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The Spatiotemporal Non-Stationary Effect of Industrial Agglomeration on Urban Land Use Efficiency: A Case Study of Yangtze River Delta, China

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Abstract: All over the world, Industrial agglomeration has become a key to improve the efficiency of urban land use and regulate the process of urbanization. Industrial agglomeration, as a universal economic geographical phenomenon, has been extensively studied, but few scholars have discussed the relationship between industrial agglomeration and urban land use efficiency. Based on this, after classifying the type of agglomeration externalities, our study uses OLS and GTWR models to explore the complex mechanism of interaction between industrial agglomeration externalities and urban land use efficiency, especially the spatiotemporal non-stationary characteristics. We found that the impact of industrial agglomeration externalities on urban land use efficiency is significantly unstable in time and space, and the coexistence, substitution and aging mechanism of agglomeration externalities among different types were also observed. Our research can provide reference for city managers to formulate reasonable industrial policies and enterprises to choose the location. Meanwhile, our research has made some contributions to the academic research on urban land use efficiency.

Keywords: industrial agglomeration; urban land use efficiency; spatio-temporal non-stationary; GTWR; Yangtze River Delta

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1. Introduction

Urban land use efficiency (ULUE) is a comprehensive topic integrating the economy, society, ecology and sustainable development, which has been of high concerned by government departments and scholars [1–3], especially under the background of biodiversity loss [4], soil pollution [5,6], excessive CO_2 emission [7–9] and so on. Since 1978, with the rapid advancement of urbanization, China's urban construction land has expanded rapidly [10,11], from 6720.0 km^2 in 1986 to 58,355.3 km^2 in 2020 (China Urban Construction Statistical Yearbook 2021). The continuous expansion of urban construction land occupies a large amount of agricultural and ecological land [12,13], leading to the increasingly prominent contradiction between regional development, agricultural land protection and ecological conservation and, thus, posing a serious threat to national food security and regional ecological environment [14]. In essence, these problems are directly or indirectly related to inefficient use of urban land [15]. In this context, it is objectively required to improve the efficiency of urban land use efficiency to reduce the occupation of agricultural land [16]. At the same time, it is predicted that the degree of global urbanization will reach 69% in 2050 [17]. In the face of the unstoppable wave of urbanization, how to optimize the urbanization process and achieve sustainable urban development by improving the utilization efficiency of urban land is an urgent issue for all countries [18–22].

Scholars have carried out rich studies on urban land use efficiency, mainly focusing on the connotation, measurement and influencing factors of urban land use efficiency. In terms of connotation, it generally focuses on the understanding from the perspective of economics, which represents the ratio between the effect of achieving goals and the resources consumed [23]. With the aggravation of habitat destruction and environmental pollution, urban land use must comprehensively consider economic, social and environmental factors to maximize economic, social and ecological utility [24]. Therefore, undesirable outputs must be considered for the evaluation of land use efficiency [25].

In recent years, scholars and government departments have paid more attention to the driving factors and mechanism of urban land use efficiency. There have been abundant studies on the driving factors of ULUE. The most obvious driving factors of ULUE come from the Cobb–Douglas production function. Capital intensity, labor intensity and land productivity are thought to be the direct determinants of ULUE [26,27]. Masini explored the nexus between economic growth and land use efficiency in 417 cities in 17 European countries and found that the richer the city, the higher the land use efficiency [3]. The second group focuses on some key economic and social factors, for example, urbanization and industrialization [28]. Furthermore, the availability of life facilities, such as transportation, electricity and education, is critical to ULUE [29]. In addition, ULUE is also thought to be related to factors like the heterogeneity of firms [30], Development strategies based on "special zones" [31] and so on. Generally speaking, globalization, marketization, urbanization and decentralization are considered to be the most important factors driving the change of ULUE, especially in developing countries [32–35]. Globalization, through foreign investment and international trade, has integrated China's economy into the world economy and participated in global competition, which has greatly increased the demand for land and helped local enterprises develop advanced production technology and management experience [36]. Market-oriented reform has gradually broken the distortion of land market caused by administrative dominance, embodied the economic value of land and improved ULUE [37]. At the institution level, the land reform characterized by marketization has brought about the improvement of land value-added and the efficiency of land use [38]. As one of the important characteristics of urbanization development, it was found that increasing population density can effectively avoid excessive urban expansion [18]. In addition to population, the adjustment of industrial structure is also considered to promote the improvement of ULUE, because it can timeously eliminate backward production capacity and guide investors to turn to high value-added and high-tech industries [34,39–41]. The completeness of infrastructure, especially transportation facilities, affects the layout of enterprises in surrounding cities through the spillover effect, thus improving ULUE [42–44]. As for the decentralization reform, local governments have gained certain political and economic autonomy, which has greatly promoted the development of local industries. However, it is also easy to encourage local protectionism and result in the convergence of industries across the country [32].

In addition to the above driving factors, more and more scholars have begun to emphasize the impact of industrial agglomeration on ULUE [45,46]. The externalities brought by industrial agglomeration can benefit the whole region. In fact, with the development of the industrial division of labor and trade globalization, industrial agglomeration is widespread in both developing and developed countries [47–49]. For example, in China, to cope with the increasing costs of land, labor and other factors, China's industrial layout has shown a very obvious agglomeration feature, especially after its accession to the WTO [50]. As the spatial carrier of industrial agglomeration, the establishment of a large number of development zones further promotes industrial agglomeration and improves the efficiency of urban land use [45,51]. In fact, with limited land resources, only by optimizing industrial layout and structure and improving the efficiency of land use can we achieve economic development goals [52]. Nowadays, it is generally accepted by scholars to divide industrial agglomeration externalities into Marshall externalities, Jacobs externalities and Porter externalities [53,54]. Existing studies have shown that agglomeration externalities have a significant impact on land use efficiency [46,55]. However, there is a lack of a systematic framework, especially from the perspective of three externalities of industrial agglomeration, to discuss the influence mechanism of industrial agglomeration on ULUE. Moreover, in recent years, with the popularity of variable coefficient models, the characteristics of spatio-temporal non-stationarity of agglomeration externalities have also been observed [55,56]. Then, does the impact of industrial agglomeration externalities on ULUE also show non-stationary characteristics in time and space?

Based on the above analysis, the following problems need to be solved: What are the impacts of different types of industrial agglomeration externalities on ULUE, and how do they work, individually or in more complex relationships? Is this interaction stable in time and space? In order to solve these problems, this study selected the urban agglomeration in the Yangtze River Delta of China as an example to explore the influence mechanism between industrial agglomeration externalities and ULUE by using the GTWR model. While making some contributions to the research in the field of urban land use efficiency, this study can provide meaningful enlightenment for decision-makers to formulate more reasonable industrial policies and also provide a certain reference for enterprises in the location choice. Specifically, the structure of this paper is as follows: the second part constructs the conceptual framework of the influence mechanism of agglomeration externalities on ULUE; the third part presents data and methods; the fourth part presents the results; the fifth part is the discussion; the final part is the conclusion of this paper.

2. Mechanism of Industrial Agglomeration Externalities on ULUE

New Economic Geography believes that spatial agglomeration of industries can integrate various market resources, accelerate factors flow, reduce transaction costs through deepening division of labor, improve industrial production efficiency, and promote the sharing of development achievements by neighboring regions through the spatial spillover effect [57]. From the perspective of differences, agglomeration externalities can be divided into three types. The first type is MAR externality, also known as Marshall externality or specialization externality. Specialization externality indicates a situation in which any company benefits from local companies in the same industry, and with the development of a specialization economy, cities will increasingly specialize, and the benefits brought by their own industrial agglomeration will exceed the costs caused by commuting and congestion, improving the overall performance of the industry [58]. Combining the ideas of Arrow and Romer, Gleaser pioneered the MAR model to describe this scenario. The model points out that the agglomeration of the same industry in a region promotes the knowledge spillovers between companies, which accelerates the technological progress of the industry and ultimately promotes economic growth. The resulting agglomeration economy is known as a dynamic externality, which is considered to be an engine of economic growth [53,58–60]. The Marshall externality shows that the geographic agglomeration of industries can increase the efficiency of industrial production, improve the performance of industries in the whole region and improve the local ULUE through three paths: reducing transport costs, creating a labor pool (reducing training costs and counteracting the risk of unemployment) and promoting the exchange and transmission of knowledge [61].

The second type of agglomeration externality is often referred to as the diversity externality or Jacobs externality. Jacobs believes that the exchange and collision of knowledge and ideas between different industries can generate new knowledge and ideas, promote industrial restructuring and give rise to new industries and that the creation of new industries and new jobs can promote a whole set of division of labor, expand the scale of the city and ultimately realize the development of the city, which makes the city full of vitality [62]. Combes takes this a step further, arguing that only technologically connected industries can fulfil the expectations of diversity externalities on urban growth, as only similar sectors can absorb intermediate products and innovative knowledge [63]. The Jacobs externality affects urban land use in many ways, one of which is improving labor productivity [64]. The improvement of labor productivity not only increases the intensity of land inputs and use, but also the income per unit of land. On the other hand, with the phased development of the industry, the transition from vertical to horizontal division of labor will inevitably occur, resulting in a corresponding development of service industries, especially the diversified agglomeration of productive services, which implies an upgrading of the industrial structure and ultimately promotes the optimization of land use structure. In addition, the agglomeration of diversified industries will be more conducive to technology transmission and knowledge spillover, thus improving the efficiency of land factors [65].

Another important externality of industrial agglomeration was proposed by Porter in 1990, and this type of externality is known as the Porter externality or competition externality [66]. Competition is better for growth, Porter argues, and intense competition in the same market provides an important incentive for innovation, which, in turn, constantly drives industrial upgrading and new processes. If an enterprise or even a country wants to maintain its competitive advantage globally, it must constantly promote innovation, which benefits from the intense competition among enterprises. The more intense the competition, the more conducive it is to the comprehensive development of enterprises and the integration of enterprises into the global economy. Competition among multiple enterprises in the same industry has been proven to be beneficial to the efficiency of land production in urban agglomerations [67]. It is important to note, however, that the effect of competition on growth is non-linear [63]. The Schumpeter model emphasizes this mechanism: intense competition motivates enterprises to make important R&D investments, but if the continuity of innovation is too fast, the return from R&D is low, which reduces the amount of R&D and, in turn, has a negative impact on innovation [68,69].

