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Evolution Model and Driving Mechanism of Urban Logistics Land: Evidence from the Yangtze River Delta

Jun Cao [1,*], Yangfei Zhu [1], Haohao Zhu [1], Sidong Zhao [1] and Junxue Zhang [1,2,*]

[1] School of Architecture, Southeast University, Nanjing 210096, China; zhuyangfei@seu.edu.cn (Y.Z.); hhzhu@seu.edu.cn (H.Z.); 230189013@seu.edu.cn (S.Z.)
[2] School of Civil Engineering and Architecture, Jiangsu University of Science and Technology, Zhenjiang 212100, China
* Correspondence: juncao_0711@seu.edu.cn (J.C.); zjx2021@just.edu.cn (J.Z.)

Abstract: Logistics land is the spatial carrier for the development of logistics enterprises. Its evolution mode and driving mechanism determine the level of high-quality development of the logistics industry, and serve as an important basis for urban planning and territorial spatial planning. This study introduced a Boston consulting group (BCG) matrix and geographically weighted regression (GWR) spatial econometric models to carry out empirical research on the Yangtze River Delta (YRD), in an effort to provide scientific information for evidence-based decision-making by governments and enterprises. The scale and ratio of logistics land (LLS and LLR) in the YRD showed significant spatial heterogeneity and autocorrelation, cities with large logistics land use converging from clusters to belts from 2000 to 2020, and agglomerations with high logistics land ratio (LLR) migrating from inland to coastal areas. Diversified models of logistics land evolution also emerged, such as high scale–high speed cities, low scale–low speed cities, high scale–low speed cities, and low scale–high speed cities. In addition, the driving mechanism of LLS and LLR was very complex, with a great difference in the intensity, nature and spatial effects of the influence of different factors. The inspiration from empirical case studies is urgent to revise the planning norms and clarify the LLS and LLR control standards for logistics land use. Meanwhile, the synergistic development target of the logistics industry in the new era is changing from the manufacturing industry to the commerce and trade industry; the establishment of planning zoning and the designing of differentiated management policies significantly improve the planning applicability.

Keywords: logistics land; urban logistics; evolution model; impact factors; spatial planning; China

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1. Introduction

In the introduction, we will briefly introduce the background of this study, review and comment on the literature, and highlight research gaps and propose questions.

1.1. Background

Modern logistics is connected to production at one end and consumption at the other, and is highly integrated and combined with transportation, warehousing, distribution, delivery, information and other service functions. As an important support for extending the industrial chain, upgrading the value chain and building the supply chain, it plays a pioneering, fundamental and strategic role in the process of building a modern circulation system and constructing a modernized economic system. With the development of global international trade and e-commerce, the logistics industry has occupied an increasingly prominent strategic position in economic development, and its development degree has grown into one of the important symbols to measure a country's modernization level and comprehensive national strength [1]. Logistics land serves as a spatial carrier for the development of the logistics industry, and it typically manifests as logistics parks, express centers, transit hubs, warehousing bases, cross docks, mini hubs, last mile deliveries, etc. The spatial distribution, expansion and evolution of logistics land reflect the development of the urban and regional logistics industry, and will also affect the layout of urban and regional transportation facilities, the function and structure of land use, ecological space and the quality of the human habitat [2,3]. In urban and spatial planning, logistics land research focuses on the analysis of area scale and proportion values. Therefore, analyzing the spatio-temporal evolution patterns of logistics land use in cities and regions and its driving mechanism to provide a basis for the design of territorial spatial planning and development policies for the logistics industry has become an urgent task in the new era [4,5]. It should be noted that logistics has been of great interest to many disciplines such as geography, planning, economics, and management. However, the extreme complexity of the logistics industry and logistics land leads to the teaching vacancy of logistics land in land use planning education, making it urgent not only for the academic but the entire industry to master the development rules and spatial design methods of urban logistics land [6,7].

The Chinese government attaches a great importance to the development of the logistics industry and the management of logistics land, as evidenced by the fact that in recent years it has successively issued national policies such as the Adjustment and Revitalization Plan for the Logistics Industry, "Opinions on Policies and Measures for Promoting the Healthy Development of the Logistics Industry", an Announcement on the Continuing Preferential Policies on Urban Land-Use Tax for Land Use for Warehousing Facilities for Logistics Enterprises for Bulky Commodities, the Medium- and Long-Term Plan for the Development of the Logistics Industry, Opinions on the Promotion of the Synergistic Development of E-commerce and Express Logistics, a Notice on the Implementation Opinions on Further Reducing the Costs of Logistics, and the "14th Five-Year Plan" for the Development of Modern Logistics. Logistics has become an emerging service sector of China's national economy, and also a fundamental industry that integrates transportation, warehousing, freight forwarding, information and other business forms [8].

Cities, as the key nodes and important carriers of logistics development, are the concentrated embodiment of the development level and the comprehensive strength of a country's logistics industry. Therefore, the central government of China has started the pilot work of modern logistics innovation and development in cities, so as to improve the influence and driving force of the urban economy and to better lead the coordinated development of regional logistics. Urban logistics is mostly concentrated in logistics parks. According to the Sixth National Logistics Park (Base) Survey Report (2022), about 43.1% of logistics parks in China believe that land resources have become a key factor restricting the high-quality development of logistics parks in the new era [9,10]. Therefore, the empirical study on the evolution model of urban logistics land and its driving mechanism will provide decision-making reference for cities and logistics parks to break land resource constraints, and it is of great significance for the optimization of the built environment of China's cities and the sustainable development of the region.

1.2. Literature Review

Logistics land belongs to an emerging research field, which is more manifested as logistics facilities and logistics parks (clusters of logistics facilities and enterprises) in the actual production and life processes. Meanwhile, logistics planning is one of the important contents of urban spatial planning, so the literature reviews focus on "Logistics Land and Logistics Park" and "Logistics Facility and Spatial Planning".

1.2.1. Logistics Land and Logistics Park

Due to the close relationship between logistics and transportation facilities, most scholars focused on the discussion of the interaction between the transportation system and logistics land use in the early studies. For example, Woudsma [11] empirically investigated the impact of the transportation system on urban logistics land patterns using a spatial autoregressive model, and Wagner [12] evaluated the impact of different logistics land designs on the reduction in traffic and the planning of the transportation system. Scholars then discussed the impact of urban and regional land use-related factors and policies on the location and business planning of logistics firms. For example, Jakubicek [13] analyzed the impact of urban land use costs, land use tax rates, and the land area expansion potential of business sites on the location of logistics firms, and Van [14] analyzed the coupling between land allocation policies and logistics agglomerations.

With the soundness of logistics land statistics and census data, more and more scholars have begun to use a variety of econometric models to study the characteristics of logistics land use in recent years. On the one hand, some scholars have analyzed the spatial growth pattern of logistics space and activities in the metropolitan area and its driving mechanism, such as the empirical study on the Wuhan metropolitan area by Zhao [15] in 2010–2018 using a polynomial and metacellular automata model. On the other hand, more and more scholars are organizing empirical and case studies on the efficiency and intensification of logistics land use. For example, Song [16] analyzed the urban logistics land use efficiency and its determinants in the Yangtze River Economic Belt from 2000 to 2017 using the Tobit model, and believed that the tertiary industry and informatization had no significant positive driving relationship to logistics land use efficiency.

In addition, since most of the urban logistics land is concentrated in logistics parks, logistics parks have gradually become the focus of scholars' research. Spatial siting, functional area arrangement, distribution route planning, park scale and investment timing are the important factors affecting the high-quality development of logistics parks and they have become the focus of scholars' attention. For example, Xu [17] proposed a heuristic algorithm-based logistics park site selection model, Luo [18] created a two-stage layout method for the functional area of the logistics parks, Liang [19] proposed an optimization approach for the distribution path of the logistics park based on the improved artificial bee colony algorithm, and Zhang [20] analyzed the optimal investment time and scale of the construction of the logistics park from the perspective of real options.

Notably, in the context of the information age, especially the construction of smart cities, some scholars have analyzed the impact of new cloud industries such as e-commerce on the utilization methods and spatial distribution of urban logistics land. For example, Xiao [21] argued that e-commerce has become a determining force for logistics land design, location change, place redevelopment and reuse, and has become a catalyst for the remodeling of the urban logistics space. The development of e-commerce has brought about a multifaceted impact on logistics and its management. Firstly, e-commerce has pushed the informatization and modernization of logistics services, and boosted the efficiency and accuracy of logistics. Secondly, the logistics system has been more intelligent and automatic with a reduction in the labor costs and errors because of it. Finally, it has also promoted the transformation and upgrading of the logistics enterprises, and sped up the innovation and development of the logistics industry.

1.2.2. Logistics Facility and Spatial Planning

The high-quality development of the logistics industry inevitably requires the support of logistics facilities and space, and most scholars have begun to try revealing the development law of logistics land by analyzing different types of logistics facilities and spatial characteristics when no logistics land statistics or census data are available. The analysis and modeling of the logistics facility siting is the most popular research area. For example, Sakai [22] developed a logistics facility siting model that allows the distinction of categories of economic activities, Tang [23] proposed a logistics facility location model based on multi-objective sustainable development, and Xu [24] further proposed a bi-objective modeling approach for emergency logistics facility siting in response to uncertainty environments. The location characteristics of logistics facilities constitute the second most significant research area. For example, Sakai [25] quantitatively portrayed the locational dynamic characteristics of dynamic logistics facilities based on large-scale freight transport survey data, and Yang [26], based on the case study of Shanghai, quantitatively analyzed the spatial agglomeration characteristics of logistics facilities and the accompanying environmental consequences in the context of economic globalization and the e-commerce boom.

With the urban spatial expansion and the regional integration development, the geographic distribution pattern of logistics facilities and their spatial expansion or relocation patterns have attracted the attention of more scholars. For the former, most scholars focus on the study of geographical distribution, spatial pattern and network structure of specific logistics spaces such as airports [27], ports [28], logistics parks [29], and logistics centers or bases [30], and the gradual agglomeration of logistics spaces to the suburbs has become a consensus in the academic community. For the latter, Kang [31], Dablanc [32] and Rivera-Blasco [33] analyzed the stage characteristics and driving factors of logistics expansion in the Seoul metropolitan area of South Korea, in Los Angeles, California, in Seattle, Washington and in Madrid, Spain. Opasanon [34] conducted an exploratory study on the urban and spatial impacts of logistics facility relocation by hierarchical analysis.

Logistics plays an important role in the increasingly fierce urban competition. However, without systematic planning, logistics activities will have serious negative impacts on urban life and production and even ecology, thus scholars turned their attention to logistics planning [35,36]. Kin [37] proposed an approach to integrate logistics space into urban planning based on case studies of Paris and Rotterdam, and Kovac [38] further proposed a method for the conceptual planning of urban logistics. Sharma [39] put forward suggestions on the optimization of urban logistics spatial planning by evaluating and sorting relevant stakeholders of urban logistics. Guo [40] and Fahimnia [41] proposed methods for planning underground logistics and industrial logistics systems, respectively. With technological innovation, more innovative methods and models are applied to urban logistics spatial planning [42], such as the spatial design of a logistics network system and distribution paths based on hybrid heuristic algorithms [43] and genetic algorithms [44], and the planning and control model of intelligent logistics facilities, spaces, and parks based on the logistics 4.0 framework [45].

1.3. Research Gap and Question

In summary, the continuous improvement of the logistics land use research system provides valuable enlightenment for the development of this study in the terms of empirical route design, methodology and indicator selection. However, there is still room for improvement in the studies available, as follows.

From the perspective of research objects, except for a small number of scholars, most use logistics enterprises or facilities as alternative variables in their analysis of logistics land, rather than directly focusing on the land itself. The study on logistics land is a new field, and there are still relatively few results obtained directly at present. Most studies focus on logistics facilities, logistics space, logistics planning and other related fields, and logistics enterprises, facilities, spaces, parks, centers or bases have become the most common substitute variables. For example, it is the logistics firm that is used as a substitute variable in the empirical study [46] of logistics land use patterns in Canadian metropolitan areas.

In terms of research methodology, more and more econometric models, especially concerning emerging technological methods, have been applied to the research process, significantly improving the level of quantification and scientification. However, most of the papers are based on traditional statistics econometric models with less attention to spatial econometric models. It should be noted that logistics land shows significant externalities, and less attention to spatial effects will affect the accuracy of the analysis results or even produce erroneous research conclusions [47].

