Hindawi
Mathematical Problems in Engineering
Volume 2020, Article ID 2343860, 12 pages
https://doi.org/10.1155/2020/2343860

Research Article

Study of the Influencing Factors on Development of Ports in Guangdong, Hong Kong, and Macao from the Perspective of Spatial Economics

Lianhua Liu and Hai Ping

Department of Business Administration, Huashang College Guangdong University of Finance & Economics, Guangzhou 510000, China

Correspondence should be addressed to Lianhua Liu; lianhua16@126.com

Received 16 August 2020; Revised 14 October 2020; Accepted 7 November 2020; Published 27 November 2020

Academic Editor: Wen Tsao Pan

Under the background of "one belt, one road initiative" and the "Outline Development Plan for the Guangdong-Hong Kong-Macao Greater Bay Area," Guangdong, Hong Kong, and Macao port group development is facing new opportunities. The port group has a large throughput, covering the hinterland with dense population and high economic density, excellent transportation infrastructure, and broad consumption market. However, the port group internal competition is fierce, and the development level is different in space. Based on this, this paper uses the HHI index and spatial economics as research method and aims to study the spatial evolution characteristics and influencing factors of Guangdong-Hong Kong-Macao port group. Firstly, the HHI index is used to describe the aggregation status. Secondly, the development level index according to port throughput and container throughput is constructed. The spatial development and evolution process of the port group of Guangdong, Hong Kong, and Macao is analyzed by combining with spatial econometrics and economic geography. In summary, the influencing factor "diamond model" is constructed and took empirical research to verify its rationality and scientificity. The empirical results show a strong spatial correlation between the development of the Guangdong, Hong Kong, and Macao port group. The government intervention and the development of port industry have a negative correlation, and this impact will be weakened over time. There is a negative relationship between the level of marketization and the development of the port industry. There is a multiple and complex relationship between the port auxiliary industry and the development of the port industry, and it shows the short-term influence is smaller than the long-term impact. The level of port transportation infrastructure, the port industry competition, and the economic openness have significant and positive effects on the development of the port group.

1. Introduction

Under the background of "one belt, one road initiative" and the "Outline Development Plan for the Guangdong-Hong Kong-Macao Greater Bay Area," Guangdong, Hong Kong, and Macao port group development is facing new opportunities. The port group of Guangdong, Hong Kong, and Macao is an important distribution point for the import and export of goods in the South Asia international logistics corridor of Sichuan, Guizhou, Guangxi, and Guangdong and also an important water node connecting Guangdong, Jiangsu, Anhui, and Jiangxi provinces. The port group of Guangdong, Hong Kong, and Macao has a large throughput. There are three top ten ports in the world in terms of container throughput in 2018, including the Hong Kong port, Shenzhen port, and Guangzhou port. The port group of Guangdong, Hong Kong, and Macao covers the hinterland with high population and economic density and has excellent transportation infrastructure and broad consumption market. However, there are great differences in the internal development level in space, and the competition within the port group is fierce.

Since the documentation of "development planning outline of the Guangdong-Hong Kong-Macao Bay Area" in

2019, this paper studies the spatial and temporal evolution characteristics and influencing factors of the spatial pattern of the Guangdong-Hong Kong-Macao port group, explores the effective measures to alleviate the spatial development differences of the Guangdong-Hong Kong-Macao port group, studies the influencing factors of its development spatial evolution, and puts forward effective development suggestions, which is conducive to promoting the coordinated development of ports in the region and improving the Guangdong-Hong Kong-Macao Greater Bay Area development level.

2. Literature Review

2.1. Theory of Port Development Stage. The formation and development of ports is the result of the development of regional economy and world economy. Based on the theory of spatial economics, this paper discusses the spatial distribution of the port industry, which provides an action theory perspective for comprehensively and scientifically explaining the development of the port industry. Scholars have studied the spatial distribution, network structure, spatial evolution mechanism, and driving factors of ports and put forward a six-stage model of port spatial evolution which covers six stages: isolated port development; route penetration stage and port concentration stage; branch line interconnection stage; hinterland traffic sustainable development stage; hinterland node concentration stage; national trunk line formation stage [1]. The port system has to go through five stages: preparation period, adoption period, concentration period, hub center period, and marginal challenge period. In the first four stages, the basic direction of spatial structure evolution of the port system is centralization [2].

2.2. Research Theory of Port Development Spatial Pattern. Spatial economics theory, Gini coefficient, Herfindahl-Hirschman index, and Theil Index are widely used in the study of spatial characteristics and structural evolution of ports [3–8]. For example, the Gini coefficient and HerfindahlHirschman index are used to study the spatial structure and competition pattern of China's container port system [3]. The Theil Index is used to study the spatial differences and evolution of port logistics economy in the Yangtze River Delta. Traffic location, related industries, and development policies are the main influencing factors of spatial differences and evolution [4]. The spatial econometric model is introduced to study the spatial spillover and threshold effect of port efficiency in the Yangtze River Delta region [5]. From the overall and local perspectives, the distribution degree and spatial structure evolution trend of the main cargo types of the port group in the Yangtze River Delta are analyzed [6]. The spatial distribution characteristics of the ports along the maritime Silk Road by are also analyzed using global spatial autocorrelation and local spatial autocorrelation [7]. Based on HHI index and spatial autocorrelation theory, the spatial structure and evolution of China's coastal container port system are studied [8].

The influencing factors of port development are few of the important contents of port development research. Relevant research shows that the main influencing factors of port development include the economic development degree of the port hinterland, port location, logistics infrastructure, aggregation of enterprises in the logistics industry, and external policy environment. The spatial linkage of port and hinterland is mainly affected by the adsorption function of port, the "water gathering" function of traffic network, the sea driving function of hinterland, and the market and policy guidance function [9]. Port logistics and regional economy coordinated the development relevance and spatial differences [10]. The better the economic development, the higher the development degree of logistics, port input-output synergies, and industrial ecology synergies [11–13]. Different regional economic development degrees form the port spatial economic pattern [14]. Logistics infrastructure affects the formation and cost of logistics network [15, 16], forming different spatial distribution of ports, and the aggregation degree of logistics enterprises is one of the main factors affecting the development of ports [17]. The main factors of the spatial evolution of port hinterland include geographical location, comprehensive scale of port city, foreign trade environment, port infrastructure, and efficiency [18, 19].

