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Evolution of Spatio-Temporal Association Model of Port Industry and Economic Growth – A Case of Five Port Groups in China

Jianping Sun
Dalian Maritime University, Dalian, China

Abstract:

Taking the five port groups in China during 1994-2014 as research objects, and using spatio-temporal autocorrelation and partial autocorrelation function to define optimal temporal lagging periods and spatial delay steps. At the same time, utilizing the global spatio-temporal autocorrelation STI index and local spatio-temporal autocorrelation PSTI index, some change rules of the port industry and economic growth spatio-temporal association model between global and local is revealed. Results indicate that: the STI value of Pan-Bohai port group decreases at first and then increases, and Dalian is treated as a core in Liaodong Peninsula with forming the port economic hinterland. The STI values of Yangtze River Delta and Pearl River Delta port groups are higher, the former forms a layout of designing Shanghai port and Suzhou port as main line ports surrounded with Nanjing port, Nantong port, and other ports along the downstream of Yangtze River. And the latter, the global spatio-temporal agglomeration has enhanced and local difference has further expanded. The STI index of southeast coastal port group increases slowly, and the area centered on Ningbo and Zhoushan shows a "V-shape" spreading to western Zhejiang and Eastern Fujian with the hub of port industry and economic moving to south. The southwest coastal port group has lower STI value and weaker agglomerated state.

Keywords*: Evolution, Spatio-temporal autocorrelation, Port group, Port industry.*

I. INTRODUCTION

The development of the port industry and economic growth affect and restrict each other, and the spatio-temporal relationship is a classic theme in economic geography and regional economics. Therefore, it is necessary to conduct in-depth research on the spatio-temporal relationship of the port industry and economic growth. Li and Cao[1] summarized the "First Law of Geography" proposed by Tobler, which points out that things distributed in space are

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related to each other, but the distance between them affects their similarity, and the similarity between things that are close is usually greater than something far away. This law effectively reveals the association model of spatial dimension between things. Mei, Xu, and Ouyang[2] pointed out that the spatial pattern, characteristics, and evolution between things and phenomena are called spatial model, the specific state changes and their characteristics at different time nodes between things and phenomena are called the temporal model. Ma, Pu, and Ma[3] believed that the connotation of spatio-temporal correlation is the change law of objects in fixed space with time, which reflects the temporal and spatial correlation of spatio-temporal data. It can be considered that the correlation between the two dimensions of time and space is the inherent cause of different spatio-temporal association model. Therefore, mining and analyzing the internal relationship between two dimensions is an important means to reveal different time-space models and spatio-temporal association model.

At present, many famous scholars have a lot of research on spatial model mining, the main method adopted is Exploratory Spatial Data Analysis (ESDA)[4-5]. ESDA is a collection of many spatial data analysis methods and technologies, which uses spatial correlation measurement as the core to describe and visualize the spatial distribution pattern of things or phenomena, and then discovers spatial agglomeration and spatial anomaly, thereby as a research method to reveal the spatial interaction mechanism between research objects. Although ESDA can better reveal the regular changes of the spatial model, it still has shortcomings. On the one hand, it only relies on spatial data for research and analysis, and does not have a good combination of time dimension; on the other, its analysis of global and local differences is too dependent on spatial data, there are also some divergences in the selection of weight matrix, and the fault tolerance is poor. For the study of spatio-temporal correlation, the spatial and temporal association and interaction are an indispensable perspective. Therefore, to study the spatio-temporal correlation between things and phenomena, we must effectively combine the two dimensions of time and space and in-depth analysis and mining.

Based on ESDA, many scholars have extended it to further reveal the characteristics of spatio-temporal dependence and spatio-temporal correlation between things and phenomena. The spatio-temporal autocorrelation technology developed based on ESDA can mine spatio-temporal correlation, agglomeration, and heterogeneity, revealing the spatio-temporal interaction mechanism[2]. In the study of overseas scholars, Astutik et al used local spatial Moran's I to predict the spatio-temporal autocorrelation of dengue hemorrhagic disease[6]. The domestic research on spatio-temporal autocorrelation started late with fewer results. By expanding the spatial Moran's I, Wang[7] obtained the form of spatio-temporal correlation statistics. Zhao et al used spatio-temporal autocorrelation function and partial autocorrelation function to analyze the global and local spatio-temporal correlation of the highway network[8].

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The above literature has a mature description and application of the spatio-temporal autocorrelation method and provides a beneficial reference for this article. Based on the above description, this paper considers the two dimensions of "time-space", and uses the autocorrelation, partial autocorrelation function and STI index to comprehensively investigate the rules and association models of the spatio-temporal correlation evolution of the port industry and economic growth to provide decision-making support.

