a local variable, is 196, with its influence presenting relevant spatial variation. The regression coefficient of this variable ranges from 0.220 to 0.692, with an average value of 0.425. The positive influence exerted by industrial platforms on the spatial distribution of the "Little Giant" enterprises within the Pearl River Delta region is primarily concentrated in the broader Shenzhen area surrounding the Pearl River Estuary and certain regions in Zhuhai, Zhongshan, Guangzhou, Dongguan, and Huizhou, with decreasing values from the southeast to the northwest. The construction of industrial platforms is closely related to local policies and industrial foundations, exhibiting regional disparities, resulting in leading to the localized influence of industrial platforms on the spatial distribution of "Little Giant" enterprises. Given the higher regression coefficient of the industrial platform than other factors, it serves as a core factor affecting the spatial distribution of "Little Giant" enterprises. Industrial parks can not only provide platform resources and technical support for enterprises but also promote enterprise innovation through the spillover effect and the incentive effect of market competition, thereby facilitating the spatial agglomeration of enterprises. Recently, the government has issued relevant policies to guide the coordinated development of industries on both sides of the Pearl River Estuary. In this context, the continuous improvement of industrial park space and related supporting construction, in conjunction with the enhancement of industrial interaction, has emerged as an essential force in promoting the transformation and upgrading of SMEs.

The degree of land development, as a local variable, shows a regression bandwidth of 692, with its influence presenting no significant spatial variation. In addition, the regression coefficient of this variable ranges from -0.097 to -0.085, with an average value of -0.090. The negative influence exerted by the degree of land development on the spatial distribution of the "Little Giant" enterprises within the Pearl River Delta region presents an east-west spatial differentiation pattern with the eastern region as the high-value area. The land resources in urban built-up areas are increasingly tense as the development of cities within the Pearl River Delta region has entered a new stage from incremental expansion to stock renewal. Meanwhile, the central city is facing numerous challenges, such as high housing prices, high land prices, brain drain, and enterprise spillover. Consequently, the degree of land development exerts a general influence on the "Little Giant" enterprises within the Pearl River Delta region. Accordingly, the specialized and sophisticated "Little Giant" enterprises gradually gather in the new urban areas to reduce their production and operation costs and obtain more room for growth by leveraging the policy advantages of the new urban areas. Over recent years, enterprises in Guangzhou and Shenzhen have gradually moved to Dongguan and Huizhou, which possess favorable manufacturing bases and low-cost advantages. In particular, the negative influence exerted by the degree of land development on the spatial distribution of enterprises is most significant in the eastern Pearl River Delta region.

The regression results of local significant variables indicates that the regression bandwidth of the distance from water is 692, with its influence presenting no significant spatial variation. Additionally, the regression coefficient of this variable ranges from 0.013 to 0.037, with an average of 0.027. The samples related to the distance from water with significant coefficients account for 8.8% of the total samples. Spatially, the positive influence of this variable manifests as a high-value area in the eastern portion of Guangzhou city, progressively diminishing in influence toward the western portion of Huizhou and the northern portion of Dongguan. Various water bodies represented by rivers and lakes are closely related to the development of cities and enterprises within the Pearl River Delta region. During the initial stage of urban development, the production process of manufacturing enterprises requires consuming extensive water resources. To this extent, the location of adjacent water bodies helps them in obtaining abundant water resources. Meanwhile, convenient waterway transportation can minimize their freight costs, thus promoting the growth of these enterprises. The construction intensity of land near water bodies has further increased along with the continuous progress of urbanization, resulting in the increasing shortage of constructive land. Benefiting from the constant development of short-distance transportation, such as roads, and long-distance transportation, such as railways, enterprises can choose more flexible freight modes according to their actual demands. Consequently, the spatial distribution of “Little Giant” enterprises in some regions is related to or negatively related to the insignificant distance from water.

The degree of government intervention, as a local variable, presents a regression bandwidth of 43, which is between the scale of district-level administrative regions and the scale of municipal administrative regions, with its influence presenting relevant spatial variation. The regression coefficient of this variable ranges from −0.819 to 0.565, with an average of −0.011. The samples related to the degree of government intervention with significant coefficients account for 18.3% of the total samples. Spatially, this variable exerts a positive influence on some areas in the central and eastern portions of the Pearl River Delta, but a negative influence on a few other areas. The influence of government intervention on the spatial distribution of “Little Giant” enterprises within the Pearl River Delta region exhibits relatively strong spatial heterogeneity. The preferential tax policies and financial subsidies introduced by the government are essential factors in supporting the development of local enterprises, which are helpful in transferring the risks faced by enterprises and attracting more enterprises to enter the local market. Nevertheless, the areas with insignificant influence do not mean that the degree of government intervention exerts no influence on the location selection of “Little Giant” enterprises. Moreover, the degree of government intervention generates insignificant influence on the spatial scale of 10 km. Specifically, the influence of government factors on enterprise location selection in combination with other indexes must be further explored.

