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Study on Gravity Center Movement and Spatial-Temporal Differences of Port Industry and Economic Growth in China's Coastal Areas between 1994 and 2014

Minghe Dai, Jianping Sun*
Dalian Maritime University, Dalian 116026, China
*Corresponding Author.

Abstract:

Taking five port groups in China as the research objects, a comprehensive system of evaluation indicators for port industry and economic growth in coastal areas was established from global to local, the spatial-temporal differences and characteristics between the port industry and economic growth in coastal areas from 1994 to 2014 were analyzed by Gravity center movement model and Exploratory spatial data model. The results indicated the gravity centers were mainly concentrated in south and moved towards Yangtze river delta gradually. On the global aspect, the port industry had a spatial-temporal difference from significant positive to significant negative correlation; the economic growth in coastal areas illustrated a spatial positive correlation and the three stages of "positive-negative-positive" in time and spatial dimension were demonstrated in the port industry-economic growth. On the local aspect, the regions with H-H type in port industry moved from Pearl river delta to Yangtze river delta regions and the regions with L-L type were concentrated in southwest and western Bohai regions; the regions with H-H type in coastal economic growth focused on Pearl river delta, Yangtze river delta and southern Bohai regions with less change and the regions with L-L type were centered on Hebei, Guangxi and Hainan; the regions with L-L type in port industry-economic growth took Pearl river delta and Yangtze river delta as the centers expanding to surrounding areas. Hebei and southwestern coastal areas were concentrated in the regions with L-L type and the range of which was shrinking gradually.

Keywords: *Port industry, Gravity center movement, ESDA.*

I. INTRODUCTION

The port industry and economic development is an evolving process, which is continuous and dynamic in time and space. On the one hand, the development of port industry and economic growth is affected by temporal dynamic changes demonstrating a changing degree of correlation between them over time, for example, the development of port industry and economic growth in different regions changed with the policy formulation and implementation in different periods. On the other hand, the development of port industry and economic development influenced by spatial heterogeneity or spatial relations shows a pattern of agglomeration and differentiation in space, such as the differentiation features of economic growth between coastal and inland, and between south and north. With the depression of global shipping industry, it is

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necessary to analyze the trend and spatial-temporal difference of port industry and economic level in the five major coastal port groups, and reveal their inherent evolution.

In recent years, scholars have carried out extensive excavation to research on space models with development of space technology, and the Exploratory space data analysis (ESDA) method is used commonly [1-4]. Based on ESDA, the scholars have expanded it to reveal the spatial-temporal difference and spatial-temporal correlation between things and phenomena. In the study of foreign scholars, Matkan et al used bivariate *Global Moran's I* to monitoring the frequency of traffic accidents [5]; Astutik et al. applied *Local Moran's I* into the spatial-temporal correlation of dengue hemorrhagic disease [6]. However, the research on spatial-temporal auto-correlation and spatial- temporal difference in China started late and achieved less. Wang (2006) and Wang (2008) were the early scholars to study the spatial-temporal auto-correlation in China who obtained the form of spatial-temporal correlation statistics by extending the spatial *Moran's I* [7]and explored the modeling of spatial-temporal correlation sequences [8]; The above literature have a very mature exposition and application of spatial-temporal difference method providing a useful reference for this article. In the existing research, there have been lots of studies on the spatial-temporal differences of regional economic growth in China [9-12]. Feng et al analyzed the spatial-temporal evolution of China's regional economic differences by the second-order decomposition of Theil index and ESDA [13]; Based on ESDA, Du et al researched the spatial pattern evolution of economic growth in the county area of Northeast China [14]; Taking 17 prefecture-level cities in Shandong province as the object of study, Zhao et al analyzed the spatial-temporal evolution and driving factors of regional economic development in the last 10 years and explored the spatial aggregation and difference by ESDA [15]. The above research methods mainly focused on the traditional spatial analysis methods and ESDA, and most of the indicators measuring the spatial-temporal relation between economic growth are GDP per capital, which cannot reflect the differences in the level of economic development among regions, moreover, few research on the spatial-temporal correlation of port industry development have been studied at home and abroad, and the exploration and analysis of spatial-temporal differences existing in the fixed time series between port industry and economic growth are less than the former.

Based on the previous results, this paper took five port groups as research objects to explore the global and local spatial-temporal difference of China's port industry and economic growth in the time and spatial dimension by Gravity center movement model and ESDA, and explained the spatial-temporal evolution process of China's port industry and economic growth at global and local level, which concluded that the spatial-temporal difference is obvious in China's port industry, whereas is weak in China's economic growth. Useful references would be provided via these conclusions for the relations between global economy and shipping markets.

II. MATERIALS AND METHODS

2.1 Establishment of Indicator System

How to evaluate the comprehensive level of port industry development and coastal economic growth and describe the relationship between them is a complicated question. The evaluation indexes of economic growth include regional population, economy, society, infrastructure, etc, the indicators influencing the development of port industry include port level, economy and trade. Considering the restrictive effects of speed and benefit indicators on the economic development, this paper screened out the indicators that have a significant impact on the evaluation results of the coastal port industry and economic growth, and selected

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the data from 1994-2014 to establish an index system. To reduce the impact of subjective factors, 20 scholars in the field of transportation and shipping, and enterprise decision-makers with practical experience were invited to score the importance of the indicators proposed in this paper, and the weight was calculated by Analytic hierarchy process (AHP) [16], the specific results are shown in TABLE I.