To sum up, the current research on the spatial characteristics and agglomeration of port industry mainly focuses on the quantitative analysis of agglomeration phenomenon. According to the situation of spatial development characteristics of ports in some river basins, the aggregation degree and reasons are analyzed and discussed. In terms of research methods, there is a lack of in-depth quantitative research. The existing research does not take the spatial correlation into the empirical study of port industry agglomeration. The agglomeration of the port industry is a geographical spatial phenomenon in the process of regional economic evolution. The spatial spillover effect will be ignored if the traditional OLS regression method is used to explain the agglomeration difference of the port industry. Based on the study of the spatial correlation of port clusters in Guangdong, Hong Kong, and Macao, this paper establishes an analysis framework of influencing factors of the port industry agglomeration from the perspective of regional evolution. Based on the port panel data from 2007 to 2017, this paper analyzes the impact on the agglomeration of port clusters in Guangdong, Hong Kong, and Macao.

3. Research Objects and Methods

3.1. Research Objects and Data Sources. Based on the port statistical yearbook, this paper breaks through the limitation of administrative region, and based on the concept of port group, this paper takes the port group of Guangdong Province, Hong Kong, and Macao as the research object. Based on the theory of port group, the Guangdong, Hong Kong, and Macao port group is divided into four groups, named the Pearl River Delta port group, including Guangzhou port, Shenzhen port, Hong Kong port, Macao port, Dongguan port, Huizhou Port, Jiangmen port, Zhongshan port, and Zhaoqing port. The Eastern

Guangdong port group includes Shantou port, Chaozhou port, Jieyang port, and Shanwei port. The Western Guangdong port group includes Zhanjiang port, Maoming port, Yangjiang port, and Yunfu port. The Inland river ports include Qingyuan port, Shaoguan port, Heyuan port, and Meizhou port. The relevant data from 2008 to 2017 are obtained from China port yearbook and statistical yearbook by city as the basic data for the study. The development level of ports in Guangdong, Hong Kong, and Macao is reviewed, and the spatial structure and evolution mechanism of the development and the influencing factors of the spatial evolution of development are studied.

3.2. Research Methods

(1) *HerfindahlHirschman index.* There are many methods to measure the industrial agglomeration, such as spatial Gini coefficient, location entropy, HerfindahlHirschman index, and Theil Index. Taking into account the characteristics of the port industry, this paper selects the HHI as the measurement of the regional concentration of ports in Guangdong, Hong Kong, and Macao. HHI is an important index to measure the specialization of industrial market, which can fully compare the agglomeration degree of port industry in different regions. The formula as follows:

$$\mathrm{HHI} = \sum_{i=1}^{n} \frac{C_i}{C}, \tag{1}$$

where "n" is the number of ports, "C_i" is the cargo throughput of port i, "C" is the total cargo throughput of the port system, and "HHI" is the HerfindahlHirschman index of the port system ($-1 < \mathrm{HHI} < 1$). The higher the HHI value, the more unbalanced the cargo throughput in the port system is, and the spatial structure of the port system tends to be centralized. On the contrary, it indicates that the port industry lacks agglomeration and the spatial structure of the port system tends to be decentralized.

(2) *Spatial Correlation Measurement Method* Spatial correlation refers to the spatial interdependence, mutual restriction, and interaction between things and phenomena in different regions, that is, the dependence between observation value and location.

The Moran index is used to measure the spatial correlation, which reflects the similarity of attribute values of spatial adjacent or spatial adjacent regional decision-making units and measures the agglomeration effect of regional decision-making units. Its calculation formula is as follows:

$$I = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n}\left(x_i - \overline{x}\right)}{S^2 \sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}}, \tag{2}$$

where $S^2 = \left(\sum_{i=1}^{n}\left(x_i - \overline{x}\right)/n\right)$ is the sample variance, W_{ij} is the (i, j) of the spatial weight matrix, which is used to measure the distance between port i and port j, and $\sum_{i=1}^{n}\sum_{j=0}^{n} W_{ij}$ is the sum of the spatial weights among all ports.

The value range of the Moran index is between $[-1, 1]$. If the economic activity of different regions shows spatial positive correlation, its value will be larger; otherwise, it will be smaller.

According to the calculation results of the Moran index, the standard normal distribution method is used to test whether there is spatial correlation among regions. Its calculation formula is as follows:

$$Z(I) = \frac{\mathrm{Moran}'s - E(I)}{\sqrt{\mathrm{VAR}(I)}}. \tag{3}$$

According to the value of "Z", we can judge whether there is spatial autocorrelation between Guangdong, Hong Kong, and Macao ports. When $Z \geq 0$ and significant, it indicates that there is a positive spatial correlation between the ports of Guangdong, Hong Kong, and Macao, which is characterized by spatial homogeneity and positive spatial spillover effect. When $Z \leq 0$ and significant, it indicates that there is a spatial negative correlation between ports in Guangdong, Hong Kong, and Macao, which shows spatial heterogeneity. When $Z = 0$, the ports of Guangdong, Hong Kong, and Macao present a random distribution.

(3) *Spatial Lag Model* (SLM). It is given as follows:

$$Y = \rho WY + X\beta + \varepsilon, \tag{4}$$

$$\begin{aligned} Y &= X\beta + \varepsilon, \\ \varepsilon &= \lambda W\varepsilon + \mu, \end{aligned} \tag{5}$$

where "Y" is the dependent variable, "X" is the matrix of exogenous explanatory variables, "ρ" is the spatial autoregressive coefficient, which reflects the influence degree and direction of the adjacent observed values on the local observation values, "WY" is the spatial lag dependent variable, and "ε" is the random error term.

(4) *Spatial Error Model (SEM).* it is given as follows:

where "ε" is the random error term, "λ" is the spatial error coefficient of the cross section dependent variable vector of $N + 1$, and "μ" is the random error vector obeying normal distribution. The spatial error model mainly investigates the degree of spatial dependence existing in the error disturbance term, and the degree to which the random impact of the corresponding variables in the adjacent area affects the local observation value.

(5) *Selection of SLM or SEM Models* through the Moran index test, lmerr, and lmlag and their robust forms r-lmerr and r-lmlag, we can judge whether there is a spatial correlation of the port industry agglomeration in Guangdong, Hong Kong, and Macao. On the

basis of scholars' research, the following rules are used as the basis of SLM and SEM model selection. Lmlag is more significant than lmerr, r-lmlag is significant, r-lmerr is not significant, and so the SLM model is suitable. lmerr is more significant than lmlag, r-lmerr is significant, and r-lmlag is not significant, so SEM model is suitable.

