

Spatial-temporal Patterns and Characteristics Analysis of the Development of Specialized, Fined, Peculiar, Innovative Small and Medium-sized Enterprises in Jiangsu Province based on MGWR Model

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Abstract: As the traditional manufacturing industries face transformation and upgrading challenges in today's dynamic economic environment both domestically and internationally, the Specialized, Fined, Peculiar, Innovative (SFPI) small and medium-sized enterprises (SMEs) have emerged as a major force in driving industrial transformation. In the context of digital economic development, these SFPI SMEs continuously address new market demands and enhance their competitiveness through technological innovation and product research and development. Jiangsu province as a manufacturing powerhouse in China has a relatively high proportion of contribution from the manufacturing sector to its GDP (with 4.66 trillion yuan in manufacturing value added in 2023, up 7.6%, accounting for 36.3% of the region's GDP). Boasting a complete industrial chain and leading scale in the country, the province provides abundant development opportunities and market demand for SFPI SMEs. Therefore, this paper takes various districts and counties of Jiangsu Province as the research object, using the economic center of gravity and the standard error ellipse analysis to explore the scope, trend, and distribution patterns of economic development in the region. Additionally, it utilizes the Geographically Weighted Regression model (MGWR) to examine the development pattern of SFPI SMEs in Jiangsu province, taking full consideration of multiple factors influencing the development of fintech, such as economic foundation, technological level, and regulation support. Due to the spatial-temporal heterogeneity of these factors, the MGWR model can effectively

capture these variations, thus providing valuable insights for Regulation crafting and resource allocation.

Keywords: MGWR; SMEs; Spatial-temporal Patterns; Characteristics Analysis; Medium-sized Enterprises

1. Introduction

In the context of economic globalization, division of labor based on specialization in the manufacturing industry has become an inevitable choice for optimizing resource utilization and enhancing efficiency. This division of labor leads to an infinite subdivision of both value chains and industrial chains, giving rise to diverse forms of enterprises. To continuously enhance their core competitiveness, SMEs need to constantly engage in technological innovation and industrial upgrading, so as to move towards the middle to high-end of the industrial chain.

SFPI SMEs play an significant role in promoting enterprise transformation, facilitating industrial structure optimization, enhancing the added value of the industrial chain and boosting high-quality economic development[1,2]. Therefore, studying the distribution and influencing factors of SFPI SMEs in Jiangsu Province is essential to better reveal the characteristics and development trend of regional economy in Jiangsu Province, promote further technological innovation and achievement transformation, and provide solutions for optimizing the business environment.

Regression model is a commonly adopted statistical tool for the analysis and prediction of correlation between different explanatory variables and dependent variables. Common regression models include Ordinary linear

regression (OLR)[3,4], logarithmic mean Dietscher exponent method[5,6], STIRPAT[7,8] and environmental Kuznets curve[9,10]. However, the majority of these studies adopt a global perspective and fail to fully consider the spatial heterogeneity and scale differences among research units, thereby imposing certain limitations. Geographically Weighted Regression (GWR)[11], being one of the superior models for addressing spatial heterogeneity, allows the regression coefficient to vary with spatial location changes, thereby standing out as an effective model to explain the local spatial correlation and spatial heterogeneity of variables. However, it fails to consider different spatial scales between different independent variables and dependent variables. The Multiscale Geographical Weighted Regression Model (MGWR) as a further refinement of the GWR model adopts specific spatial bandwidth for each variable to allow different degrees of spatial smoothness[12]. It enables better consideration of the spatial scale and location influences, resulting in more realistic and reliable results. Therefore, the MGWR model has gained extensive application in the research of economics, sociology, geography and so on.

To sum up, this paper focuses on SFPI SMEs in Jiangsu Province as the research object, and successively uses center of gravity analysis and standard deviational ellipse analysis to explore their spatial distribution law. It further uses the MGWR model to explore the spatial relationship between various factors that influence the development of SFPI SMEs. The aim of this study is to provide strong support for precise policymaking and industrial development planning targeting at SFPI SMEs in Jiangsu Province and promote the strategic decision-making of fintech enterprises.