TABLE I. Evaluation index system of development capability of port industry and economic growth

Classification	Comprehensive Indicators	Weights of Composite Indicators	Specific Indicators	Weight of Sub-Indicators	Time Series
Indexes of Economic Growth	Basic Economic Indicator	0.45	GDP of A City/Province (1 million yuan)	0.6	1994-2014
			Local Financial Revenue (1 million yuan)	0.2	
			Local Fiscal Expenditure (1 million yuan)	0.2	
	Benefit Index	0.18	GDP Per Capita (yuan per perspn)	0.3	
			Local Fiscal Revenue per Capita(yuan)	0.7	
	Speed indicator	0.37	GDP Growth Rate	0.3	
			GDP Growth Rate per Capita	0.7	
Indexes of Port Development	Economic and Trade	0.5	Volume of Exports and Imports (million dollar)	0.4	
			Sea Freight Volume	0.6	

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	Port Development	0.5	Port Throughput	1.0

Source: web of National Bureau of Statistics, China city statistical yearbook and China regional economic statistical year books.

2.2 Area Division

The premise of using ESDA to analyze the spatial-temporal difference in study regions is spatial regionalization, thus the port group areas studied in this paper are divided into Bohai area, Yangtze river delta region, Southeast coastal Area, Southwest coastal area and Pearl river delta region to reflect the development level of China's port industry comprehensively. The representative ports were selected in the specific port groups to describe the development of port industry. As for the economic growth in coastal areas, Liaoning, Hebei, Tianjin, Shandong, Shanghai, Jiangsu, Zhejiang, Fujian, Guangdong, Guangxi and Hainan were selected to reflect the macro level of coastal economic growth considering the internal spatial-temporal difference between port industry and coastal economic level, the division of specific study areas are shown in TABLE II.

TABLE II. Division of specific study areas

Division of Port Groups	Provinces for Specific Regions	Ports for Specific Regions
Bohai area	Liaoning	Dalian Port, Yingkou Port
	Hebei	Qinhuangdao Port
	Tianjin	Tianjin Port
	Shandong	Yantai Port, Qingdao Port, Rizhao Port
Yangtze River Delta Region	Shanghai	Shanghai Port
	Jiangsu	Lianyungang Port
	Zhejiang	Ningbo-Zhoushan Port
Southeast Coastal Area	Fujian	Xiamen Port, Fuzhou Port
Pearl River Delta Region	Guangdong	Guangzhou Port, Shantou Port
Southwest Coastal Area	Guangxi	Fangchenggang Port
	Hainan	Haikou Port

2.3 Methodology

2.3.1 Gravity center movement model

The gravity center movement analysis could determine the change in position of gravity center in specific space areas over a longer period of time to calculate the spatial dynamics of gravity center [17]. The gravity center movement model postulates that a region is made up by n units, the COI (center of inertia) of m unit is (X_i, Y_i) and the index value is E_i, the calculation (Xu et al, 2009) of attribute coordinates T_i (x_i, y_i) [18]is as follows:

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$$x_i = \frac{\sum_{i=1}^{n} E_i X_i}{\sum_{i=1}^{n} E_i}, \quad y_i = \frac{\sum_{i=1}^{n} E_i Y_i}{\sum_{i=1}^{n} E_i} \tag{1}$$

In this paper, the port throughput and the GDP of each coastal province are referred to E_i, the coordinate of economic gravity center is the central coordinate of the studied region (X_i, Y_i) as the administrative center is usually the most concentrated and developed area in the entire region.

2.3.2 Exploratory spatial data analysis (ESDA)

Exploratory spatial data analysis (ESDA) can identify and analyze the nature of spatial information to direct the structure and algorithms of some specific models [19], the combination of statistical principles and graphical expression is the main way to merge time and space which visualizes geographic and thematic data [1]. There are two types of Moran's: one is the *Global Moran's I* revealing the spatial-temporal difference between things and phenomena within a general region; the other is *Local Moran's I* based on LISA proposed by Anselin et al [20], which could explore the spatial-temporal difference between sub-regions in a fixed region.

The definition of *Global Moran's I* [21] is:

$$I = \frac{N \sum_i \sum_j w_{ij} (x_i - \bar{x})(x_j - \bar{x})}{\left(\sum_i \sum_j w_{ij}\right)(x_i - \bar{x})^2} \tag{2}$$

The Z test is as follows:

$$Z(I) = \frac{1 - E(I)}{\sqrt{VAR(I)}} \tag{3}$$

In the formula (2), N is the total number of regions within the study area, x_i and x_j are the observed values of region i and j, respectively, $\bar{x}$ is the mean of attributes, w_{ij} is a binary adjacent matrix. Whether things and phenomena are aggregated or abnormal in space can be judged by Global Moran's I [22], and the value of Global Moran's I is generally between [-1,1]. The port industry and economic development have a significant aggregation in space when the value is close to 1, in contrast, the port industry and economic development are polarized when it is close to -1. The spatial auto-correlation in N regions can be detected by Z test, and the Z value is positive and significant in the presence of spatial positive auto-correlation, namely the similar observations tend to cluster in space, instead, the Z value is negative and significant in the presence of spatial negative auto-correlation, which means the similar observations are scattered.

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The definition of Local Moran's I [21] is:

$$I_i = \frac{(x_i \quad x)}{S_x^{\,2}} \sum_j \left[w_{ij} \left(x_j \quad \bar{x} \right) \right] \tag{4}$$

Among these, $S_x^{\,2} = \sum_j \left(x_j \quad \bar{x} \right)^2 / n$ .The I_i is positive when the similarity values (high or low values) around the area unit are spatial agglomeration and the I_i is negative when the non-similar values are spatial agglomeration.