II. MATERIALS

2.1 Study Area

Aiming at the development of the port industry and according to the needs of the model, the port group are divided into five areas: Pan-Bohai area, Yangtze River Delta area, southeast coastal area, southwest coastal area, and Pearl River Delta area. This division can more comprehensively reflect the development level of China's port industry. Aiming at the development of economic growth, considering the internal spatio-temporal relationship between port industry and economic growth, the coastal provinces are selected. Therefore, Liaoning, Hebei, Tianjin, Shandong, Shanghai, Jiangsu, Zhejiang, Fujian, Guangdong, Guangxi, Hainan, and other provinces are selected to analyze the relationship between port industry and economic growth (Table I).

TABLE I. Regional division of the port industry and economic growth

Division of Port groups	Selection of Economic Growth Areas
Pan-Bohai Region	Liaoning, Hebei, Tianjin, Shandong
Yangtze River Delta Region	Shanghai, Jiangsu
Southeast Coastal Area	Zhejiang, Fujian
Pearl River Delta Region	Guangdong
Southwest Coastal Area	Guangxi, Hainan

2.2 Data Source

The main data used in this article are from the website of The National Bureau of Statistics of the People's Republic of China, China City Statistical Yearbook, China Regional Economic Statistical Yearbook and Social and Economic Statistical Yearbook. Considering factors such as regional planning adjustments and changes in the statistical caliber of individual years in individual provinces in the coastal economic belt, some data have been adjusted or amended regarding data released by The National Bureau of Statistics. This paper selects the data of

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index factors that affect China's port industry and economic growth in 1994-2014 and analyzes the spatio-temporal correlation between economic growth and port industry.

2.3 Establishment of an Indicator System

The change of the general trend of the port industry is an utterly complicated process, and the comprehensive development level of economic growth is a more comprehensive and complex system, which should include the population, economy, society, infrastructure, and sustainable development. Based on some other studies, factors for sustainable development have been added. For the selection of indicators that affect the development of port industry, we measure from four aspects of the development level of the port-related industries, the port, the shipping fleet, and the economy and trade, and establish an index system. In the process of establishing indicator system, it is upheld that the selection of indicators follows the principles of scientific, systematic and availability. The evaluation indicators for economic growth, includes traditional evaluation indicators for economic development and indicators that can reflect the constraints of the environment and resources on economic development; among the comprehensive indicators for the development of port industry, the fleet and port level are fully reflected. See Table II for the economic growth index evaluation system, and Table III for the port industry evaluation index system.

TABLE II. The index system of economic growth ability

Indicator Type	Specific Indicators	Weight
Basic economic indicators	GDP (100 million yuan)	0.3257
	Local fiscal revenue (100 million yuan)	0.0588
	Local fiscal expenditure (100 million yuan)	0.0287
Benefit indicators	GDP per capita (yuan / person)	0.0131
	Local fiscal revenue per capita (yuan)	0.0759
Structural indicators	Proportion of output value of tertiary industry (%)	0.0155
	Foreign trade dependence	0.089
Speed indicator	GDP growth rate	0.0985
	GDP growth rate per capita	0.0942
Sustainable development indicators	Electricity consumption per 10,000 GDP (kW·h/10,000 yuan)	0.101
	Water consumption per 10,000 yuan GDP (t/10,000 yuan)	0.0996

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TABLE III. The index system of port development ability

Indicator Type	Specific Indicators	Weight
Development level of port-related industries	Development level of shipbuilding industry	0.0609
	Development level of maritime trade service industry	0.0999
	Return on average capital of shipping companies	0.0702
Shipping fleet	China's shipping fleet capacity (100 million dwt)	0.3462
	Proportion of domestic imports and exports carried by domestic ships	0.0615
	Fleet structure	0.0027
	Fleet age structure	0.1033
Economic and trade	China's import and export trade (10,000 US dollars)	0.0083
	Sea freight	0.1059
Port level	Port throughput	0.0311
	Port infrastructure completeness	0.1100

III. SPATIO-TEMPORAL AUTOCORRELATION

3.1 Spatio-Temporal Autocorrelation and Partial Autocorrelation Function

Let $X_t = [x_1, x_2, x_3, \dots, x_n]$ represent the observation values of n units in plane space at time t=1,2,3,…,T, the sample spatio-temporal autocorrelation function of spatial delay h step and time delay k period[9-10] is

$$\rho(h,k) = \frac{\sum_{t=1}^{T-k} Z_t{}' W_h Z_{t-k}}{\sum_{t=1}^{T} Z_t{}' Z_t} = \frac{\sum_{t=1}^{T-k} Z_t{}' W_h Z_{t-k}}{nT} \tag{1}$$

where $Z_t{}'$, Z_t are the normalized vectors of the mean values of X_t, X_{t-k}, respectively; $Z_t{}'$ denotes the transpose of Z_t; W_h denotes the spatial weight matrix of h-step spatial delay.