2 Overview of the Study Area, Data and Methods

2.1 Overview of the Study Area

Jiangsu Province is situated in the central region of China's eastern coastline, in the lower reaches of the Yangtze River and Huaihe River, bordered to the east of the Yellow Sea, at the confluence of China's East

coast Economic belt and the Yangtze River Economic Belt. Jiangsu comprises 13 prefecture-level cities and 95 counties (including cities and districts), as illustrated in Figure 1. In response to the national decision of accelerating the cultivation of SFPI SMEs, Jiangsu has implemented a three-year action plan to promote SMEs towards developing into Specialized, Fined, Peculiar and Innovative enterprises through policy guidance and support. By 2025, the province aims to cultivate a total of 300 manufacturing champions alongside no fewer than 1,500 SFPI "small giant" enterprises, as well as a number of SFPI SMEs.

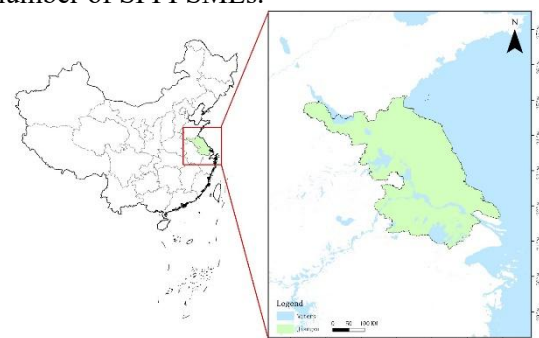


Figure 1. Map of the Study Area

In response to the national call to promote the high-quality development of SMEs, Jiangsu Province has put forward a three-year action plan (2023-2025) for the cultivation of SFPI SMEs. Through policy guidance and support, the province aims to promote SMEs towards developing into Specialized, Fined, Peculiar and Innovative enterprises, and enhance the core competitiveness and market position of SMEs. Various cities in Jiangsu Province exhibit notable disparities in the level of development. On one hand, there are economically advanced cities with rich scientific and technological resources, such as Nanjing, Suzhou, and Wuxi, which exhibit coordinated industrial chain development, thereby forming a relatively comprehensive ecological system. On the other hand, some cities in Jiangsu Province remain economically underdeveloped, such as Suqian and Huai'an, which lag behind in technological innovation and industrial agglomeration processes, resulting in the absence of a clearly defined resource support framework and business ecosystem.

2.2 Research Data

In this study, natural factors, social and

economic factors are considered as research variables. The data used in the analysis are obtained from the “Jiangsu Statistical Yearbook 2020-2023” and the Enterprise Records website. Based on relevant literature,

12 factors that have a significant impact on the development of SFPI SMEs are selected as explanatory variables, which include year-end registered population, land area and so forth. As shown on Table 1:

Table 1. Explanatory Variable Description

VARIABLE	VARIABLE DESCRIPTION	Unit	SPACIAL RESOLUTION	TEMPORAL RESOLUTION
NO. OF SMES	No. of SFPI SMEs	No.	County scale	Annual
LAND AREA	County land area	km ²	County scale	Annual
POPULATION	Year-end registered population	10,000	County scale	Annual
GDP	Gross Regional Product	100 million yuan	County scale	Annual
ADDED VALUE OF SECONDARY AND TERTIARY INDUSTRIES	Total output of secondary and tertiary industries - intermediate input of secondary industries	100 million yuan	County scale	Annual
GENERAL PUBLIC BUDGET	General Public Budget Revenue	100 million yuan	County scale	Annual
INVESTMENT IN REAL ESTATE DEVELOPMENT	Engagement in Real estate development or operations	100 million yuan	County scale	Annual
TOTAL RETAIL SALES OF CONSUMER GOODS	Retail sales of consumer goods in society	100 million yuan	County scale	Annual
TOTAL VOLUME OF FOREIGN TRADE	Import and export situation	100 million yuan	County scale	Annual
ACTUAL UTILIZATION OF FOREIGN CAPITAL	Utilization of foreign capital	100 million dollars	County scale	Annual