III. RESULTS AND DISCUSSION

Calculating the gravity center of port industry and economic growth in coastal areas by gravity center model and visualizing the calculation data can intuitively indicate the characteristics of the gravity center changes in position, reveal the spatial dynamic changes of gravity center in the study period and area, and measure the spatial differences in different port groups in both port industry and development of coastal area; meanwhile, the relation between the development of port industry and the changes of economic growth in coastal regions could be analyzed by ESDA. The Global Moran's I could draw the agglomeration and dispersion degree of coastal port industry and coastal regional economy, the spatial-temporal differences within provinces and cities could be illustrated by Local Moran's I.

3.1 Analysis of Gravity Center Movement

3.1.1 The gravity center movement of port industry

According to the formula (1), data from five nodes of 1994, 1999, 2004, 2009 and 2014 were brought into gravity center movement model, the gravity center coordinates (x_i , y_i) were calculated and the gravity center movement was demonstrated in figure 1 and 2. As we can see from figure 1, the ellipse formed by the development of port industry from 1994 to 2014 are distributed in east-south region, which demonstrated that the gravity center of port industry is inclined to south, and the ports in south are better than the ones in north in general. In the early days of China's reform and opening up, Shenzhen, Zhuhai, Shantou, and Xiamen were established as the special economic zones which introduced the advanced foreign technology and experience, expanded foreign investment and enhanced the internationalization level of China's coastal areas by relying on Hong Kong, Macao and Taiwan with more developed economies. As a window of China's foreign trade, the areas transporting the domestic and foreign goods has developed port industry rapidly. The improving structure of southern port industry promoted the economic development in southeast and provided economic security for the further improvement of port industry.

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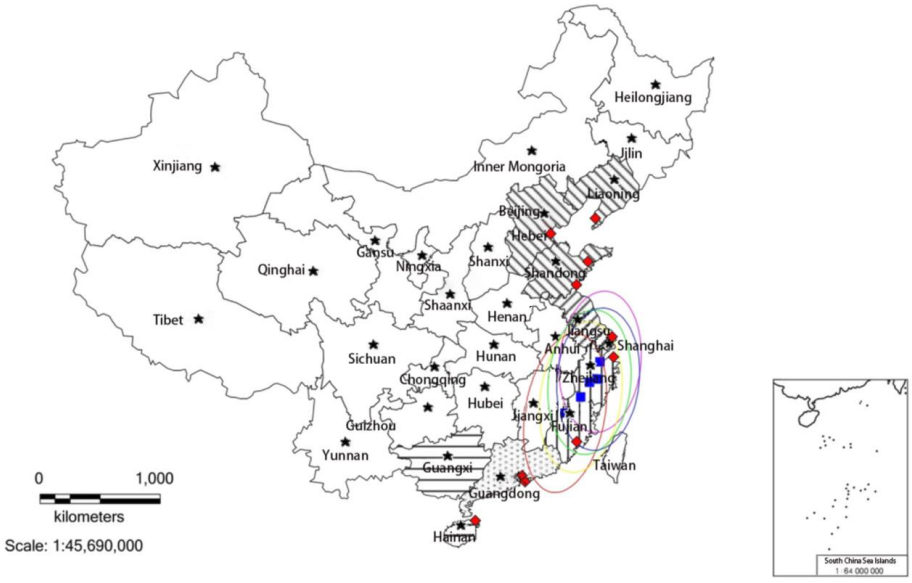

Fig 1. The spatial-temporal pattern and evolution of port industry development

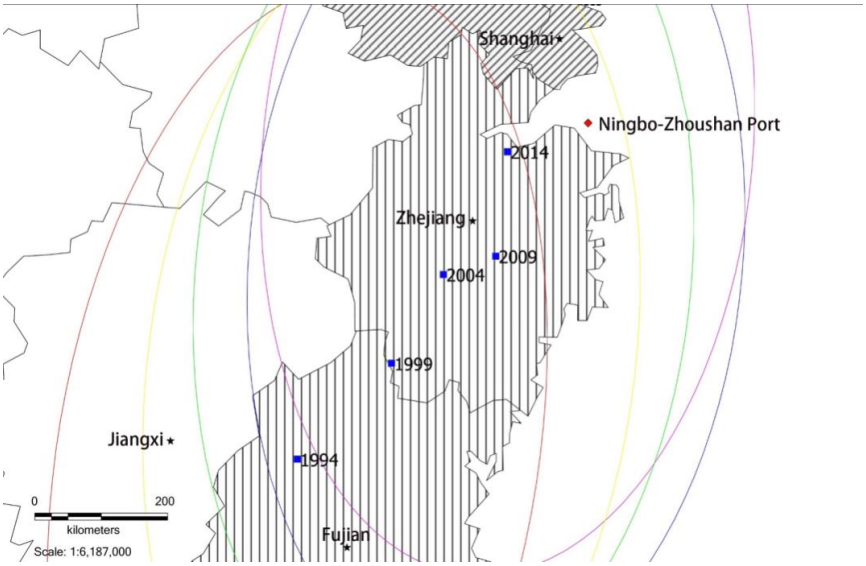

Fig 2. The gravity center shift of port industry development

As we can see from figure 2, the gravity center of port industry has moved to north and formed a development pattern of port industry centered around Shanghai and its surroundings during the period of 1994-2014, which is consistent with the goal of building Shanghai into an international shipping center. Since the China's Ministry of Communications comprehensively organized and implemented the long-term plan: to develop highway, water transport and port, and support the traffic security system, the port industry has developed rapidly and formed a transport system for coal, oil, iron ore, grain and containers which takes the pivotal ports as center and the large professional berth and specialized transport fleet as foundation. As the sea gate of Yangtze river, Shanghai undertook for almost all the foreign trade in Yangtze river delta and

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promoted the inland trade effectively as the ships in Shanghai could reach Chongqing directly. The gravity center of China's port industry is approaching to Shanghai in terms of time and it is getting closer for Shanghai for becoming a world shipping center.