The spatio-temporal autocorrelation function mainly counts the global spatio-temporal autocorrelation relationship and can be used to identify the number of temporal lagging periods and the step of spatial delay of the spatio-temporal autocorrelation process. The spatio-temporal partial autocorrelation function excludes the influence of other spatio-temporal variables or intermediate variables, and truly reflects the correlation between the two spatio-temporal variables of $X_{i+h,t}$ and $X_{i,t-k}$. Its function form[9-10] as follows:

$$\rho'(h,k) = \sum_{k=1}^{k} \sum_{h=1}^{H_k} \varphi_{kh} \rho'(h-1,k) \tag{2}$$

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where K and H are the time delay and space delay step of the spatio-temporal autocorrelation process; φ_{kh} is the spatio-temporal partial autocorrelation coefficient.

3.2 Global Spatio-Temporal Moran's I

For spatial autocorrelation analysis can only explore the aggregation of the spatial distribution of regional variables, Moran's I index can only research and analyze the spatial dimension, and cannot give the spatio-temporal autocorrelation characteristics in the time-space dimension. Wartenberg[11] analyzed the spatio-temporal autocorrelation structure of variables by using spatio-temporal Moran's I (STI). The equation for the STI index[12] as follows:

$$STI = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n} W_{t-k,t} W_{ij}^{h} (X_{i,t-k} - \overline{X}_{t-k})(X_{j,t} - \overline{X}_{t})}{\sqrt{\sum_{i=1}^{n}(X_{i,t-k} - \overline{X}_{t-k})^2} \times \sqrt{\sum_{i=1}^{n}(X_{j,t} - \overline{X}_{t})^2}} \tag{3}$$

where W_{ij} denotes the element of the spatio-temporal weight matrix W, $W_{t-k,t}$ denotes the weight from time t-k to t, N denotes the number of study areas, and $X_{i,t}$ and $X_{j,t}$ denote the observation values of port industry development and economic growth in units i and j at time t, respectively; $X_{i,t-k}$ denotes the observation values of port industry development and economic growth in unit i at time t-k; $\overline{X_{t-k}}$ and $\overline{X_t}$ denote the mean values of the observed measurements at t-k and t, respectively; k and h denote the number of temporal lagging periods and the steps of spatial delay, respectively. When the number of lagging period k is 0, the STI index is called Global Moran's I. The significance level of STI needs to be tested by Z test. E(STI) denotes the mathematical expectation of STI, Var(STI) denotes the variance of the Moran's I. When $|Z|$>1.96, the autocorrelation of the representative variable is significant.

$$Z = \frac{1 - E(STI)}{\sqrt{\mathrm{Var}(\mathrm{STI})}} \tag{4}$$

3.3 Local Spatio-Temporal Moran's I

The global STI index is similar to the Global Moran's I, which can only reflect the overall spatio-temporal correlation of the attributes of geographical things. Analyzing the change of the overall trend from a macro perspective, it cannot reveal the spatio-temporal correlation of fixed geographic research within a local scope. Therefore, it is necessary to introduce local spatio-temporal autocorrelation coefficient to further reflect the spatio-temporal correlation

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between specific research areas, and the local STI index is[13]:

$$PSTI = \frac{nW_{t-k,t}(X_{i,t-k} - \overline{X}_{t-k})\sum_{j=1}^{n} W_{ij}{}^{h}(X_{j,t} - \overline{X}_{t})}{\sqrt{\sum_{i=1}^{n}(X_{i,t-k} - \overline{X}_{t-k})^2} \times \sqrt{\sum_{i=1}^{n}(X_{j,t} - \overline{X}_{t})^2}} \tag{5}$$

where W_{ij}, $W_{t-k,t}$, $X_{i,t}$, $X_{j,t}$, and $X_{i,t-k}$ all represent the same meaning as equation (4), but the meaning represented by the PSTI is the similarity degree of port industry development and economic growth in a local region at time t-k and the change range of surrounding region at time t. Compared with the four spatial association models obtained by the Local Moran's I, there are also four combinations of different spatio-temporal association models obtained from PSTI calculations, analogous to the Moran's I scatter plot, which corresponds to four quadrants respectively. Four kinds of correlations are "H-H-type", "H-L-type", "L-L-type" and "L-H-type". The four quadrants correspond to four regions of different properties[14].

