A Study on the Spatial Distribution Characteristics and Changes of Cities Undertaking Manufacturing Transfer in Central China

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Abstract- In the context of global restructuring of manufacturing spatial layout, studying the temporal and spatial characteristics of manufacturing transfer at the urban scale is of great significance for optimizing urban industrial layout. Based on the data from China Urban Statistical Yearbook, this study adopts geographic information analysis models such as the Industrial Transfer Undertaking Index and GIS spatial autocorrelation analysis to study the spatial characteristics of manufacturing transfer undertaken by cities in central China. The study shows that: (1) The hot cities in the central region that undertake manufacturing transfer were mainly in Henan Province from 2011 to 2014, and in the surrounding areas centered around Wuhu and Tongling in Anhui Province and Jingmen and Shiyan in Hubei Province from 2015 to 2019. (2) The number of cities with basic manufacturing functions in the central region has increased, and the impact of manufacturing transfer on the level of manufacturing specialization reflects a two-way driving effect of increasing and decreasing; (3) The manufacturing scale of some major cities in the central region is insufficient, and the position of manufacturing center cities needs to be consolidated and strengthened.

Keywords- Manufacturing Spatial Transfer,Undertaking index,Industrial spatial distribution, Central China

1 .Introduction

Industrial transfer is an economic phenomenon which occurs in the process of economic development, and the concept of industrial transfer more widely accepted in China refers to the transfer of industries from some countries or regions to others[1].Since the 21st century, along with the rapid rise of the cost of labor, land and other factor, the transfer of low-end resources and labor-intensive industries in the value chain has been accelerated in China's eastern coastal regions[2], and a new round of industrial undertaking has emerged in the central and western regions to undertake international and domestic industrial transfers side by side and to undertake domestic transfers dominance[3].Optimizing the layout of regional manufacturing industries, strengthening the capacity building of the central and western regions and northeast regions to undertake industrial transfer, and promoting the orderly transfer of manufacturing industries have become an important part of the national industrial layout strategy in the new period[4].The quality and scale of manufacturing industry is an important indicator to classify developing

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countries and developed countries, which represents the comprehensive productivity level of a country[5, 6].The central region includes six provinces, namely, Shanxi, Henan, Hubei, Anhui, Hunan and Jiangxi. The undertaking of manufacturing transfer is significant to the stable development of the central regional economy. Paying attention to the spatial and temporal patterns of manufacturing transfer in the past certain period is conducive to a more in-depth understanding of the current situation of manufacturing transfer, thus exploring the possibilities of future development.

At present, the analysis methods for spatial transfer of manufacturing industry both domestically and internationally include the coefficient of industrial competitiveness[7], as well as the quantitative measurement model of industrial transfer based on the inter regional input-output table[8, 9]. Due to the comprehensive data on enterprise location changes in European and American countries[10, 11], scholars use this data to study industrial transfer. scholars' research on the spatial layout of manufacturing industry mainly focuses on two aspects: firstly, the study of international migration of manufacturing industry and its driving factors; secondly, in-depth analysis of the spatial migration of manufacturing industry within cities and its influencing factors based on the phenomenon of urban suburbanization. Some scholars have studied the spatial transfer of manufacturing in the United States by comparing the changes in manufacturing value added and the proportion of employed population between the North, South, and West regions of the United States, while others have studied industrial geographical agglomeration within countries and regions[12, 13].Chinese scholars' research on the spatial pattern of manufacturing industry has been explored at different scales such as the country, urban agglomerations, provinces, and cities. A large amount of empirical research has focused on the spatial reconstruction of manufacturing industry within cities, as well as the research on the factors influencing the spatial pattern of manufacturing industry. Scholars have used typical regions and cases to illustrate the changes in their location and the influencing factors during the transfer process, explaining the level of industrial agglomeration from the perspective of industrial clusters. Overall, existing literature in China has mostly focused on provincial-level research, and has not fully revealed the role and spatial layout changes of cities as a regional unit in undertaking regional manufacturing transfer[14]. Due to significant regional differences within the province, analysis at the provincial and economic zone levels cannot effectively reveal the spatial pattern characteristics formed by different cities as industrial transfer destinations, which directly affects the targeted formulation of relevant industrial layout policies.