4. Change of the Concentration Degree of Ports in Guangdong, Hong Kong, and Macao

Based on the port cargo throughput and the formula (1), the HerfindahlHirschman index of the Guangdong, Hong Kong, and Macao port group is shown in Table 1. The HHI index value of Guangdong, Hong Kong, and Macao ports decreased from 0.1719 in 2008 to 0.1269 in 2017. This change trend shows that the development of the port group system in Guangdong, Hong Kong, and Macao is increasingly dispersed, and there is spatial spillover effect.

As shown in Figure 1, the HHI values of the four port systems in Guangdong, Hong Kong, and Macao have different spatial distribution trends. The overall HHI value of the Guangdong, Hong Kong, and Macao port group is lower than the internal major groups, which indicates that the concentration degree of spatial distribution tends to be decentralized, but the local area tends to be concentrated. The HHI index of eastern Guangdong port group has a very obvious downward trend, while that of Pearl River Delta port group decreases slowly. The HHI index of the western Guangdong port group fluctuates and shows an upward trend. The HHI index of inland river port group in mountainous area rises rapidly.

Combined with the market share, the Guangzhou port, Shenzhen port and Hong Kong port accounts for a high proportion of the market share in the whole Guangdong-Hong Kong-Macao port group. However, the total market share of the three ports has decreased year by year. The market share of the three ports was 67.14% in 2008 and 49.1% in 2017. The market share of Guangzhou port's cargo throughput was 29.54% in 2008 and decreased to 26.4% in 2017. The market share of Shenzhen port's cargo throughput was 16.9% in 2008 and decreased to 10% in 2017. Hong Kong's 20.7% fell to 12.7% from 2008 to 2017. In the port group of Guangdong, Hong Kong, and Macao, the source of goods gradually diverted from the three major ports to the surrounding ports, which led to the development of Zhuhai, Zhaoqing, Huizhou, Dongguan, and other ports, resulting in spatial spillover effect.

The HHI index of the Pearl River Delta port group decreased year by year from 0.2242 in 2008 to 0.1823 in 2017, which shows that under the background of the construction of Guangdong-Hong Kong-Macao Greater Bay Area, the division and cooperation of ports in the bay area are promoted, and the phenomenon of space spillover exists.

The HHI index of the port group in western Guangdong is relatively stable, which fluctuates between 0.5814 and 0.6498. The reason is that the market share of Zhanjiang port remains stable, ranging from 74.8% to 79.2%, which forms the spatial distribution of the port group in western Guangdong.

Among the port group in eastern Guangdong, the market share of Shantou Port decreased year by year from 73.9% in 2008 to 47.6% in 2017. The HHI index of the eastern Guangdong port group also reflects the spatial change characteristics of this cargo source from concentration to dispersion. The HHI index decreases from 0.4937 to 0.3375, which reflects the spatial trend of the eastern Guangdong port group system tends to be decentralized, and the competition among ports is intensified.

The HHI index of inland river ports in mountainous areas increased from 0.4536 to 0.9225, reflecting the spatial characteristics of highly concentrated distribution of inland river ports in mountainous areas. The reason is the rapid development of the Qingyuan port. The Qingyuan port is an important port in the Beijiang River Basin. It has rich natural resources and faces the vast market of the Pearl River Delta. Besides, it is close to Guangzhou and has certain geographical advantages. The Qingyuan port market share of inland river port group increased from 70.3% in 2008 to 96% in 2017, forming the phenomenon of high spatial agglomeration of the inland river port group in inland area.

5. Spatial Evolution Characteristics of Port Group in Guangdong, Hong Kong, and Macao

5.1. Development Level Index of Port Group in Guangdong, Hong Kong, and Macao. In order to further explore the spatial characteristics and evolution characteristics of the port development in Guangdong, Hong Kong, and Macao, this paper constructs the port development capacity index system to study the spatial distribution of the port group development in Guangdong, Hong Kong, and Macao. The agglomeration level index of port development is a comprehensive study on the development of port logistics. From the perspective of comprehensiveness and availability, based on the two indicators which are port container throughput X_1 (teu) and port cargo throughput of X_2 (ton) as the port development capacity index of ports in Guangdong, Hong Kong, and Macao. The port development capacity index is constructed to reflect the development capacity of Guangdong, Hong Kong, and Macao ports. The mean-square difference method is used to determine the port development capacity index of Guangdong, Hong Kong, and Macao. Firstly, normalization is used to normalize the original data of the indicators, and the weights of the two indicators are obtained by means of mean-square deviation normalization, indicating the dispersion degree of the data samples under a certain index. Finally, the port development level index of Guangdong, Hong Kong, and Macao is obtained by weighted sum, as shown in Table 2.

5.2. Evolution of Spatial Pattern of Port Clusters in Guangdong, Hong Kong, and Macao. In order to study the evolution process of the spatial pattern of ports in Guangdong, Hong Kong, and Macao, this paper selects the port development level indexes of 2008, 2012, and 2017 for spatial processing.

Table 1: HHI values of the Guangdong, Hong Kong, and Macao port group and subport group.

Port system	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Total ports	0.1719	0.1672	0.1523	0.1441	0.1374	0.1381	0.1267	0.1263	0.1265	0.1269
Pearl River Delta port group	0.2242	0.2240	0.2046	0.1960	0.1900	0.1955	0.1787	0.1815	0.1815	0.1823
Eestern Guangdong port group	0.6498	0.6474	0.6127	0.6131	0.6001	0.5814	0.6006	0.6019	0.6329	0.6342
Eastern Guangdong port group	0.4937	0.4851	0.4167	0.3947	0.4000	0.3898	0.3830	0.3676	0.3480	0.3375
Inland Guangdong river port	0.4536	0.5810	0.6344	0.6338	0.5596	0.6639	0.8289	0.8555	0.8752	0.9225

Source: according to the calculation criteria.

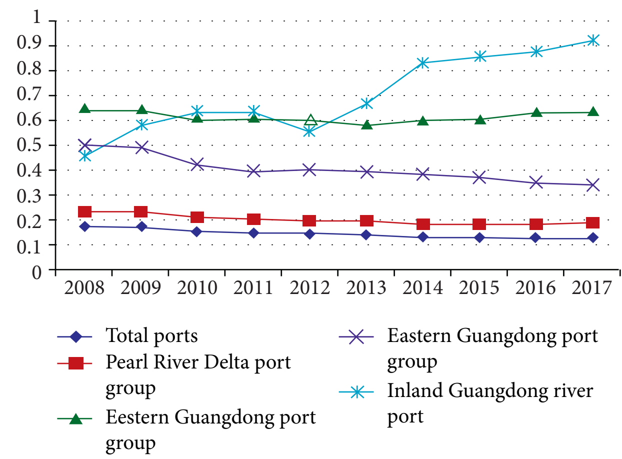

Figure 1: HHI value change chart.