IV. SPATIO-TEMPORAL CORRELATION EVOLUTION

Three-time sections (1994, 2004 and 2014) are selected to calculate the global spatio-temporal autocorrelation by using the bivariate spatio-temporal correlation analysis provided by GeoDA. The global aggregation and polarization characteristics of the five port groups are preliminarily judged through Mapinfo/ArcGIS further explains the spatial agglomeration or polarization characteristics of specific regions showing similarities, and finally analyzes the LISA clustering map.

4.1 Determination of Temporal Lagging Periods and Spatial Delay Steps

For continuous data from 1994 to 2014, the optimal temporal lagging periods and spatial delay steps should be selected. The best temporal and spatial scale are more conducive to the analysis of the global and local spatio-temporal correlation. The first-step Bishop weighting method is used to assign the spatial weight matrix, and the spatio-temporal autocorrelation and partial autocorrelation function are used to calculate $\rho(h,k)$ and $\rho'(h,k)$ (Tables IV-V).

TABLE IV. Values of spatio-temporal and partial autocorrelation function ($\rho(h,k)$)

Function $\rho(h,k)$		Temporal Lagging Period			
		$k=1$	$k=2$	$k=3$	$k=4$
Spatial	$h=0$	0.831	0.624	0.519	0.231

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Delay Step	$h = 1$	0.689	0.443	0.254	0.171
	$h = 2$	0.401	0.305	0.177	0.041
	$h = 3$	0.211	0.177	0.098	0.026

TABLE V. Values of spatio-temporal and partial autocorrelation function ($\rho'(h,k)$)

Function $\rho'(h, k)$		Temporal Lagging Period			
		$k = 1$	$k = 2$	$k = 3$	$k = 4$
Spatial Delay Step	$h = 0$	0.431	0.348	0.071	0.032
	$h = 1$	0.327	0.256	0.054	0.021
	$h = 2$	0.097	0.084	0.013	0.007
	$h = 3$	0.021	0.017	0.009	0.003

4.2 Analysis of Global Spatio-Temporal Autocorrelation Index

Substituting the values in the comprehensive indicator system of the port industry and economic growth into equation (3), the global spatio-temporal autocorrelation index STI of the five port groups is calculated as shown in Table VI, which shows that the STI index of Pan-Bohai port group is always positive in three-time sections, showing a state of agglomeration, but the STI index decreases first and then increases, indicating that the spatio-temporal positive correlation has fluctuated slightly; the STI index of Yangtze River Delta port group has always been positive, and there is an increasing trend, indicating that the port industry-economic development has always been in a high agglomeration state and developing rapidly; the STI index of southeast coastal port group has always been positive and slowly increasing, which is in a state of global positive correlation and high agglomeration, and the STI index value is larger and well developed after 2004; the STI index of Pearl River Delta port group is second only to Yangtze River Delta port group and is also at a high level of positive spatio-temporal correlation, which is closely related to geographical advantages of Guangdong, and the STI index has increased significantly in the whole time span; the spatio-temporal relationship has changed from polarization to agglomeration.

TABLE VI. Values of STI in global spatio-temporal autocorrelation

Regional Division	Primitive Time	Spatial Lag (h=1)	STI	P-test	Time Series
Pan-Bohai port group	1994	2004	0.403	<0.01	1994 - 2014
	2004	2014	0.322	<0.01	
	2004	-	0.341	0.0274	

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Yangtze River Delta port group	1994	2004	0.573	<0.01	
	2004	2014	0.621	<0.01	
	2004	-	0.774	<0.01	
Southeast Coastal port group	1994	2004	0.443	0.0107	
	2004	2014	0.513	<0.01	
	2004	-	0.505	0.0176	
Pearl River Delta port group	1994	2004	0.497	<0.01	
	2004	2014	0.543	<0.01	
	2004	-	0.698	0.0224	
Southwest Coastal port group	1994	2004	-0.216	<0.01	
	2004	2014	0.401	<0.01	
	2004	-	0.477	<0.01	

4.3 Analysis of Global Spatio-Temporal Association Model

The analysis of global spatio-temporal autocorrelation STI index describes the spatio-temporal association model of port industry and economic growth of the five port groups in the overall study area. It ignores the spatio-temporal correlation between different provinces and cities within the study area and fails to investigate local spatio-temporal heterogeneous regions so that we need to use the local spatio-temporal autocorrelation PSTI index for further analysis.