With the advancement of the strategy of the rise of the central region, the ability of the central region of China to undertake industrial transfer from developed regions is constantly strengthening. Given the previous research results, this study aims at analyzing the spatial and temporal patterns of manufacturing transfer in six provinces and regions in central China from two levels of time and space, as well as multiple scales of provinces and cities, with the application of the methods of static industrial agglomeration index, industrial location quotient, industrial transfer acceptance index, and GIS spatial autocorrelation analysis, which can contribute to assess more accurately the spatial and temporal patterns of industrial transfer in central China.

2. Materials and Methods

2.1.Research Methodology

1) Industry Static Agglomeration Index

Industrial static agglomeration index, also known as industrial concentration, reflects the existing production capacity and output of a specific industry in a certain region to a certain percentage in the nation, and can usually be calculated by indicators such as total industrial population, total industrial output value, sales volume, and total asset. In this study, the static industry agglomeration index is used to measure the share of regional, provincial or urban manufacturing population in the country, which can quantitatively reflect the absolute degree of manufacturing industry agglomeration in a certain region and the influence of the local manufacturing industry in the country, as is calculated in the following:

$$CR_n = \frac{X_n}{\sum_{i=1}^{N} X_i} \tag{1}$$

Where CR_n represents the static agglomeration index of an industry in sub-region n, X_n represents the employment population or total output value of sub-region n, and N represents the number of sub-regions in a region.

2) Industrial Location Business

The location quotient, also known as the specialization rate, is used to reflect the degree of specialization in a particular industrial sector in a region[15].In this study, the location quotient is calculated by dividing the ratio of the city's manufacturing population to the city's total population in all industries by the ratio of the national manufacturing population to the national total population in all industries. A location quotient greater than 1 indicates that the city's manufacturing industry is more specialized than the national average, hence this city is with the basic functions of manufacturing industry.The larger the location entropy, the higher the degree of concentration and specialization of the manufacturing industry in the city.

$$E_{ij} = \frac{q_i}{\sum_{i=1}^{n} q_i} / \frac{Q_i}{\sum_{i=1}^{n} Q_i} \tag{2}$$

Where E_{ij} denotes the location quotient of sector i of a region relative to higher-level regions, q_i denotes the relevant index of sector i of a region, which can usually be expressed in terms of output value, employment, etc., and Q_i denotes the relevant index of higher-level regions; n represents the number of all sectors.

3) Industry Transfer Acceptance Index

Industrial transfer refers to the increase or decrease of production share and scale of industry in a region caused by the migration of industry in geographical location[3].In this paper, we cite the model of industrial transfer undertaking index constructed by Ma[1], and the calculation formula is as follows:

$$\overline{RI_{ij}} = \frac{1}{t} \times \left(\frac{X_{ij}^{t}}{X_{j}^{t}} - \frac{X_{ij}^{0}}{X_{j}^{0}}\right) \times 100\% \tag{3}$$

Where $\overline{RI_{ij}}$ is the industry transfer taking index of region i, which indicates the average percentage value of industry transfer taking by region i in the time period [0, t]; X_{ij}^0、X_j^0 indicate the number of employed persons in industry j of region i and industry j of the whole country in the initial period respectively; X_{ij}^t、X_j^t indicate the number of employed persons in industry j of region i and industry j of the whole country in period t respectively[16].

According to the above concept of industry transfer, if the value of $\overline{RI_{ij}}$ is greater than 0, it means that region i has taken over the transfer of industry j, that is., industry j is transferred to region i.If the value of $\overline{RI_{ij}}$ is equal to 0, it means that region i has not taken over the transfer of industry j.If the value of $\overline{RI_{ij}}$ is less than 0, it means that region i has transferred out of industry j.