In conclusion, the scientific analysis of the distribution and change law of logistics land to analyze the evolution models of logistics land and its influencing factor is of great significance in guiding the rational layout and intensive use of logistics land and promoting the high-quality development of the regional logistics industry and urban economy. Therefore, this study integrates spatial econometric models such as the Boston consulting group (BCG) matrix, the global Moran's index and cold-hotspot analysis, and geographically weighted regression (GWR), with an attempt to quantitatively analyze the spatial and temporal evolution patterns of logistics land use in the YRD and its driving mechanisms so as to provide important information and evidence for evidence-based decision-making by governments and enterprises, and to provide a reference for urban planning and territorial spatial planning. In addition to applying the BCG model to integrate the spatio-temporal dimensions to analyze the evolutionary pattern of logistics land use in the YRD, this paper leverages the global Moran's index, cold-hotspot analysis and GWR to detect the spatial effects of logistics land use in the YRD, and to measure the strength, nature and mechanism of the impact of each factor.

2. Materials and Methods

In this section, a brief introduction is given to the location and basic situation of the case region, a detailed analysis is conducted on the research technology route and methods, and the reasons for constructing the indicator system and variable selection, as well as their data sources, are specifically introduced.

2.1. Study Area

The YRD is the spatial scope of this empirical case study, geographically covering four provincial-level administrative regions, namely, Shanghai, Zhejiang, Jiangsu, and Anhui, including 41 prefecture-level cities. It should be noted that since this study is based on data for a period of up to 20 years, when there have been changes in the administrative divisions of the cities in the YRD, the most recent administrative division maps are used to visualize them in map analysis. In order to circumvent the interference of repeated names of cities in different provincial administrative regions, Suzhou and Taizhou in Jiangsu Province were written as Suzhou–Jiangsu and Taizhou–Jiangsu, respectively, Taizhou in Zhejiang Province was written as Taizhou–ZheJiang, and Suzhou in Anhui Province was written as Suzhou–Anhui in data processing (Figure 1).

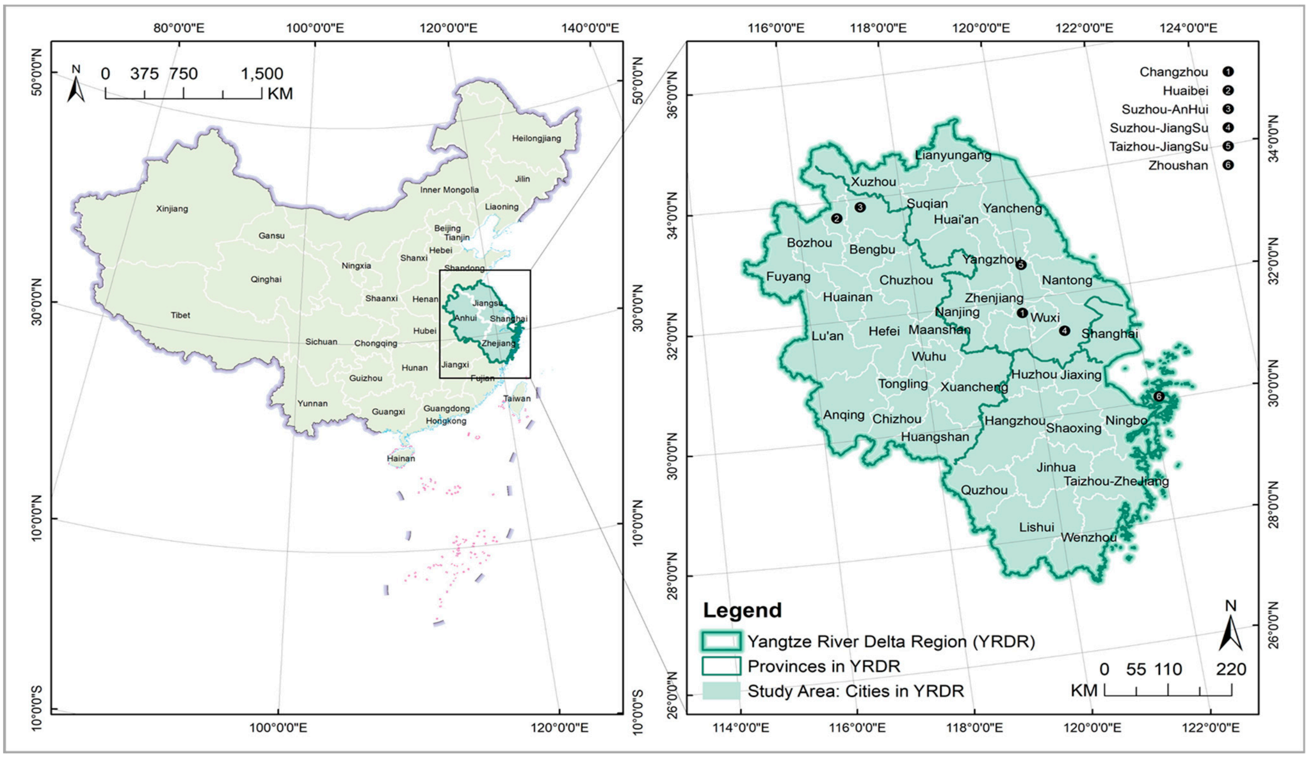

Figure 1. Study area: the Yangtze River Delta and its location in China.

There are two main reasons for choosing the YRD as the study area: firstly, it is the most developed region in China's logistics industry. As the economic zone with the strongest integrated development in China, YRD is the most developed and competitive logistics region, and it is also the largest area in China that provides a 24-h free delivery service. Secondly, both the central and city governments in the YRD attach great importance to the development of the logistics industry. The Plan for Higher Quality and Integrated Development of Transportation in the Yangtze River Delta Region calls for comprehensively upgrading the functions of integrated and efficient logistics services, improving logistics efficiency, reducing logistics costs, and promoting a rational division of labor and deeper integration of the industrial chain in the YRD. From the perspective of current development strength, future development potential, and national policy support and guidance, YRD is significantly representative in China and the world [48]. Therefore, the analysis of the spatio-temporal evolution patterns of logistics land use and its driving mechanisms based on the case study of YRD will provide useful references for similar regions and countries in China and the world.

2.2. Research Method

Based on the research background and literature review analysis, we chose the Yangtze River Delta as the study area and established a quantitative index system for data collection and processing. First, we introduced quantile spatial clustering, the global Moran's index and the cold-hotspot analysis tool to quantitatively analyze the geographical distribution pattern of logistics land. Second, we applied the BCG matrix to quantitatively analyze the spatio-temporal evolution pattern of logistics land. Third, we employed the GWR model to quantitatively analyze the driving mechanism of the spatial differentiation of logistics land. Finally, we discussed the results of the analysis and proposed the logistics land use planning implications (Figure 2).

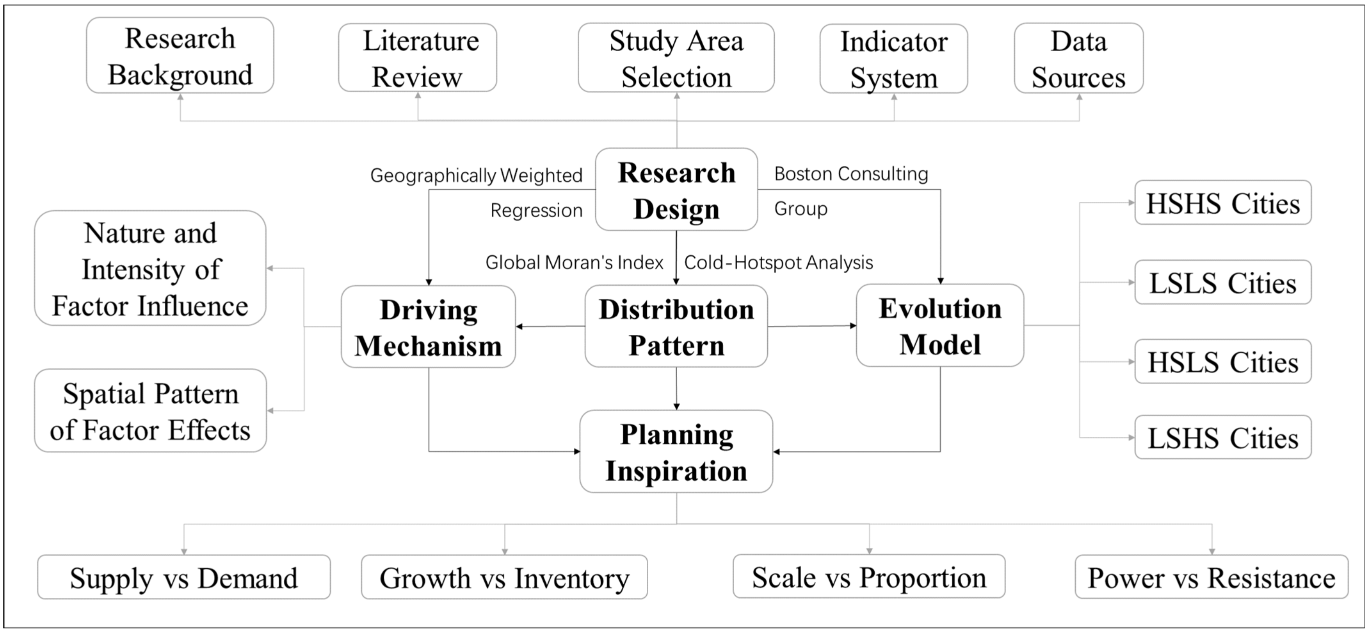

Figure 2. Research ideas and technical roadmap.

2.2.1. Boston Consulting Group (BCG) Matrix

In the quantitative analysis of the evolutionary pattern of urban logistics land use in the YRD it is important to consider the growth capacity in the time dimension and also emphasize the regional status in the spatial dimension. Therefore, the Boston matrix is a suitable econometric model, which is mostly used in analyzing the development strategy of enterprises. By analyzing the interaction of product market share and growth rate, it classifies the products into star, gazelle, cow, and dog types [49]. In this study, the average growth rate (GR_i) of logistics land in each city of YRD from 2000 to 2020 is used to represent the change in the time dimension, and ULL_{i-end} and ULL_{i-star} are used to represent the scale or density parameters of logistics land in the i-th city at the end of the period and in the base period, respectively. And the regional status in the spatial dimension is represented using the relative share (RS_i) of logistics land for each city in the YRD in 2020, with $\text{ULL}_{max-end}$ representing the maximum value of logistics land in the study area at the end of the period. GR_i and RS_i are calculated as follows [50]:

$$RS_i = \frac{\text{CEDIL}_{i-end}}{\text{CEDIL}_{max-end}} \times 100\% \quad (1)$$

$$GR_i = \left(\frac{\text{CEDIL}_{i-end} - \text{CEDIL}_{i-star}}{\text{CEDIL}_{i-star}} - 1 \right) \times 100\% \quad (2)$$

To exclude human interference, the mean value of GR_i and RS_i is used as the threshold in this study. In the evolution model classification, the 41 cities in the YRD are divided into multiple types of high scale–high speed cities (HSHS cities), low scale–low speed (LSLS cities), high scale–low speed cities (HSLS cities), and low scale–high speed cities (LSHS cities). HSHS cities represent that both GR_i and RS_i of logistics land in City i are higher than the mean value of YRD, and are in a state of high scale and high speed incremental development. LSLS cities represent that both the GR_i and RS_i of logistics land in City i are lower than the mean value of YRD, and are in a state of low scale and low speed growth stock with reduced development. HSLS cities represent that the GR_i of logistics land in City i is lower than the mean value of YRD, but RS_i is higher than the mean value, showing a trend of transformation from growth to inventory and even reduction. LSHS cities represent that the GR_i of logistics land in City i is higher than the mean value of YRD, but RS_i is lower than the mean value, showing a trend of transformation from stock to incremental development.