3.1.2 The gravity center movement of coastal economy

Calculating the economic data for five time points could obtain the gravity center movement illustrated in figure 3 and 4. As is shown in figure 3, the spatial ellipse formed by the economic growth in 1990s is distributed in the east coast with port groups in Yangtze river delta as gravity center, which illustrated that the economic level of China's coastal areas changed slightly within a small range relating to the strong economic strength of port groups in Yangtze river delta and the economic incentives for coastal policy. Fourteen coastal cities as the external windows in China promoted the constant changes in industrial structure of coastal economic areas. Among these, the proportion of primary industry is gradually decreasing in the process of development, the proportion of secondary and tertiary industries has increased a lot providing many employment positions, meanwhile, the influx of population has brought the sustained vitality to the development of coastal economy to maintain Yangtze river delta as the gravity center of port industry.

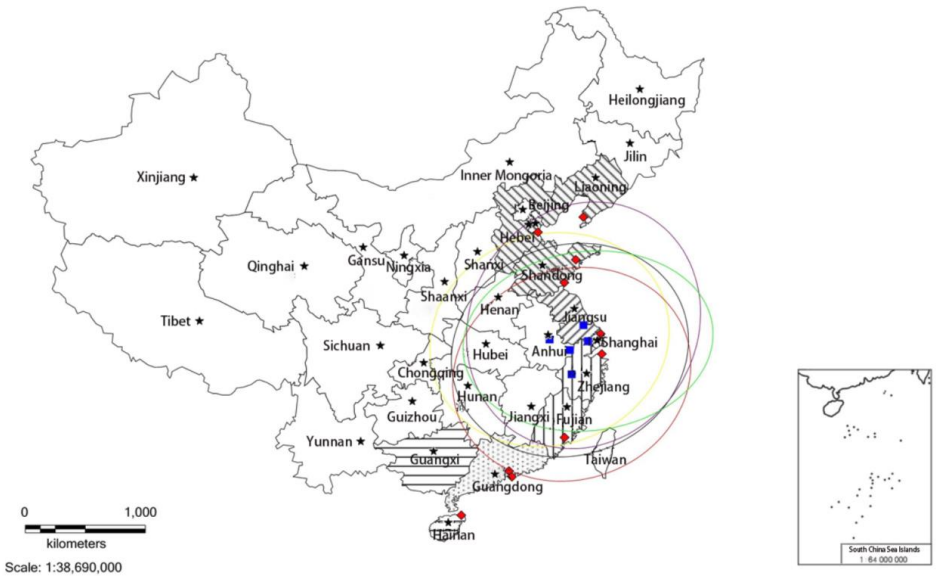

Fig 3. The spatial-temporal pattern and evolution of economic growth

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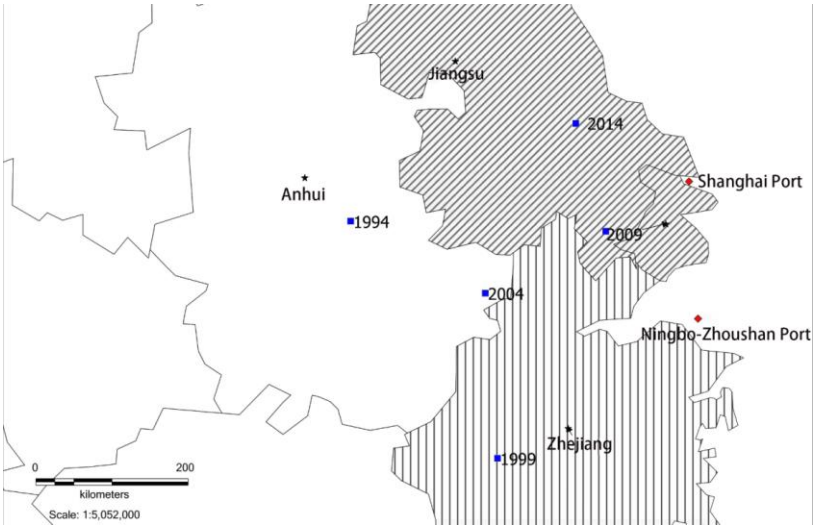

Fig 4. The gravity center shift of economic growth

As we can see from figure 4, several minor fluctuations existed in the gravity center of economy. In the first stage from 1994 to 2004, the coastal gravity center of economy moved from south to north and the overall gravity center of economy shifted towards the east. China's economic development has risen in this period and the international level has improved as China accession into WTO in 2001, the gravity center of economy moved to south slightly with the rise of economic strength in south, after that, the economy shifted to south again due to the booming economy of Shanghai area during 1999 to 2004. The second stage is from 2004 to 2014, the gravity center of coastal economy moved to the northeast gradually. The strategy for large-scale development of western China and the strategy for the rise of central China were proposed to balance the unbalanced economic development among regions, the heavy industries in southeast coast and some handicraft manufacturing started moving inland, some notable changes were shown in the pattern of economic growth and the transfer of some other industries to north-central areas has contributed the economic gravity center of the entire coastal area to shift north slightly.