The road network density, a local variable, showcases a regression bandwidth of 88, which is close to the scale of municipal administrative districts, with its influence presenting relevant spatial variation. In addition, the regression coefficient of this variable ranges from 0.070 to 0.999, with an average of 0.363. The samples related to road network density with significant coefficients account for 74.7% of the total samples, suggesting that it exerts a substantial influence on most areas of the Pearl River Delta. Spatially, its positive influence demonstrates a differentiation pattern, with the southeast parts serving as the high-value area and the influence degree gradually decreasing to the northwest portions. The influence of road network density on the spatial distribution of enterprises in most areas is positive and significant. The reason that a higher road network density indicates a more developed regional traffic network and higher transportation accessibility to a certain extent. Convenient transportation is capable of driving the construction of surrounding supporting facilities, enabling enterprises to reduce their transportation costs and improve their profitability. Simultaneously, this variable can alleviate the crowding effect caused by industrial and population agglomeration, thereby facilitating the exchange of factors between enterprises and the outside world. Road network density, a local variable, exerts the same positive influence on the spatial distribution of “Little Giant” enterprises within the scope of municipal administrative regions. Once this scale is exceeded, relevant coefficients will dramatically change. Moreover, the spatial distribution and agglomeration of the “Little Giant” enterprises are closely related to the road network construction of each city, with its influence being most significantly reflected in the southeastern portion of the Pearl River Delta region.

Living convenience, a local variable, presents a regression bandwidth of 43, which is between the scales of the district-level administrative region and the municipal administrative region, with its influence presenting relevant spatial variation. In addition, the regression coefficient of this variable ranges from −1.092 to 0.342, with an average of −0.177. The samples related to living convenience with significant coefficients account for 34.1% of the total samples. The samples with negative influence account for 33.96% of the total samples, whereas the samples with positive influence account for 0.14%. As a whole, living convenience exerts a negative impact on the spatial distribution and agglomeration of enterprises, which is reflected in the pattern of high-value areas in parts of Shenzhen and Dongguan in the southeast. The influence exerted by living convenience on the spatial distribution of enterprises can be attributed to the joint action of a host of mechanisms. On the one hand, some "Little Giant" enterprises are located in the newly developed areas of cities, where the perfection of residential facilities must be improved. On the other hand, the rising housing prices in urban areas have increased the living costs of workers, making the phenomenon of separation of workplace and residence increasingly prevalent. In this context, the difference in labor commuting cost results in the spatial classification and agglomeration of enterprises with heterogeneous productivity, which is reflected in the negative correlation between the number of residential communities and the spatial distribution of enterprises. Particularly, the living convenience generates a significant influence on economically developed cities such as Guangzhou, Shenzhen, Foshan, and Dongguan. Notably, its influence exhibits obvious spatial heterogeneity.

Collaborative innovation environment, a local variable, shows a regression bandwidth of 141, with its influence presenting relevant spatial variation. Additionally, the regression coefficient of this variable ranges from −0.136 to 1.761, with an average of 0.332. The samples related to collaborative innovation environment with significant coefficients account for 39% of the total samples, which all reflect the positive influence on the spatial distribution of enterprises. Spatially, the positive influence of this variable is concentrated in Shenzhen in the southeast, especially in the eastern part of the Pearl River Delta region. The specialized and sophisticated "Little Giant" enterprises serve as a crucial carrier for the Pearl River Delta region to implement the innovation-driven development strategy. The proximity of these enterprises to universities and scientific research institutions facilitates the formation of a favorable collaborative innovation environment, enabling the establishment of innovation cooperation platforms. Furthermore, the "Little Giant" enterprises can more quickly realize technological innovation while enhancing the technical content and added value of their products through cooperation with universities and scientific research institutions. In Shenzhen, a representative region that proactively promotes school-enterprise cooperation, the collaborative innovation environment exerts a significant positive influence on the spatial agglomeration and distribution of enterprises. Nonetheless, the western region of the Pearl River Delta requires further strengthening industry–university–research cooperation construction in an attempt to cultivate more "Little Giant" enterprises with innovative impetus.