2.2.2. Global Moran's Index and Cold-Hotspot Analysis

Relevant studies have demonstrated the spatial effect and externality of the development and evolution of the logistics industry, so it is necessary to carry out spatial effect detection in empirical research on logistics land use to provide evidence and information for the selection of econometric models for mechanism measurement [51,52]. The coefficient of variation (CV) is a key parameter for quantitatively measuring geographic differences and spatial heterogeneity, with 0.36 being the threshold for strong and weak [53,54]. In this paper, Moran's Index is used to quantify the global spatial autocorrelation of LLS and LLR in the YRD. It ranges from −1 to 1, with a larger absolute value representing a stronger correlation between a city and its neighbors. A value greater than zero indicates that the attributes of a city are isotropic with those of neighboring cities. On the contrary, it represents anisotropy. By using the cold-hotspot analysis tool of GIS and introducing the $Getis - Ord\ G_i^*$ index, the local autocorrelation map can be made. W_{ij} represents the spatial weight matrix between cities in the YRD, where 1 indicates adjacent spaces and 0 indicates non-adjacent spaces; ULL_i represents the logistics land of City i in the YRD, $\overline{\text{ULL}}$ is the mean value of urban logistics land in the YRD, and n = 41. Moran'sI and $G_i^*(d)$ are calculated as follows [55,56]:

$$CV = S/\overline{ULL}, S = \sqrt{\frac{\sum_{i=1}^{n}\left(ULL_i - \frac{\sum_{i=1}^{n} ULL_i}{n}\right)^2}{n}}, \overline{ULL}\frac{\sum_{i=1}^{n} ULL_i}{n} \quad (3)$$

$$\text{Moran's I} = \frac{n}{S_0} \times \frac{\sum_{i=1}^{n}\sum_{j=1}^{n} W_{ij}\left(\text{ULL}_i - \overline{\text{ULL}}\right)\left(\text{ULL}_j - \overline{\text{ULL}}\right)}{\sum_{i=1}^{n}\left(\text{ULL}_i - \overline{\text{ULL}}\right)^2}, S_0 = \sum_{i=1}^{n}\sum_{j=1}^{n} = W_{ij} \quad (4)$$

$$G_i^*(d) = \frac{\sum_{i=1}^{n} W_{ij}(d)\mathrm{ULL}_i}{\sum_{i=1}^{n} \mathrm{ULL}_i} \tag{5}$$

2.2.3. Geographically Weighted Regression

When the dependent variable has a spatial effect, it is necessary to choose a spatial econometric model to accurately measure the driving mechanism of factors. In this paper, the geographical weighted regression model is selected for the influence analysis of factors, and its advantage is that it can reveal the variation in each influence factor in the local space, as described below. First, the least squares linear regression model (OLS) is used to measure the degree of collinearity between different factors. A VIF (variance inflation factor) smaller than 10 indicates very weak covariance [57]. Second, the all variables are imported into the geographically weighted regression software to calculate the factor impact coefficients and support relevant parameters. Third, the comparative analysis of the parameters related to the results of GWR and OLS calculations allows for the determination of the extent to which the results of the spatial econometric modeling analysis improve the traditional statistics models. If the R^2 of GWR is greater than that of OLS, especially if the difference between the two in AICc (Akaike Information Criterion, corrected) is more than 3, then this indicates the need to consider the influence of spatial effects in the regression analysis process [58]. The AICc is a standard based on the concept of entropy, used to measure the goodness of fit of statistics models, and it was founded and developed by Japanese statistician Hiroshi Akike.

Y_i represents the dependent variable, including LLS and LLR; $\overline{Y}$ and S represent the mean and standard deviation of the dependent variable of YRD, respectively. X_{ik} represents the dependent variable, and it is a factor in the YRD that may have an impact on urban logistics land use. β_0 is a constant term, (μ_i, v_i) is the spatial coordinates of City i in the YRD (using the coordinate of the center of gravity point of the city polygon); $\beta_{k_{(\mu_i, v_i)}}$ is the regression coefficient of the independent variable of City i in the YRD, and ϵ_i is the error in the regression equation. The geographical weighted regression coefficient is calculated as follows [59,60]:

$$Y_i = \beta_{0_{(\mu_i,\ v_i)}} + \sum_k \beta_{k_{(\mu_i,\ v_i)}} X_{ik} + \epsilon_i \tag{6}$$

2.3. Indicator System and Data Sources

The "Pressure-State-Response" (PSR) model was proposed by Canadian scholars in 1979, and was later improved by the United Nations Environment Programme (UNEP) and the Organization for Economic Cooperation and Development (OECD) in 1994 to be a worldwide model for evaluating the state of the environment [61]. The PSR model can be used to reasonably analyze the relevance relationship between urban logistics land use and related factors. It is used in this paper as the analysis framework for indicator selection and system construction. The indicators that measure state are dependent variables, and those that measure stress and response are independent variables (Table 1).

Table 1. Indicator system of empirical research on logistics land in the YRD.

Framework	Indicator	Abbreviation	Variable
State	Scale of Urban Logistics Land Proportion of Urban Logistics Land	SULL PULL	Dependent
Pressure	Gross Domestic Product Economic Density GDP Per Capita Population Density	GDP ED GDPPC PD	Independent
Response	Highway Length Road Network Density Industrial Land Ratio Commercial Land Ratio	HL RND ILR CLR	

2.3.1. Dependent Variable

The dependent variable is logistics land in the YRD cities, including the two indicators of scale and ratio, represented by Y_{SULL} and Y_{PULL}, respectively. The scale represents the area of logistics land, measured in square kilometers. The proportion is calculated by dividing the area of logistics land by the area of urban construction land, and the unit is %. Logistics land is the land used for material storage, transit, distribution and other purposes in the city, including land for ancillary roads, parking lots, and stations for freight company fleets. The definition comes from the code for classification of urban land use and planning standards of development land (GB 50137-2011) [62]. Logistics land is a type of urban construction land, and it is juxtaposed with residential land, land for public administration and public services, land for commercial service facilities, industrial land, land for roads and transportation facilities, land for public utilities, and land for green areas and squares. In China, logistics land is categorized into three types according to the degree of disturbance, pollution and safety hazards to the residential and public environments. Class I logistics sites are in general free of disturbance, pollution or safety hazards, Class II logistics sites are subjected to some disturbance, pollution and safety hazards, and Class III logistics sites are dedicated to the storage of hazardous materials such as flammable, explosive and highly toxic materials. Notably, the management of land use in urban planning and territorial spatial planning is mainly controlled based on state parameters such as use, scale and ratio. LLS and LLR are equally important key parameters, so this study simultaneously conducts an empirical analysis of the scale and ratio of urban logistics land.

2.3.2. Independent Variable

The status of logistics land is the result of a combination of urban development pressures and logistics-related stakeholder responses, so both pressures and responses should be taken into account when selecting influencing factors. From the point of view of pressure, the supply and evolution of logistics land must be commensurate with the needs of economic development, especially industrialization. The Gross Domestic Product (GDP), economic density and per capita GDP are common indicators representing the size and quality of the economy and the industrialization process; they are used in this study to measure the pressure brought by economic development on logistics land [63,64]. The boom in e-commerce has brought logistics land closer to the convenience and livability of residents' lives [65]. Therefore, population density is used in this paper to measure the pressure brought by population, especially residents' living demand [66,67]. From the perspective of response, since transportation facilities are directly related to the layout and utilization of logistics land, this paper uses highway length and road network density to measure the impact of the response to the supply of transportation facilities on logistics land [68]. And given the fact that logistics mainly serves the manufacturing and service industries, this makes the proportion, size and distribution of industrial and commercial land in the city negligible, so this paper also borrows the proportion of industrial land and the proportion of commercial land to express their impact on logistics land [69].

2.3.3. Data Sources

All the dependent variable data came from China Urban Construction Statistics Yearbook [70], independent variable data came from China Urban Statistics Yearbook [71], Shanghai Municipal Statistics Yearbook [72], Jiangsu Provincial Statistics Yearbook [73], Zhejiang Provincial Statistics Yearbook [74] and Anhui Provincial Statistics Yearbook [75], and a small amount of missing data came from the city statistics bulletin or government work report. The data were standardized using the Max–Min method for a period starting from 2000 to 2020.

3. Results

3.1. Distribution Pattern

This section comprehensively applies quantile spatial clustering, global Moran's index and cold hotspot analysis methods to quantitatively and visually analyze the geographical distribution characteristics of urban logistics land scale and proportion.

3.1.1. Scale of Urban Logistics Land

The total area of logistics land in the YRD from 2000 to 2020 increased from 141.67 to 235.81 km^2, and the average value of 41 cities increased from 3.46 to 5.75 km^2, which was an annual growth of 2.58%, indicating a large land area of logistics land and its fast expansion. Shanghai remained at the top of YRD, with its logistics land area declining from 54.42 to 52.31 km^2 from 2000 to 2020; Lishui was at the bottom of the list, but its change in land area was the opposite of that of Shanghai, with an increase from 0.06 to 0.35 km^2.

The coefficient of variation in the LLS in the YRD from 2000 to 2020 decreased from 2.40 to 1.55, which was much higher than 0.36, indicating that the inter-city differences were gradually reduced, but still at a high level. In 2000, cities with high value of logistics land use in the YRD gathered in clusters, mostly in Shanghai, Nanjing, Hefei and Xuzhou metropolitan areas, including Shanghai, Zhenjiang, Ningbo, Nanjing, Hefei, Lianyungang, Nantong, Huzhou, Suzhou–Anhui, Wuhu, Xuzhou, Lu'an, Changzhou, Suzhou–Jiangsu, and Huainan. Low-value cities were gathered in southern Anhui province, western Zhejiang province, and central Jiangsu province, including Anqing, Huaibei, Yancheng, Taizhou–Jiangsu, Chizhou, Xuancheng, Fuyang, Quzhou, Bozhou, Huangshan, Zhoushan, Suqian, Huai'an and Lishui. In 2020, high-value cities were clustered in a finger pattern along the traffic corridor with Shanghai as the core, Shanghai–Suzhou–Jiangsu–Nanjing–Huanan–Lianyungang as the main axis, and Shanghai–Jiaxing–Hangzhou as the sub-axis. During the same period, most of the low-value cities in the YRD were clustered in Anhui, and a few in central Zhejiang, including Lu'an, Tongling, Chizhou, Huzhou, Chuzhou, Huainan, Xuancheng, Jinhua, Taizhou–ZheJiang, Huangshan, Zhoushan and Lishui (Figure 3).

Moran's index of the LLS in the YRD from 2000 to 2020 increased from 0.01 ($P = 0.08$, $Z = 1.44$) to 0.04 ($P = 0.09$, $Z = 1.41$), which was greater than zero and passed the significance test, indicating strong and increasing inter-city correlation. The members of the hotspot cities were the same in 2000 and 2020, including Shanghai, Nantong, Suzhou–Jiangsu, and Jiaxing. There are few cold spot cities in 2000, mostly clustered in the western region where Zhejiang and Anhui meet, including Lishui, Quzhou, Jinhua, Huangshan and Chizhou. While in 2020, the number of coldspot cities grew rapidly, largely covering the western region of YRD. The sub-hotspot cities in 2000 were gathered in the Nanjing–Hefei metropolitan areas in a continuous belt. But in 2020, they contracted to only the Nanjing metropolitan area, with a slight expansion in the Ningbo metropolitan area. Most of the sub-coldspot cities in 2000 were gathered in the Xuzhou metropolitan area and the Zhejiang–Anhui junction area, while in 2020 there were few sub-cold spot cities with a small cluster area emerging in the northern part of Anhui Province.

3.1.2. Proportion of Urban Logistics Land

The average LLR in the YRD from 2000 to 2020 rose from 1.43 to 2.40%, an increase of 1%, indicating a steady increase in the position of logistics land in the urban construction land structure. The city with the largest ratio of urban logistics land in 2000 is Lu'an at 4.47%; in 2020 it shifted to Bengbu at 10.46%. The city with the smallest ratio in 2000 was Huai'an at 0.14%; in 2020 it shifted to Taizhou–ZheJiang, at 0.68%.