4) Local Spatial Autocorrelation Analysis of GIS Space

GIS spatial local spatial autocorrelation analysis（Getis-Ord G_i^*）is used to examine whether there is a geographic proximity effect in space for cities to undertake manufacturing transfer, and to classify the overall manufacturing transfer types in central cities using the unique value method[1].

The main equations are as follows:

$$G_i^* = \frac{\sum_{j=1}^{n} W_{ij} x_j}{\sum_{j=1, j\neq i}^{n} x_j} \tag{4}$$

Normalization of G_i^*:

$$Z(G_i^*) = \frac{G_i^* - E(G_i^*)}{\sqrt{Var\,(G_i^*)}} \tag{5}$$

Where n represents the number of observations; i and j represent position i and position j, x_j represents the observations at position j, W_{ij} represents the spatial weight, which is 1 when the spaces are adjacent and 0 when they are not, $E(G_i^*)$ and $\mathrm{Var}\,(G_i^*)$ are the mathematical expectation and standard deviation of G_i^* respectively, and a positive Z value with a higher value indicates a tighter clustering of high values (hot spots), while a negative Z value with a lower value indicates a tighter clustering of low values (cold spots).

2.2.Data Source and Processing

This paper examines a total of 80 prefecture-level cities in six provinces in central China including Hunan, Hubei, Henan, Anhui, Jiangxi, and Shanxi provinces. The analysis data are obtained from those of manufacturing year-end municipal employment population in *China City Statistical Yearbook*, and the study period is 2010-2020.Due to incomplete data for some cities, there are 284 prefecture-level cities (states and districts) in China, excluding Enshi Tujia and Miao Autonomous Prefecture, Shennongjia Forestry District, Tianmen City, Xiantao City, Qianjiang City in Hubei Province, Xiangxi Tujia and Miao Autonomous Prefecture in Hunan Province, and Jiyuan City in Henan Province. Due to data limitations, Tibet and Hong Kong, Macao, and Taiwan are not covered in this study.

3. Results & Discussion

3.1. The Temporal Characteristics of Manufacturing Transfer in Western Provinces

With data on the population employed in the urban manufacturing industry from the China City Statistical Yearbook, this study analyzes the changes and trends of taking over manufacturing industries in the central provinces and the entire central region from the year 2010 to 2019 by using equation (1) and equation (3)[17, 18] .The results show that from 2010 to 2013, the total national manufacturing population was increasing, reaching a peak in 2013.After 2013, the total national manufacturing population kept decreasing, from 53,666,400 in 2013 to 39,519,570 in 2019, with an average annual decrease rate of 7.83%.The total manufacturing population in the eastern, central, western, and northeastern regions from 2010 to 2019 also showed different degrees of change, as is shown in Figure 1.The total manufacturing population in the central region is increasing from 2010 to 2016, with 6,773,800 in 2010 and 10,631,883 in 2016, and then it began to decrease continuously after 2016, to 8,375,596 in 2019.The absolute index of manufacturing static agglomeration is measured using the proportion of the manufacturing population in the six provinces in the central region to the total manufacturing population in the country, and the results are shown in Figure 2.The results show that from 2010 to 2019, the changes in the absolute index of manufacturing static agglomeration in six provinces in the central region also show some variability: Henan Province has witnessed a significant increase from 2010 to 2017 and then a decrease from 2017 to 2019; Jiangxi Province and Anhui Province have been stable with a small increase from 2010 to 2019; Hubei Province, Hunan Province, as well as Shanxi Province, have reflected a decrease and then a relatively small increase.