Table 2: Guangdong-Hong Kong-Macao port development level index (2008–2017).

Port	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Guangzhou	0.2263	0.2381	0.2224	0.2120	0.2310	0.2360	0.2329	0.2449	0.2511	0.2597
Shenzhen	0.2614	0.2496	0.2520	0.2056	0.2490	0.2472	0.2378	0.2377	0.2281	0.2026
Zhuhai	0.0193	0.0201	0.0222	0.0242	0.0250	0.0274	0.0307	0.0330	0.0354	0.0417
Zhaoqin	0.0063	0.0072	0.0081	0.0106	0.0124	0.0125	0.0118	0.0115	0.0117	0.0191
Foshan	0.0418	0.0465	0.0407	0.0333	0.0350	0.0353	0.0350	0.0364	0.0377	0.0437
Huizhou	0.0109	0.0144	0.0148	0.0162	0.0153	0.0195	0.0146	0.0161	0.0167	0.0125
Dongguang	0.0123	0.0153	0.0194	0.1314	0.0339	0.0418	0.0488	0.0531	0.0563	0.0484
Zhongshan	0.0192	0.0118	0.0235	0.0229	0.0226	0.0266	0.0266	0.0254	0.0235	0.0254
Jianmen	0.0198	0.0194	0.0193	0.0213	0.0216	0.0230	0.0237	0.0237	0.0245	0.0243
Qingyuan	0.0015	0.0016	0.0020	0.0021	0.0020	0.0024	0.0054	0.0068	0.0070	0.0078
Maoming	0.0064	0.0074	0.0065	0.0065	0.0063	0.0062	0.0062	0.0062	0.0057	0.0053
Zhanjiang	0.0367	0.0410	0.0391	0.0435	0.0433	0.0444	0.0447	0.0485	0.0545	0.0582
Shantou	0.0157	0.0159	0.0174	0.0177	0.0213	0.0221	0.0207	0.0197	0.0192	0.0186
Chaozhou	0.0012	0.0013	0.0020	0.0025	0.0022	0.0024	0.0023	0.0023	0.0022	0.0023
Jieyang	0.0020	0.0024	0.0034	0.0041	0.0037	0.0057	0.0054	0.0056	0.0057	0.0056
Shanwei	0.0015	0.0017	0.0017	0.0016	0.0018	0.0016	0.0014	0.0018	0.0023	0.0021
Yuanfu	0.0025	0.0025	0.0032	0.0036	0.0039	0.0046	0.0047	0.0050	0.0055	0.0061
Shaoguan	0.0002	0.0001	0.0001	0.0001	0.0002	0.0001	0.0001	0.0001	0.0001	0.0001
Heyuan	0.0000	0.0000	0.0000	0.0000	0.0000	0.0006	0.0006	0.0005	0.0000	0.0000
Meizhou	0.0008	0.0005	0.0004	0.0004	0.0003	0.0003	0.0003	0.0002	0.0002	0.0002
Yangjiang	0.0008	0.0011	0.0021	0.0030	0.0037	0.0046	0.0035	0.0042	0.0042	0.0051
Mocao	0.0021	0.0015	0.0013	0.0007	0.0010	0.0010	0.0011	0.0012	0.0011	0.0010
Hong kong	0.3049	0.2942	0.2744	0.2318	0.2599	0.2483	0.2384	0.2126	0.2037	0.2064

According to the data processing principle of the natural breakpoint method, the same type of ports is divided into two groups.

According to the principle of the biggest difference among different types of ports, the classification should be based on the classification criteria of less than 0.012, 0.012–0.034, and 0.034–0.231 and greater than 0.231. It is divided into four levels: low-level development, medium-level development, medium- and high-level development, and high-level development. The port group of Guangdong, Hong Kong, and Macao in 2008, 2012, and 2017 shows obvious spatial development differences. The spatial pattern of ports in Guangdong, Hong Kong, and Macao is characterized by polarization. As shown in Table 3, the high-level ports covered Shenzhen and Hong Kong in 2008 and 2012, and the Guangzhou port became the only high-level port in 2017. According to the data of three time sections in 2008, 2012, and 2017, the number of ports with low development level was 14, 11, and 11, respectively; the number of ports with medium development level was 4, 6, and 5, respectively; there are 3 ports, 4 ports, and 6 ports with medium and high development levels.

In 2008 and 2012, Guangzhou port was a medium and high development level port, and in 2017, it was upgraded from medium high development level to the only high development level port. In 2012, Dongguan port directly jumped from low development level to medium and high development level and maintained a good situation of medium and high development level in 2017. Zhuhai port was a port of general development level in 2012 and rose to medium and high levels in 2017. Under the fierce port competition, Shenzhen port and Hong Kong port were downgraded from high development level to medium high development level in 2017.

The development level of ports in Guangdong, Hong Kong, and Macao is highly concentrated. The development level of ports in Guangdong, Hong Kong, and Macao is mainly distributed around the Pearl River estuary waters and evenly distributed along the Xijiang River, Beijiang River, and Dongjiang River. The Pearl River estuary is the center, and Hong Kong, Shenzhen, and Guangzhou are the port centers of the whole Guangdong, Hong Kong, and Macao bay area. The eastern and western wings of Guangdong present regional centralization, forming the port group in western Guangdong with Zhanjiang as the center and Shantou as the center in eastern Guangdong.

5.3. Spatial Autocorrelation Analysis of Port Group Development in Guangdong, Hong Kong, and Macao. Spatial correlation of the port group development in Guangdong, Hong Kong, and Macao. This paper uses the development capacity index of Guangdong, Hong Kong, and Macao ports from 2008 to 2017 to calculate Moran's I index by using Geoda software, in which the spatial weight matrix adopts to the adjacent space matrix. Basis on the formula (2) and formula (3), the calculation results are shown in Table 4.

According to Table 4, Moran's I is positive and Z values of normal statistics pass the significance level test of 5%. It shows that the port development in the Guangdong, Hong Kong, and Macao port group has obvious spatial positive correlation, that is, there is a tendency of spatial dependence and homogenization. This shows that the development of ports in Guangdong, Hong Kong, and Macao ports is not randomly distributed in space and has certain similarity. Specifically, ports with high development level tend to cluster, while those with low development level tend to gather, which has obvious spatial spillover effect. Ports with high development level tend to be close to ports with high development level, and ports with low development level are close to ports with low development level. From 2008 to 2017, overall, Moran's I value showed an increasing trend, and the Z value of normal statistics showed an increasing trend, which was greater than 1.96 from 2013 to 2017. The research results show that the development of ports in Guangdong, Hong Kong, and Macao has obvious spatial autocorrelation characteristics. The Lisa clustering maps of 2008, 2012, and 2017 are shown in Figure 2.