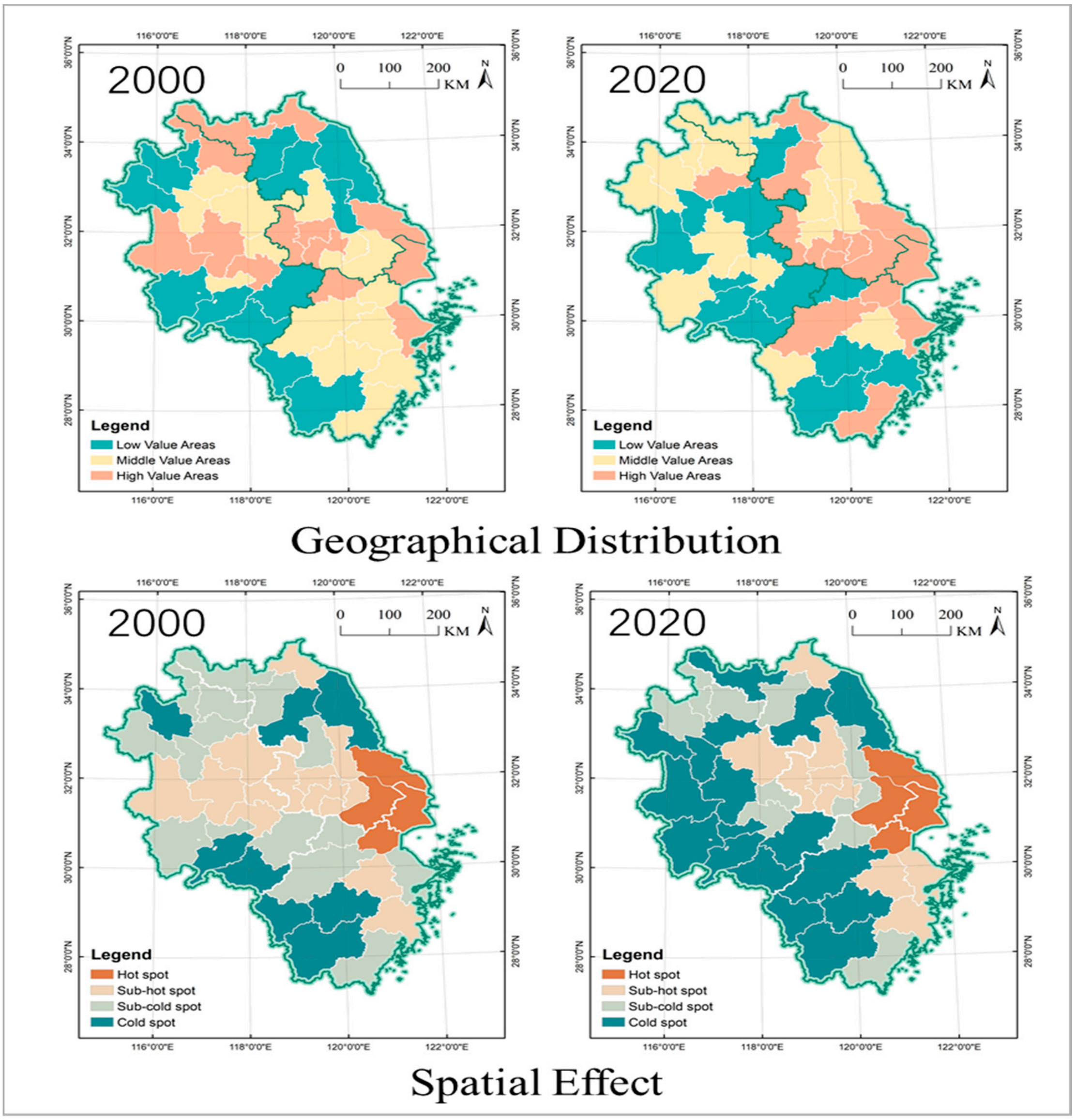

Figure 3. Geographical distribution pattern and its spatial effects of SULL in the YRD.

The CV of the LLR in the YRD from 2000 to 2020 increased from 0.71 to 0.80, which was much larger than 0.36, indicating a large and gradually increasing inter-city difference. Most of the cities with high values of the ratio in the YRD were clustered in a band in Anhui in 2000, including Lu'an, Huainan, Zhenjiang, Anqing, Huzhou, Shanghai, Suzhou–Anhui, and Tongling. And most of the cities with low values were clustered in Jiangsu, including Yancheng, Taizhou–Jiangsu, Wuxi, Nanjing, Shaoxing, Huaibei, Suzhou–Jiangsu, Bozhou, Suqian, Hangzhou, Lishui, and Huai'an. In 2020, a large number of high-value cities were concentrated in Hangzhou Bay and Anhui, including Lu'an, Huainan, Zhenjiang, Anqing, Huzhou, Shanghai, Suzhou–Anhui, Tongling, Wuhu, Bengbu, and Maanshan. Most of the cities with low values in the YRD were clustered in central and southern Zhejiang and Anhui provinces, including Yangzhou, Hangzhou, Huzhou, Xuancheng, Huangshan, Lishui, Zhoushan, Jinhua, Chuzhou, Hefei, and Taizhou–ZheJiang (Figure 4).

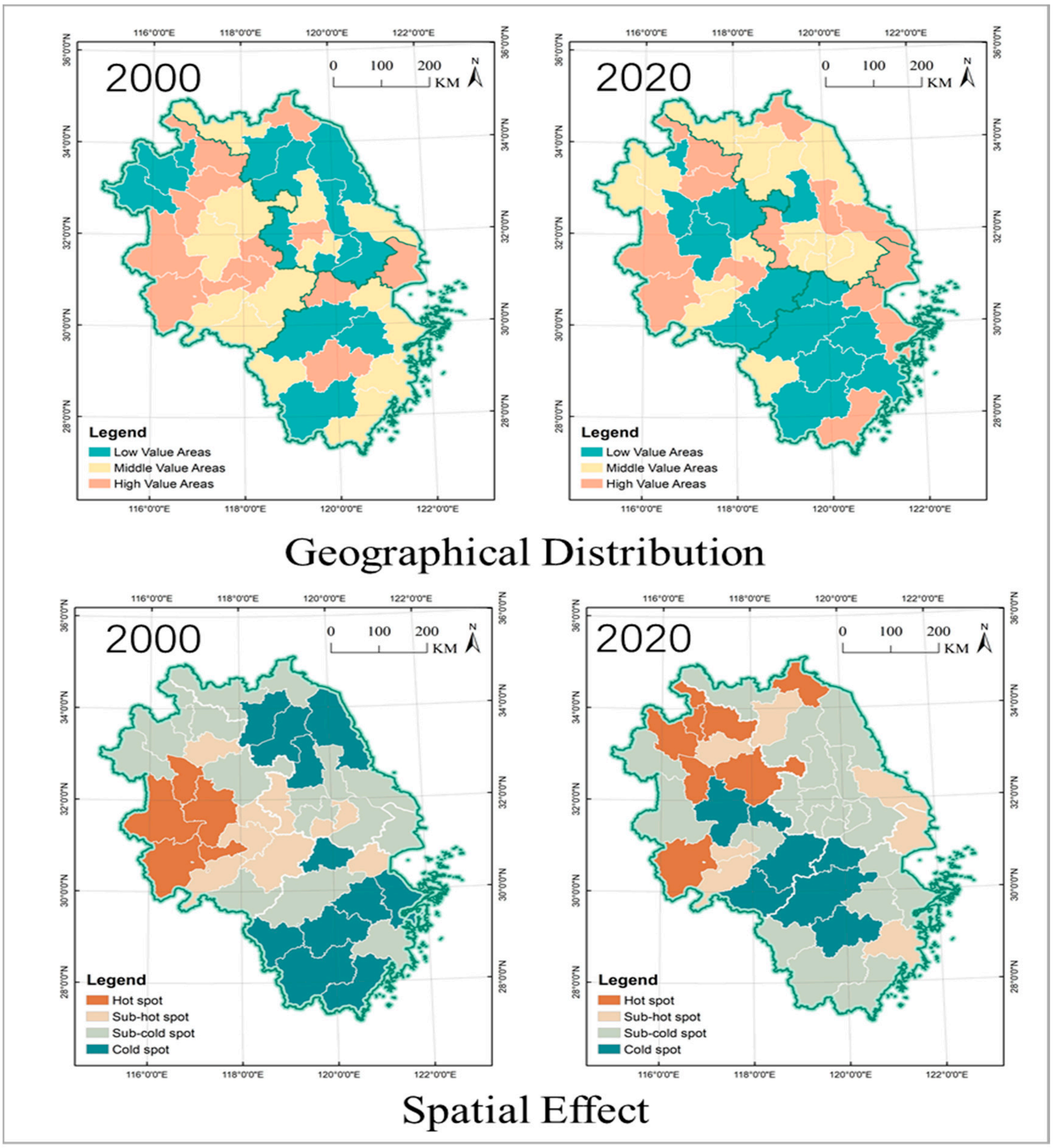

Figure 4. Geographical distribution pattern and its spatial effects of PULL in the YRD.

The Moran's index of the LLR in the YRD increased from 0.06 (P = 0.12, Z = 1.22) to −0.12 (P = 0.04, Z = −1.50) from 2000 to 2020, suggesting that the intercity correlation shifted from a non-significant positive autocorrelation to a significant negative autocorrelation. Hotspot cities in 2000 were clustered in western Anhui, including Hefei, Lu'an, Anqing, Huainan, and Tongling. In 2020, the agglomeration moved to northern Anhui and changed from clusters to banded beads, including Suzhou–Anhui, Huaibei, Bozhou, Huainan, and Chuzhou. Coldspot cities formed two agglomerations in southern Zhejiang and central Jiangsu in 2000, and shrank to one agglomeration in 2020 in the junction area of Zhejiang and Anhui provinces.

3.2. Spatiotemporal Evolution Model

When analyzing the spatiotemporal evolution pattern of urban logistics land, the BCG matrix is applied to quantitatively analyze the relative share and growth rate corresponding to scale and proportion, and their mean is used as the threshold. The minimum and average values of relative shares in the YRD are 0.67% and 10.99%, respectively; and the maximum, minimum, and average of growth rates are 1486.21%, −62.87%, and 151.71%, respectively. The practice of using the Boston matrix for high and low value clustering is essentially a translation of abstract data into an easy-to-understand and visual Cartesian two-dimensional coordinate system.

3.2.1. Scale of Urban Logistics Land

HSHS cities included Nanjing, Wuxi, Changzhou, Suzhou–Jiangsu, Lianyungang, Hangzhou, Ningbo, Wenzhou, and Bengbu, mostly clustered in the Nanjing metropolitan area. There were very few HSLS cities, only Shanghai and Nantong. LSHS cities included Huai'an, Yancheng, Fuyang, Suqian, Jiaxing, Shaoxing, Quzhou, Lishui, Bozhou, Fuyang, Taizhou–Jiangsu, and Anqing, mostly clustered in central Jiangsu and Zhejiang, and a few in northern Anhui. LSLS cities included Xuzhou, Yangzhou, Zhenjiang, Huzhou, Jinhua, Zhoushan, Taizhou–ZheJiang, Hefei, Huaibei, Suzhou–Anhui, Huainan, Chuzhou, Lu'an, Maanshan, Wuhu, Xuancheng, Tongling, Chizhou, and Huangshan, mostly clustered in Anhui and penetrating into northern and central Jiangsu (Figure 5).

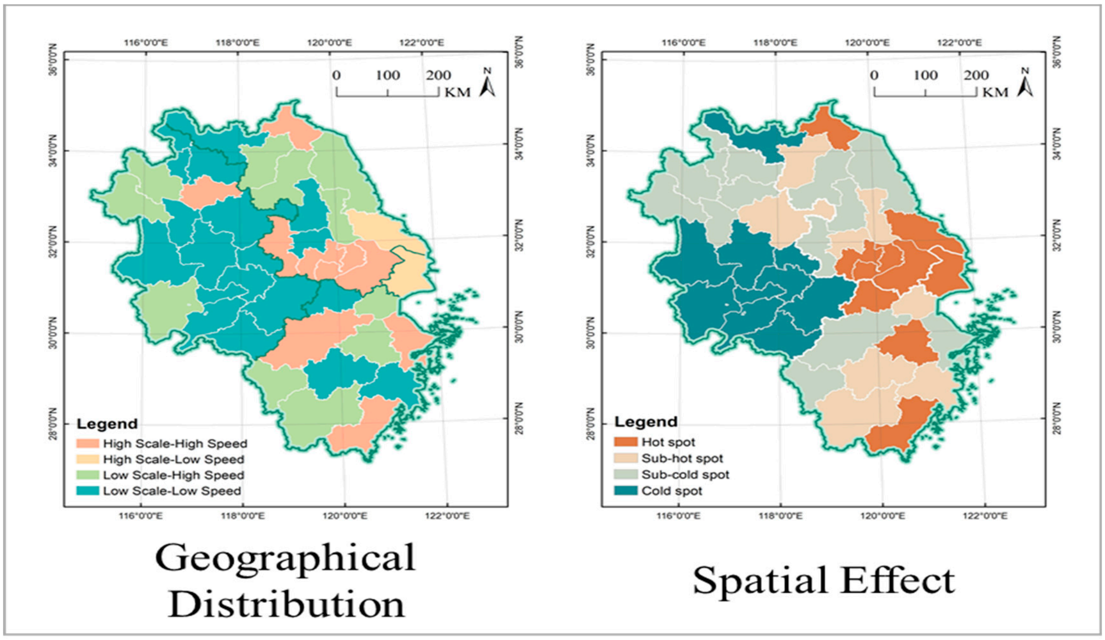

Figure 5. Spatiotemporal evolution model and its spatial effects of SULL in the YRD.