4.3.1 Pan-Bohai Port Group

According to Figure 1, it can be seen that in the three-time sections of 1994, 2004 and 2014, the proportion of prefecture-level cities with positive spatio-temporal correlation is 63%, 56%, and 56%, respectively. In the time series, there is a local spatio-temporal positive correlation, which tends to cluster in the regions with similar development levels and is consistent with the global spatio-temporal correlation conclusion of the Pan-Bohai port group. H-H-type spatio-temporal related area expanded eastward to the Bohai Bay, and gradually formed the Pan-Bohai port economic circle centered on Dalian, Tangshan, Tianjin, Yantai, Weihai, and Qingdao. Meanwhile, the port hinterland economy has also played an important role in promoting the economic recovery of the whole Northeast. Within the scope of the Shandong Peninsula, it can be found that the port industry-economic center is moving to the southwest, and the economic center is focusing on the Qingdao-Jinan direction. The large-scale reduction of L-L-type area indicates that the development momentum of China's port industry and economy has been advancing rapidly during this period.

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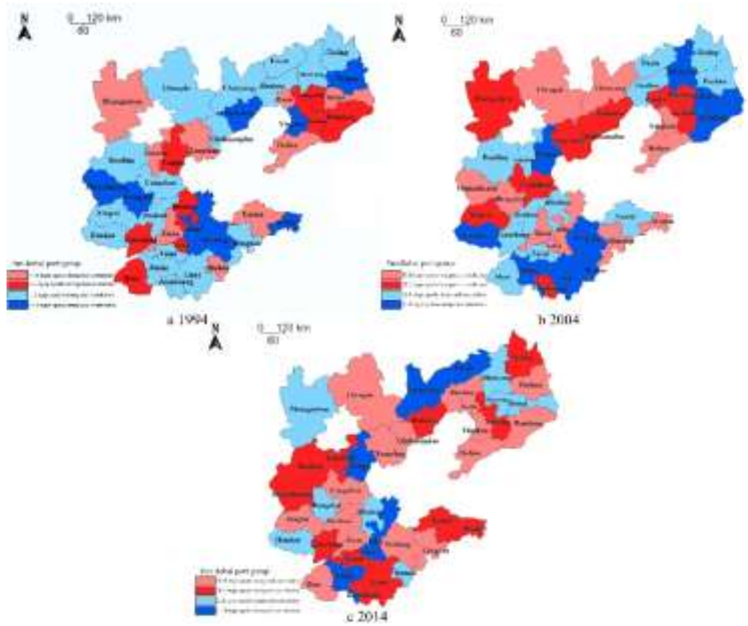

Fig 1: Local spatio-temporal correlation of Pan-Bohai Port Group in 1994-2014

4.3.2 Yangtze River Delta Port Group

The Yangtze River Delta port group is located in the estuary of the Yangtze River Delta, and its good geographical advantage has made Yangtze River Delta always in the leading position of the national economy, and the positioning of port development is also quite clear. As early as 1997, three provinces and cities of Jiangsu, Zhejiang, and Shanghai jointly established Shanghai Combined Port Office to coordinate port and container terminal planning. Among them, the Yangtze River Delta port group relies on the construction of advantages of the Shanghai International Shipping Center, which will more effectively promote the economic and social development of the Yangtze River Delta and areas along the Yangtze River. During the research period, the H-H-type spatio-temporal correlation area moved radiantly from Nanjing to the mid-east of Jiangsu province, showing a strong spatio-temporal agglomeration in the middle and east, while the core of the entire port industry and economy also gradually moved to the central part; for port industry and economic development of Yangtze River Delta port group are both at a relatively higher autocorrelation level, the L-L-type areas are only Xuzhou, Suqian, etc.

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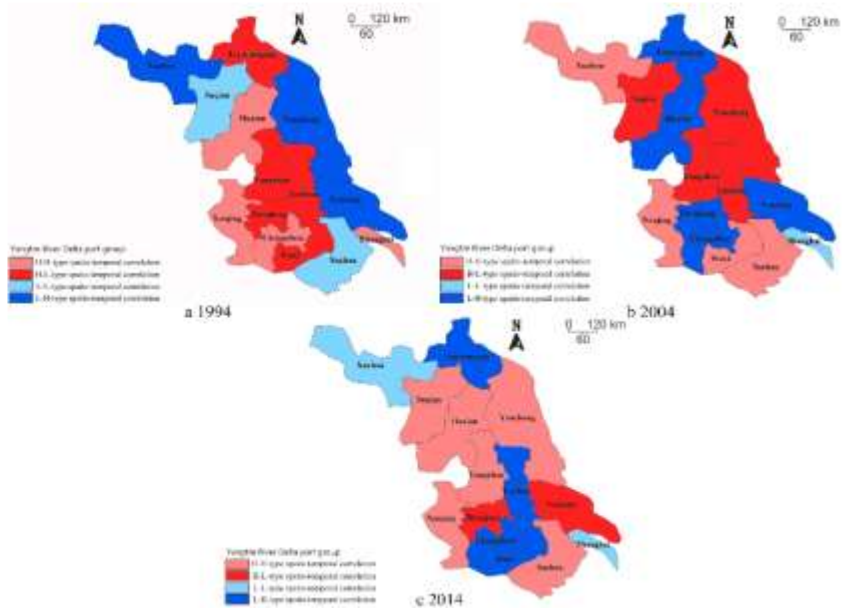