According to the Lisa cluster diagram, this paper classifies the spatial relationship of ports in Guangdong, Hong Kong, and Macao, as shown in Table 5. High-high (HH) means that the high growth region of the port industry is surrounded by other regions with high growth; low-low (LL) means that the low growth area of the port industry is surrounded by other regions with low growth; low-high (LH) means that the low growth area of the logistics industry is surrounded by other regions with high growth; and high-low (HL) means that the high growth area of the port industry is surrounded by other regions with low growth. Not significant means there is no obvious correlation between the development space of ports. In 2008 and 2012, the aggregation of ports in Guangdong, Hong Kong, and Macao was consistent. The port areas with no significant correlation in spatial spillover included 14 ports including the western Guangdong port group and mountainous port group. Ports with certain spatial development correlation and spatial spillover effect were mainly concentrated in Pearl River Delta port group and eastern Guangdong port group.

The 2017 Lisa cluster map shows the port space spillover effect in the Pearl River Delta region is obvious. The reason is, under the policy guidance of the development of Guangdong, Hong Kong, and Macao Bay area, the coordinated development advantages of the Pearl River Delta port group are reflected, which promotes the cooperation and division of labor of the Pearl River Delta port group and forms a positive correlation relationship between the spatial development of Guangzhou, Shenzhen, Hong Kong, Foshan, and Dongguan. That is a regional synergy effect. Huizhou, Zhongshan, and Zhuhai have formed the relationship of regional competition, heterogeneity of regional development, and negative correlation of low and high spatial development. The results show that there is a certain spatial correlation in the development of Guangdong, Hong Kong, and Macao port group. Therefore, it is necessary to incorporate the spatial correlation into the influencing factors of port industry development and explore the development characteristics of Guangdong, Hong Kong, and Macao port group from the perspective of spatial economics.

6. Influencing Factor Model of the Port Development Spatial Pattern

6.1. Theoretical Framework of Influencing Factors on Spatial Pattern of Port Cluster Development in Guangdong, Hong Kong, and Macao. At present, the research on the spatial pattern of the development of ports in Guangdong, Hong Kong, and Macao has not formed a complete theoretical analysis framework. Combining with the theory of spatial

Table 3: Classification of development level of the port group of Guangdong, Hong Kong, and Macao in different periods.

Year	High level	Medium and high levels	Medium level	Low level
2008	Shenzhen, Hong Kong	Guangzhou, Foshan, Zhanjiang	Jiangmen, Zhongshan, Zhuhai, Macao, Shantou	Shaoguan, Qingyuan, Zhaoqing, Yunfu, Maoming, Yangjiang, Heyuan, Meizhou, Chaozhou, Jieyang, Shanwei, Huizhou, Dongguan
2012	Shenzhen, Hong Kong	Guangzhou, Foshan, Zhanjiang, Dongguan	Zhaoqing, Jiangmen, Huizhou, Zhongshan, Zhuhai, Macao, Shantou	Shaoguan, Qingyuan, Yunfu, Maoming, Yangjiang, Heyuan, Meizhou, Chaozhou, Jieyang, Shanwei
2017	Guangzhou	Foshan, Zhanjiang, Dongguan, Zhuhai, Shenzhen, Hong Kong	Zhaoqing, Jiangmen, Huizhou, Zhongshan, Macao, Shantou	Shaoguan, Qingyuan, Yunfu, Maoming, Yangjiang, Heyuan, Meizhou, Chaozhou, Jieyang, Shanwei

Table 4: Moran index and Z value of port group development in Guangdong, Hong Kong, and Macao.

Year	Moran's I	Sd	Z value	P value
2008	0.1798	0.1254	1.7874	0.0481
2009	0.181	0.1266	1.7781	0.0487
2010	0.1964	0.1266	1.9009	0.0452
2011	0.2872	0.1325	2.4993	0.0274
2012	0.2055	0.1277	1.9561	0.0434
2013	0.221	0.1282	2.0686	0.0417
2014	0.228	0.1286	2.1158	0.0406
2015	0.2322	0.1284	2.1522	0.0398
2016	0.2321	0.1283	2.1519	0.0397
2017	0.2232	0.1277	2.0914	0.04

Source: according to the calculation criteria.

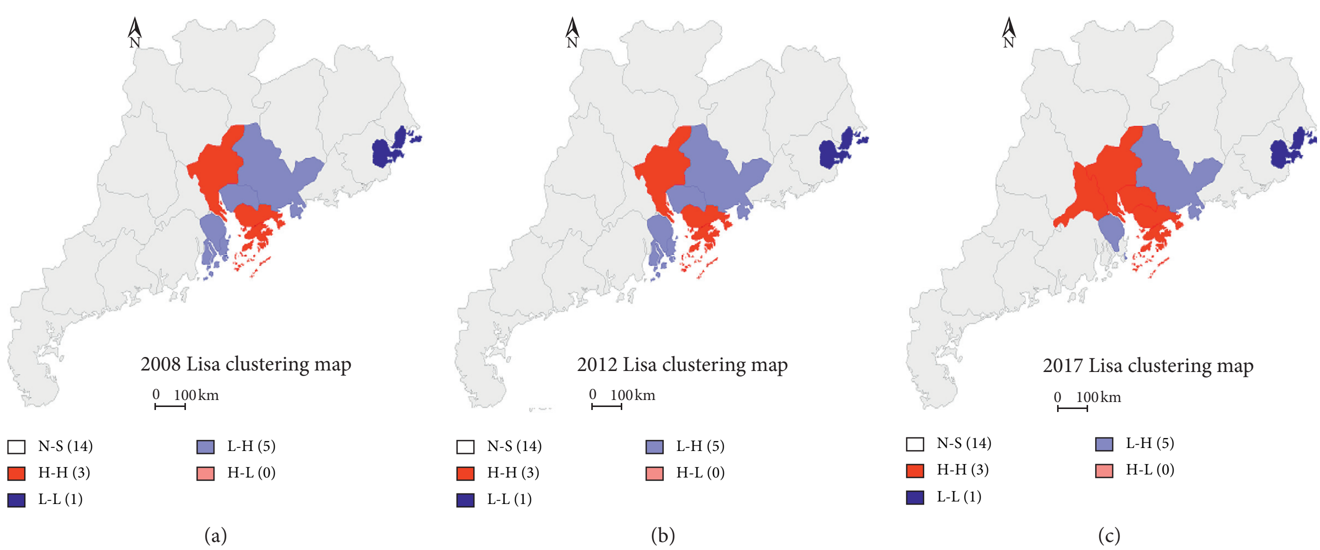

Figure 2: Lisa clustering map of the spatial pattern of the development of the Guangdong-Hong Kong-Macao port group.