The Moran's index of the evolutionary pattern of LLS in the YRD was 0.10 (P = 0.04, Z = 2.0144), indicating a significant positive spatial autocorrelation. Most of the hotspot cities were clustered in the Shanghai and Southern Jiangsu regions, including Shanghai, Suzhou–Jiangsu, Nantong, Changzhou, Wuxi, Zhenjiang, and Nanjing. Sub-hotspot cities were mostly distributed in Zhejiang, including Jiaxing, Lishui, and Jinhua. Most of the cold spot cities were clustered in Anhui region, including Hefei, Anqing, Tongling, Chizhou, Xuancheng, and Wuhu. Most of the sub-cold spot cities were clustered in northern Anhui and central Jiangsu, including Bozhou, Suzhou–Anhui, Huaibei, Yangzhou, Yancheng, Huaian, Hangzhou, Quzhou, and Ningbo.

3.2.2. Proportion of Urban Logistics Land

HSHS cities included Nanjing, Lianyungang, Taizhou–Jiangsu, Ningbo, Wenzhou, Jiaxing, Quzhou, Bengbu, and Anqing, with a very decentralized spatial distribution in the YRD. HSLS cities were also few in number and scattered in distribution, including Shanghai, Nantong, Zhenjiang, Suzhou–Anhui, Lu'an, and Wuhu. LSHS cities included Wuxi, Changzhou, Hangzhou, Huai'an, Yancheng, Suqian, Shaoxing, Lishui, Bozhou, Suzhou–Jiangsu, and Fuyang, mostly clustered in Anhui. LSLS cities included Xuzhou, Yangzhou, Huzhou, Jinhua, Zhoushan, Taizhou–ZheJiang, Hefei, Huaibei, Huainan, Chuzhou, Maanshan, Xuancheng, Tongling, Chizhou, and Huangshan, mostly clustered in central and southern Jiangsu, the capital metropolitan area of Zhejiang, and northern Anhui (Figure 6).

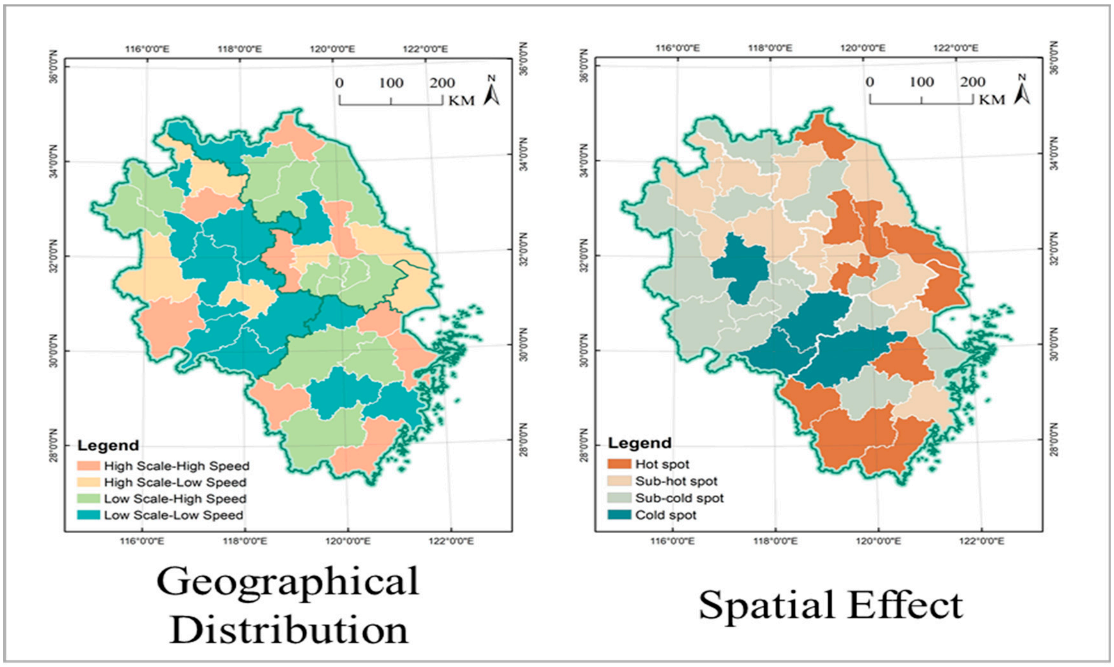

Figure 6. Spatiotemporal evolution model and its spatial effects of PULL in the YRD.

The Moran's index of the evolutionary pattern of the LLR in the YRD was −0.10 (P = 0.10, Z = −1.21), indicating a significant negative spatial autocorrelation. The hotspot cities were clustered in a band from the Shanghai urban agglomeration area to central Jiangsu and the southwest corner of Zhejiang, including Shanghai, Nantong, Taizhou–Jiangsu, Yangzhou, Wenzhou, Lishui, and Quzhou. Most of the sub-hotspot cities were distributed in the periphery of the hotspot cities and expanded to the inland areas of Anhui, including Chuzhou, Huainan, Bozhou, Huaibei, and Suzhou. Most of the cold spot cities were clustered in the junction area of Anhui and Zhejiang provinces, including Hangzhou, Xuancheng, Huangshan, and Hefei. Most of the sub-coldspot cities were clustered in Anhui province, including Lu'an, Maanshan, Wuhu, Tongling, Chizhou, Anqing, and Jinhua.

3.3. Driving Mechanism Analysis

Spatial effects and collinearity detection are important prerequisites for selecting regression analysis models. Through statistics analysis of regression coefficients, it is helpful to understand the heterogeneity of factor effects and further use the geographically weighted regression analysis graphs to display the spatial pattern of factor influencing.

3.3.1. Descriptive Statistics Analysis of Regression Coefficients

The maximum value of VIF for all factors was 2.78, much less than 10, indicating no collinearity between the factors. In terms of goodness of fit, the OLS parameter of LLS in the YRD increased from 0.826 to 0.998, and the OLS parameter of LLR increased from 0.228 to 0.991, indicating that the spatial econometric model outperforms the traditional statistics model. And the AICc parameter of GWR was much higher than that of OLS, further corroborating the previous findings.

The statistics characteristics of the GWR regression coefficients of LLS in the YRD showed a complicated driving mechanism of all factors on LLS. The comparison of the minimum, upper quartile, median, lower quartile, and maximum values showed that the coefficient values all shifted from negative to positive, indicating the complex nature of the effect of the influencing factors. Of note is that the shift from resistance to impetus was not synchronized, with GDP having achieved the shift in the upper quartile, while ED and RND delayed to the median, and the other factors further delayed to the lower quartile. Furthermore, the large differences in the mean values of the coefficients indicate a high degree of heterogeneity and a hierarchical nature of the forces influencing the factors. According to the mean value overall, GDP and ED had a leading influence on the LLS in the YRD as key impetus factors, while PCGDP and PD were key resistance factors, HL was an important impetus factor, RND was an auxiliary impetus factor, and ILR was auxiliary resistance factor (Table 2).

Table 2. Geographically weighted regression coefficients for SULL in the YRD.

Indicator	Mean	Min	Upper-Quarter	Median	Lower-Quarter	Max
GDP	2.89	−12.89	1.21	4.01	5.72	12.36
ED	1.99	−3.28	−0.01	1.09	2.86	16.66
PCGDP	−1.39	−10.42	−4.98	−1.42	1.29	9.08
PD	−1.13	−20.61	−1.78	−0.97	0.39	4.31
HL	0.58	−4.68	−1.33	−0.40	1.71	8.55
RND	0.06	−6.49	−1.63	0.22	1.39	5.40
ILR	−0.07	−4.26	−1.93	−0.41	1.21	6.12
CLR	−0.85	−9.42	−1.76	−0.26	1.19	3.88

All factors had a complex driving mechanism for the LLR, which was similar to the LLS, but different in details. In terms of the nature of the influencing factors, there were no changes in the nature in the upper quartile, with the shift from resistance to impetus delayed to the median for ED, PCGDP, PD, RND and ILR, and further delayed to the lower quartile for GDP, HL, and CLR. In terms of the intensity of the influencing factors, ED was a key impetus factor and GDP was a key resistance factor; RND, PCGDP, and PD were important impetus factors and CLR was an important resistance factor; PD, HL, and ILR were auxiliary impetus factors, and no auxiliary resistance factor was found (Table 3).

Table 3. Geographically weighted regression coefficients for PULL in the YRD.

Indicator	Mean	Min	Upper-Quarter	Median	Lower-Quarter	Max
GDP	−1.04	−14.89	−0.99	−0.13	0.32	3.09
ED	1.22	−0.74	−0.24	0.54	1.59	10.87
PCGDP	0.48	−5.82	−0.50	0.38	1.96	6.06
PD	0.39	−5.41	−0.09	0.20	0.66	4.22
HL	0.03	−1.72	−0.69	−0.42	0.07	4.47
RND	0.55	−1.73	−0.26	0.20	0.74	4.98
ILR	0.34	−2.85	−0.42	0.16	0.74	4.71
CLR	−0.49	−3.09	−1.19	−0.20	0.33	1.38

3.3.2. Spatial Pattern of Factor Effects

From the spatial pattern of the effect of pressure factors on the LLS, the influence of GDP gradually changed from positive to negative from coastal to inland, with the characteristics of high at both ends and low in the middle. The high values of impetus were clustered in the north of Suzhou, with Suqian, Huaian, and Wenzhou as pole cities; the high values of resistance were clustered in the north of Anhui, with Bozhou and Fuyang as pole cities. The influence of ED gradually changed from negative to positive from coastal to inland areas. Northern Anhui, southern Anhui and southwest Zhejiang were high-value cluster areas of impetus, with Bozhou, Fuyang, Ningbo and Taizhou–ZheJiang as pole cities. The Shanghai metropolitan area was a high-value cluster area of resistance, with Nantong and Jiaxing as pole cities. High-value clusters of per capita GDP impetus appeared in southeastern Zhejiang and northwestern Anhui, with Bozhou, Ningbo, and Taizhou–ZheJiang as pole cities, and high-value clusters of resistance appeared in Jiangsu, with Xuzhou, Suqian, and Wenzhou as pole cities. High-value clusters of PD impetus appeared in northern Anhui, with Huaibei, Bozhou and Fuyang as pole cities, while other regions generally played a resistance role, with Wenzhou as a pole city. The belt area from southern Anhui to Shanghai also showed a high resistance (Figure 7).