2.3 Research Methods

2.3.1. Calculation method of economic center of gravity

The economic center of gravity is the central equilibrium point of economic power in all directions of regional economy, and its coordinate migration reflects the development trend of SFPI SMEs in urban agglomerations. The main parameters include the economic center of gravity, the moving distance and moving direction of the economic center of gravity. The calculation formula is shown below:

$$G_x = \frac{\sum_{i=1}^n w_i x_i}{\sum_{i=1}^n w_i} \quad (1)$$

$$G_y = \frac{\sum_{i=1}^n w_i y_i}{\sum_{i=1}^n w_i} \quad (2)$$

In the formula, G_x and G_y represent the economic center of gravity coordinates of the ellipse, w_i represents the weight, here we use

the number of SFPI SMEs, x_i represents the latitude of the i-th county or city, while y_i represents the longitude;

2.3.2. Calculation method of standard error ellipse

It is often used to analyze the spatial distribution characteristics of economic geographic elements in economics and geography, and its parameters include barycentric coordinates, rotation angle θ , standard deviation of major semi-axis and standard deviation of minor semi-axis, etc.

2.3.3. Calculation method of MGWR model

The MGWR model is constructed based on the development data of SFPI SMEs in various districts and cities of Jiangsu Province, while taking into account the unique driving factors for each region. The mathematical expression is as follows:

$$y_i = \beta_0(u_i, v_i) + \sum_{k=1} \beta_k(u_i, v_i)x_{ik} + \varepsilon_i \quad (3)$$

In this formula, y_i is the dependent variable,

representing the development level of SFPI SMEs in a certain city at a certain time;

(u_i, v_i) : coordinates of the i -th district or county;

$\beta_0(u_i, v_i)$: Regression constant term of the i -th district or county;

x_{ik} : Explanatory variables of the i -th district or county at time t (e.g., economy, scientific and technological input, infrastructure, etc.);

$\beta_k(u_i, v_i)$: The k -th regression coefficient of the i -th district or county, specifically it is the regression coefficient with spatial variation, which is used to explain the development disparities of SFPI SMEs in different regions and periods.

ε_i : Random error term for the i -th district or county observation area.

3. Experimental Results and Analysis

3.1 Analysis of Spatial Distribution Characteristics

As shown in the Figure 2, the results of economic center of gravity analysis show that from 2015 to 2021, the economic center of gravity of Jiangsu Province is basically located near the Yangtze River Basin, which obviously deviates from the geometric center of Jiangsu, reflecting unbalanced economic development in the Province.