3.2 The Analysis of Spatial-Temporal Difference based on ESDA

3.2.1 The spatial-temporal difference analysis of global port industry

Taking the data on port industry into the GeoDa software providing univariate spatial auto-correlation analysis, the univariate Global Moran's I of port industry development in China from 1994 to 2014 (TABLE III) was calculated, the P values of Global Moran's I for all time series tested by Z-value method are less than 0.05 in TABLE II, which is statistically significant as the data results all passed the Z-value test. The Global Moran's I of China's port industry changing from positive to negative between 1994 and 2014 demonstrated a polarization characteristics in port industry; Moran's I, which is positive from 1994 to 2002 and concentrates between 0.4 and 0.6 indicated that the strong spatial positive correlation and the orderly arrangement are existed between the five port groups, moreover, the agglomeration state in the regions with higher level of port development illustrated that the rapid development and steady rise of port industry existed under the economic globalization; the Moran's I changing from positive to negative and increasing its absolute value from 2002 to 2014 indicated that there is significant negative correlations and differences

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in space between the development of China's port industries, the differences are expanding at the same time, thus the gradient between the development of port industry in the five port groups is significant.

TABLE III. The Global Moran's I of China's port industry from 1994 to 2014

Variables	Year	Global Moran's I	P-value	Year	Global Moran's I	P-value
Port Industry	1994	0.575	0.0014	2006	-0.701	0.0101
	1996	0.458	0.0032	2009	-0.769	0.0140
	1999	0.678	0.0019	2010	-0.707	0.0220
	2002	0.613	0.0044	2012	-0.694	0.0340
	2004	-0.674	0.0130	2014	-0.652	0.0370

Note: Values are obtained by GeoDA, P-value is the level of significance and considered meaningful when less than 0.05.

3.2.2 The spatial-temporal difference analysis of local port industry

There are three stages existed in China's port industry according to the Global Moran's I. The relation between provinces are portrayed by LISA-Local Moran's I and the spatial-temporal differences between specific areas could be further analyzed by GeoDA/ArcGIS/Echarts. The agglomeration graph (Figure 5) of LISA presenting the pattern evolution and spatial anomaly between and within the five port groups was obtained by calculating the data in 1994, 2004 and 2014. As we can see from figure 5, the trend of H-H type moving from Pearl river delta to Yangtze river delta on three time sections illustrated that the gravity center of port industry is biased towards Yangtze river delta region and the development level of southern port industry is better than the north; the port industry with strong agglomeration in Pearl river delta and Yangtze river delta has influence on surroundings and closer trade relations with ports in neighboring province. Hebei, Guangxi and Hainan are the regions with L-L type while Hainan transformed from L-L to H-L in 2004. As the underdeveloped areas of China's port industry, there are less changes in Hebei and Guangxi due to the low connection with the surrounding areas, the weak agglomeration, the poor geographical advantages and the poor absorption with neighboring provinces and cities.

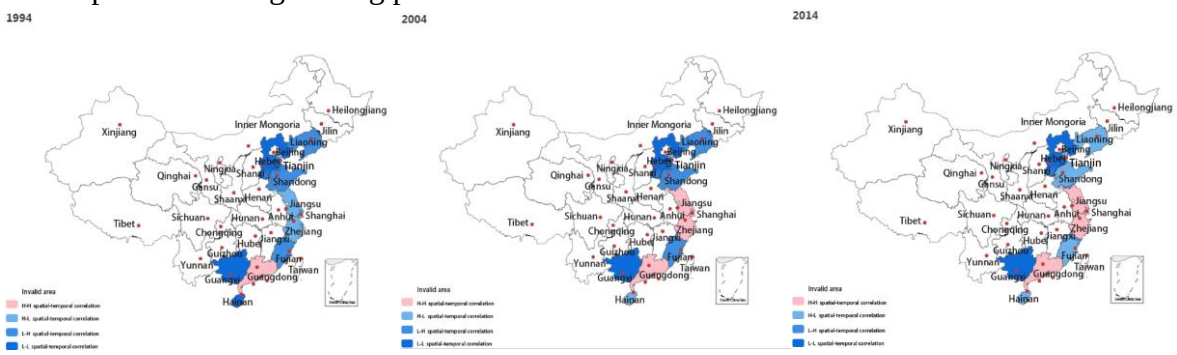

Fig 5. Local Moran's I of China's port industry from1994 to 2014

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3.2.3 The spatial-temporal difference analysis of global coastal economy growth

Taking the data measuring economic development into the formula (2) by GeoDa software and treating the economic scale of coastal provinces and cities in five port groups as the general trend of coastal economic development could obtain the univariate Global Moran's I of economic growth. The positive Global Moran's I of coastal economic growth illustrated in TABLE IV during 1994 and 2014 demonstrated that the economic growth has a significant spatial positive correlation and the regions with higher level of economic development tend to be adjacent, so does the lower ones. In summary, the spatial pattern of coastal economic growth could divide into three stages by analyzing the spatial-temporal difference of economic growth combined with time dimension: the Global Moran's I rising from 0.577 to 0.673 at the first stage from 1994 to 2004 illustrated that the economic development in the study regions is stable, the provinces with similar level of economic development are spatially concentrated, the connection between provinces and cities is stronger, the gap in economic development is narrowing and the economic scale is more rational with the gradual strengthening of national policy support; as for the second stage from 2004 to 2010, the Global Moran's I falling from 0.673 to 0.594 demonstrated that a closer relation emerged between the underdeveloped and faster-growing regions enlarging the economic differences in the study area; in the third stage from 2010 to 2014, the Global Moran's I rose from 0.594 to 0.691, the regions with similar economic development has an agglomeration which narrowed the differences in overall economic development, combing with the historical background in 2010, China's economy has emerged from the financial crisis, the overall economic is recovering, the regional economy is developing and the coastal economic development is stable gradually.