Table 5: Spatial correlation models of development of ports in Guangdong, Hong Kong, and Macao in different periods.

Year	HH	LL	LH	HL	Not significant
2008	Guangzhou,	Shantou	Huizhou, Dongguan,	None	Shaoguan, Qingyuan, Zhaoqing, Yunfu, Maoming, Yangjiang,
2012	Shenzhen, Hong Kong		Zhongshan, Zhuhai, Macao		Jiangmen, Heyuan, Meizhou, Chaozhou, Jieyang, Shanwei, Zhanjiang, Foshan
2017	Guangzhou, Shenzhen, Hong Kong, Foshan, Dongguan	Shantou	Huizhou, Zhongshan Zhuhai	None	Shaoguan, Qingyuan, Zhaoqing, Yunfu, Maoming, Yangjiang, Jiangmen, Heyuan, Meizhou, Chaozhou, Jieyang, Shanwei, Zhanjiang, Macao

economics and the analysis results of agglomeration characteristics, the affecting factors of the spatial agglomeration in the Guangdong, Hong Kong, and Macao port group are studied. Referring to Michael Porter's diamond model, the theoretical framework model of influencing factors of the spatial pattern of port clusters in Guangdong, Hong Kong, and Macao is constructed, which is shown in Figure 3. This model covers the port production factors like transportation infrastructure; port market development level such as social retail, GDP, and secondary industry development; the port auxiliary industry which includes the development of related industries and upstream industries; the port industry formats include the strategy, structure, and horizontal competition of port enterprises; and the port industry development opportunities and the business environment.

(1) Port transportation infrastructure level: the level of port traffic infrastructure is the basic element and resource condition of port development. It includes the physical and geographical environment, the infrastructure and equipment, and the collection and distribution system of the port. Convenient and good port production infrastructure is conducive to the cluster development of ports. The level of port transportation infrastructure can promote the efficiency of port resource allocation and improve the efficiency of regional scale economy.

Hypothesis 1: there is a positive correlation between port infrastructure level and port industry agglomeration.

(2) Development level of port market: as a logistics transportation node, the development level of the port market affects the development of the port industry. The level of port market development is mainly affected by the level of economic development and the degree of socialization of transportation services. The development and distribution of hinterland economy and manufacturing industry affect the market distribution and demand levels.

Hypothesis 2: there is a positive correlation between the level of market development and the agglomeration of the port industry.

(3) Port industry structure: the structure of the port industry includes the development cycle, development strategy, and competition situation.

Hypothesis 3: there is a positive correlation between the competitive situation of port industry and the agglomeration of the port industry.

(4) Auxiliary industry: to a certain extent, supporting industries of port industry affects the development level and agglomeration degree of ports. It mainly includes the development of related industries of port logistics, such as the cargo freight market and transportation industry. The higher the development degree of the transportation industry, the more conducive it is to the agglomeration of the port industry.

Hypothesis 4: there is a positive correlation between the development degree of port supporting industries and the agglomeration of the port industry.

(5) The opening environment of the port: the opening environment of the port refers to foreign trade development situation. The higher the degree of development of foreign trade, the stronger the demand of foreign trade logistics, and the more conducive it is to the development of the port industry, the more stable it is to the effect of port industry agglomeration.

Hypothesis 5: the opening environment is positively related to the agglomeration of port industry.

(6) Government: the policy and service of the government affect the development of the port. The policy environment of the government refers to the government's policies and systems to support the development and construction of ports. Government service environment refers to the influence of government's work efficiency, customs clearance policy, and port service ability.

Hypothesis 6: the government intervention on the port industry development presents agglomeration in the initial stage, showing a positive correlation in short-term and a long-term negative correlation.

6.2. Econometric Model of Influencing Factors of Port Cluster Development Spatial Pattern in Guangdong, Hong Kong, and Macao Port Group. According to the above theories and assumptions, this paper sets up the linear model of the influencing factors of the port cluster development spatial pattern in the Guangdong, Hong Kong, and Macao port group as follows:

$$F(Y_i) = \beta_0 + \beta_1 \mathrm{Fac} + \beta_2 \mathrm{Dev} + \beta_3 \mathrm{Com} + \beta_4 \mathrm{Transport} + \beta_5 \mathrm{Trade} + \beta_6 \mathrm{Gov} + \mu, \tag{6}$$

where "β" is the regression parameter, "i" is the port, "Y" is the dependent variable that is the port development agglomeration level index, "Fac" is the transportation infrastructure, expressed by the highway mileage and the number of port berths in the land area, "Dev" is the market development level, mainly expressed by per capita GDP, secondary industry output value, and total social retail sales, "Com" is the competitive of the port industry which is expressed by the number of transportation enterprises, "Transport" is the auxiliary industry of port industry, expressed by the total freight volume, "Trade" is the degree of opening, expressed by the total amount of foreign trade, "Gov" is the government environment, expressed by the proportion of financial expenditure in GDP, and "μ" is the error item.

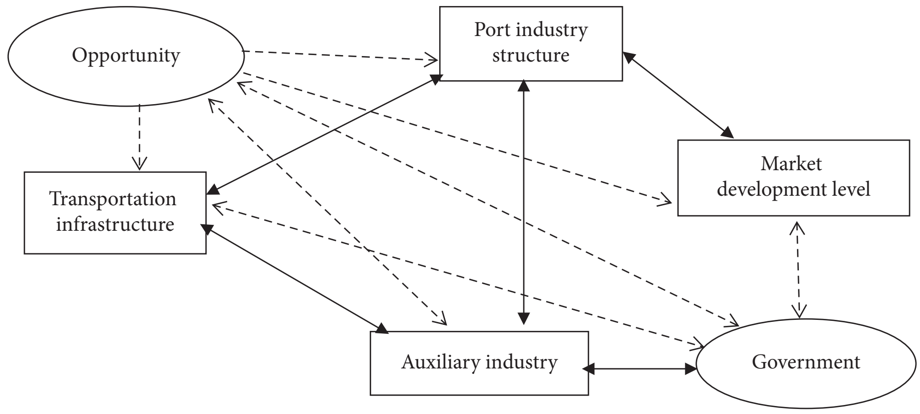

Figure 3: Theoretical model of influencing factors of spatial pattern of port development.