It should be pointed out that the agglomeration externalities will be uneven in time and space, as the industrial structure will be obviously spatially heterogeneous due to historical and natural conditions. Uneven inter-provincial development exists even in the urban agglomeration of the Yangtze River Delta, which promotes regional integration. Anhui Province, which still has a large proportion of primary industries, is not considered to be well integrated into the integration process of the Yangtze River Delta. In contrast, superior location conditions and more favorable industrial policies can attract various industries to take root in Jiangsu, Zhejiang and Shanghai, and therefore, these regions can have a more diversified industrial structure. In addition, there is always an optimal level of factor agglomeration due to both congestion and agglomeration effects in cities [70]. Excessive agglomeration may have a negative impact on land use efficiency [71]. The theoretical framework of the impact of industrial agglomeration externalities on ULUE is shown in Figure 1.

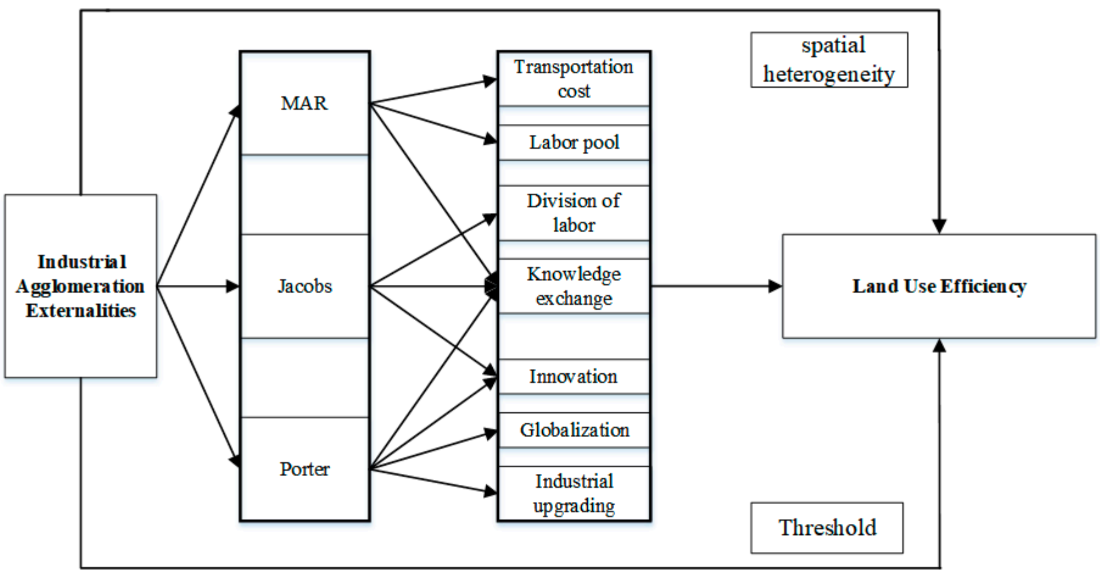

Figure 1. Theoretical framework of Industrial Agglomeration Externalities affecting ULUE.

3. Methods and Data

3.1. Study Area

Located between 29°20′–32°34′ north latitude and 115°46′–123°25′ east longitude, the Yangtze River Delta region is a flood plain formed before the Yangtze River enters the sea, bearing 41 cities in Shanghai, Jiangsu, Zhejiang and Anhui provinces (see Figure 2). As these regions are adjacent to each other and have similar cultural backgrounds, they have become increasingly economically integrated through human and economic ties. Today, this region has become the largest and most comprehensive economic center in China, as well as one of the six city clusters in the world [72]. As the driving force of China's economic growth, the industrial structure of the Yangtze River Delta is dominated by the second and third industries [73] and shows a high degree of spatial agglomeration [74].

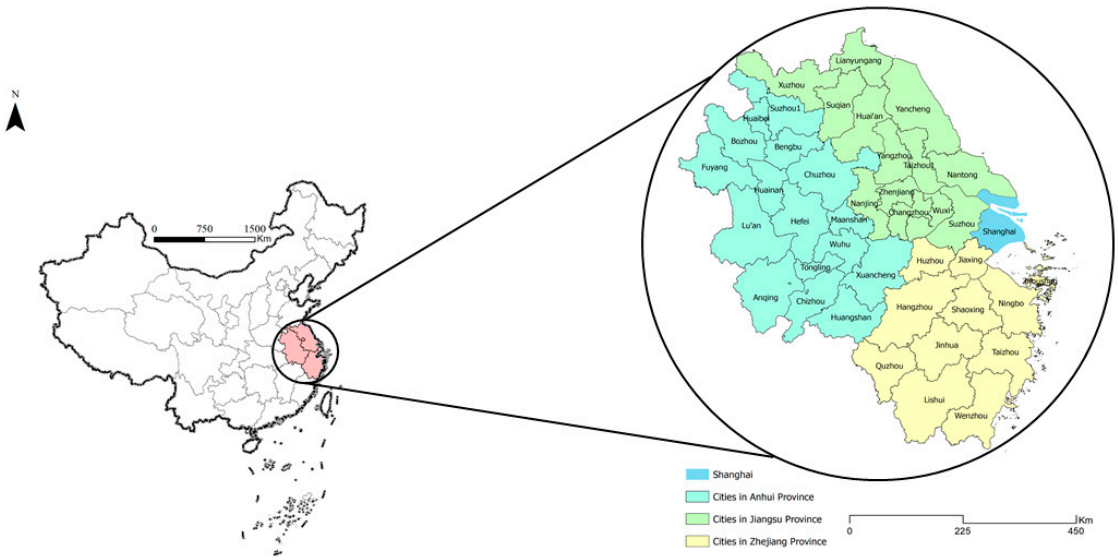

Figure 2. Location of the Study Area.

The selection of the Yangtze River Delta urban agglomeration as the research area is mainly based on the following three considerations: (1) the Yangtze River Delta is densely populated and has complete industries. Therefore, a reasonable industrial classification can be carried out to meet the premise of the study; (2) The Yangtze River Delta is composed of three provinces and one city. It is home to both highly developed cities, such as Shanghai, and many underperforming third-tier cities, making the findings more general based on the Yangtze River Delta; (3) Although the Yangtze River Delta city cluster is economically active and industrially prosperous, the unreasonable industrial structure and slow industrial transformation are still important problems plaguing the urban development of the Yangtze River Delta [74]. Therefore, how to carry out industrial layout is a key issue worth studying.

3.2. GTWR Model

The traditional GWR model takes extra spatial dimensions into account on the basis of the ordinary OLS regression, while the GTWR model introduces a temporal dimension on the basis of GWR model. Therefore, the GTWR model can fully consider the non-stationary property of time and space and has incomparable advantages over ordinary OLS fixed coefficient estimation, which can produce more accurate estimation effects. Therefore, this paper adopts the GTWR model to estimate the impact of different externalities of industrial agglomeration on ULUE. The basic form of the GTWR model is as follows:

$$y_i = \beta_0(u_i, v_i, t_i) \sum_{k=1}^{p} \beta_k(u_i, v_i, t_i) x_{ik} + \varepsilon_i \tag{1}$$

where y_i is the observed value; (u_i, v_i, t_i) are the spatiotemporal co-ordinates of the i-th observation point. $\beta_0(u_i, v_i, t_i)$ is a regression constant; $\beta_k(u_i, v_i, t_i)$ is the regression coefficient of the k−th independent variable. x_{ik} is the value of the k-th independent variable at the i-th observation point, and ε_i is the residual error.

The key of the. GTWR model is to determine the spatio-temporal weight matrix and bandwidth. According to the research method of Huang. et al., the gaussian function is used to calculate the spatio-temporal weight matrix, the specific form is as follows [75]:

$$w_{ij} = exp\left(-\frac{\left(d_{ij}^S\right)^2 + \left(\frac{\mu}{\lambda}\right)\left(d_{ij}^T\right)^2}{h_{ST}^2}\right) \tag{2}$$

The cross validation (CV) method is used to select the bandwidth. When CV reaches the minimum value, the corresponding b is the optimal bandwidth, which is expressed as follows:

$$CV = \sum_i^n \left[Y_i - \hat{Y}_i(b)\right]^2 \tag{3}$$

3.3. Variable Selection and Data Processing

3.3.1. ULUE Evaluation

Before evaluation, it is necessary to define "city". According to the National Bureau of Statistics of the People's Republic of China, a city refers to an urban area with the approval of The State Council of the People's Republic of China for the establishment of a city system. China's National Bureau of Statistics provides two statistical standards for cities' economic and social indicators: Total City and Districts under City. In this study, "City" refers to "Total City", namely, the whole city.

In terms of ULUE measurement, the Stochastic Frontier Analysis (SFA) and Data Envelopment Analysis (DEA) are two mainstream methods to measure urban land use efficiency. Among them, SFA is an estimation method with a specific function form. Generally, it uses the maximum likelihood method for estimation, which has the advantages of not being affected by extreme values and considering residual terms when measuring absolute efficiency [76]. DEA, originally invented by Charnes, is a non-parametric method used to measure the relative efficiency of a set of decision-making units (DMU). Since there is no need to set a specific function form, DEA avoids subjective weighting and is widely used in various performance evaluations [77]. In comparison, SFA has more advantages in measuring productivity, but this model is only applicable to projects with single unit output, and it fails to compare the economic efficiency and environmental efficiency of multi-output projects [78]. In view of this, the DEA method is more advantageous in evaluating the efficiency of land use as a synthesis of economic, social and environmental factors.

However, the classical DEA model does not take into account undesired factors, such as wastewater, exhaust gas and soot, but these factors are widely present in actual production activities and constitute the part that people do not want to produce [25], especially in the context of China's policy of high-quality development and harmonious coexistence between humans and the environment, and undesirable outputs must be considered in the evaluation system of production efficiency. The SBM model can well solve the efficiency evaluation problem of DMU considering undesirable outputs [79], but general SBM cannot distinguish the difference between multiple efficient DMU with an efficiency of 1. Therefore, this paper used a super-efficient SBM model to evaluate the efficiency of each unit in the study area, which is shown below:

$$min\rho = \frac{\frac{1}{m}\sum_{i=1}^{m}\left(\frac{\overline{x}}{x_{ik}}\right)}{\frac{1}{r_1+r_2}\left[\sum_{S=1}^{r_1}\frac{\overline{y^d}}{y_{sk}^d} + \sum_{q=1}^{r_2}\frac{\overline{y^u}}{y_{qk}^u}\right]} \tag{4}$$

$$\left\{\begin{array}{c} \overline{x} \geq \sum\limits_{j=1,\neq k}^{n} x_{ij}\lambda_j; \overline{y^d} \leq \sum\limits_{j=1,\neq k}^{n} y_{sj}^d \lambda_j \\ \overline{y^d} \geq \sum\limits_{j=1,\neq k}^{n} y_{qj}^d \lambda_j; \overline{x} \geq x_k \\ \overline{y^d} \leq y_k^d; \ \overline{y^u} \geq y_k^u; \\ \lambda_j \geq 0, i = 1,2,\ldots,m; j = 1,2,\ldots,n; \\ s = 1,2,\ldots,r_1; q = 1,2,\ldots,r_2; \\ \sum\limits_{j=1}^{n} \lambda_j = 1 \end{array}\right. \quad (5)$$

where ρ represents urban land use efficiency (ULUE); n represents decision units; m represents inputs; r_1 represents expected outputs; r_2 represents undesirable outputs and x, y^d, y^u are elements in the corresponding input matrix, desired output and undesired output matrix.