TABLE IV. Global Moran's I of coastal economic growth from 1994 to 2014

Variables	Year	Global Moran's I	P-value	Year	Global Moran's I	P-value
Coastal Economic Growth	1994	0.577	0.0073	2006	0.643	0.0051
	1996	0.599	0.0047	2009	0.608	0.0041
	1999	0.604	0.0162	2010	0.594	0.0327
	2002	0.651	0.0034	2012	0.684	0.0421
	2004	0.673	0.0030	2014	0.691	0.0120

3.2.4 The spatial-temporal difference analysis of local coastal economy growth

The local spatial evolution of economic development, namely the agglomeration state of LISA, is shown in figure 6. From figure 6 we can learn that, the provinces with H-H type are concentrated in Pearl river delta, Yangtze river delta and southern Bohai sea during 1994 to 2014 which is consistent with China's economic development level. As an economic province with strong agglomeration, Guangdong, Jiangsu and Shandong have a strong effect on the surrounding provinces due to the close connection with them; the major regions with L-L type concentrating in Hebei, Guangxi and Hainan illustrated that the economic development level and agglomeration in this region are poor because of the unclear economic construction ideas and unreasonable economic structure, moreover, the impact of national policy and the absorptive effect of neighboring provinces depressed the local economic for long.

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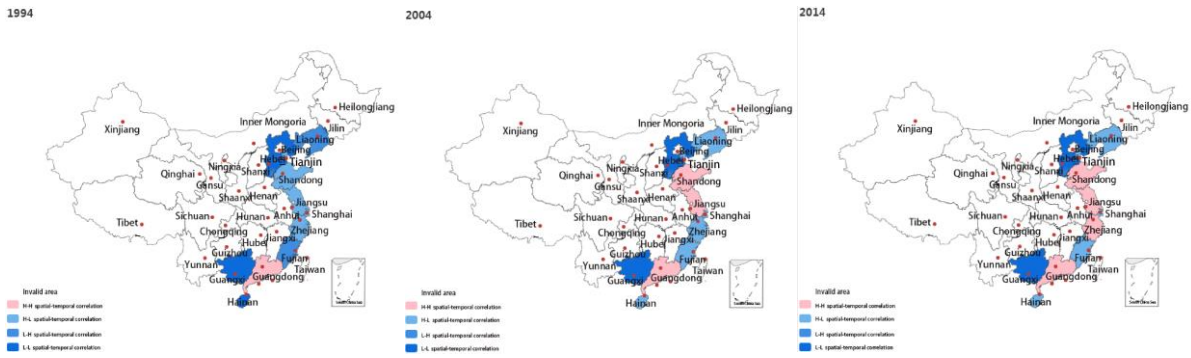

Fig 6. Local Moran's I of coastal economic growth from 1994 to 2014

3.2.5 The spatial-temporal difference analysis of global port industry-coastal economy growth

The data of sub-indicators in port industry-coastal economic growth were taken into GeoDA which has bivariate spatial auto-correlation analysis method to obtain the Global Moran's I (TABLE V) of port industry and-coastal economic growth from 1994 to 2014, all the data result are passed by Z-value test and statistically significant. As we can see from the TABLE IV, the Global Moran's I of port industry and coastal economic growth shows a "positive-negative-positive" pattern with obvious polarization. Specifically, the Moran's I from 1994 to 2014 which is positive and growing continually illustrated that the port industry and coastal economic growth with aggregation in spatial dimension and strong spatial positive correlation are at a high level of development; the Moran's I transforming from positive to negative during 2002 to 2009 and its decreasing absolute values demonstrated that the areas with better port industry and coastal economy show a degree of negative correlation in space and the correlation is diminishing gradually, as the development of port industry influenced by national policies has changed the structure and increased the coupling between port industry and economic growth; during 2009 to 2014, the Moran's I shifted from negative to positive, the overall level in space has higher aggregation and the development level is improving owing to the recovery of global economic and the strategy proposed by China. Taking the coastal economic growth and port industry as univariate, the mutual restraint were existed between the recovering coastal economic growth and rebounding port industry. The economic recovery has driven the development of port industry to some extent as the country responded to the financial crisis positively, the implementation and deviation of policy on the port industry have promoted the growth of coastal economy actively.

TABLE V. Global Moran's I of port industry-coastal economic growth from 1994 to 2014.

Variables	Year	Global Moran's I	P-value	Year	Global Moran's I	P-value
Port Industry-Coastal Economic Growth	1994	0.577	0.0073	2006	0.643	0.0051
	1996	0.599	0.0047	2009	0.608	0.0041
	1999	0.604	0.0162	2010	0.594	0.0327
	2002	0.651	0.0034	2012	0.684	0.0421
	2004	0.673	0.0030	2014	0.691	0.0120

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3.2.6 The spatial-temporal difference analysis of local port industry-coastal economy growth

The global spatial change of bivariate port industry-coastal economic growth in the study area was revealed by Global Moran's I and the internal changes were gotten by Local Moran's I. The results were shown in figure 7 by taking the data of port industry-coastal economic growth into calculation. The trend of H-H type presented two centers on three time sections and expanded to the surroundings around the gravity centers in time series, the gravity centers of port industry-economic development are moving from Pearl river delta to Yangtze river delta region, which is inseparable with the rapid economic growth in Yangtze river delta, moreover, the two regions with obvious agglomeration has a strong driving effect on surroundings; the regions with L-L type are mainly concentrated in Hebei province in Bohai region and southwest coast which are poor in port industry and economic level, less connection with surroundings, and have weak agglomeration. The extent of regions with L-L type is shrinking due to the changes in the global economic environment and China's adjustment on the economic and port policies.