Fig 2: Local spatio-temporal correlation of Yangtze River Delta port group in 1994-2014

4.3.3 Southeast coastal port group

Figure 3 shows that in the three-time sections of 1994, 2004 and 2014, the southeast coastal areas have positively spatio-temporal correlation as a whole, and tend to expand. The proportion of prefecture-level cities with local negative spatio-temporal correlation on the three-time nodes is 35%, 50%, and 40%, respectively. In the time series, there is an overall positive local spatio-temporal correlation, but the negative correlation has an increasing trend. The level gradient of the port industry and economic development in local areas has increased, and certain polarization characteristics have appeared. During the research period, the H-H-type area of the southeast coastal port group centered on Ningbo and Zhoushan, spreading in a "V-shape" to western Zhejiang and eastern Fujian. As shown in Fig 3(a), it can be seen that in 1994, port industry and economic development level of the whole southeast coastal area was concentrated in the north of Zhejiang province, and with the development of national economy and the support of policies, the center of port industry and economy had gradually moved southward. On the one hand, it has promoted economic development and the shipping level of Fujian province; on the other, the port economy of Fujian has also effectively produced a good radiation impact on the northern Guangdong region.

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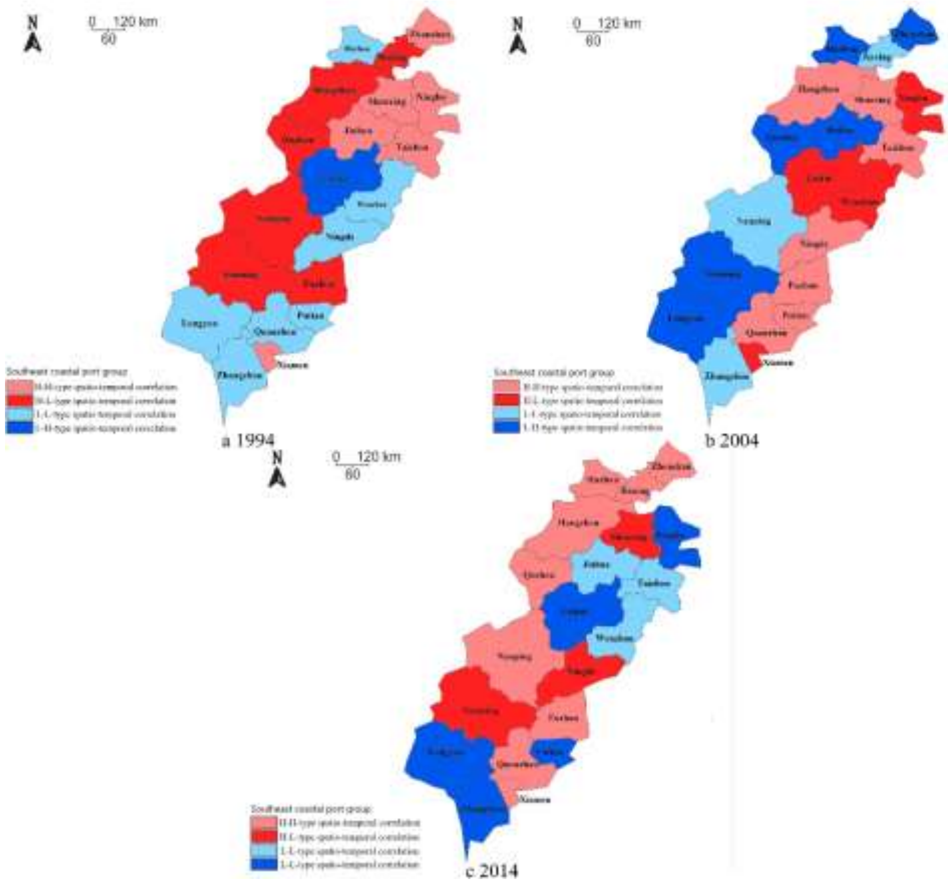