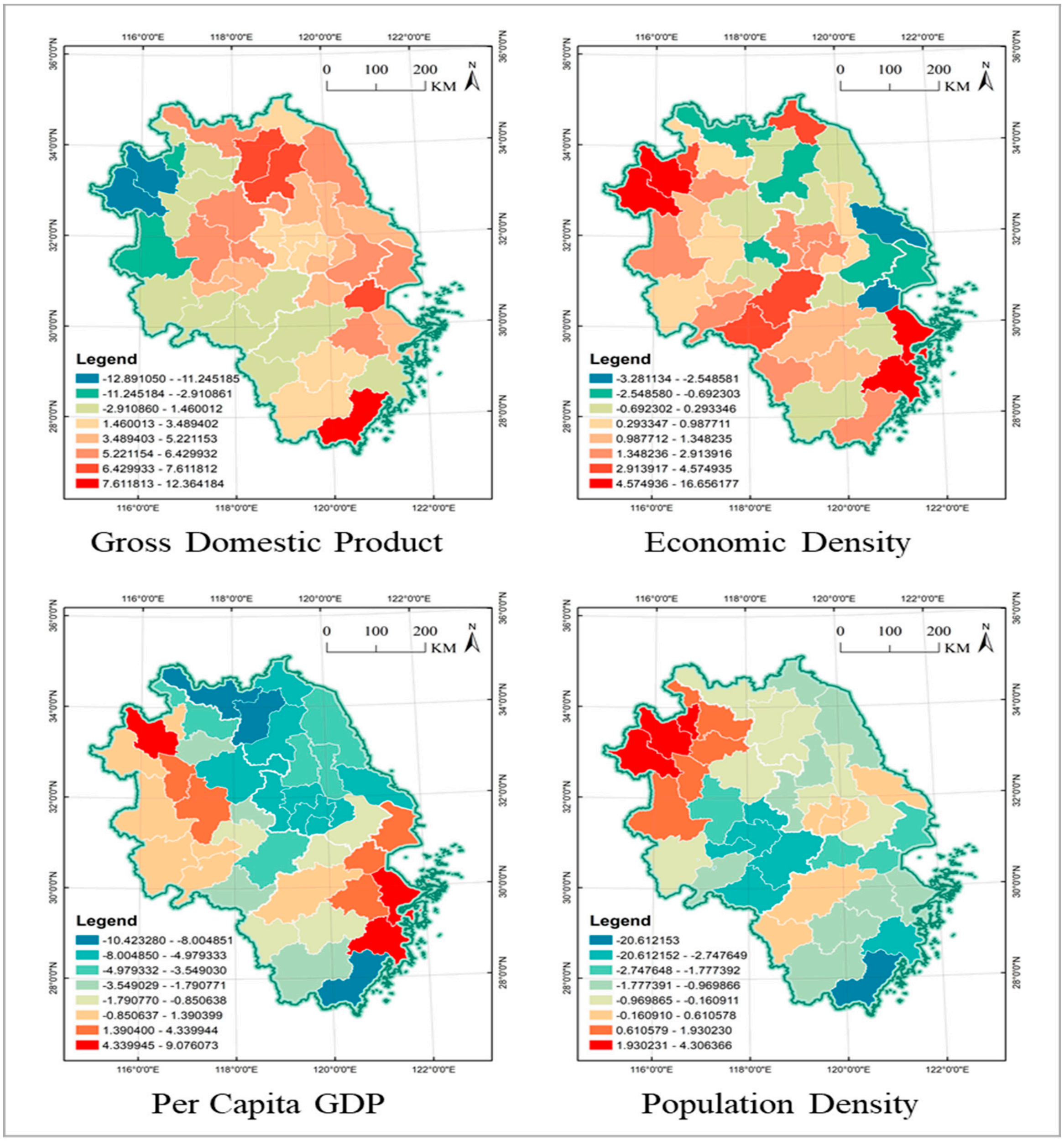

Figure 7. Analysis on pressure driving factors impact of SULL in the YRD.

According to the spatial pattern of the role of the response factor on the size of logistics land, HL showed a north–south gradient distribution characteristic, with the high values of impetus being clustered in southern Zhejiang, and with Wenzhou, Lishui, Taizhou–ZheJiang, and Quanzhou as pole cities; the high values of resistance were clustered in the junction area of Anhui and central Jiangsu, with Chuzhou, Hefei, and Jiaxing as pole cities. RND mainly showed a resistance in coastal regions, with Lianyungang and Jiaxing as pole cities. In the inland area, it mainly showed impetus, with the members in the region from Xuzhou metropolitan area to Hefei metropolitan area as pole cities. Two high-value clusters with ILR impetus appeared in Xuzhou metropolitan area and Zhejiang, with Xuzhou, Suqian, Chuzhou, Lishui, and Shaoxing as pole cities; high-value clusters with resistance appeared in South Anhui, south Jiangsu and 0north Anhui, with Wuhu, Xuancheng, Yangzhou, Taizhou–Jiangsu, Bozhou, and Ningbo as pole cities. The high-value clusters of CLR impetus and resistance were similar to those of ILR, except that the positive pole cities shifted to Xuzhou, Suqian, Huaian, Nantong, Taizhou–ZheJiang, and the negative pole cities changed to Bozhou, Lianyungang, Shanghai, Jiaxing, and Ningbo (Figure 8).

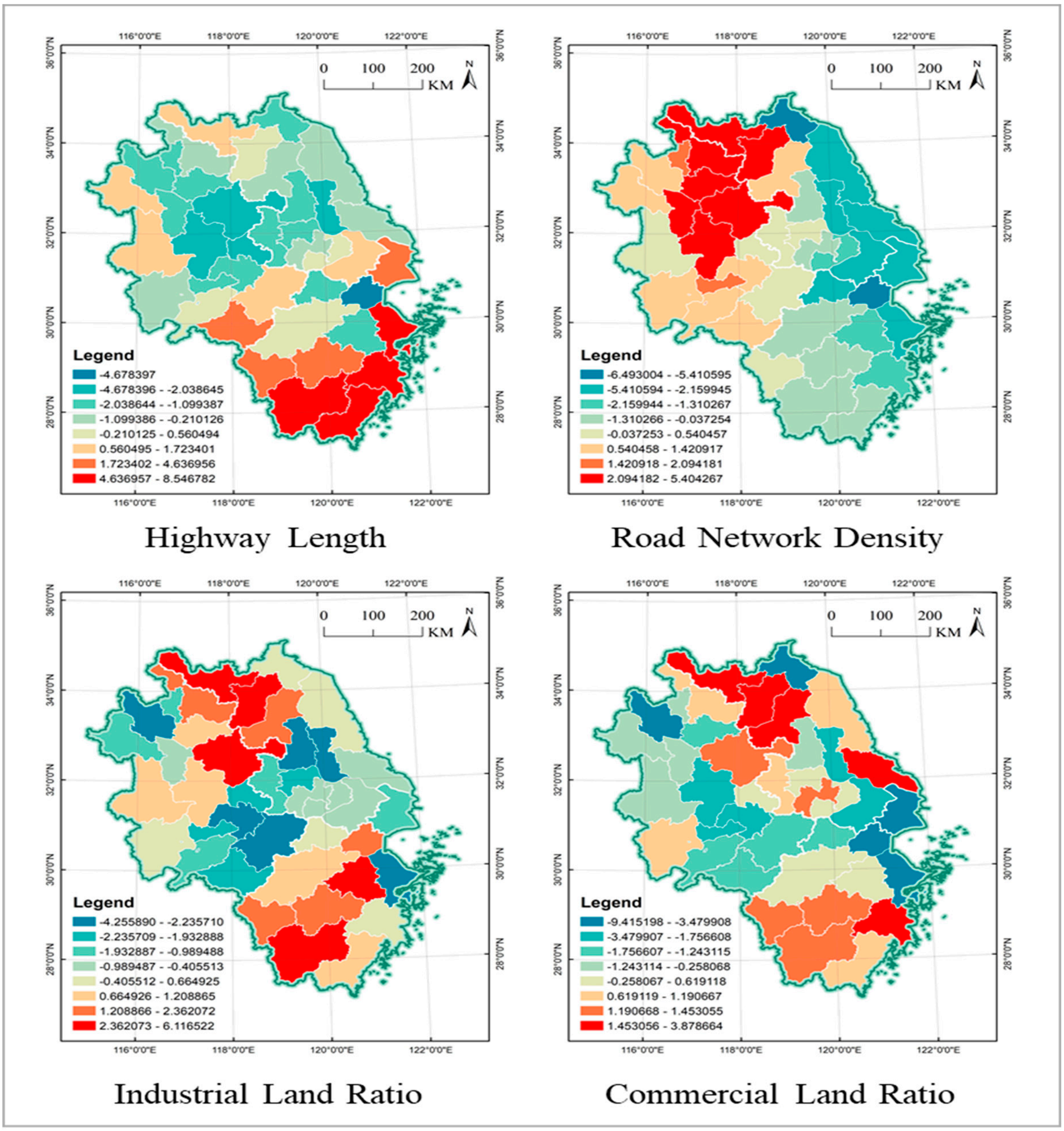

Figure 8. Analysis on response driving factors impact of SULL in the YRD.

From the spatial pattern of the effect of pressure factors on the LLR, we see that the high value distribution of positive and negative influences of the GDP showed spatial correlation characteristics, and northern Jiangsu was the high value cluster area of impetus, with Xuzhou, Suqian, Huaian, Chuzhou, and Wenzhou as pole cities; northern Anhui was the high value cluster area of resistance, with Bozhou, Huaibei, Fuyang, Bengbu, and Huainan as pole cities. The influence of ED was manifested as the impetus in northern Anhui and the junction areas of Anhui, Zhejiang and Jiangsu, with Bozhou and Fuyang as polar cities. The T-shaped belt area of Jiangsu–Yancheng–Anqing and the southwest of Zhejiang were high-value cluster areas of resistance, with Lishui and Shanghai as pole cities. GDP per capita showed resistance at the north and south ends of YRD, with Xuzhou, Suqian, and Lianyungang as pole cities and the impetus was in the center, with Bozhou, Huainan, Hefei, Ningbo, and Taizhou–ZheJiang as the pole cities. PD formed a high-value cluster area of impetus in northern Anhui, with Huaibei as a pole city; the southwest of Anhui, the northeast of Jiangsu and the southern tip of Zhejiang were high-value cluster areas of resistance, with Wenzhou as a pole city. It is important to note that impetus high-value clusters are developing in southern Anhui and central Zhejiang, and Hangzhou may grow into a pole city for the emerging cluster areas in the future (Figure 9).

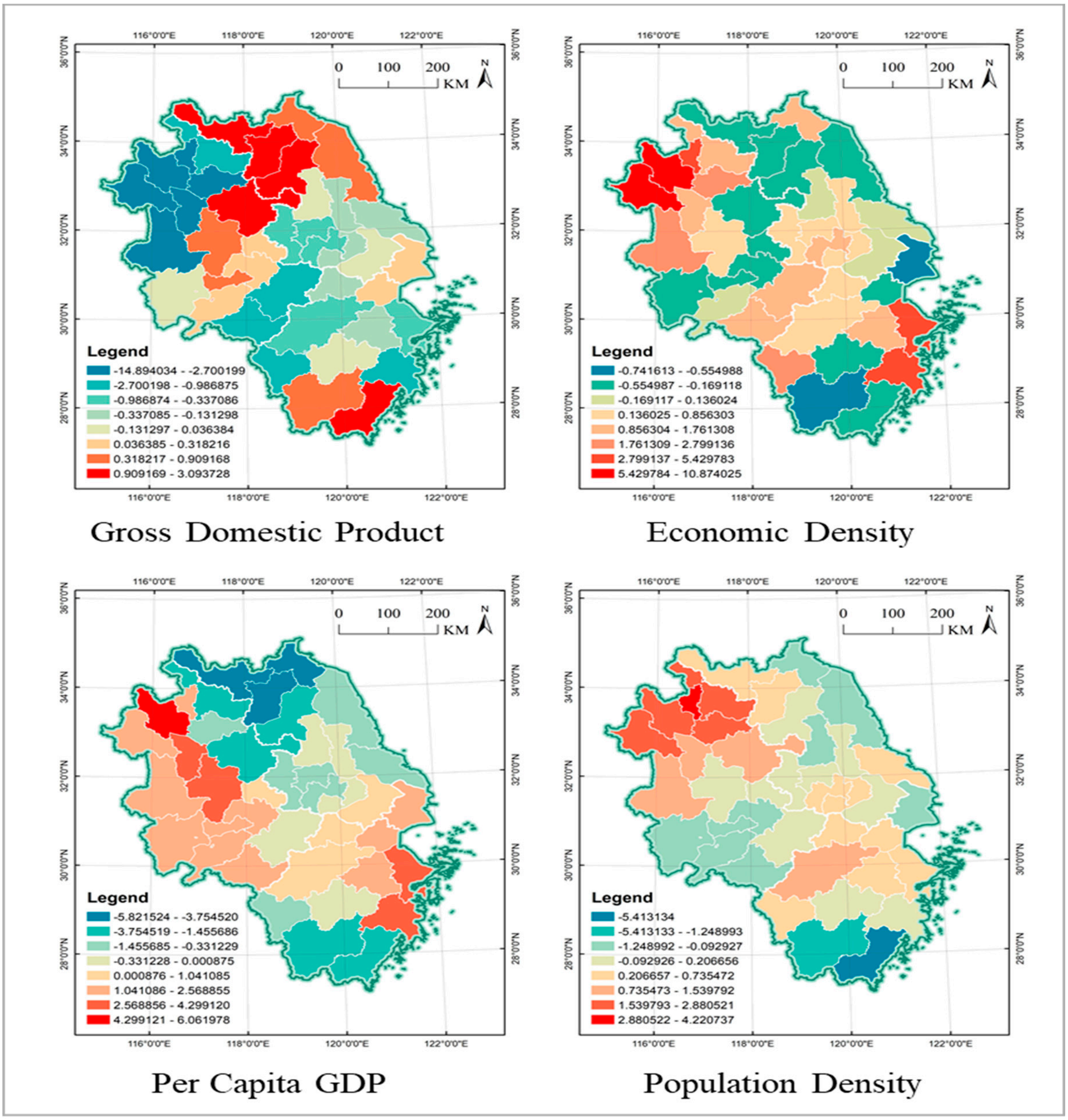

Figure 9. Analysis on pressure driving factors impact of PULL in the YRD.