In this paper, construction Land area (Land), Capital investment in fixed assets (Capital) and Labor in secondary and tertiary industries (Labor) were selected as input indicators. The output value of secondary and tertiary industries (Output value), Road per capita (Road) and the green area of built-up areas (Green area) were selected as expected output indicators. Wastewater, soot and SO_2 emissions were selected as undesirable output indexes. All the above indicators, except the green coverage rate of built-up areas, were from the China Urban Construction Statistical Yearbook, and the data of other indicators were from the CHINA CITY STATISTICAL YEARBOOK, with the years ranging from 2005 to 2016 (as shown in Table 1).

Table 1. Statistical description of Input-output indicators.

Composition of Indicator		Description	Unit	Sources	N	Mean	Max	Min	SD
Inputs	Land	The area of urban built-up area	km^2		492	191.6	2916	13	402.5
	Capital	The gross investment in fixed assets	10,000 yuan		492	14,800,000.00	67,500,000.00	756,084.00	14,200,000.00
	Labor	The number of jobholders in secondary and tertiary sectors	10,000 people		492	68.98	724.9	6.24	90.46
Outputs	Output value	Output value of secondary and tertiary sectors	100 million yuan		492	2458	28,069	84.55	3351
	Road	The per capita urban road area	m^2	CHINA CITY STATISTICAL YEARBOOK	492	12.78	37.95	1.43	5.957
	Green area	The green ratio of a built-up area	%	China Urban Construction Statistical Yearbook	492	39.67	49.78	14.18	5.176
Undesirable outputs	Wastewater	The volume of discharged industrial wastewater	10,000 tons		492	13,105	85,735	626	15,396
	soot	The volume of discharged industrial soot emissions	tons	CHINA CITY STATISTICAL YEARBOOK	492	55,654	496,377	1925	55,725
	SO_2	The volume of discharged industrial SO_2 emissions	tons		492	25,335	131,433	971	20,369

3.3.2. Agglomeration Externalities

As discussed above, this paper classifies industrial agglomeration externalities into three categories, namely specialization agglomeration externalities (MAR), diversity agglomeration externalities (Jacobs) and competition agglomeration externalities (Porter). The premise for the correct measurement of industrial agglomeration externalities is to carry out reasonable industrial classification. Combining the data availability with the research carried out by relevant scholars, the basic idea of industrial classification is to classify according to the three industries. On this basis, according to the United Nations Standard Industrial Classification (SIC), the service industries in the tertiary industry are further subdivided into four categories: Producer Services, Consumer Services, Circulation

Services and Social Services [80]. Ultimately, we obtained six broad industrial categories. The six broad industrial categories and their specific sub-industries are shown in Table 2.

Table 2. Classification of industry categories and more specific industries.

Industry Categories		Specific Industries
Primary industry		Agriculture, forestry, animal husbandry and fishery
Secondary industry		Mining, manufacturing, electricity, gas and water production and supply and construction
Tertiary industry	Producer Services	Finance, real estate, leasing and business services
	Consumer Services	Accommodation and catering, residential and other services, culture, sports and entertainment
	Circulation Services	Transportation, warehousing and postal services, information transmission, computer services and software, wholesale and Retail
	Social Services	Scientific research and technical services, qualified exploration, water conservancy environment and public facilities management, education, health and social security and social welfare, public administration and social organizations

(1) Specialization agglomeration externalities (MAR)

Gleaser published Growth in Cities in 1992, which invented the measurement methods of various agglomeration externalities and systematically discussed the mechanism of various externalities on urban economic growth, which is a classic work in the field of industrial agglomeration externalities [53]. The measurement method of industrial specialization proposed by him is essentially the same as the location quotient widely used in economics. Therefore, the location quotient is used to represent the specialization level of industrial agglomeration, and its calculation formula is as follows:

$$LQ_{ij} = \frac{\frac{L_{ij}}{L_J}}{\frac{L_i}{L}} \tag{6}$$

where LQ_{ij} stands for location quotient, L_{ij} represents the number of employments in industry i in region j, L_j represents the total number of employments in all industries in region j, L_i represents the total number of employments in industry i within the region and L represents the total number of employments in all industries within the region. In general, when $LQ > 1$, it means that the specialization degree of industry i in region j exceeds the average level of the research area. The larger the value of LQ is, the higher the specialization level of industry is. When $LQ = 1$, it means that the specialization of industry i in region j is equivalent to the average level of specialization of industry i across the whole research region. When $LQ > 1$, it means that the industry specialization is below the average level of industry specialization within the study area.

(2) Diversity agglomeration externalities (Jacobs)

The most common way to measure the agglomeration externalities of industrial diversity is to use the Hirschman–Herfindahl index or its reciprocal form, the reciprocal form of which is shown in Equation (4):

$$DI_i = \frac{1}{\sum s_{ij}^2} \tag{7}$$

where i represents industry, and j represents region. If industry in region j is highly concentrated in a certain category, then $DI_i = 1$, and the index will rise as the increase of regional industry diversification occurs. Combes pointed out that industrial diversity works on the premise that sectors are technologically closely related. In other words, inventions in one sector can be incorporated into production in another industry. Therefore, it is necessary to consider whether the sectors are closely related or not [63]. On this basis, Frenken was the first to decompose the diversity index based on the entropy index and define the concepts of Related Variety (RV) and Unrelated Variety (UV) [81]. Further decomposition of diversity is undoubtedly beneficial for us to have a deeper understanding of the role of industrial agglomeration, and the level of industrial diversity can be expressed as:

$$\begin{aligned} E_T &= \sum_{s=1}^{s} \sum_{i \in s} P_i \ln\left(\frac{1}{P_i}\right) = \sum_{s=1}^{s} \left[\sum_{i \in s} (P_s/P_s) P_i \left(\ln(P_s/P_i) + \ln\left(\frac{1}{P_s}\right) \right) \right] \\ &= \sum_{s=1}^{s} P_s \left(\sum_{i \in s} \left(\frac{P_i}{P_s}\right) \ln\left(\frac{P_s}{P_i}\right) \right) + \left(\sum_{s=1}^{s} P_s \ln\left(\frac{1}{P_s}\right) \right) = \sum_{s=1}^{s} P_s E_w + E_A \end{aligned} \quad (8)$$

Among them, $\sum_{s=1}^{s} P_s E_w$ is the product of E_w and P_s, where E_w represents the entropy indicator of diversity between broad sectors in an economic system, and P_s represents the share of this sector. $\sum_{s=1}^{s} P_s E_w$ measures the industrial connections within each broad sector, namely the degree of diversity of subdivided industries, called Related Variety (RV); E_A is the entropy indicator of diversity between each industry category, called Unrelated Variety (UV). Unrelated Variety (UV) is not completely devoid of correlation; it represents sectoral diversity where industry correlations are relatively weak.

(3) Competition agglomeration externalities (Porter)

For the measurement of the Porter externality, the main method used by scholars is to use indicators such as the number of employments, the number of enterprises and the value added of industries within a city to find the proportion of the number of enterprises or value added of industries per capita in the local area to that of the whole study area. The higher the index value, the greater is the number of enterprises and the more competitive the city [53,82]. We use the ratio of the number of enterprises in industry j in region i to the added value of that industry divided by the value of this proportion in the whole research area, as shown below:

$$C_{i,j} = \frac{\frac{NBE_{i,j}}{Y_{i,j}}}{\frac{NBE_{g,j}}{Y_{g,j}}} \quad (9)$$

where $NBE_{i,j}$ represents the number of enterprises in industry j in region i, $NBE_{g,j}$ represents the number of enterprises in industry j in the whole research area and the corresponding $Y_{i,j}$ and $Y_{g,j}$ represent the industrial added value of enterprises engaged in activities of industry j in region i and the whole research area, respectively.

3.3.3. Control Variables

According to the above discussion, urban land use efficiency (ULUE) is mainly influenced by globalization, marketization, decentralization and urbanization. Accordingly, we adopted per mu foreign direct investment (FDI) to represent the impact of globalization on ULUE; labor flow (LF) as a marketization proxy variable [34]; fiscal revenue and the expenditure ratio of local government (DEC) as a decentralization index and population density (POP), industrial structure (IS) and the number of public buses per 100 people (TP) as the urbanization index. In addition, according to the research of scholars, the average salary of employees (ED) was selected to represent the difference of the general economic development level, and the number of college students (EDU) was selected as the characteristic variable of human capital. In order to ensure the consistency of magnitude among variables, the four variables, namely FDI, POP, ED and EDU, were logarithmically treated. All the data above, except the green coverage rate of the built-up area, were obtained from CHINA CITY STATISTICAL YEARBOOK, with the years range from 2005 to 2016. See Table 3 for details of each variable.

Table 3. Statistical description of the selected variables.