Fig 3: Local spatio-temporal correlation of southeast coastal port group in 1994-2014

4.3.4 Pearl River Delta Port Group

During the research period, the port industry and economic development of the whole Pearl River Delta port group have been relatively rapid, the local spatio-temporal autocorrelation region has increased from 19% to 47% in 1994, and the spatio-temporal agglomeration of port industry-economic growth in the overall scope is greatly enhanced. According to Fig 4, observing the spatio-temporal correlation changes of the entire area, it is found that the H-H-type spatio-temporal correlation area with Guangzhou as the center is constantly spreading to eastern and northern Guangdong, and also has a combined effect on the two administrative regions of Hong Kong and Macau, forming Zhuhai, Hong Kong, and Macau economic development area continues to generate favorable economic radiation to the north of Guangdong. For the L-L-type, it is mainly concentrated in northwestern Guangdong, but it was reduced on a large scale around 2004. As of 2014, L-L-type area was more concentrated, forming an area centered on Heyuan, Shantou, and Shanwei. However, for the entire Pearl

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River Delta region, the differences in port industry-economic growth levels between local areas have further expanded. From 1994 to 2014, the four types of local spatio-temporal correlation have been frequently transformed and the differences in the spatio-temporal association model between prefecture-level cities have been narrowed first and then expanded.

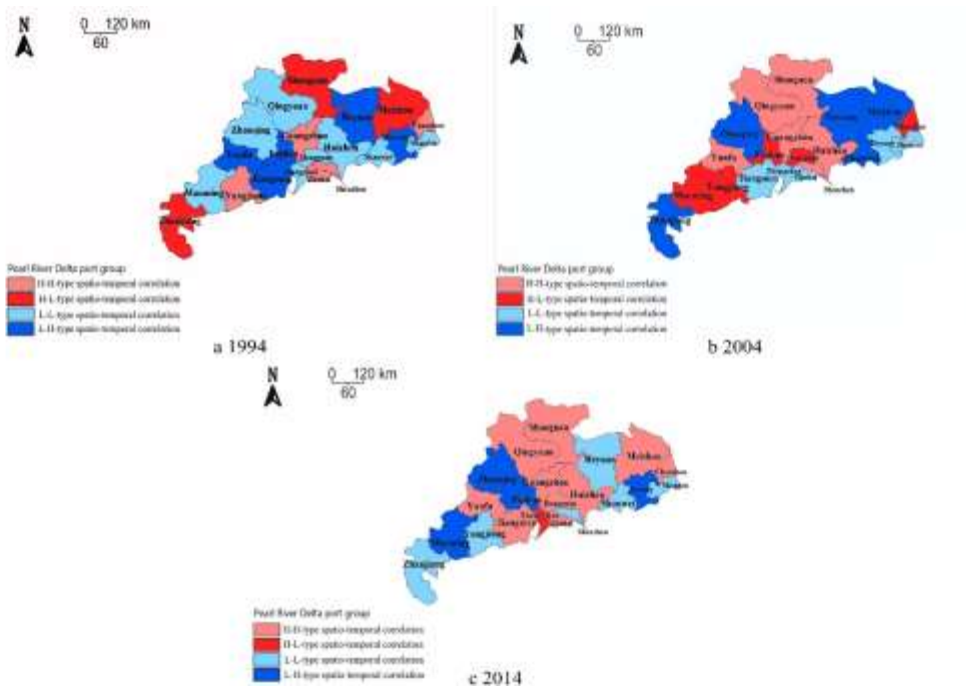

Fig 4: Local spatio-temporal correlation of Pearl River Delta port group in 1994-2014

4.3.5 Southwest coastal port group

The prefecture-level cities with positive spatio-temporal correlations in the southwest coastal areas accounted for 41%, 54%, and 58% in the three-time sections of 1994, 2004 and 2014, respectively. During the research period, the overall spatio-temporal correlation change was from negative to positive. Throughout the study area, the development level of port industry-economic growth tended to agglomerate from polarization, and the evolution process was closely related to the strong impact of economic globalization. According to Fig 5, it can be seen that the H-H-type spatio-temporal correlation area continuously extended to the northwest with Nanning as the center during the study period, and gradually formed an H-H cluster area with Nanning, Baise, and Hechi as the centers.In Hainan province, there were no significant changes in the H-H-type spatio-temporal correlation area. After 2004, Sanya gradually turned into H-H-type, which indirectly proved that the economic level of

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Sanya has progressively improved. There was no significant change in the number of L-L-type spatio-temporal correlation regions, but gradually clustered and moved to the east, forming L-L-type spatio-temporal correlation area with Guigang and Wuzhou as the center, which was also consistent with the increasing proportion of spatio-temporal positive correlation regions after 2004. The long-term high development and high agglomeration of Haikou in Hainan province also provides a strong transportation guarantee for expanding the level of material and capital exchange between Hainan province and other islands.