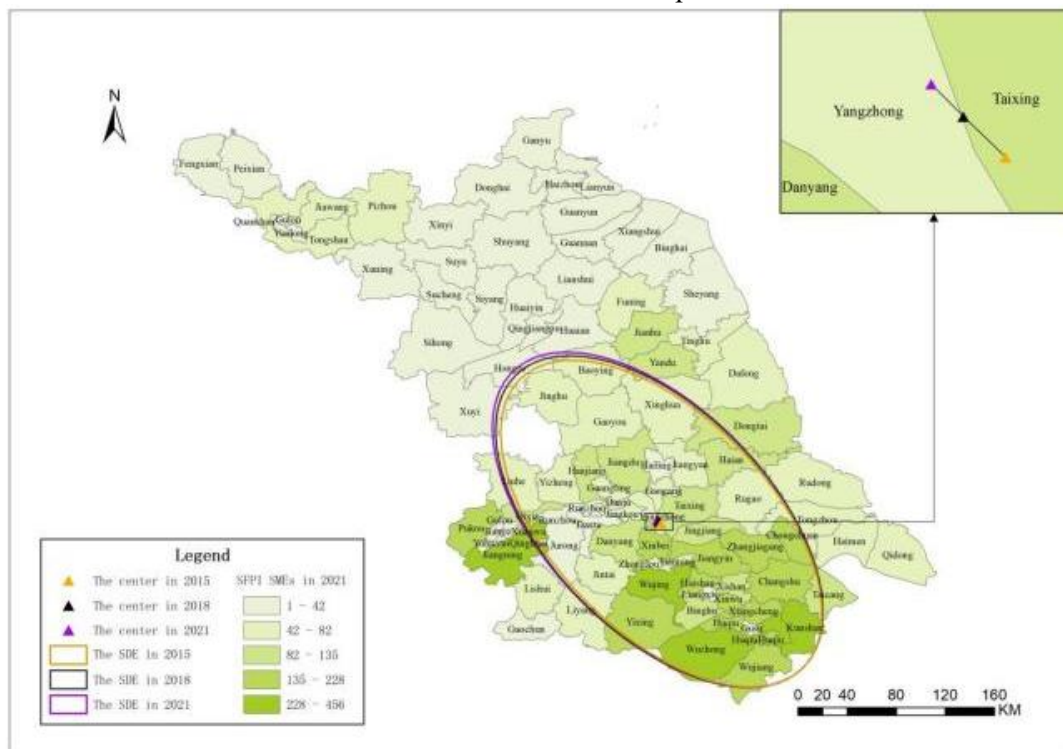


Figure 2. Economic Gravity Center Migration and Standard Deviation Ellipse of Jiangsu Province based on Data of SFPI SMEs

Table 2. Regression Analysis of Explanatory Variables based on MGWR

VARIABLE	BANDWIDTH	MEAN	STD	MIN	MAX
INTERCEPT	44	0.18	0.086	-0.005	0.378
YEAR-END REGISTERED POPULATION	52	0.416	0.083	0.258	0.539
LAND AREA	43	0.702	0.158	0.411	1.006
SECONDARY INDUSTRIES	45	13.213	0.332	12.723	13.752
TERTIARY INDUSTRIES	94	10.608	0.007	10.597	10.626
GENERAL PUBLIC BUDGET REVENUE	94	0.199	0.006	0.188	0.214
INVESTMENT IN REAL ESTATE DEVELOPMENT	94	-0.197	0.017	-0.232	-0.176
TOTAL RETAIL SALES OF CONSUMER GOODS	93	0.196	0.015	0.168	0.23
TOTAL VOLUME OF FOREIGN TRADE	94	-0.629	0.017	-0.645	-0.596

The results of standard deviation ellipse

analysis show that the region along the

southeast to northwest direction of Jiangsu Province dominates the province's economic volume from 2015 to 2021 (Figure 2). With the progression of time, the standard deviational ellipse gradually expands, with the elliptic oblateness increasing from 0.79 in 2015 to 0.81 in 2018 and further to 0.82 in 2021, indicating a growing dispersion in economic development and a continuous rise in economic equilibrium within Jiangsu.

Since the unbalanced development of regional economy is caused by agglomeration economy, the rise of economic agglomeration will inevitably lead to the problem of unbalanced development. The balanced economic development of various cities in Jiangsu Province provides a good demonstration for the comprehensive, coordinated and sustainable development of the country.

3.2 Scale Analysis and Regression Analysis

Based on the MGWR model, the regression results of the development of SFPI SMEs in Jiangsu Province and their influencing factors are shown in the following Table 2. It can be seen from the Table 2 that the bandwidth value is 43 for land area, 45 for the secondary industries, and 52 for the year-end registered population, which indicate a significant spatial heterogeneity in the development of SFPI SMEs. That means that these variables have a greater impact on the development of SFPI SMEs in a local scope. The bandwidth value of the variables such as gross regional product, general public budget revenue, investment in real estate development, and total volume of foreign trade is 94, indicating an absence of spatial heterogeneity, which means that these variables impact on the development of SFPI SMEs in the global scope.