Layer	Layer 2	Variable	N	Mean	Max	Min	SD
Dependent variables		ULUE	492	0.88	1.534	0.314	0.264
Independent variables		MAR	492	4.526	46.06	1.255	5.958
		UV	492	1.199	1.558	0.667	0.181
		RV	492	0.923	1.168	0.377	0.142
		Porter	492	1.275	2.707	0.25	0.545
Control variables	Globalization	FDI	492	6.232	9.951	2.52	1.034
	Marketization	LF	492	0.136	1.841	0.0022	0.206
	Government behavior	DEC	492	0.664	1.174	0.0686	0.245
	Urbanization	POP	492	7.694	9.149	5.226	0.535
		IS	492	0.831	2.339	0.313	0.254
		TP	492	7.573	21.05	0.43	4.386
		ED	492	10.54	11.7	9.318	0.461
		EDU	492	10.84	13.63	7.445	1.102

4. Results

4.1. Spatiotemporal Distribution of ULUE

According to the calculation of the super-efficiency SBM model, the ULUE of 41 prefecture-level cities during 2005–2016 is shown in Figure 3. The annual average value of ULUE fluctuates around 0.88. Among them, Shanghai has the highest ULUE, with an annual average value of 1.11, followed by Zhejiang province, with an annual average value of 0.96. Jiangsu province and Anhui province have a lower ULUE, with an annual average of 0.85 and 0.84, respectively. After more than a decade of development, the gap of ULUE between cities has narrowed, and cities in the Yangtze River Delta are increasingly tending to develop in a balanced way. Cities with a high rank in hierarchy always have high ULUE, for example, Shanghai, Hangzhou and so on. Due to spatial spillover effects, their surrounding cities' ULUE also perform well. Some cities have got high ULUE, even if they do not have the location advantages. The reason is that these cities are well-known tourist cities in China. On the one hand, they can obtain considerable economic income by relying on tourism resources. On the other hand, for the sustainable development of tourism resources, the local governments of these cities have imposed strict restrictions on pollution emissions, so their ULUE performance is generally good. ULUE in the marginal cities of the study area is significantly lower than that in other cities. These cities are poorly located, far from the economic centers, and have a weak industrial base, resulting in poor performance of urban land use efficiency. From 2005 to 2016, the ULUE of prefecture-level cities showed obvious spatial correlation. In the early years, high ULUE values were scattered, and cities with high ULUE values existed in the northern, central and eastern parts of the study area. After 2014, ULUE showed an obvious trend of agglomeration toward the center and the south.

4.2. Spatiotemporal Distribution of Three Agglomeration Externalities

4.2.1. Spatiotemporal Distribution of MAR

Figure 4 shows the temporal and spatial characteristics of MAR. Cities with high MAR values are mainly concentrated in the northern and western parts of the study area, while those in the middle and southern of the study area have low MAR values. The annual mean value of MAR in Anhui province was 7.37, which was much higher than that in other provinces and cities (2.35 in Zhejiang province, 2.80 in Shanghai and 3.00 in Jiangsu province). This is related to the level of development of prefecture-level cities in the region. Anhui province still faces difficulties in integrating into the regional integration of Yangtze River Delta. Its primary industry still accounts for a large proportion and absorbs a considerable part of the labor force [83]. Cities with low MAR values are mainly located in the central and southern part of the study area. Most of these cities are located on the eastern coast of China, which are the first to initiate market-oriented reforms and participate in global competition. Thanks to geographical conditions and policy support, these cities have attracted different kinds of enterprises to settle in, so their industrial specialization is not high. In addition, it can be seen that after more than a decade of development, MAR values of most cities in the Yangtze River Delta have decreased significantly, indicating that the overall industries of the urban agglomeration in the Yangtze River Delta tend to develop in a diversified way. By 2016, only several prefecture-level cities, such as Ma'anshan, Huainan and Huaibei, showed highly specialized industrial characteristics.

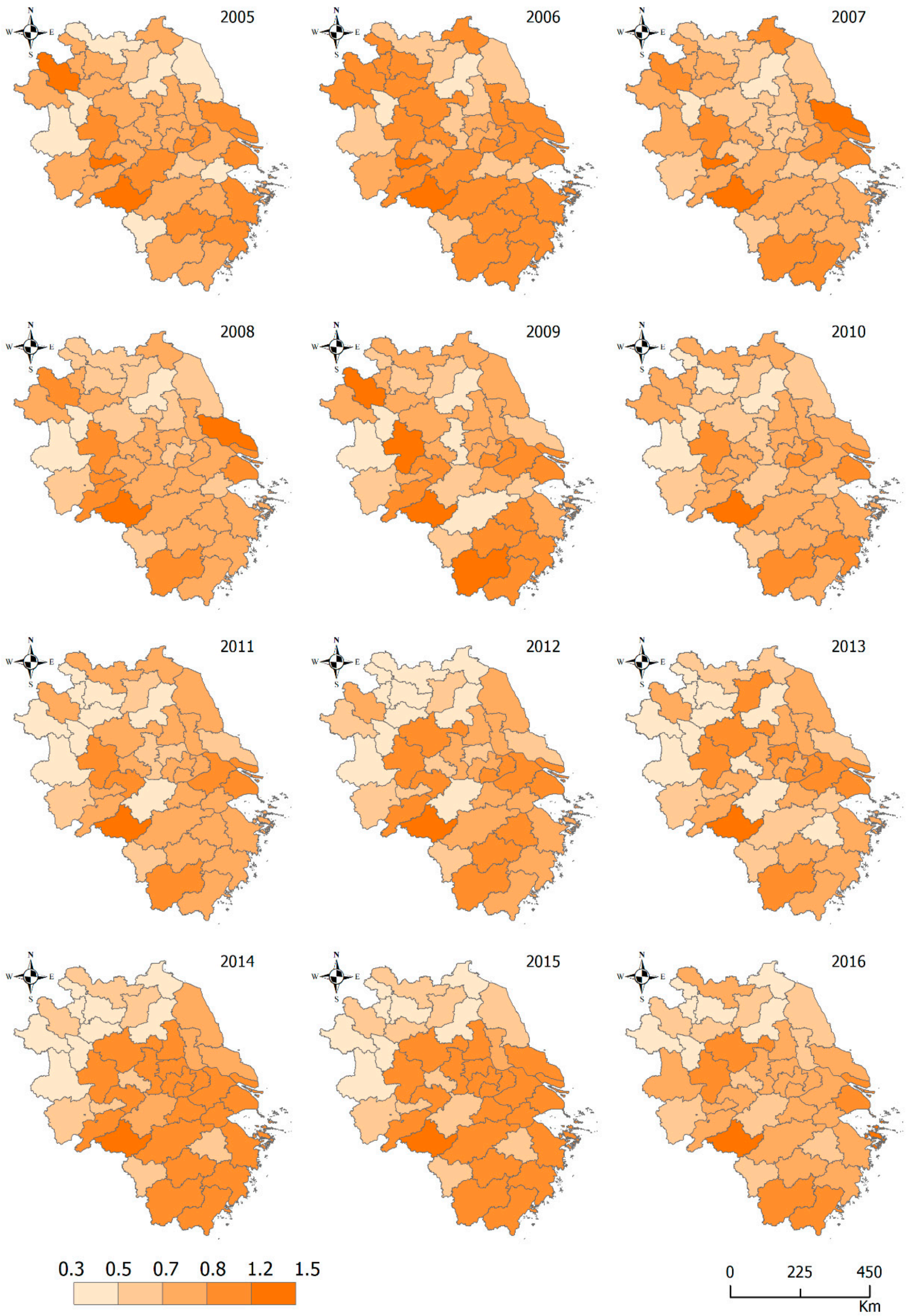

Figure 3. Spatiotemporal distribution of ULUE.

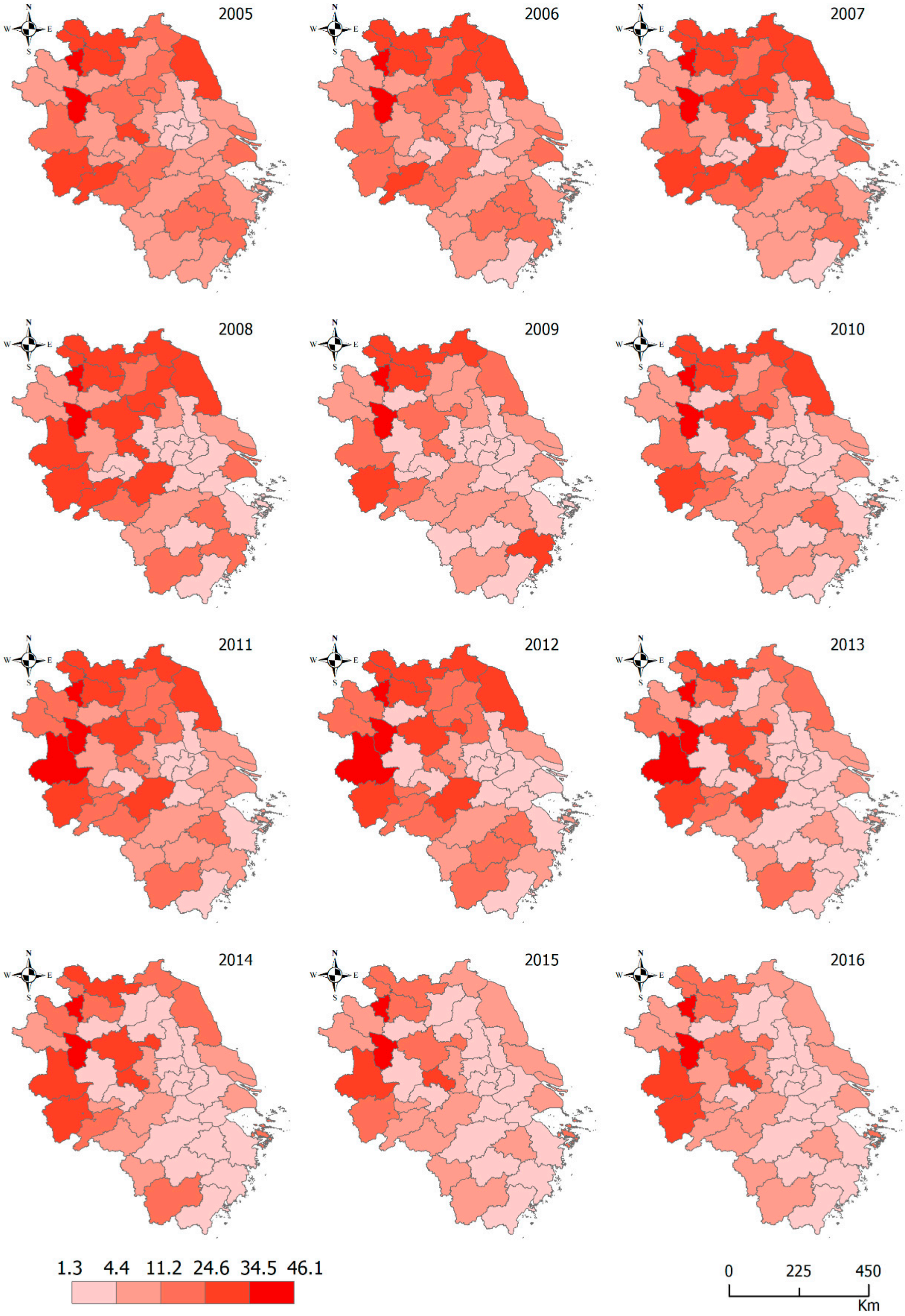

Figure 4. Spatiotemporal distribution of MAR.