According to the spatial pattern of response factors on logistics land use, HL showed the impetus in the south of YRD and clustered in Zhejiang, with Wenzhou, Lishui, Taizhou–ZheJiang, Quzhou and Fuyang as pole cities; resistance was in the middle of YRD, with Bengbu, Huainan, Maanshan, Jiaxing, Taizhou–Jiangsu, and Lianyungang as pole cities. RND mainly showed resistance in coastal regions, with Shanghai, Jiaxing, and

Lianyungang as pole cities. In the inland area, it mainly showed impetus, with the members in the region from the Xuzhou metropolitan area to the Hefei metropolitan area as pole cities. Two high-value clusters with an ILR impetus appeared in Xuzhou metropolitan area and Zhejiang, with Xuzhou, Suqian, Huaian, Suzhou–Anhui, and Quzhou as the pole cities; high-value clusters with resistance appeared in northern Anhui, southern Anhui, and southern Jiangsu, with Bozhou, Huaibei, Fuyang, Huainan, Tongling, and Taizhou–Jiangsu as the pole cities. CLR showed impetus in southern Zhejiang and northern Jiangsu, with Lishui, Quzhou, Taizhou–ZheJiang, Xuzhou, and Yancheng as the pole cities; there was resistance in the Anhui and Shanghai metropolitan area, with Shanghai, Jiaxing, Hefei, and Bozhou as the pole cities (Figure 10).

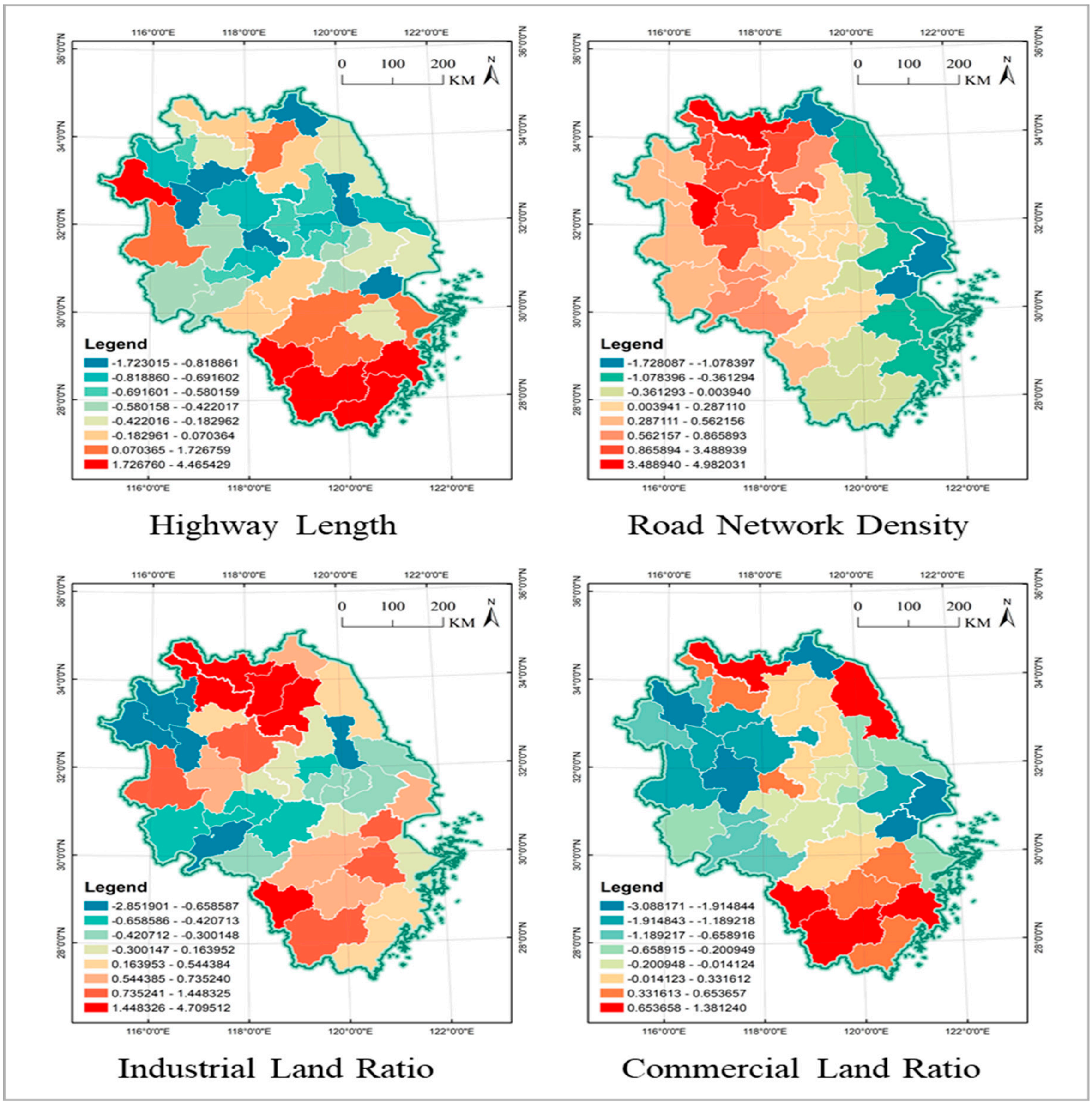

Figure 10. Analysis on response driving factors impact of PULL in the YRD.

4. Discussion

This section involves the discussion of the evolution mode of urban logistics land from the perspectives of supply and demand, growth and inventory, revealing the driving mechanism of urban logistics land from the perspectives of scale and proportion, and power and resistance; also, there is a summary of the important analysis results of this study, comparing these findings with the views of other scholars to identify their commonalities and differences, and ultimately providing direction for theoretical construction and result application.

4.1. Evolution Model: Supply vs. Demand and Growth vs. Inventory

The evolution pattern of logistics land is the spatial projection of the result of the dynamic equilibrium of supply and demand in the YRD logistics market, so accurately determining the quantity, quality, structure, space, practice, coupling relationship of regional logistics supply and demand and its change is the key to enhancing the scientific and forward-looking spatial planning of logistics land [76]. The demand for logistics land is the basis of logistics land supply, while logistics land supply is the prerequisite guarantee for logistics land demand [77]. Demand for logistics land is a product of regional economic and social development, specifically referring to the material flow demand and its spatial projection generated by the relevant subjects in their economic and social activities (enterprises, institutions or government departments, social organizations, individuals, etc.) in order to satisfy their needs of production, operation, business, and life. The supply of logistics land is the service capacity of material flow (transportation, storage, loading and unloading, circulation processing, distribution, packaging, etc.) and its spatial projection (all types of freight yards, warehousing facilities, logistics parks, logistics centers, and logistics villages, etc.) that the logistics supplier provides to the logistics demander [78]. According to the general supply and demand equilibrium theory, only when the demand and supply of logistics land are in a dynamic equilibrium state can the sustainable development of urban and regional economy and society be guaranteed [79,80]. In China, the supply of land resources is monopolized by the government, so the policies and spatial planning for the development of the logistics industry enacted by the government have a direct impact on the supply and allocation of logistics land [81]. The spatial planning of logistics land is mainly to study the logistics development strategy, industrial policy and management mechanism from the government's standpoint, and to coordinate, rationally plan and overall control the flow of urban and regional materials for the sustainable development of economy and society [82].

The evolution mode of logistics land in the YRD is diversified, and has changed from a growth-oriented stage to a stage where both growth and inventory coexist. The analysis for 2000–2020 shows that Shanghai, Zhenjiang, Huzhou, Jinhua, Zhoushan, Taizhou–ZheJiang, Hefei, Suzhou–Anhui, Huainan, Chuzhou, Lu'an, Xuancheng, and Tongling are in the stage of reduction development with a gradual reduction in both LLS and LLR, and the contraction of logistics space. Therefore, due to the oversupply of logistics land and the saturation of the logistics market, these cities should emphasize the reuse and quality improvement of their stock land in logistics spatial planning in the future. They should strictly control the approval of the conversion of non-logistics land, such as arable land, into logistics land, conduct surveys and consider the integration of logistics land, promote the redevelopment of inefficient logistics land or even its conversion into non-logistics land, and push the transformation of logistics land from a state of oversupply to a state of balanced supply and demand. In addition, they should strengthen the remediation and upgrading of the stock logistics land, renovate old logistics facilities, introduce new logistics technologies, enhance the material attractiveness and service support of logistics land to the surrounding areas, and promote the transformation of the development of logistics land from extensive use to high-end use.

For the rapidly developing and underdeveloped cities in the YRD, such as Nantong, Lianyungang, Hangzhou, Ningbo, Wenzhou, Quzhou, Lishui, Huaibei, Bozhou, Fuyang, Maanshan, and Bengbu, the supply of logistics land is still in short supply, so they should implement the incremental development strategy in future planning and management. First, they should prepare logistics industry development and land use planning, with focus placed on safeguarding the demand for new land for the construction of national and regional logistics hubs, centers, bases, parks and other key facilities, increasing support for logistics land for logistics end points, and comprehensively enhancing the security of land resources for logistics development. Second, they should push transformation of other idle stock land resources into logistics use, focusing on the study of the use of old factory buildings and warehouses of industrial enterprises as the representatives of the inefficient stock of land resources for investment in the construction of logistics facilities. Third, they should, in accordance with urban renewal and facility renovation planning, provide policy support to enterprises that use their original land for logistics infrastructure renovation and upgrading in applying for planning conditions, planning permits, and the transfer of allocated land, while designing and establishing a system of preferential policies for taxes and fees for logistics land (Figure 11).

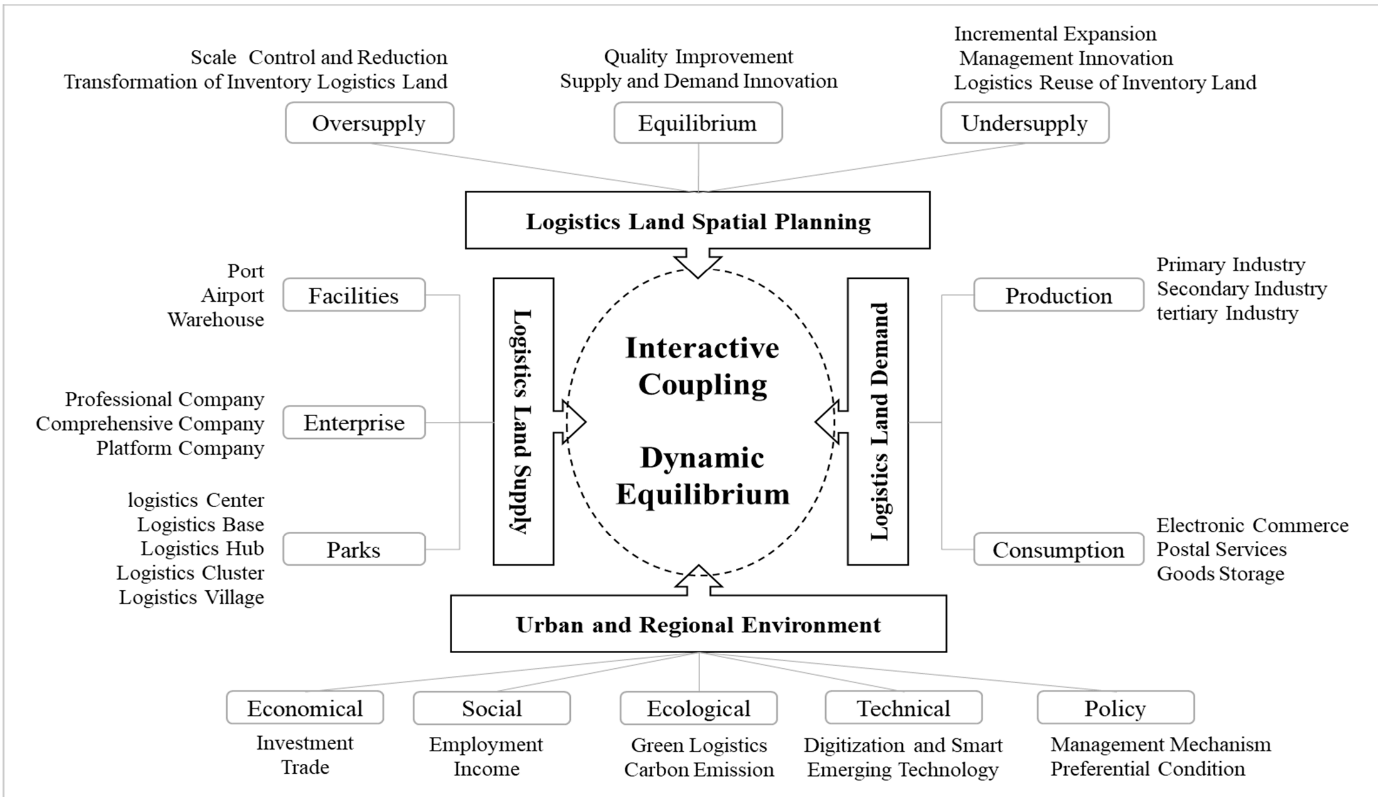

Figure 11. Spatial planning inspiration from the evolution model of logistics land.