In the regression results of MGWR, the regression coefficients of year-end registered population, land area, secondary industries, tertiary industries, general public budget revenue, housing, total retail sales of consumer goods, total exports and actual use of foreign capital are all positive. The average value of the secondary industries is the largest, indicating the greatest positive impact on the development of SFPI SMEs. The regression coefficients of gross regional product, investment in real estate development and

total volume of foreign trade are all negative, with the average value of gross regional product being the smallest, which has the greatest negative impact on the development of SFPI SMEs.

3.3 Spatial Pattern Analysis of Regression Coefficients

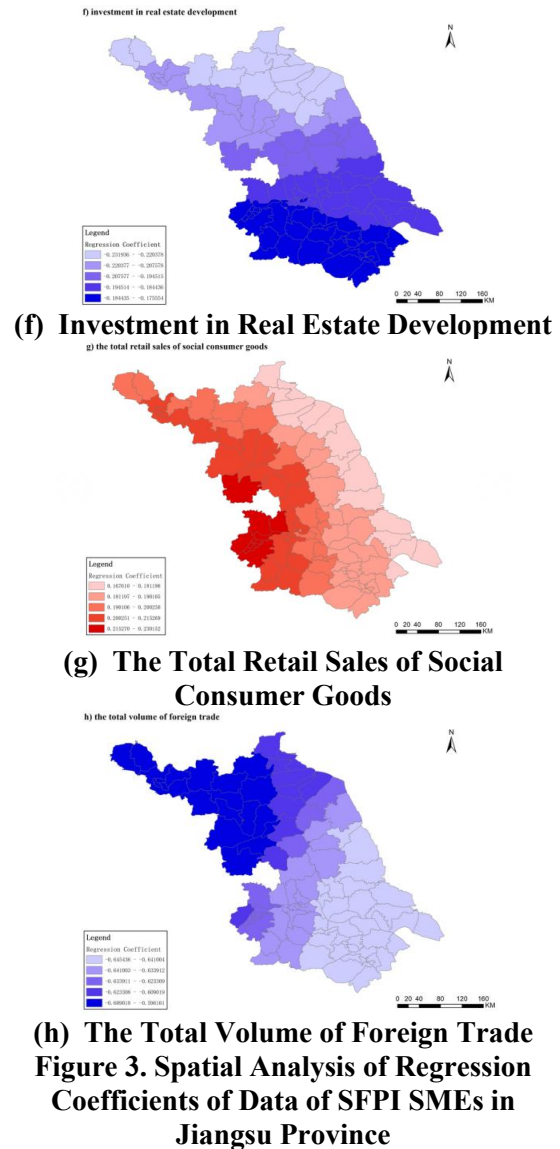
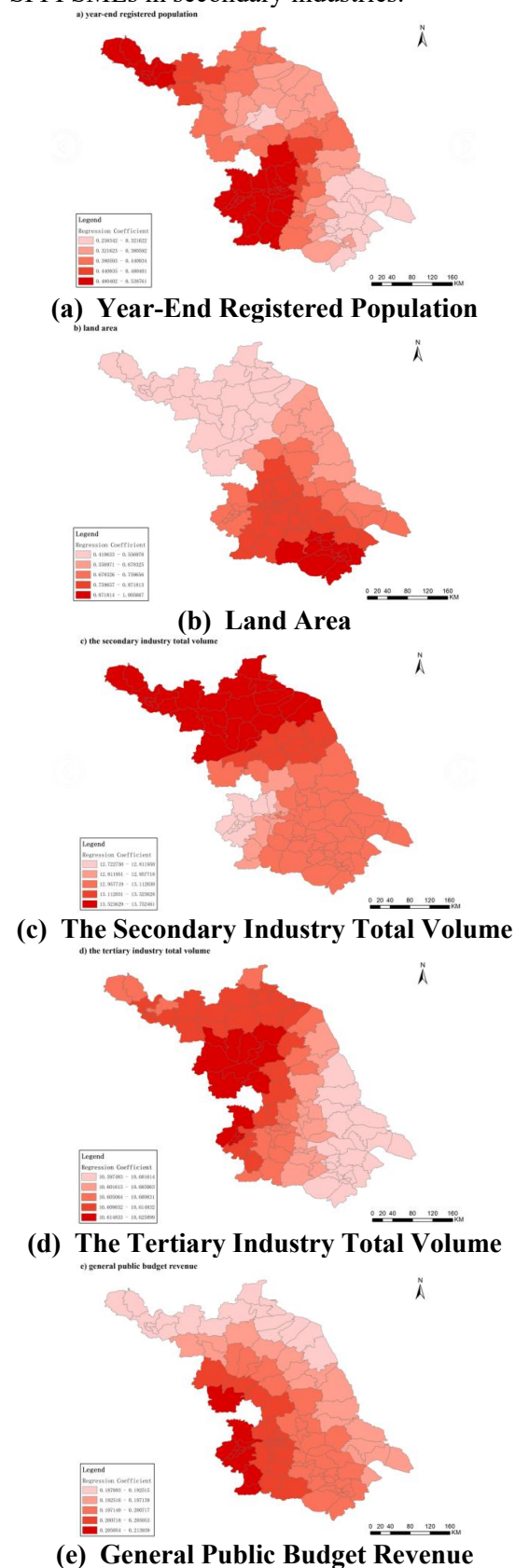
Through spatial regression analysis, this paper explores how various variables impact on the development of SFPI SMEs from multiple perspectives, and analyzes the distribution pattern of regression coefficients of each variable under different action scales. As shown Figure 3:

The bandwidth value of the year-end registered population is 52, indicating a great impact on the development disparities of SFPI SMEs. The regression coefficient is positive, indicating a greater number of SFPI SMEs with a larger year-end registered population. It exhibits a greater positive impact on the development of SFPI SMEs in the southwest of Jiangsu Province, which reaches the maximum value near Nanjing, Zhenjiang and Yangzhou. The relatively greater impact of the population factor in this region is primarily due to the population siphon effect in southern Jiangsu and Shanghai.

The bandwidth value of land area is 43, indicating a great impact on the development disparities of SFPI SMEs. The regression coefficient is positive, indicating a greater number of SFPI SMEs being attracted to regions with larger land area and stronger development degree. Especially in Suzhou, Wuxi and Changzhou, relying on excellent location advantages and high degree of land development in this region, a high-quality business environment has been created to provide ample opportunities for vigorous development of SFPI SMEs.

The bandwidth value of the secondary industry total volume is 45, indicating a great impact on the development disparities of SFPI SMEs. The regression coefficient is positive, indicating a greater number of SFPI SMEs with more total volume generated in secondary industries. Its positive impact on SFPI SMEs exhibits a stepped distribution from northwest to southeast. And the impact is greater in Xuzhou, Huai'an, Suzhou and Yancheng due to a larger number of secondary industries such as construction machinery,

steel, coal, chemical engineering and equipment manufacturing in this region, which leads to an agglomeration effect of SFPI SMEs in secondary industries.



The bandwidth value of the tertiary industry total volume is 94, indicating an absence of special heterogeneity for the development of SFPI SMEs. The regression coefficient is positive, indicating a greater number of SFPI SMEs with more total volume generated in tertiary industries. This index as a global influencing factor suggests that moderate scale agglomeration of the tertiary industries is conducive to the cultivation and growth of SFPI SMEs.

The bandwidth value of general public budget revenue is 94, indicating an absence of special heterogeneity for the development of SFPI SMEs. The regression coefficient is positive, indicating a greater number of SFPI SMEs with more general public budget revenue. It shows a decreasing trend from southwest to northeast, which reaches the highest value in Nanjing. With the overlapping advantages of a

state-level new district and Jiangsu Free Trade Zone, Nanjing has invested continuous efforts in improving its infrastructure construction, implementing preferential tax policies and optimizing the business and market environment, thereby promoting the robust and stable development of SFPI SMEs.