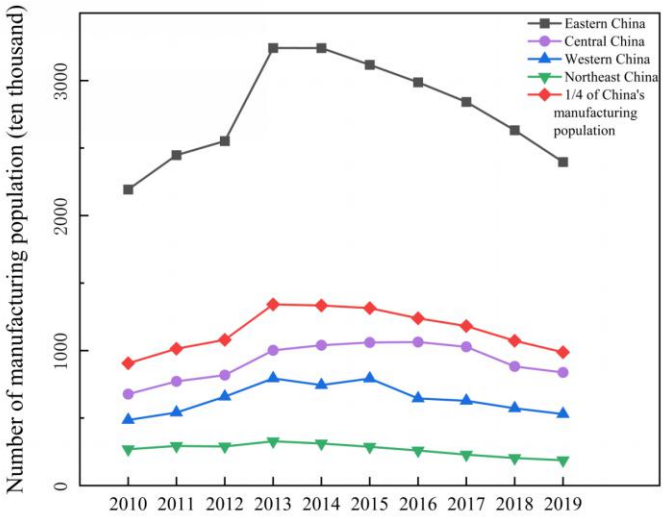

Figure 1. Changes in the total scale of manufacturing industry in central China vs. Other Regions 2010-2019

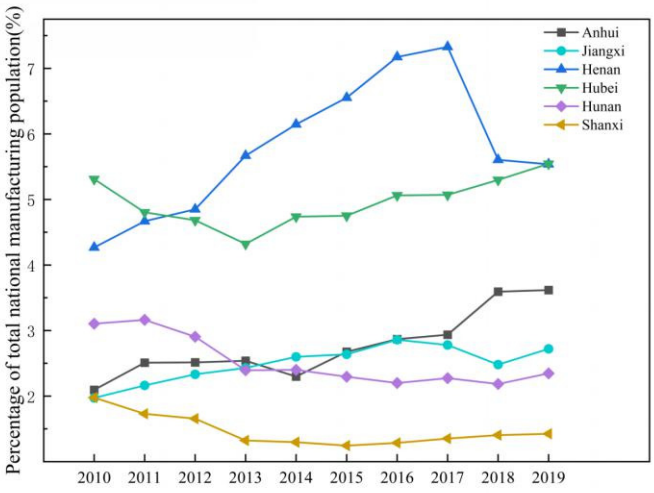

Figure 2. Changes in the Manufacturing Agglomeration Index of Various Provinces in Central China 2010 - 2019

3.2. The Temporal Characteristics of Manufacturing Industry Transfer in Western Cities

There are a total of 80 cities above the prefecture level in the six central provinces, including one mega-city ---- Wuhan, three supercities ---- Zhengzhou, Changsha, and Hefei, 43 large cities, and 33 small and medium-sized cities.Equation (3) was used to analyze the average value of the manufacturing transfer acceptance index for each city in the central region for two time periods: 2011-2015 and 2015-2019.The results show that there is a big difference in the manufacturing transfer acceptance index between the two periods, with 41 cities accepting manufacturing transfer in the first period and 47 cities accepting manufacturing transfer in the second period.Table 1 reveals substantial disparities in the transfer acceptance index of manufacturing transfer cities among the top 20 cities during the two specified periods. Cities in Henan Province, namely, Zhengzhou, Jiaozuo, Xuchang, Xinyang, and Puyang, witness a considerable decline in the proportion of undertaking manufacturing transfer. On the other hand, cities like Luoyang in Henan Province and Xiangyang, Xiaogan, Shiyan, and Jingmen in Hubei Province experience a noteworthy increase in the proportion of undertaking manufacturing transfer.Equation (2) was utilized to analyze the relative index of static manufacturing concentration in cities above the prefectural level for the years 2010, 2015, and 2019.This index is represented by the manufacturing location quotient and provides insights into the degree of specialization of urban manufacturing relative to the national average.A location quotient bigger than 1 indicates that the city's manufacturing specialization is higher than the national average and hence with external service capability.The larger the location quotient, the higher the level of manufacturing specialization in the city.The results of the study show that there are respectively 19, 33 and 31 cities with location quotient greater than 1 in 2010, 2015 and 2019, and the relative indexes of static manufacturing concentration in Ji'an, Chuzhou, Xuancheng, Yichun, Jiaozuo and Hebi cities are remarkably raised, indicating that from 2010 to 2019, the manufacturing specialization function of some cities in the central region has been significantly enhanced in the context of the transfer of manufacturing industries from the east to the central and western regions. Meanwhile, the relative

index of static manufacturing agglomeration in Yueyang City, Yuncheng City and Jingzhou City has decreased, with the specific changes shown in Table 2.