4.2.2. Spatiotemporal Distribution of UV

Figure 5 shows the spatio-temporal characteristics of UV. In general, the UV difference in the Yangtze River Delta urban agglomeration is small. Shanghai has the highest annual mean UV value of 1.48, followed by Anhui province with 1.25. Jiangsu province and Zhejiang province have relatively close UV values of 1.17 and 1.13, respectively. Specifically, cities with high UV values are mainly concentrated in Shanghai, the southwest of Anhui province, the northeast of Jiangsu province, the north of Jiangsu province and some cities of Zhejiang Province. After more than a decade of development, UV has not only shifted significantly among the Yangtze River Delta urban agglomerations but has also shown proximity. From 2005 to 2009, the UV high values were significantly concentrated in the north and northeast of the study area, and since 2010, the UV high values have gradually shifted to the southwest, with the UV of Suzhou and Anqing in Anhui province gradually rising, indicating the existence of an inter-provincial industrial transfer phenomenon in the Yangtze River Delta in recent years. Overall, the differences in UV among cities in the Yangtze River Delta have been narrowing, with the annual mean value of UV in the Yangtze River Delta urban agglomeration decreasing from 1.28 in 2005 to 1.17 in 2016. In the past 12 years, the UV gap among provinces has also been narrowing, with Shanghai dropping from 1.52 to 1.50, Jiangsu province from 1.31 to 1.04, Zhejiang province from 1.20 to 1.12 and Anhui province from 1.29 to 1.28. This indicates that the link between the Yangtze River Delta industry sectors has weakened.

4.2.3. Spatiotemporal Distribution of RV

Figure 6 shows the spatio-temporal characteristics of RV. RV fluctuated within the range of 0.38~1.17, with a mean value of 0.92. In terms of provinces, RV fluctuation in Shanghai is the smallest, with an average value of 0.85, a minimum value of 0.80 and a maximum value of 0.92 in 12 years, which indicates that the linkages between industries in Shanghai is the most stable and close. The mean value of RV in Anhui province was the highest in the study range, with a value of 1.00. RV changes in Zhejiang province and Jiangsu province were the most dramatic. The 12-year mean value of RV in Jiangsu province was 0.86, which fluctuated in the range of 0.44~1.12. The mean value of RV in Zhejiang province in 12 years was 0.89, which fluctuated in the range of 0.38~1.11. As can be seen from the characteristics of RV, the industrial structure of Jiangsu and Zhejiang provinces is relatively diversified, but there is a great difference in the tightness of the industrial technology connection between prefecture-level cities. Geographically, RV high values are mainly concentrated in northern Jiangsu province, western Anhui province and central and western Zhejiang Province (e.g., Jinhua and Lishui). RV is generally at a low level in the eastern part of the study area, except Shanghai. High RV values show a trend of migrating to the west, especially after 2008. This shows that Anhui province has begun to pay attention to its own industrial structure and is constantly optimizing its industrial structure, promoting the complementary advantages and joint development of various industries.

4.2.4. Spatiotemporal Distribution of Porter

Figure 7 shows spatio-temporal characteristics of Porter. On the whole, the Porter externality shows obvious center-edge characteristics, and the Porter value in the center of the study area is significantly lower than that in the periphery. On a local scale, the Porter externality shows an obvious spatial agglomeration, forming the "Fuyang-Bozhou-Huaibei-Suzhou1" patch in the northwest, the "Cangzhou-Huangshan-Xuancheng" patch in the west, and the "Wenzhou-Jinhua-Taizhou" patch in the south of the study area. This can be explained by the current situation of the local industry. Wenzhou is the world-famous shoe manufacturing base, which gathers a large number of shoe factories, and the local shoe enterprises are increasingly competitive under the effect of the price mechanism. Yiwu, located in Jinhua, is responsible for the global distribution of small commodities. With the training of the global market and the support of local government, Yiwu's small and medium-sized enterprises have upgraded rapidly and have strong competitiveness. Geographically, the intensity of industrial competition in each province is different. Over a 12-year time span, Shanghai's industrial competition fluctuated the most stably, fluctuating in the range of 0.65 to 0.78, with an average of 0.70. The remaining three provinces experienced a rather severe and unstable industrial competition during the past decade.

However, from an overall perspective, the intensity of the industrial competition in the Yangtze River Delta has eased, with the mean value of Porter dropping from 1.30 in 2005 to 1.28 in 2016, indicating that the industrial competition among prefecture-level cities is in a relatively balanced state and that the strategic promotion of the integration of urban agglomeration in the Yangtze River Delta has been effective.

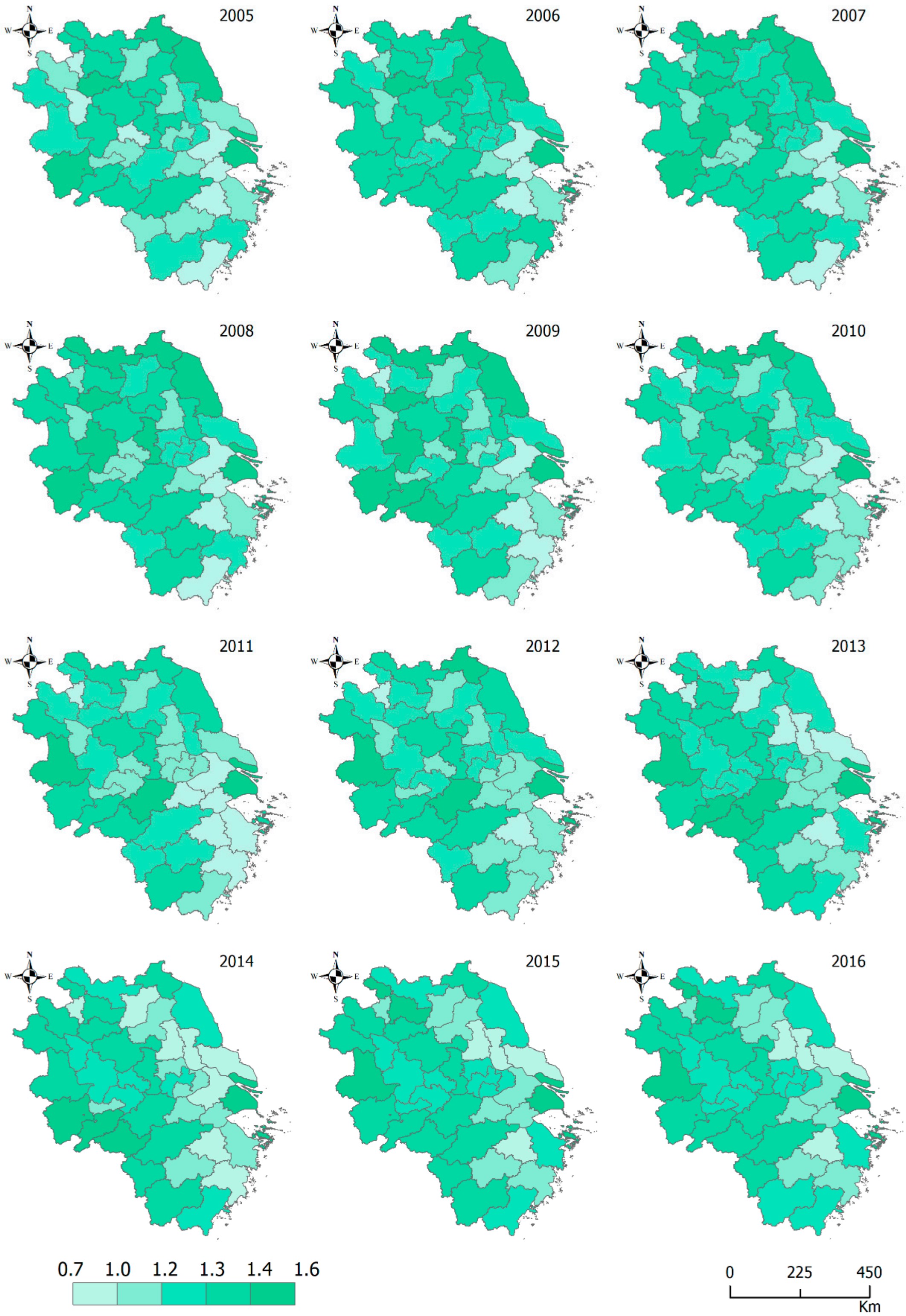

Figure 5. Spatiotemporal distribution of UV.