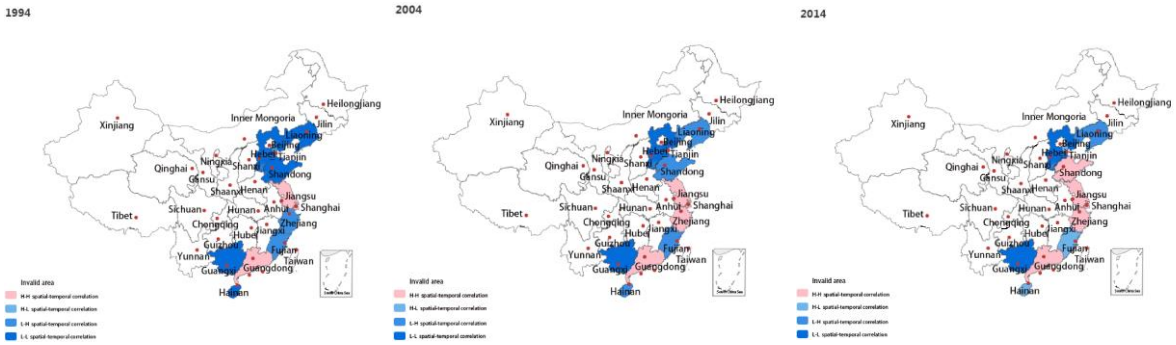

Fig 7. *Local Moran's I* of port industry-economic growth from 1994 to 2014

IV. CONCLUSIONS

(1) The development level of port industry needs to be improved and there is a large gradient between the development level in different regions. Moreover, the entire correlations in the study regions have changed from positive into negative correlation. According to the spatial characteristics of local area, the changing trend of whole regions with H-H type moving from Pearl river delta to Yangtze river delta region at the point of 1994, 2004 and 2014 demonstrated that the development of port industry has been gradually inclined to Yangtze river delta, and the port industries in Pearl river delta and Yangtze river delta are still in the stage with strong agglomeration; the regions with L-L type are concentrated in the southwest coastal port groups and Bohai port groups with minor trends. With the promotion of "One Belt One Road" and the development of the 21st Century Maritime Silk Road, the southwest coastal port groups will be vigorously built in the future which may decrease the space with L-L type; as the development strategy of coordinating Beijing-Tianjin-Hebei has been implemented, the port resources in Bohai port groups such as Hebei and Tianjin will be integrated effectively, and the positive correlation between port groups will also increase significantly. Thus, there will be a huge increase for southwest coast and Bohai port groups.

(2) The economic growth of coastal areas and the global correlation have increased gradually. The significant spatial positive correlation between the economic growth in coastal areas we studied always exists, and the changes of waveform are shown in the development level of economy, as the peaks occurred in 1994~2002 and 2010~2014, respectively, while the troughs occurred in 2002~2010. In the times of 1994, 2004 and 2014, the provinces with H-H type were mainly concentrated in Pearl river delta, Yangtze river delta and the south of Bohai region with less changing trend. The economic development of larger provinces

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such as Guangdong, Jiangsu and Shandong with stronger agglomeration and less influence on surrounding areas are only concentrated in the regions with L-L type such as Hebei, Guangxi and Hainan. The following two aspects have produced this result in the regions with L-L type: one is the unclear thought of economic construction in region and the unreasonable economic structure; the other is the impact the national policies have and the absorption the neighboring provinces have on the regions with L-L type. It is worth noting that the change in speed, structural optimization and kinetic energy conversion in the economic development of regions with L-L type, such as Hebei, Guangxi and Hainan will be promoted by the steady improvement of China's economic stability and the gradual implementation of "One Belt One Road" initiative. For example, the construction of Xiong'an New District will promote the development of real estate, infrastructure, transportation and other related industries to drive the development in this region. Meanwhile, the regions with L-L type should take good use of their good location and resources to strengthen their economic construction, pay attention to the connectivity with neighboring provinces, promote economic relations with inland regions, extend the value chain internally and strengthen the spatial-temporal agglomeration with the surrounding regions.

(3) There is mutual influence and restriction between the development of port industry and coastal economy. The bivariate Global Moran's I shows a clear "positive- negative-positive" change during the study period and the obvious polarization characteristics is appeared in the development of port industry and economic growth of coastal areas. The local correlation characteristic are that: the changing trend of regions with H-H type takes the Pearl river delta and Yangtze river delta region as two centers and expands to the periphery gradually, furthermore, the gravity center of port industry and economic development is transforming from Pearl river delta to Yangtze river delta region, which demonstrates the two regions have an obvious agglomeration and a strong driving effect on surrounding areas; the regions with L-L type are mainly concentrated in Hebei, Bohai region and southwest coastal area with poor port industry, economic level and agglomeration, however, the range of the two large regions with L-L type are shrinking as the recovery of global economic, the emphasis and deviation of national export-oriented economic policy and the gradual increase in imports and exports. Thus, the regions with L-L type in Heibei and southwest coastal provinces should seize the opportunities, strengthen the economic cooperation and develop the land transportation channels and maritime port hubs to provide strong support for the balanced and coordinated development of port industry and economy in this region by the construction of "one belt and one road". Besides that, measures such as reducing shipping construction costs, stimulating the vitality of shipping enterprises to invest in product innovation, transformation and upgrading, could increase the intensity of contribution to the regional economy.

DATA AVAILABILITY

The data used to support the findings of this study are included within the article.

CONFLICTS OF INTEREST

The authors declare that there is no conflict of interest regarding the publication of this paper.