6.3. Empirical Analysis on Influencing Factors of Port Cluster Development Spatial Pattern in Guangdong, Hong Kong, and Macao Port Group. In order to explore the influence of the above factors in different periods on the aggregation level of port development, model I is set as the current model, the value of the dependent variable is the port level development index in 2017, and the independent variable is the value of each influencing factor in 2017, reflecting the influence degree of the current independent variable on the current dependent variable and the direction of spatial evolution. Model II is an intertemporal model. The dependent variable value is the port development level index in 2017, and the independent variable value is the value of various influencing factors in 2007, reflecting the intertemporal influence of initial variables on the current variables.

6.3.1. Estimation Results and Analysis Based on OLS Regression of Model I and Model II. Firstly, OLS regression was used to analyze model I and model II. The results are shown in Tables 6 and 7. The goodness of fit's R-squared values of model I and II were 0.9657 and 0.9511, which indicated that the regression line fitted the observed values well. The results show that the above five variables have a positive impact on the agglomeration level of the port industry, which is consistent with the theoretical hypothesis. However, the coefficient of market development level is negative, which is inconsistent with the hypothesis, which means the market development level variable can not explain the regional differences of port industry development in Guangdong, Hong Kong, and Macao. There may be omissions of important explanatory variables, or problems related to spatial analysis are not considered in the model. Therefore, we introduce the spatial econometric model to correct the problems of the OLS model.

6.3.2. Estimation Results and Analysis Based on SLM Model I and Model II. In order to further test whether the spatial autocorrelation exists in the Guangdong, Hong Kong, and Macao port group, we use the spatial lag model to further study model I and model II. Based on formula (4) and formula (5), the spatial dependence results of model I in Table 8 show that Moran index is -0.2452 which shows that the classical regression error has spatial correlation. LM (lag) and R-LM (lag) pass the significance level test of 5%; the significance level of R-LM (err) is 10%, LM(err). The err value did not pass the significance level test. It shows that SLM is more suitable for model I. Similarly, model II is more suitable for the SLM model.

The spatial effect is added to models I and II, and the current and intertemporal SLM models of the theoretical model for the development of the Guangdong, Hong Kong, and Macao port group is established. The calculation results are shown in Tables 9 and 10. Compared with the OLS model, the goodness of fit values of SLM model I and II were 0.9713 and 0.9488, which were both improved. The logarithm likelihood function (LOGL) value was greatly improved. AIC and SC values were smaller than those of the OLS model. It shows that the model considering the spatial lag effect can more scientifically explain the relationship between the development of port industry spatial evolution. Most of the parameters in the model pass the significance level test of 5%, which shows that, with the integration and development of regional transportation and the improvement of opening-up level, the development of auxiliary industries of the port industry, and the concentration of port competition, the spatial dependence of port industry is strengthened and the spatial spillover effect is obvious.

Based on the SLM model, this paper analyzes the influencing factors of port cluster development spatial pattern in the Guangdong, Hong Kong, and Macao port group.

(1) The improvement of port transportation infrastructure promotes the development of the port industry in Guangdong, Hong Kong, and Macao. The Fac coefficients of model I and model II are all positive, which indicates that the improvement of the transportation infrastructure level is conducive to the development of the port industry and can contribute to the economic spillover of port space. The Fac correlation coefficient of model I is smaller than that of model II, which indicates that the level of transportation infrastructure has a long-term effect on the agglomeration of the port industry, and the

Table 6: OLS estimation results of models I and II

Model	C	FAC	Dev	Com	Transport	Trade	GOV
Model I	−0.0125* (−1.7236)	0.0166 (0.8284)	−0.0901** (−2.5742)	8.5533** (2.2355)	1.5387*** (6.3983)	5.8404 (1.4504)	1.4456 (0.9694)
Model II	−0.0149* (−0.9452)	0.0484** (2.1726)	−0.1450** (−3.6382)	5.8031*** (7.4780)	4.1558*** (5.4361)	3.4461*** (2.3601)	−0.0001** (−2.5819)

Remarks: *, **, and ** denote 10% significance level, 5% significance level, and 1% significance level, and the figures in brackets are t-statistical value.

Table 7: OLS estimation results of models I and II

Model	R-squared	Ad R-squared	LOGL	AIC	SC
Model I	0.9657	0.9657	67.1263	−120.253	−112.615
Model II	0.9511	0.9511	63.2261	−112.152	−104.815

Table 8: Spatial dependence test of models I and II

Model	Moran I	LM (lag)	R-LM (lag)	LM (err)	R-LM (err)
Model I	−0.2452	9.8056**	9.5609**	0.3429	0.0982
Model II	0.5593	8.1953**	9.3265**	0.0155	1.1467

Remarks: *, **, and ** denote 10% significance level, 5% significance level, and 1% significance level, and the figures in brackets are t-statistical value.

Table 9: SLM estimation results of models I and II

Model	C	FAC	Dev	Com	Transport	Trade	GOV
Model I	−0.0062 (−1.4727)	0.02799** (2.437)	−0.0565** (−2.7596)	1.1981** (5.3236)	1.3104*** (9.2340)	1.6500*** (5.4089)	−8.0131 (−0.851)
Model II	−0.0029 (−0.5244)	0.04329** (3.1283)	−0.1585*** (−6.3897)	5.8132*** (12.1547)	4.7384*** (9.6236)	5.8036*** (5.4424)	−0.0002*** (−5.4554)

Remarks: *, **, and ** denote 10% significance level, 5% significance level, and 1% significance level, and the figures in brackets are t-statistical value.

Table 10: SLM estimation results of models I and II

Model	R-squared	LOGL	AIC	SC
Model I	0.9887	75.4016	−134.803	−126.075
Model II	0.9806	69.4392	−122.878	−114.151

investment in transportation infrastructure lags behind the development of the port industry, which means the impact of transportation infrastructure on the development of port industry is long term.

(2) In models I and II, there is a negative correlation between the development level of port market and the development of the port industry in Guangdong, Hong Kong, and Macao. Generally speaking, the higher the market level, the more concentrated the development of the port industry. The emergence of negative correlation is caused by the change of market development level logistics mode. With the development of manufacturing industry agility, the poor timeliness of marine transportation makes it difficult to meet the requirements of timeliness.

(3) The development cycle of the port group in Guangdong, Hong Kong, and Macao is in a concentrated period. In the models I and II, the correlation coefficient of the index is positive, and both pass the significance level test of 5%. It reflects the development trend of the port industry, with the increase of the number of enterprises in the industry; the port industry shows the characteristics of specialization, socialization, networking, and large-scale development.