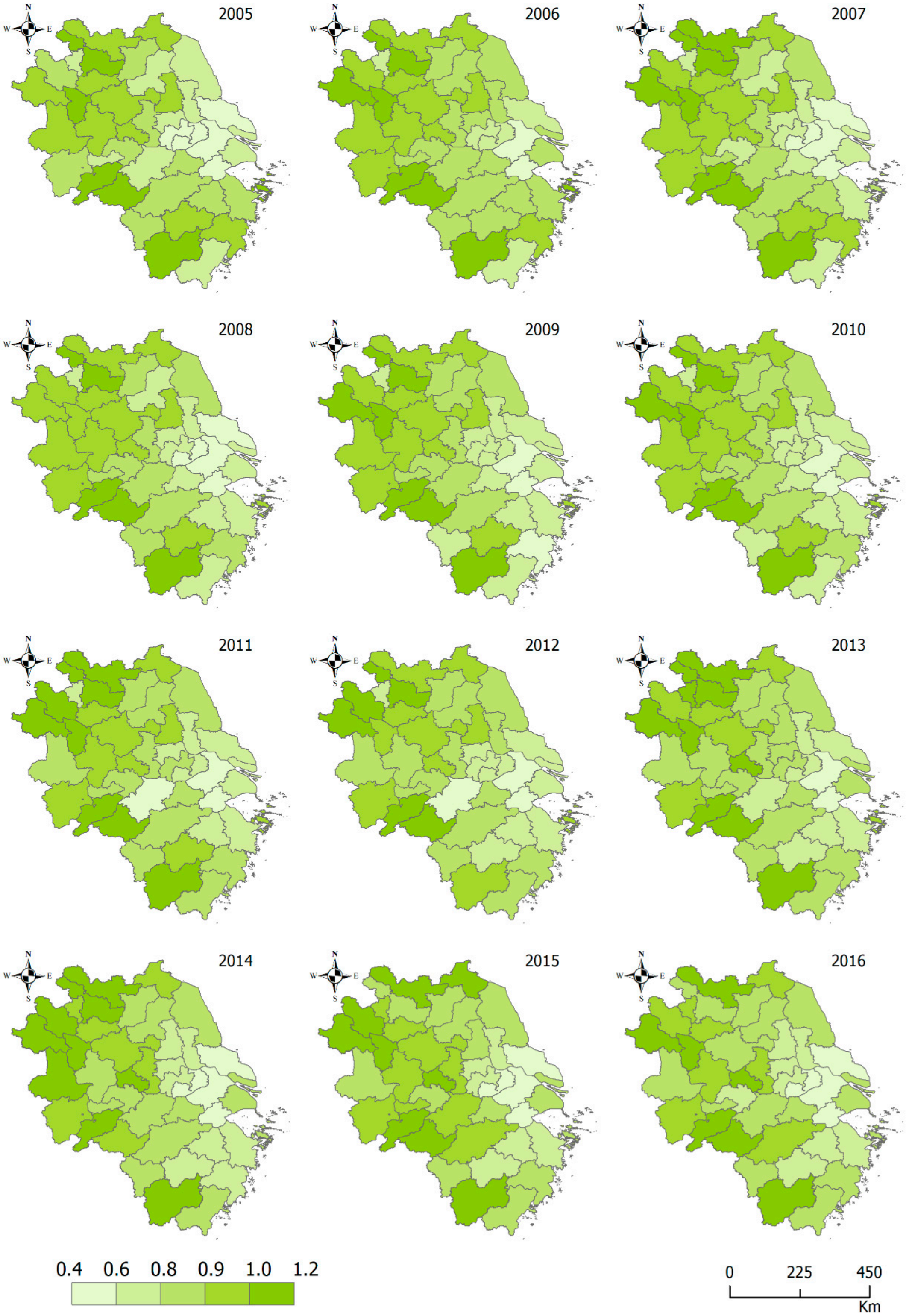

Figure 6. Spatiotemporal distribution of RV.

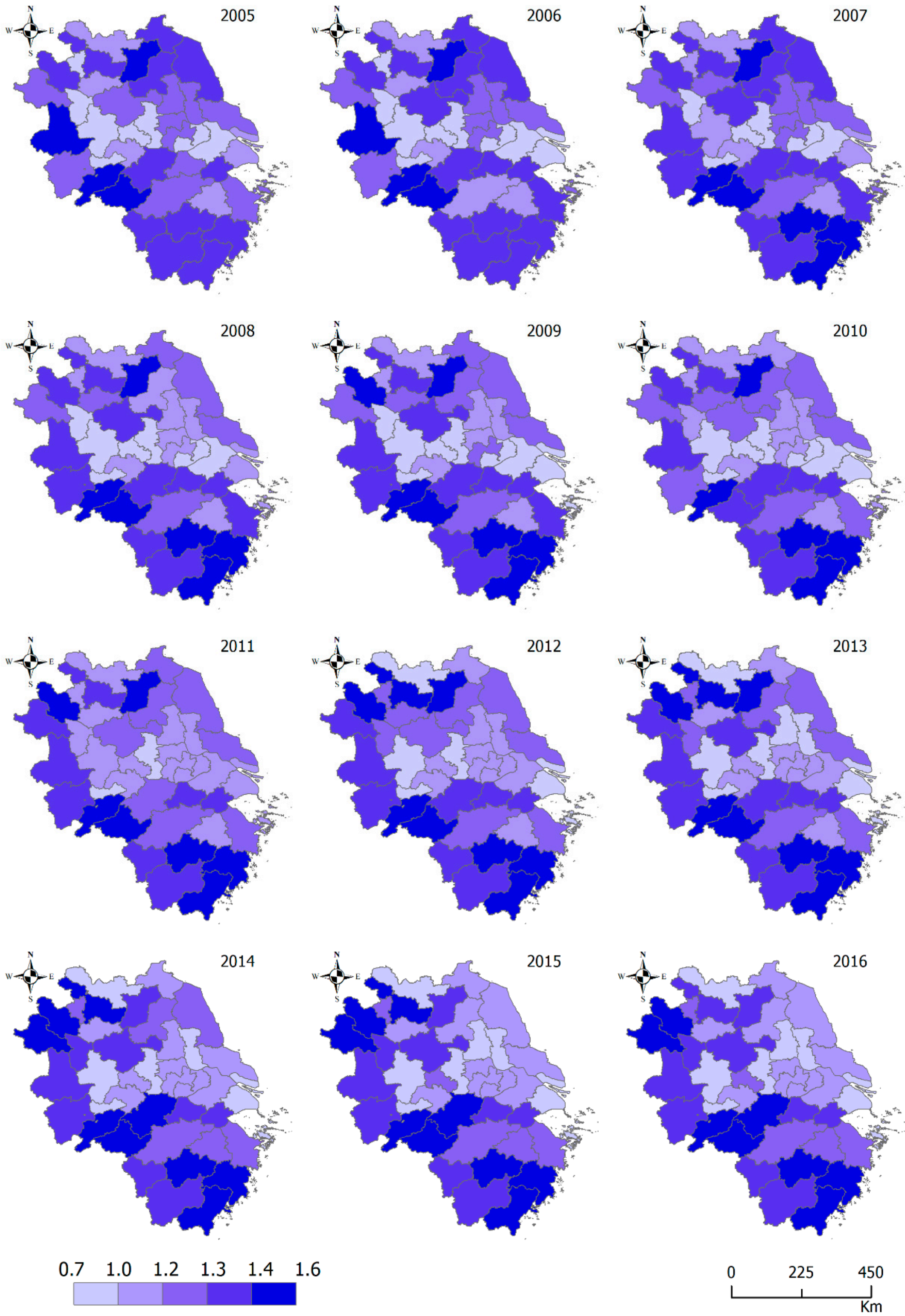

Figure 7. Spatiotemporal distribution of Porter.

4.3. Spatial Autocorrelation Analysis

Due to the characteristics of the variable coefficients of the GTWR model, the spatial autocorrelation test of the dependent variable was carried out before modeling. If there is a significant spatial autocorrelation in the dependent variable, then the use of the GTWR model is appropriate. After determining the use of the binary adjacency matrix, we used

Stata17.0 to calculate the global Moran index, and the results are shown in Table 4. It can be seen from the figure that the values of the Moran index are all between [−1, 1], and the absolute value of Moran index has an overall upward trend, with its significance becoming more obvious. This indicates that there is a spatial agglomeration between urban land use efficiency, meaning there is an obvious spatial autocorrelation. Therefore, it is reasonable for us to use the GTWR model for analysis.

Table 4. Moran's I test.

Year	Moran's I	z	*p*-Value *
2005	−0.044	−0.247	0.403
2006	−0.034	−0.115	0.454
2007	−0.019	0.081	0.468
2008	0.066	1.193	0.116
2009	−0.077	−0.679	0.248
2010	0.090 *	1.502	0.067
2011	0.183 **	2.703	0.003
2012	0.271 ***	3.838	0.000
2013	0.076 *	1.298	0.097
2014	0.348 ***	4.833	0.000
2015	0.355 ***	4.906	0.000
2016	0.257 ***	3.638	0.000

***, ** and * denote significance at the 1, 5, and 10-percent level respectively.

4.4. Estimation Results of OLS and GTWR Model

In order to avoid the influence of multicollinearity, we first calculated the variance inflation factor of each variable, and the VIF value of each independent variable was less than 10, indicating that there was no multicollinearity problem between the variables. Considering that the GTWR model cannot test the significance of variable coefficients, we used Ordinary Least Squares (OLS) and GTWR to study the effects of three agglomeration externalities on ULUE. It can be seen from Table 5 that the three agglomeration externalities have a highly significant impact on ULUE. Among them, the MAR externality and Porter externality, whether put into the regression model alone or together with other externalities, showed negative effects on ULUE. This shows that in a global sense, high industrial specialization and excessive industrial competition are not conducive to the improvement of ULUE. The effect of diversity externalities is unstable. After considering specialization externalities and competition externalities, diversify externalities, or, more precisely, unrelated diversity, show an improved effect on ULUE. This is similar to the findings of most scholars that agglomeration externalities do not act independently [57]. Unrelated Variety replaces Related Variety in making improvements in ULUE, indicating that the technological connections between industries in the Yangtze River Delta urban agglomeration as a whole are still not close enough and that the industrial externalities are limited to large industrial sectors, while specific industries do not benefit from it. The coefficients estimated by the GTWR model are also shown in Table 5. Table 5 reflects the dynamic impact of each variable on ULUE. The maximum, minimum and mean values of the coefficients of MAR externality are 0.15, −0.06 and −0.005, respectively. The maximum, minimum and mean values of the coefficients of the UV externality are 2.17, −1.70 and −0.26. The maximum value, minimum value and mean value of the coefficients of the RV externality are 3.60, −1.33 and 0.47. The maximum, minimum and mean value of the coefficients of the Porter's externality are 0.41, −0.47 and −0.006, respectively. This indicates that the impacts of various agglomeration externalities on ULUE have significant spatio-temporal heterogeneity. In addition, according to the reported GTWR model parameters, R^2 is 0.804, which is much higher than OlS's, indicating that the model fits well. Therefore, the GTWR model can be used to deal with the spatio-temporal heterogeneity between agglomeration externalities and ULUE.

Table 5. Regression coefficient results of each variable of OLS and GTWR.

VARIABLES	OLS	GTWR		
	Coef.	Max	Min	Mean
MAR	−0.012 ***	0.1508711132	−0.0607905963	−0.0052732571
UV	0.227 **	2.1743913471	−1.6965369279	−0.2644367352
RV	−0.179	3.6012901471	−1.3257455998	0.4657644234
Porter	−0.168 ***	0.4097858984	−0.4741365000	−0.0058395606
FDI	0.047 ***	0.3582414797	−0.0915614750	0.0560940909
LF	−0.037	2.0845341573	−2.2141543222	−0.0683669281
DEC	−0.222 *	2.1450094485	−2.0230748214	0.0766327641
POP	0.043	0.4790694941	−0.4903563348	−0.0364431313
IS	0.296 ***	1.4901585525	−1.0841017332	0.1370764120
TP	0.002	0.0473856253	−0.0255634035	0.0011525221
ED	−0.101 ***	0.2626034279	−0.4263408446	−0.0544773004
EDU	−0.054	0.2802125440	−0.3129669496	−0.0019328456
R^2	0.186	0.804		
Bandwidth	-	0.111311		
CV	-	23.5291		

***, ** and * denote significance at the 1, 5, and 10-percent level respectively.

4.5. Spatiotemporal Impacts of Three Agglomeration Externalities on ULUE

We combine Figures 8 and 9 to reflect the influence of three industrial agglomeration externalities on ULUE. Figure 8 shows that the impact of the Industrial agglomeration externalities on ULUE has obvious spatial heterogeneity. Figure 9 mainly reflects the trend of time evolution. Our results show that the influence of agglomeration externalities on ULUE has obvious non-stationary characteristics.