The result of the synthesis of the bandwidth of each variable indicated that all areas within the Pearl River Delta region share a similar natural geographical condition characterized by a low-altitude and dense water network. Accordingly, natural geographical conditions (i.e., altitude, slope, and distance from water) exert a similar influence on the spatial distribution of the "Little Giant" enterprises within the Pearl River Delta region, which is manifested as a large-scale global influence. Meanwhile, the Pearl River Delta region, a region with rapid urban development and an active economy in China, is gradually promoting urban integration. In this context, various cities focus on inter-city cooperation to build industrial clusters while developing industries in a dislocation way, thus making diverse factors such as industrial structure and the degree of land development generate a global influence on the spatial distribution of "Little Giant" enterprises. Furthermore, regarding some factors concerning market and society dimensions, such as industrial platform, road network density, living convenience, collaborative innovation environment, etc., the construction and distribution of specific facilities in various regions show the corresponding heterogeneity in space. Specifically, the spatial differences between different factors and their interaction lead to differences in the influence on the spatial distribution of the "Little Giant" enterprises, which is ultimately manifested as the scale difference of the influential effect.

5 CONCLUSIONS AND DISCUSSION

Taken together, with the Pearl River Delta region where "Little Giant" enterprises are concentrated as the research area, this work utilizes global Moran's I, multi-distance spatial cluster analysis (Ripley's K-function), kernel density analysis, and standard deviational ellipse to visualize and explore the spatial and temporal distribution characteristics of "Little Giant" enterprises. On these grounds, this research further explores the spatial distribution driving mechanism of specialized and sophisticated "Little Giant" enterprises on the grid scale of 10 km×10 km by using MGWR, thereby summarizing relevant laws.

This work has two main contributions. First， this work reveals the spatial differentiation and spatial-temporal evolution characteristics of the specialized and sophisticated "Little Giant" enterprises within the Pearl River Delta. From the perspective of the evolution of the agglomeration scale, the spatial distribution of the "Little Giant" enterprises has exhibited agglomeration to a certain extent, with the agglomeration gradually degree each passing year, and the distribution characteristics of these enterprises are related to the development scale and regional collaboration of the Pearl River Delta metropolitan area where these enterprises are located. From the perspective of the overall spatial and temporal distribution pattern, the enterprises exhibit the spatial distribution characteristics with Shenzhen as the main core as well as a significant agglomeration effect in Shenzhen, Dongguan, and Guangzhou, with the agglomeration degree annually increasing.

Another major contribution of this work is the comprehensive identification of the factors affecting the distribution of the specialized and sophisticated "Little Giant" enterprises within the Pearl River Delta in terms of the four dimensions of physical geography and location, government, market, and society, as well as their scaling effects, which can serve as a reference for the formulation of policies related to the selection of SMEs' locations and planning in the region. Specifically, five factors, encompassing altitude, slope, industrial structure, industrial platform, and the degree of land development, exert a significant influence on the global spatial distribution of the enterprises. Meanwhile, another five factors, including distance from water, the degree of government intervention, road network density, living convenience, and collaborative innovation environment, pose a significant influence on the local spatial distribution of the enterprises. The industrial platform, as a core factor, exhibits the most significant degree of influence. In addition, the factors influencing the spatial distribution of the enterprises present scale effect differences in their functions. Specifically, the influence of five factors, encompassing altitude, slope, distance from water, industrial structure, and the degree of land development, is close to the global scale, displaying insignificant spatial heterogeneity. Enterprises should give full consideration to natural and locational conditions when choosing a site. At the same time, by strengthening the construction of industrial cooperation platforms and improving the system of financial and tax protection, we can give full play to the role of global factors in promoting the development of the"Little Giant" enterprises. The degree of government intervention, industrial platform, road network density, living convenience, and collaborative innovation environment, as local variables, reflect a relatively limited influence scale on the spatial distribution of the "Little Giant" enterprises, showcasing spatial heterogeneity. Regarding such factors, more targeted measures must be takes according to the local conditions.

Our research still has some limitations. First, the work has only considered the influence of the external environment in the selection of enterprise influencing factors, ignoring the influence of intra-enterprise and inter-enterprise factors. Future research can go deeper from the perspectives of micro-enterprise employees and leaders, meso-enterprise organizations and networks, macro-institutions and cultures, etc., and through the analysis of enterprise patents, investment flows and other organizational and operational data, we can build a relationship network between enterprises or between enterprises and other actors, and further explore how the network affects the "Little Giant" enterprises. Second, there are differences in the size and industry of the"Little Giant" enterprises, and the spatial distribution and influencing factors of these heterogeneous enterprises may also differ, but the work does not distinguish between them. These shortcomings will be emphasized and remedied in subsequent studies.

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