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REFERENCES

[1] L. Zou, G. Zeng, Z.X. Cao, "The Spatial Variation and Spatial-Temporal Evolution of R&D Input in the Yangtze River Delta City Group—Based on ESDA Analysis," Economic Geography, vol. 35, no. 3, pp. 73-79, 2015.
[2] J.H. Pan, and J. Yin, "Analysis on the Urban Development Efficiency of Cities at Prefecture Level or above in China Based on DEA-ESDA," Economic Geography, vol. 34, no. 12, pp. 1438-1444, 2014.
[3] C.Y. Wang and C. Zhang, "Spatial-temporal Pattern of Prefecture-level Innovation Outputs in China: An Investigation Using the ESDA," Scientia Geographica Sinica, vol. 34, no. 12, pp. 1438-1444, 2014.
[4] D. Li, X.M. Ye, and S.L. Wang, "Research on Evolutionary Process and Driving Forces of Spatially Economic Disparity Within Counties Based on Technology of ESDA—GIS," Economic Geography, vol. 32, no. 12, pp. 31-36, 2012.
[5] A.A. Matkan, A.S. Mobaymany, M. Shahri, et al, "Detecting the Spatial-temporal Autocorrelation among Crash Frequencies in Urban Areas," Canadian Journal of Civil Engineering, vol. 40, pp. 195-203, 2013.
[6] S.Astutik, B. Rahayudi, A. Iskandar, et al, "Detection of Spatial-temporal Autocorrelation Using Multivariate Moran and Lisa Method on Dengue Fever(DHF) Incidence, East Java, Indonesia," European Journal of Scientific, vol. 49, no. 2, pp. 279-285, 2011.
[7] J.F. Wang, "Spatial Analysis," Science Press: Beijing, China, pp. 182-188, 2006.
[8] J.M. Wang, M. Deng, T. Cheng, et al, "Analysis and Modeling of Spatial-Temporal Sequences," Science Press: Beijing, China, pp. 28-30, 2012.
[9] K. Zhang, et al, "Spatial Differential Characteristics and Driving Factors of Land Urbanization in Anhui Province," Resources Science, vol. 10, no. 10, pp. 2060-2072, 2018.
[10] G.J. Zhong, Q.B. Zhou and D. Wang, "Advances in Spatial Sampling of Crop Area Considering Spatial Autocorrelation of Survey Units," China Agricultural Informatics, vol. 30, no. 3, pp. 54-62, 2018.
[11] C.M. Zhang, X.L. Zhang, H.Y. Xu, et al, "Evolution of Regional Economic Polarization Structure Based on Spatial Autocorrelation: A Case Study of Jiangsu Province," Scientia Geographica Sinica, no. 4, pp. 557-563, 2018.
[12] K. Li, Y. Liao, Y. Yang, "Empirical Analysis of Spatial Measurement on the Agglomeration and Difference of Regional Economic Growth," Statistics & Decision, no. 11, pp. 141-143 ,2018.
[13] C.C. Feng, Z.R. Zeng, N.N. Cui, "The Economic Disparities and Their Spatio-Temporal Evolution in China since 2000," Geographical Research, vol. 34, no. 2, pp. 234-246, 2015.
[14] P. Du, Z.L. Han, L. Wang, et al, "Spatial pattern evolution of economic growth in counties and districts of Northeastern China," Geographical Research, vol. 34, no. 12, pp. 2309-2319, 2015.
[15] M.H. Zhao and Y.W. Zheng, "Dynamics of Temporal-spatial Pattern of Economic Differences and Driving Forces in Shandong Province in the Past 10 Years," Economic Geography, vol. 33, no.1, pp. 79-85, 2013.
[16] X. Deng, J.M. Li, H.J. Zeng, et al, "Research on Computer Methods of AHP Wight Vector and Its Applications," Mathematics in Practice and Theory, vol. 42, no. 7, pp. 93-100, 2012.
[17] C.Z. Pan, "Factor Analysis of China's Economic Center of Gravity Shifted since the Reform and Opening Up," Master's Thesis, Shanghai Jiaotong University, Shanghai, 2013.
[18] Y.X. Xu and Z.Y. Ren, "Analysis of the Spatial Change of Ecological Footprint in Guanzhong from 1996 to 2005 based on the Model of Regional Gravity," System Sciences and Comprehensive Studies in Agriculture, vol. 25, no. 1, pp. 63-68, 2009.
[19] Y.J. Zhang, H. Jin, and X. Gu, "The Economic Spatial Pattern Evolution Based on ESDA-GER Multiple Variables Effect—The Yangtze River Middle Reaches Urban Agglomerations as an Example," Economic Geography, vol. 35, no. 3, pp. 28-35, 2015.
[20] L. Anselin, and S. Rey, "New Tools for Spatial Data Analysis: Proceedings of the Specialist Meeting; Center for Spatially Integrated Social Science (CSISS)," University of California, Santa Barbara, 2002.

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ISSN: 1520-0191
September-October 2022 Page No. 1135– 1150
Article History: Received: 06 April 2022, Revised: 28 April 2022, Accepted: 04 May 2022, Publication: 31 May 2022

[21] L. Anselin, I. Syabri, and Y. Kho, "GeoDa: an Introduction to Spatial Data Analysis," Geographical Analysis, vol. 38, no. 1, pp. 5-22, 2006.
[22] Anselin, L. "Local Indicators of Spatial Association- Lisa," Geographical Analysis, vol. 27, no. 2, pp. 93-115, 1995.
[23] Y.W. Duan, X.Y. Duan, and C.H. Yang, "Contribution of Processing Exports and Ordinary Exports to China's Regional Economic Growth," Management Review, no. 05, pp. 76-83, 2018.