Specifically, the regression coefficient of the MAR externality fluctuates in the range of −0.06~0.15, and after more than a decade of development, the role of industrial specialization has been shrinking (the coefficient has become smaller). MAR externalities have shifted significantly in space. Before 2012, positive values were mainly concentrated in eastern Jiangsu province. After 2012, positive MAR values showed a shift towards Zhejiang province and Anhui province, with Hangzhou and Quzhou being the most prominent regions. Thanks to policy conditions and the industrial status, industrial specialization in these two cities made positive improvements to urban ULUE. The negative values of MAR are mainly concentrated in the western part of our study area (Anhui Province), but they tend to be positive.

The spatio-temporal effects of diversity agglomeration externalities are represented by UV and RV in the figure. In terms of regression coefficients, the externality of industrial diversity is the most powerful and unstable externality. Among them, the UV high values are mainly concentrated in some cities in the northeast of Jiangsu province and some cities in Zhejiang province. The geographical distribution of RV and UV shows opposite characteristics, with high values of RV mainly concentrated in the western Jiangsu province and eastern Anhui province. These cities are located in the border area between the two provinces, with frequent economic contacts and active industrial exchanges. Therefore, RV shows an improvement on ULUE. In terms of intensity, RV increased over time (the overall color became darker), while UV weakened (the color became lighter).

The regression coefficient of the Porter externality fluctuated between −0.47 and 0.41. The spatio-temporal heterogeneity of the Porter externality is particularly obvious. In general, positive Porter values are concentrated in the eastern part of the study area, while negative Porter values are concentrated in the western part of the study area and occupy most of the area. After 2012, the Porter coefficient showed an obvious spatial transfer. Jiangsu province, Zhejiang province and Shanghai gradually benefited from industrial competition, while industrial competition in Anhui province showed an obstacle to ULUE.

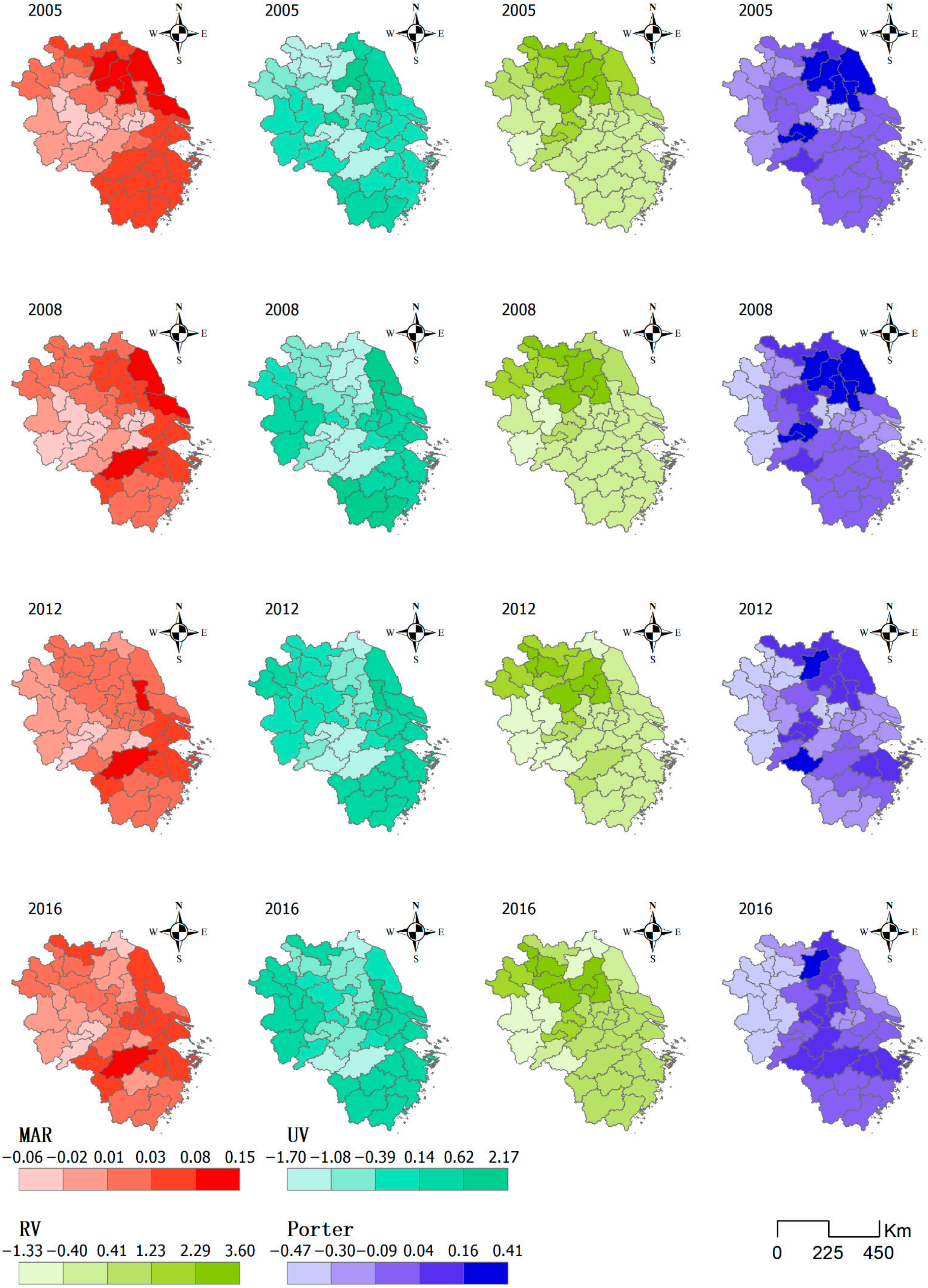

Figure 8. Spatiotemporal distribution of Porter.

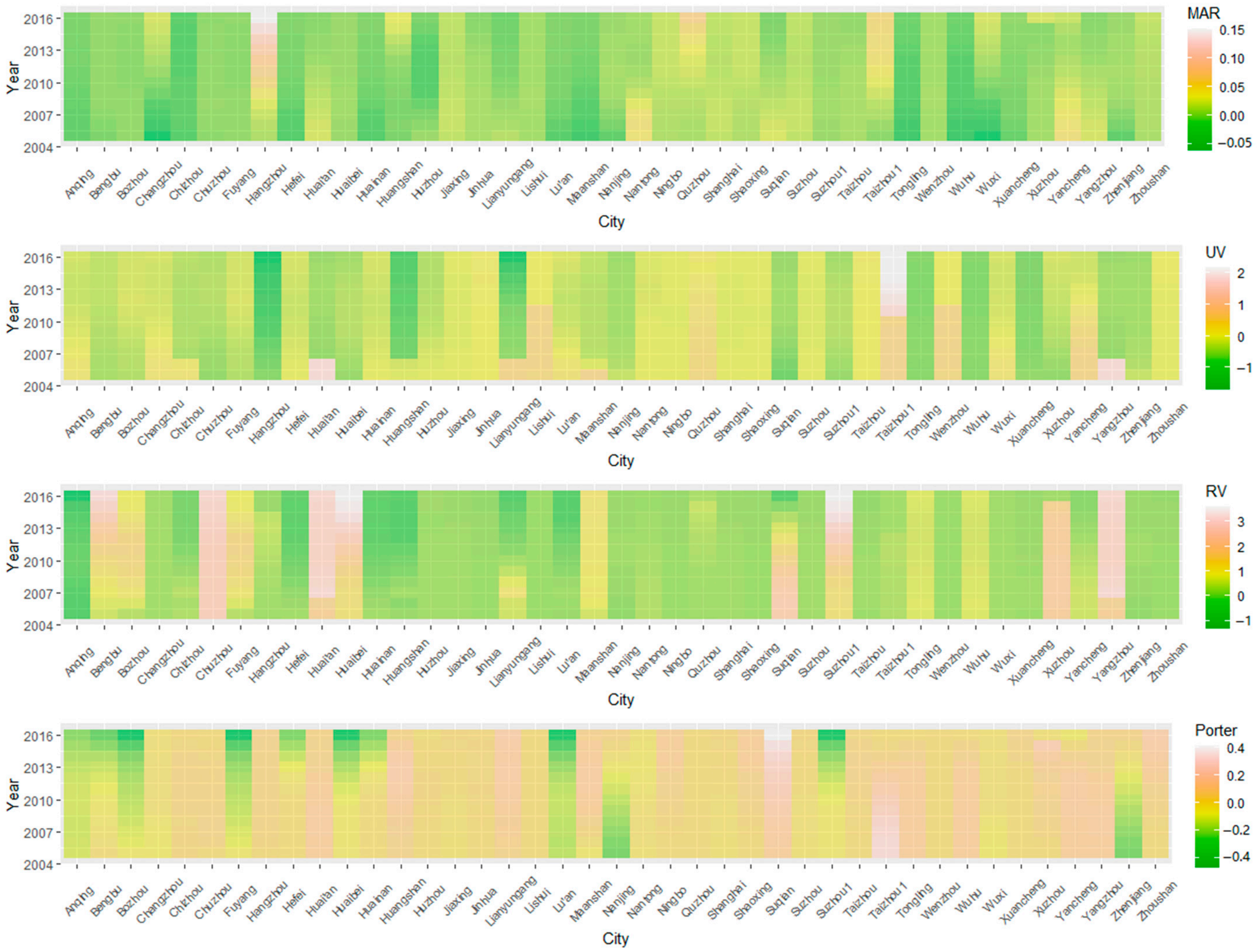

Figure 9. Annual Regression Coefficients of Three Agglomeration Externalities.

Our results also show that each city may be affected by multiple types of agglomeration externalities, such as Shanghai, which benefits from both industrial specialization externalities and industrial competition externalities.