The bandwidth value of investment in real estate development is 94, indicating an absence of special heterogeneity for the development of SFPI SMEs. The regression coefficient is negative, indicating a smaller number of SFPI SMEs with more investment in real estate development. It shows a decreasing trend from southern Jiangsu, to central Jiangsu and the northern Jiangsu. With the boom of the real estate market, financial institutions are more inclined to invest in the high-profit real estate industry, resulting in greater difficulties in financing and rising rental costs for SFPI SMEs.

The bandwidth value of the total retail sales of social consumer goods is 93, indicating an absence of special heterogeneity for the development of SFPI SMEs. The regression coefficient is positive, indicating a greater number of SFPI SMEs with more investment in the total retail sales of social consumer goods. The consumption capability and willingness of residents in the retail market provide an important reference for the market demand of SMEs. Compared to southern Jiangsu, Nanjing exhibits a slightly lower proportion of foreign capital. However, in comparison to northern and central Jiangsu, the residents of Nanjing enjoy a relatively higher living standard and experience stronger market demand. Consequently, this region witnesses greater investment in SFPI SMEs, making it easier for them to gain favor and support from financial institutions.

The bandwidth value of the total volume of foreign trade is 94, indicating an absence of special heterogeneity for the development of SFPI SMEs. The regression coefficient is negative, indicating a greater number of SFPI SMEs with more total volume of foreign trade. With the advancement of globalization and the continuous development of international trade, an increasing number of SFPI SMEs are engaging in the global market, intensifying market competition. Enterprises in northern Jiangsu often face disadvantages in terms of capital, technology, and brand, making it

challenging to compete with large enterprises or multinational companies. In contrast, enterprises in southern Jiangsu possess well-established upstream and downstream industry chains and have more capabilities and experience to withstand market risks.

4. Conclusions and Discussions

This study focuses on SFPI SMEs in Jiangsu Province as the research object, integrating natural and social-economic statistics with geospatial data to investigate the spatial displacement characteristics and aggregation distribution of SFPI enterprises using models such as economic center of gravity and annotated difference ellipse. Additionally, a Multi-scale Geographical Weighted Regression model (MGWR) is employed to analyze the influencing factors and spatial heterogeneity of the spatial distribution of SFPI SMEs. The key findings are as follows:

(1) In terms of spatial distribution, the majority of regions in southern Jiangsu serve as primary hubs for SFPI enterprises. Meanwhile, Nanjing, the provincial capital city, and regions along the Yangtze River also attract a substantial number of SFPI enterprises. Regarding industry composition, SFPI enterprises in Jiangsu Province exhibit a distinct “unbalanced trend, wherein sectors such as electronic information, biomedicine, new energy, intelligent equipment, and high-tech manufacturing and other real economy industries account for a relatively high proportion. This aligns with the original intention of the policy promoting the development of SFPI enterprises.

(2) In terms of center of gravity and displacement, the focus of SFPI enterprises in Jiangsu Province is located along the Yangtze River, which deviates significantly from the geometric center of Jiangsu Province. Moreover, there is an overall southeast to northwest displacement, with a faster pace observed between 2015 and 2018, followed by a deceleration from 2018 to 2021.

(3) Regarding influencing factors, the spatial distribution of SFPI enterprises is jointly influenced by physical geography, industrial policy, and social dimensions. Among these factors, the tertiary industries, general public budget revenue, investment in real estate development, and total volume of foreign trade are considered core factors with the

highest correlation values.

This paper focuses on analyzing the spatial distribution and agglomeration characteristics of SFPI SMEs, providing a brief demonstration of the distribution patterns and evolution trends. In future research, the Moran index, cold hot spot analysis, Theil index and GTWR can be employed to further explore the correlation factors and temporal changes impacting SFPI SMEs, analyze the causes and predict future development trends, thereby offering valuable insights for Jiangsu Province in formulating tailored support policies for SFPI enterprises.

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