Table 1 Changes in the Manufacturing Undertaking Index of Cties in Central China 2011 - 2019

Top 20 Cities 2011-2015		**Top 20 Cities 2015-2019**	
City	**Average Manufacturing Undertaking Index (*10000)**	**City**	**Average Manufacturing Undertaking Index (*10000)**
Zhengzhou	15.33122575	Xiangyang	6.902682415
Shangqiu	5.589971956	Liuan	5.628585449
Zhoukou	5.06830824	Chuzhou	4.078569449
Liuan	4.78753396	Ji'an	3.966990825
Ji'an	4.463044047	Hefei	3.836483359
Zhumadian	4.160327614	Shiyan	3.834126306
Suzhou	3.818052366	Xiaogan	3.590381197
Hefei	3.636493689	Huanggang	2.670285771
Xuchang	3.170441517	Jingmen	2.501680751
Yichang	3.068074564	Wuhu	2.24369036
Xiangyang	3.05645534	Fuyang	2.135677227
Yichun	2.965558731	Taiyuan	1.898235105
Jiaozuo	2.758421881	Ma'anshan	1.866108506
Huanggang	2.526578818	Xuancheng	1.860623148
Kaifeng	2.298092546	Anqing	1.809406783
Xinyang	2.131763006	Wuhan	1.698272218
Shangrao	1.844142654	Changde	1.282266041
Puyang	1.81479614	Luoyang	1.280484923
Nanchang	1.71070433	Tongling	1.080301807
Anqing	1.701974055	Bozhou	1.069721292

Table 2 Manufacturing specialized citys in central China （with a Manufacturing Location Quotient ≥1）

Year	**Manufacturing Location Business**	**Cities with a Manufacturing Location Quotient ≥1**	**Quantity Statistics**
2010	1.8-2.0	None	0
	1.6-1.8	None	0
	1.4-1.6	Maanshan, Xinyu, Luohe, Tongling, Wuhu, Ezhou	6
	1.2~1.4	Shiyan, Zhuzhou, Huangshi, Jingmen, Jingdezhen, Xiangyang	6
	1-1.2	Jingzhou, Yueyang, Yichang, Xiaogan, Xinxiang, Yingtan, Yuncheng, Jiaozuo	8

2015	1.8-2.0	Luohe	1
	1.6-1.8	Xinyu	1
	1.4-1.6	Xuchang, Jiaozuo, Yingtan, Hebi	4
	1.2~1.4	Ezhou, Wuhu, Yichang, Jingmen, Yichun, Tongling, Huangshi, Shiyan, Zhengzhou, Ji'an	10
	1-1.2	Luoyang, Pingxiang, Xiaogan, Xiangyang, Zhuzhou, Huanggang, Jingdezhen, Kaifeng, Jiujiang, Xinxiang, Zhoukou, Chuzhou, Suizhou, Ganzhou, Xuancheng, Maanshan, Jingzhou	17
2019	1.8-2.0	Luohe	1
	1.6-1.8	Ji'an, Xuchang, Jiaozuo	3
	1.4-1.6	Chuzhou, Wuhu, Jingmen, Yingtan, Ezhou, Xinyu, Tongling, Shiyan	8
	1.2~1.4	Xiangyang, Jingdezhen, Xuancheng, Yichun, Xiaogan, Luoyang, Hebi, Maanshan, Yichang, Zhuzhou	10
	1-1.2	Huangshi, Jiujiang, Zhoukou, Huanggang, Anqing, Suizhou, Ganzhou, Kaifeng, Zhengzhou	9