4.6. Impacts of the Control Variables on ULUE

This study selected population density (POP), transport infrastructure (TP), human capital (EDU), economic development level (ED), foreign direct investment (FDI), marketisation level (LF), industrial structure (IS) and decentralization (DEC) as the control variables for the GTWR model. The mean regression coefficients of the control variables for each year from 2005 to 2016 are shown in Figure 10. The results show that high population density and differences in economic development are important causes of urban underutilization of land. Economic development levels have a negative impact on the ULUE. In other words, economic development constitutes a threat to ULUE, indicating that the growth of the Yangtze River Delta urban agglomeration may be crude, and therefore, we are concerned that the development of the Yangtze River Delta over the past decade or so is not consistent with the connotation of high-quality development. Foreign direct investment and industrial structure are important drivers, leading to steady improvement, suggesting that engaging in global competition, learning advanced technology and guiding industrial transformation are important directions for the Yangtze River Delta's future urban development strategy. Marketisation (LF) has experienced a negative to positive change over the 12-year period, indicating that the Yangtze River Delta is becoming increasingly market-oriented, market operations are becoming more regulated and various factors of production can circulate freely. Decentralization shows a clear inverted 'U' trend, indicating that local fiscal incentives can indeed motivate local governments to develop industries, but a performance assessment-centered system and blind imitation may lead to disorderly competition among local governments, resulting in a convergence of industrial structures and duplication of construction [32,84].

Figure 10. Regression coefficients of control variables.

5. Discussion

We selected 2005, 2008, 2012 and 2016 as representatives to discuss the relationship between the three agglomeration externalities on ULUE.

As for The Marshall externality, we observed that, in general, it gradually played a negative role in the improvement of ULUE in Jiangsu and Zhejiang provinces over time. However, two exceptions attracted our attention, namely, Hangzhou and Quzhou. Industry has always been an important engine of urbanization and the main channel to absorb employment in Hangzhou. In 2012, The Hangzhou Municipal Government issued several Opinions of the Hangzhou Municipal People's Government on Accelerating the Industrial Transformation and Upgrading and Promoting the Sustainable and Healthy Development of the Real Economy, providing a large amount of funds to enterprises meeting the requirements to help traditional industries upgrade to modern industries. In recent years, with the widespread application of advanced information and communication technology, especially the settlement of Alibaba, Hangzhou's Internet information industry has made great development. Hangzhou has developed a distinctive industrial system dominated by modern industry and the Internet industry, which plays a key role in the overall performance of Hangzhou. The situation of Quzhou can be explained by its specific industrial structure. Paper making and chemical industry are the two leading industries in Quzhou. The companies engaged in paper making and chemical industry absorbed a large number of the labor force, which makes Quzhou's industry highly specialized. For Anhui province, the role of the Marshall externality is gradually strengthened, and the sign tends to become positive over time. For example, the Marshall externality of Huangshan has played a positive role in the improvement of urban ULUE, which indicates that a specialized agglomeration mode has the potential to improve urban ULUE in Anhui province in the future. The current situation of Anhui province can be explained from the theory of industry cycle. According to industry cycle theory, the benefits an industry gets from the local environment are closely related to its life cycle stage. For new industries, innovation is crucial, and the Jacobs externality plays an important role in this stage. As the period of strong expansion passes, the technological innovation of products becomes difficult, and the industry reaches a more mature stage. At this point, products tend to be homogeneous and will compete in the local market with price advantages, at which point the performance of enterprises becomes more dependent on Marshall externality [85]. In comparison, Jiangsu, Zhejiang and Shanghai regions have advantages in economic strength and openness. Therefore, the growth of local cities will not completely depend on some mature industries. Comparatively speaking, traditional industries in Anhui province still have a large market, which means that Anhui province can gain advantages from professional industrial agglomeration. These local dominant industries can reduce factor costs in the form of economies of scale and participate in market competition at lower prices. With the strengthening of this trend, the Marshall externality gradually shows an improvement effect on ULUE.

As for the externalities of diversity agglomeration, our study revealed an important phenomenon, that is, the effect of UV on the improvement of ULUE on the whole becomes weaker over time, while the effect of RV on ULUE becomes stronger over time. In addition, from the perspective of the time trend, another phenomenon that can be observed is that in addition to Taizhou1, UV almost had negative effects on the improvements of ULUE, while RV had an opposite effect. This is basically consistent with the prediction of Freken et al. [81], that technology spillovers only occur between related industry sectors, and the extent of spillovers is limited between unrelated sectors. Therefore, UV, which represents the diversified pattern of industry sectors, has a poor performance, while RV, which represents the diversity of specific industries, has a positive performance. Diversity externalities with negative signs are likely to be caused by infrastructure. The key is whether firms can benefit from local infrastructure. Although physical infrastructure in cities is shared by all industries, much of the infrastructure is built for specific industries. Therefore, the more diverse a city's industrial mix, the more difficult it is to provide tailored solutions for each industry, which can well explain why diversified agglomeration externalities do not improve the performance of a large city, such as Shanghai and Hangzhou. However, the diversity of industries can be beneficial for a region as long as they are not too fragmented [63]. Therefore, we can find the positive effects of diversity externalities in other cities, such as Taizhou1, Bengbu and Huaibei. Although the performance of these cities is not as good as that of Shanghai and Hangzhou, their industries are supported by complementary infrastructure. Even with an imperfect industrial structure, its local firms can still benefit from diverse agglomeration externalities.

The temporal and spatial heterogeneity of the Porter externality is particularly obvious. For ULUE improvements in Jiangsu, Zhejiang and Shanghai, Porter externalities play a positive role, while for ULUE of almost all cities in Anhui province, the effect of the Porter externality is obviously negative, and the negative effect showed an intensified situation. In fact, the smooth realization of China's economic transformation is largely attributed to the introduction of market competition, which has brought remarkable economic growth to the country [86]. However, competition is not as orderly as people think. In China, there is a special form of "race to the bottom" competition, which means that too much competition is not conducive to growth [87]. One possible explanation is that the industrial structure in these regions is still dominated by traditional low-tech industries, consisting of many relatively small companies, and that the companies operating in these industries are characterized by traditional management systems and simple internal organizational models. As a result, these companies are primarily concerned with exploiting cheap labor rather than raising productivity levels and introducing technological and organizational innovations. Therefore, competition among local enterprises will be based on price and cost-cutting (especially labor costs) rather than product quality. In addition, fierce local competition also squeezes the profits of enterprises and reduces their investment in innovation, which may have a negative impact on local economic development. In our opinion, another possible reason is that in order to maintain advantages in local competition, local enterprises block their core technologies rather than exchange them, which will lead to market segmentation. Therefore, the Porter externality will also show a negative impact on urban development. However, the Porter externality will play a positive role when it is linked with globalization and local government fiscal capacity. When local governments have greater economic autonomy to support and promote related industries to participate in global competition, the Porter externality can significantly promote growth, which can explain why the. Porter externality shows positive effects in Jiangsu, Zhejiang and Shanghai [88].

Our study also proves that different types of agglomeration externalities have aging mechanisms [58]. The effects of the Marshall and Porter externality are not sustainable. In our cases, the prominent MAR values of Hangzhou and Quzhou underwent a rapid decline within four years, and their prominent role disappeared within a decade. However, diversity agglomeration externalities can play a lasting role. Even after a decade, its prominent position is still very obvious, such as Huai'an and Yangzhou. This is consistent with Jacobs's own speculation that a diversified industrial structure is better for the city's long-term development.

Furthermore, we find that to some extent, the contribution of these three agglomeration externalities to ULUE are substitutable for each other. It means that if the MAR externality plays an obvious role on ULUE, then the Jacobs and Porter externalities will play a relatively weak role in this city, such as Hangzhou. If the Porter externality plays an obvious role, the corresponding effects of the MAR and Jacobs externalities are not so strong, such as Yancheng. Therefore, one possible policy implication is that regions should formulate strategies for industrial distributions according to their own conditions, rather than taking advantages of all types of agglomeration externalities.

The results of the study should provide insights for policy makers. Specifically, it can be divided into the following points:

(1) Selectively cultivating agglomeration externalities according to the status quo of local industries. Although agglomeration externalities have been proven by many scholars to be beneficial to urban development, not all agglomeration externalities can be beneficial to local economic activities. Specialization, diversity or competition externalities may not affect or even hinder the development of the city. For cities with incomplete infrastructure, it is still recommended to focus on cultivating some related industries, rather than advocating a balanced development of each industry.
(2) Following the laws of industry cycle and giving support to enterprises in industrial transformation. Industrial transformation is still a trend within the Yangtze River Delta urban agglomeration, but in the process of industrial transformation, the environment faced by each economic subject will undergo drastic changes, and the agglomeration externalities that previously played an important role in urban development may become an obstacle to development. To this end, local governments need to provide subsidies to enterprises within their capacity to promote the smooth transformation of local enterprises.
(3) Regulating market order and achieving healthy competition. Local governments should pay attention to the internal development of local enterprises and impose severe sanctions against monopolies, vicious competition and other behaviors that

destroy the market environment, so as to guide the free flow of production factors and cultivate the international competitiveness of enterprises.

(4) Looking to the future and purposefully cultivate diversified industries. Diversified industries help cities develop in the long run, but many cities do not have the resources to do so now. To this end, local governments should take a progressive reform approach on the basis of respecting basic economic laws and develop diversified industries with the purpose to lay a foundation for long-term urban development.

6. Conclusions

This paper introduces the effect of industrial agglomeration externalities on urban land use efficiency. By using OLS and GTWR models, we prove the complex mechanism between industrial agglomeration externalities and urban land use efficiency. Our study shows that (1) The impact of three types of industrial agglomeration externalities on urban land use efficiency is unstable both in time and space; (2) The three industrial agglomeration externalities do not function independently, meaning that they often occur simultaneously or are replaced by each other; (3) Different agglomeration externalities have different aging mechanisms, and diversity externalities have the most lasting effect. Our study is helpful for city managers to make reasonable industrial decisions, and it can also provide useful references for enterprises to choose their sites.

The contribution of this study is to explore the impact and mechanism of industrial agglomeration on urban land use efficiency, especially at the temporal- and spatial-level, which further strengthens the complex relationship between urban land use efficiency and industrial development. On the one hand, it is one of the important development directions of the existing urban land use efficiency research. On the other hand, it can provide useful theoretical and practical guidance for urban industrial development planning.

Admittedly, the current study still has several research limitations. Due to limited data availability, we excluded some meaningful indicators when calculating urban land use efficiency, for example, greenhouse emissions and cultivated land erosion. Due to the change of the statistical caliber, panel data can only support the research span of 12 years, which means that it is difficult to observe the long-term mechanism of agglomeration externalities on urban land use efficiency. The consideration of industrial heterogeneity is still insufficient in this study. Even though we made a more careful division of the tertiary industry, the existing data do not allow us to pay more attention to the second industry, which affects the accuracy of the results to some extent. In future studies, research design can be more subtle, for example, by carefully considering and contrasting the interactions between each of the two aggregate externalities. In addition, due to the geographical adjacency of each observed object, the application of spatial econometric methods should also be considered.

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