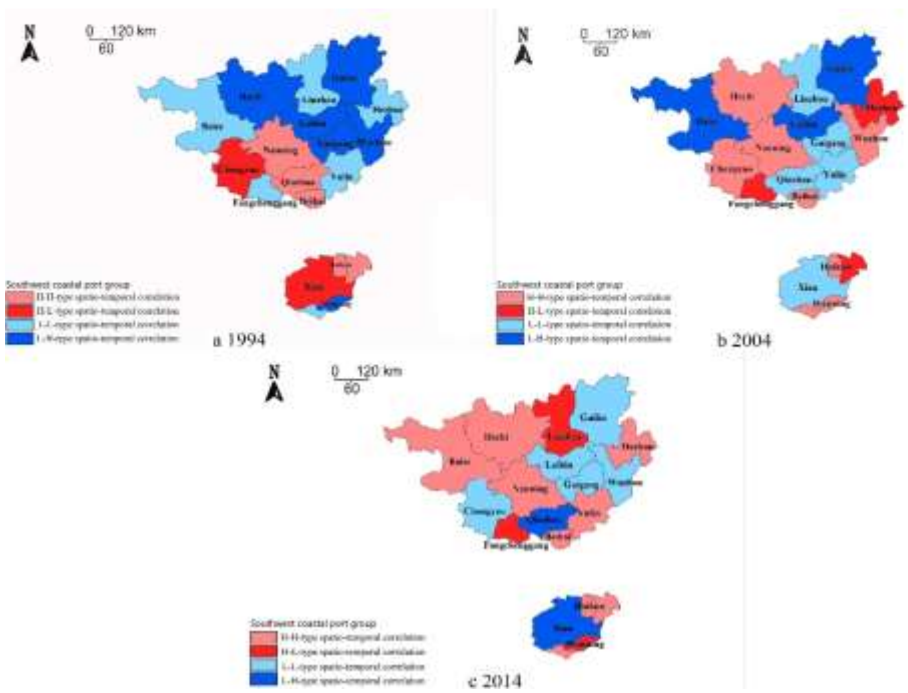

Fig 5: Local spatio-temporal correlation of southwest coastal port group in 1994-2014

V. CONCLUSION

In the global scope, the STI value of the Yangtze River Delta and Pearl River Delta port group are higher, and port industry-economic development has been in a higher agglomeration state with a high level of development. The southwest coastal port group has a lower STI value, a weak agglomeration state and a poor level of development. The STI index of the Pan-Bohai port group decreases first and then increases, with a slight fluctuation in the positive spatio-temporal correlation; the STI index of the southeast coastal port group is always positive and slowly increasing, which is in the state of global positive spatio-temporal correlation and high agglomeration. After 2004, the STI value is larger, and the development speed increases.

In the local scope, H-H-type region in the Pan-Bohai region moves towards the Bohai Bay, forming a Pan-Bohai economic circle, which promoted the port industry and economic growth. At the same time, the Liaodong Peninsula radiates northward and eastward with Dalian as the center, forming the port economic hinterland and providing favorable economic conditions for Dalian to build the Northeast Asia International Shipping Center; the Yangtze River Delta region moved radiantly from Nanjing to the mid-east of Jiangsu province, it has gradually formed the port industry layout with the Shanghai Port and Suzhou port as the main line ports, and the downstream of Yangtze River ports such as Nanjing, Nantong, and Zhenjiang as surrounding ports; the southeast coastal area has a "V-shape" spread to eastern Zhejiang and western Fujian with Ningbo and Zhoushan as the center, and port industry and economic center have moved southward; the agglomeration of port industry-economic growth in the whole Pearl River Delta region is greatly enhanced, but the differences in the level of port industry-economic growth among local areas have further expanded; the southwest coastal area continues to extend to the northwest with Nanning as the center, gradually forming an H-H agglomerated area centered on Nanning, Baise, and Hechi has effectively promoted the economic development of the West.

However, this paper also has many shortcomings. Since the research is based on certain assumptions, this paper ignores some major environmental background and some secondary factors. At the same time, there is no in-depth analysis on the changes of port industry and economic growth in the continuous time series, which need to be further studied.

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