3.3. The spatial pattern and changes of manufacturing population distribution in central cities

According to population data from the China City Statistical Yearbook of urban manufacturing industry, we have obtained the relevant employed population data of cities above prefecture level in 2010, 2014 and 2019, and calculated the manufacturing industry employed population of each province in China, and consequently analyzed the spatial characteristics of static agglomeration of manufacturing industry in central region from 2010 to 2019 with the help of Arcgis software[19, 20].The changes in the distribution pattern of the number of employees are shown in Figure 3.

Equation (1) is used to calculate the proportion of manufacturing population in each city in the country to the total manufacturing population in the country, and the cumulative value of the proportion is sorted from the highest to the lowest. With the cumulative value reaching 60% as the boundary, the city with a manufacturing ratio greater than that is defined as the national manufacturing center city. The results show that in 2010, there were 49 manufacturing center cities in the country, and there were 7 in the central region, namely, Wuhan, Changsha, Taiyuan, Zhengzhou, Xiaogan, Yichang and Yueyang, and in 2014, there were 47 manufacturing center cities in the country, including 7 in the central region, namely, Zhengzhou, Wuhan, Changsha, Hefei, Yichang, Xiangyang and Nanchang, and in 2019, there were 42 manufacturing center cities in the country.Among them, there are six in the central region, namely, Zhengzhou, Wuhan, Xiangyang, Hefei, Changsha and Xiaogan.

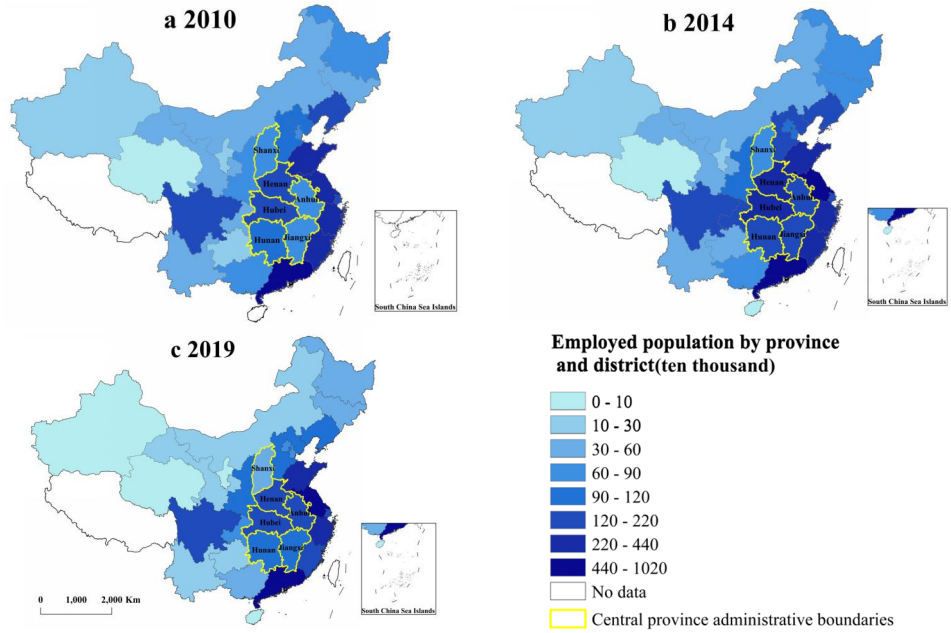

Figure 3 Distribution Pattern of the Number of Employees in the Manufacturing Industry by Province in China