4.2. Driving Mechanism: Scale vs. Proportion and Power vs. Resistance

From the perspective of dependent variables, there are great differences in the driving mechanism of different factors on LLS and LLR (Figure 12). According to the action intensity, all factors have greater influence on scale than ratio. From the nature of action, the nodes of factor resistance and impetus transformation were not the same, although had both positive and negative effects. For the spatial effects, the spatial extent and pattern characteristics of each factor's influence varied greatly, as did the pole cities [83]. Therefore, LLS and LLR should be managed differently, and designed neither in favor of one over another nor in a "one-size-fit-all" manner. Unlike residential land, land for public administration and public services, industrial land, land for transportation facilities, and green space, logistics land does not have planning and control requirements regarding scale and ratio in the Urban Land Classification and Planning Construction Land Use Standards. The Chinese government's current land supply management is characterized by a distinct economic orientation, with land-per-capita investment and tax revenues commonly used as the key performance assessment indicators. The investment and tax contribution per unit area brought by logistics land is significantly smaller than that of productive industrial land, consumptive commercial land, and living residential land, thus leading to no intrinsic motivation of local and city governments for logistics land supply, which further exacerbates the dilemma of insufficient and difficult supply of logistics land. Notably, the public welfare and operational nature of logistics facilities have led to the strong social benefits of logistics land, and there is an urgent need for the government to reverse the idea of "economy-only" or "economy-focus" in land supply. Therefore, the suggestion for the government is to set reasonable performance assessment indicators for logistics land, replace investment intensity and tax contribution with logistics intensity, and gradually include logistics land into the scope of urban infrastructure and public service facilities land. It should also revise the Urban Land Classification and Planning Construction Land Use Standards as soon as possible to clarify the standards for the control of LLS and LLR and provide a legal basis for the spatial planning of logistics land use.

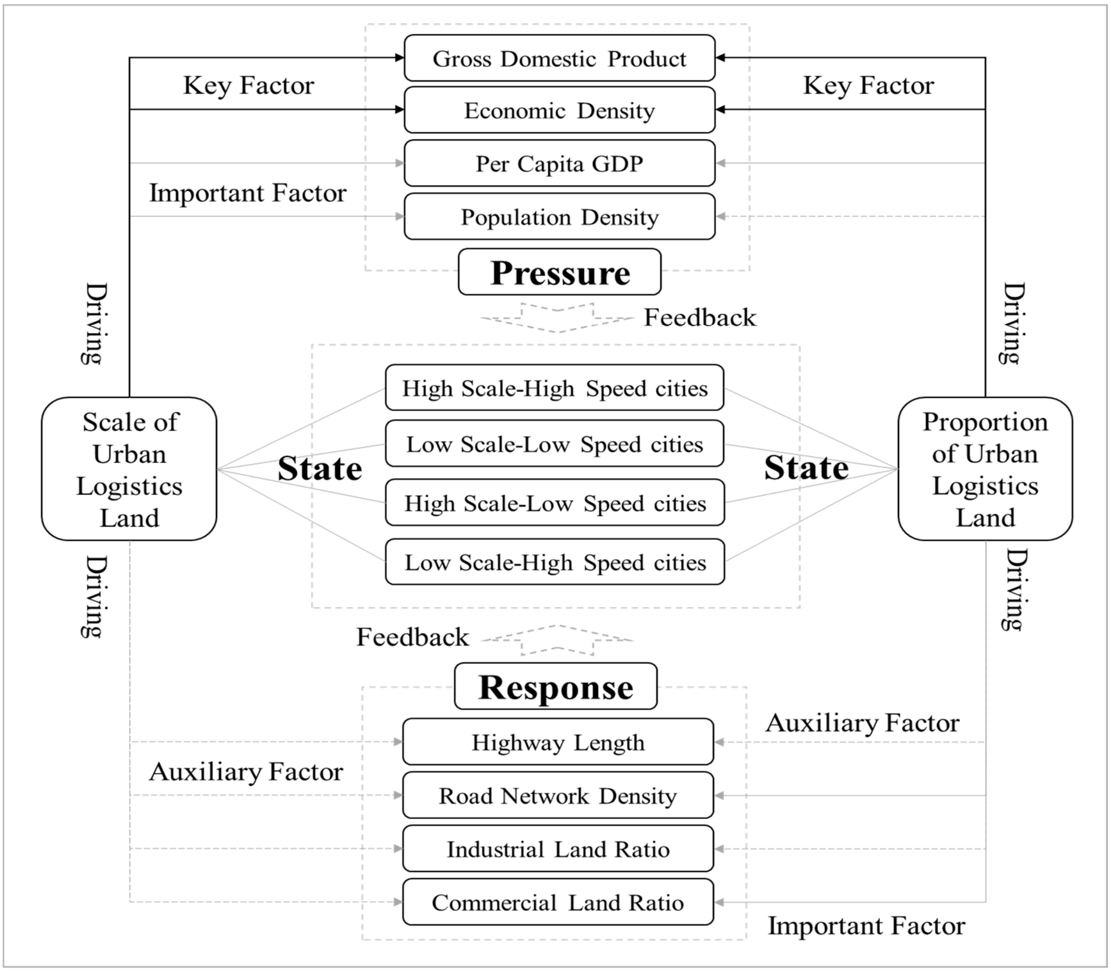

Figure 12. Spatial planning inspiration from the driving mechanism of logistics land.

From the perspective of independent variables, the influence of different factors varies greatly, and their hierarchy, complexity and spatial effects are very significant, so for the planning and management of logistics land, it is necessary to identify and highlight the value of single factor, while emphasizing the superimposed effect of multiple factors and figuring out the comprehensive impact, to propose the most appropriate planning strategy and optimization policy [84]. In terms of the single factor, the influence of the pressure factor is stronger than that of the response factor in both LLS and LLR. Pressure is the source of demand and response is the behavior of supply, thus proving that demand is the mainstay in the dynamic equilibrium system of supply and demand for logistics land, and therefore demand survey and mapping analysis should be the precondition for logistics land and spatial planning [85]. It is necessary to note that a single-factor influence is not the same as social consensus. For example, traditionally the government has attached great importance to the synergistic development of the logistics industry and the manufacturing industry, and introduced a series of development policies [85]. However, the empirical study in the YRD shows that the influence of commerce on logistics land use is higher than that of industry, indicating that along with the improvement of the quality of urbanization and the quality of life, especially the development of e-commerce, the government should highlight the position of commerce and trade while emphasizing the coordinated development of logistics and manufacturing [86]. The combined influence of environmental factors on logistics land should be calculated by inverse operations using geographically weighted regression coefficients as weights. For example, the final impact of all factors on logistics land use in cities such as Taizhou–ZheJiang, Ningbo, Quzhou, Shanghai, Shaoxing, Xuzhou, Lishui, Suqian, Bengbu, Jinhua, Suzhou–Anhui, and Lu'an was shown as the impetus. However, it was shown as the resistance in cities such as Jiaxing, Xuancheng, Wenzhou, Suzhou–Jiangsu, Yancheng, Maanshan, Wuhu, Yangzhou, Lianyungang, Nantong, and Taizhou–Jiangsu, and therefore they should be categorized into different zonings in the regional logistics land and spatial planning of YRD, with a design of differentiated management policies.

5. Conclusions

Based on BCG and GWR spatial metrology models, this research has built an empirical case on the evolution model and impact mechanism of urban logistics land use in the YRD from 2000 to 2020, and has reached the following conclusions:

Firstly, logistics land in the YRD varied greatly between cities, with significant hierarchical and spatial agglomeration. In terms of LLS, high-value cities were clustered in the Shanghai, Nanjing, Hefei and Xuzhou metropolitan areas in the early stage, and evolved to be distributed along transportation corridors in the form of fingers and belts in the later stage. The LLR showed that high-value cities were mostly clustered inland in the early stage, but migrated and expanded to the coast in the later stage.

Secondly, the spatiotemporal evolution of logistics land in the YRD has led to the emergence of four models, which are as follows: high scale–high speed cities, low scale–low speed, high scale–low speed cities, and low scale–high speed cities. Among them, the scale of logistics land has a positive spatial autocorrelation, and the proportion is exactly the opposite. It is worth noting that there is a phenomenon of both growth and inventory changes in the trend of logistics land use, and Shanghai, Zhenjiang, Huzhou, etc. are already in the stage of reduced development.

Thirdly, both the geographic distribution of logistics land and the evolutionary pattern showed significant spatial effects. The positive spatial autocorrelation of LLS was getting higher, while the spatial autocorrelation of the LLR turned from positive to negative and from insignificant to significant. The hotspot urban clusters of LLS and LLR were distributed in opposite directions, with the former in the Shanghai urban agglomeration area in the coastal region for a long time, and the latter in Anhui in the inland region for a long time. The evolution pattern of LLS showed a positive spatial autocorrelation, with hotspot cities clustered in coastal areas and cold spot cities in inland areas. The evolution pattern of LLR showed a negative spatial autocorrelation, but both hotspot and coldspot cities had a weak spatial agglomeration.

Fourthly, LLS and LLR had a very complex driving mechanism, and there was great heterogeneity in the intensity, nature and spatial effects of the influence of different factors. The level of influencing factors is divided into three levels (key, important and auxiliary), and the intensity of the pressure factor's influence on LLS and LLR was higher overall than that of the response factor. The factors are shown as the impetus and resistance in nature, with large differences in positive and negative action transition nodes. The influence of the factors showed a significant spatial agglomeration, while the influence of the Gross Domestic Product, economic density, highway length, and road network density on the

LLS exhibited gradient asymptotic characteristics, and the spatial effects of the other factors all manifested as cluster agglomerations.

Fifthly, the empirical study of logistics land use in the YRD has brought about the following spatial planning implications. First, logistics land demand survey and mapping analysis are the prerequisites and basis for territorial spatial planning. Second, logistics land planning in the new era should be city-specific, and the planning idea and mode are changing from growth to both growth and inventory. Third, the government should rationalize the performance assessment indicators for logistics land while weakening its economic contribution, and include logistics land in the scope of urban infrastructure and public service facility land. Fourth, a revision should be made to the Urban Land Classification and Planning Construction Land Use Standards to clarify the standards for controlling LLS and LLR. Fifth, in the planning and management of logistics land, it is necessary to identify and highlight the value of a single factor, and update the idea in a timely manner (e.g., suggest the synergistic of the logistics industry from the manufacturing to the business); it is also necessary to emphasize the superimposed effect of multiple factors, set up planning zoning, and design differentiated management policies.

The marginal contribution of our research is to quantitatively analyze the geographic distribution characteristics and evolution patterns of logistics land by introducing a spatial measurement model, and to further reveal the driving mechanism behind them, thus establishing a technical framework that integrates "evolution model-driving mechanism-spatial planning". The research methodology, analytical results, and policy recommendations of this research will provide important information and evidence for the spatial planning of logistics land in the YRD and even in China, and will also serve as a reference for the design of logistics spatial policies in other urban agglomerations around the world.

There are also some limitations in this study. First, due to the complexity of the components of logistics land and the lack of further detailed statistics and survey data, this study only dealt with the scale and ratio of logistics land as a whole, failing to measure the characteristics and change in the urban logistics land structure. Second, factors such as government policy and planning, logistics technology innovation, land prices and carbon emissions also have a large impact on the distribution and evolution of logistics land. Due to the difficulty of quantifying these factors and with no sufficient complete data available, this study did not include them in the driving mechanism analysis. These limitations inevitably have an impact on the results of the analysis, so the government and business decision makers should optimize and improve the results of the study based on the actual conditions during the use of them.

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