3.4. The Spatial Agglomeration Characteristics of Cities in the Central Region that Undertake Manufacturing Transfer

Equation (3) was used to analyze the manufacturing transfer acceptance index of cities in the central region for the periods of 2011 - 2014 and 2014 - 2019.The results show that there are 41 manufacturing transfer-in cities and 39 transfer-out cities in the central region during 2011-2014, and 47 manufacturing transfer-in cities and 33 transfer-out cities in the central region during 2014-2019.According to the calculation results of the manufacturing transfer acceptance coefficient of each city, the spatial proximity effect of the transferring cities of manufacturing industries in the central region was analyzed by using the local spatial autocorrelation analysis method of Equation (5).The results show that there are obvious hotspots of high-value clustering in the cities that take up manufacturing transfer in the central region, and the hotspots during 2011-2015 are mainly distributed in Henan Province and its border area with Shanxi Province and Anhui Province, while the hotspots during 2015-2019 are significantly shifted, mainly distributed in Wuhu and Tongling in Anhui Province and Jingmen in Hubei Province, Tongling and Jingmen and Shiyan cities in Hubei Province as the center of the surrounding areas. The LISA analysis chart of the cities in central region to undertake manufacturing transfer is shown in Figure 4.

3.5. The Specialization Level and Spatial Characteristics of Manufacturing Functions in Cities in the Central Region

By using Equation (2), the manufacturing location quotients of cities above prefecture level nationwide for three years, namely, 2010, 2015 and 2019, were analyzed to screen out cities

with manufacturing location quotients greater than 1 in the central region[21-23].Meanwhile, the spatial distribution and changes of manufacturing function city specialization in the central region were analyzed as well in Arcgis according to the magnitude of location quotient values.The results show that from 2010 to 2019, the number of manufacturing function cities in the central region increased significantly, from 20 to 31.In 2015 and 2019, the manufacturing function cities in Henan Province, Hubei Province, Anhui Province and Jiangxi Province increased significantly, and the specialization level of manufacturing function cities also improved remarkably.The manufacturing location quotients of Luohe, Xinyu, Ji'an, Xuchang and Jiaozuo cities reached more than 1.6, which is much higher than the national average.The spatial distribution characteristics of manufacturing function cities' specialization level in central region in 2010, 2015 and 2019 are shown in Figure 5.

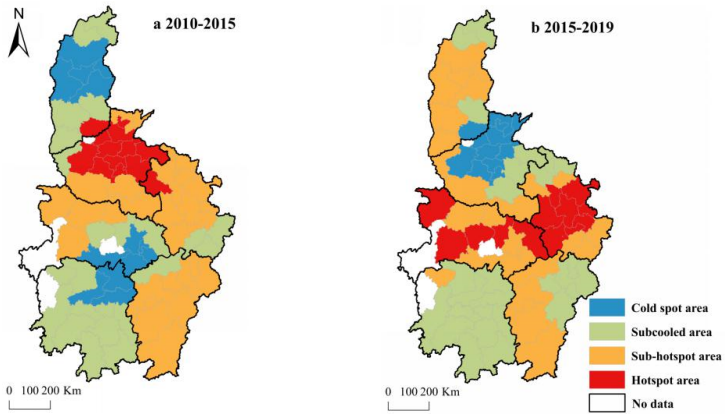

Figure 4. The Spatial Correlation of the Manufacturing Transfer Index of Cities in Central China

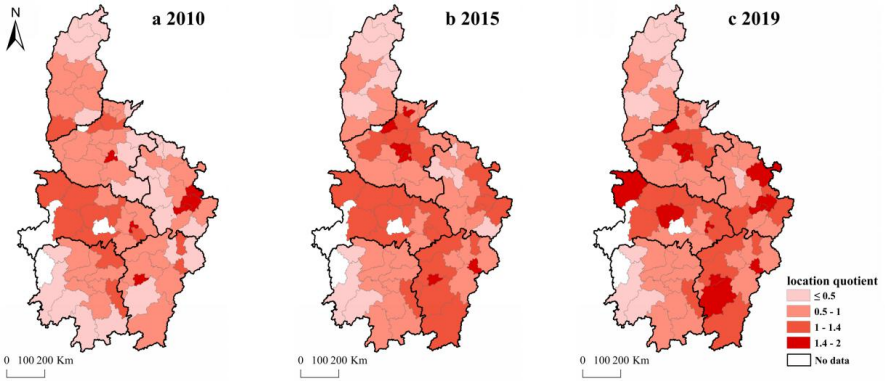

Figure 5. Spatial distribution characteristics and changes of specialization level of manufacturing functions in cities in central China

4.Conclusions

Based on the data of the population employed in the urban manufacturing industry in China City Statistical Yearbook from 2010 to 2019, this paper analyzes the spatial and temporal patterns of the manufacturing industry transfer undertaken by six provinces and regions in central China from two levels of time and space as well as multiple scales of provinces and cities, with the application of analytical models and methods, such as static industrial agglomeration index, industrial location quotient, industrial transfer undertaking index, GIS spatial autocorrelation analysis. Eventually, the conclusions are drawn as follows:

① Due to the influence of the reduction of the total number of manufacturing industries in the country and the adjustment of the layout of manufacturing industries, the spatial changes of manufacturing population concentration in six provinces in the central region show some variability: a significant increase from 2010 to 2017 and a decrease from 2017 to 2019 in Henan Province; a small increase from 2010 to 2019 in a basically stable manner in Jiangxi and Anhui Provinces; a decrease and then an rather small increase in Hubei, Hunan and Shanxi Provinces.

② During the period of 2010-2019, the number of cities receiving manufacturing industries transferred to the central region and the spatial layout of cities have changed significantly. During 2011-2014, there were 41 cities receiving manufacturing industries transferred to the central region, and the hotspots of cities receiving industries transferred to the central region were mainly in Henan Province and its border area with Shanxi Province and Anhui Province. During 2015-2019, the number of cities taking over manufacturing industries transferred increased to 47, and the hot areas taking over manufacturing industries transferred into the city were mainly in the surrounding areas centered on Wuhu and Tongling in Anhui Province and Jingmen and Shiyan City in Hubei Province.

③ The number of cities with basic manufacturing functions in the central region increased significantly between 2010 and 2019, and the number of cities with manufacturing function location quotient greater than 1 increased from 19 in 2010 to 31 in 2019.Influenced by the industrial layout adjustment, the manufacturing function location quotient of cities changed significantly, and the manufacturing location quotients of cities such as Ji'an, Chuzhou, Xuancheng, Yichun, Jiaozuo, and Hebi were significantly enhanced, indicating that the specialization of manufacturing functions in some cities in the central region was significantly strengthened in the process of undertaking the industrial transfer from the east. Meanwhile, the manufacturing location quotient of Yueyang City, Yuncheng City and Jingzhou City decreased noticeably, reflecting the multi-directional driving effect of manufacturing industry transfer on the industrial structure adjustment of cities in the central region.

④ In the process of undertaking the transfer of manufacturing industries from the east, the manufacturing industries of some big cities and mega-cities in central China are not strong enough, and the status of manufacturing center cities needs to be consolidated and strengthened. Among 49 manufacturing center cities in 2010, only 7 are in central China, namely, Wuhan, Changsha, Taiyuan, Zhengzhou, Xiaogan, Yichang and Yueyang.whereas 47 manufacturing center cities in 2014, only 7 of them in the central region, namely, Zhengzhou, Wuhan, Changsha, Hefei, Yichang, Xiangyang and Nanchang.While in 2019, there are 42 manufacturing center

cities in the country, of which 6 are in the central region, namely, Zhengzhou, Wuhan, Xiangyang, Hefei, Changsha and Xiaogan. Further enhancement should be made for the status of manufacturing center cities with larger populations, such as Taiyuan, Linfen, Ganzhou, Luoyang, Wuhu, Fuyang, Nanyang and so forth.

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