(4) The relationship between port auxiliary industry and the development of port industry in Guangdong, Hong Kong, and Macao is complex, showing the short-term influence is smaller than the long-term impact. The correlation coefficient of the index is 1.1981 in model I and 5.8132 in model II, both of which pass the significance level test of 1%. Model I shows that the increasing demand of auxiliary industries related to port development, such as land transportation, will promote the development trend of port spatial agglomeration. From the intertemporal model II, because the infrastructure construction of other logistics modes has been improved, the business volume of the port industry has been greatly impacted, which is greater than that of the current period model I.

(5) The opening environment has a positive correlation with the development of the port industry. In models I and II, the correlation coefficient of the index was positive, which passed the significance level test of 5%. It shows that the strength of opening to the outside world promotes the development of

international trade, and the development of international trade promotes the demand of international freight transport, so as to improve the demand of port service and promote the further development of the port industry.

(6) Excessive government intervention will result in low efficiency of port development. The short-term impact of government intervention is greater than the long-term impact. The correlation coefficients of GOV index in models I and II are negative, the short-term correlation coefficient is −8.0131, and the long-term correlation coefficient is −0.0002.x. The negative coefficient of the index in model I is not significant, which indicates that excessive government intervention will lead to low efficiency of port development. In model II, the index is negative and passes the 1% significance test, which shows that the negative impact of government intervention has a certain lag. The reason is the investment cycle of the port industry is long, especially the construction period of infrastructure. Therefore, the negative effect of government intervention on port construction and operation is reflected in the long-term market operation.

7. Conclusions and Suggestions

In this paper, the HHI index is used to describe the aggregation status of the Guangdong, Hong Kong, and Macao port group, and the development level index is constructed according to the port throughput and container throughput. Combined with spatial econometrics and economic geography, the influencing factors of the development of the Guangdong, Hong Kong, and Macao port group are analyzed. Basic on this, the diamond model of influencing factors on the spatial pattern of the port group development in Guangdong, Hong Kong, and Macao is modeled. For the lack of spatial factors in classical economics and to explain the regional differences in the development level of the Guangdong, Hong Kong, and Macao port group, this paper introduced the partial measurement method to further study the scientific of the influencing factor model. The empirical results show that there are strong spatial autocorrelation and heterogeneity in the development of the Guangdong, Hong Kong, and Macao port group. There is a negative correlation between government intervention and the development of the port industry, and the influence of government intervention will be weakened as time goes on. The level of marketization weakens the efficiency of port development. The port auxiliary industry and the development of the port industry have many repetitions and miscellaneous relations, showing the short-term influence is smaller than the long-term impact. The reason is that the supply capacity of the auxiliary industry is limited in the near future, and the port industry plays a role in diverting the service demand of the auxiliary industry. There is a positive correlation between the level of port transportation infrastructure, the level of port industry competition, and the environment of opening to the outside world.

Based on the analysis of the empirical results, some suggestions are put forward to promote the development of the Guangdong, Hong Kong, and Macao port group.

Firstly, the development of the port industry in Guangdong, Hong Kong, and Macao has obvious spatial correlation. The suggestion is the local government should improve its own transportation infrastructure, increase the intensity of opening to the outside world, and coordinate different transportation modes from the perspective of the overall economic development of Guangdong, Hong Kong, and Macao. The integration of the regional port industry should be actively promoted, and the overall development level of the Guangdong, Hong Kong, and Macao port industry is improved.

Secondly, we should reduce the administrative intervention on the port industry, relax the control over the development of the port industry, actively change the role of the government, especially the intervention of the port and shipping administrations in the development of the port industry, do a good job in guiding the role, focus on the construction of infrastructure, improve the business environment, and provide convenient customs clearance conditions and promotional policy for the port industry.

Thirdly, we should guide and support port enterprises to actively participate in market competition, strengthen the cooperative operation mechanism between port industry and other transportation modes, and promote the restructuring of port enterprises and participate in market-oriented competition. We should do a good job in the division of labor and cooperation between different ports to avoid homogeneous competition. The overall development of the port industry should be promoted and the development of transportation infrastructure, bonded insurance, finance, legal consultation, port warehousing and logistics should be improved to build a good ecological environment for the development of the port industry.

Data Availability

The data used to support the findings of this study are available from all the corresponding author upon request.

Conflicts of Interest

The authors declare there are no conflicts of interest regarding the publication of this paper.

Acknowledgments

This research was financially supported by the 2018 Social Science Planning Project of Guangzhou “Research on the Construction and Development of Guangzhou Smart International Shipping Center Based on the One Belt One Road Strategy” (Grant no. 2018GZGJ169); 2019 Construction of Provincial Characteristic Specialty in Guangdong Province (Grant no. HS2019CXQX04); and 2016 Humanities and Social Sciences Research Projects of Universities in Guangdong Province “Construction of key disciplines in business administration” (Grant no. 2015WTSCX126).

References

[1] E. J. Taaffe, R. L. Morrill, and P. R. Gould, "Transport expansion in underdeveloped countries: a comparative analysis," *Geographical Review*, vol. 53, no. 4, pp. 503–529, 1963.

[2] Y. Hayuth, "Rationalization and concentrati on of the U.S. container port system," *The Professional Geographer*, vol. 40, no. 3, pp. 279–288, 1988.

[3] Y. Cao, H. Li, and C. Wen, "Spatial structure and competition pattern of container port system in China," *Acta Geographica Sinica*, vol. 6, pp. 1020–1027, 2004.

[4] S. Liang, Y. Cao, W. Cao, and W. Wu, "Analysis on spatial difference and evolution of port logistics economy in Yangtze River Delta," *Economic Geography*, vol. 29, no. 7, pp. 1081–1086, 2009.

[5] M. Song and H. Huang, "Research on spatial spillover and threshold effect of port efficiency in Yangtze River Delta," *Shanghai Economy*, vol. 2, pp. 33–44, 2018.

[6] G. Dong and X. Chen, "Spatial structure evolution and collaborative strategy of Yangtze River Delta port group from the perspective of regional expansion," *Journal of Dalian Maritime University (Social Science Edition)*, vol. 16, no. 4, pp. 61–66, 2017.

[7] Q. Zeng, K. Wu, and T. Teng, "Spatial distribution characteristics of ports along the maritime Silk Road," *Journal of Dalian University of Technology (Social Science Edition)*, vol. 37, no. 1, pp. 25–30, 2016.

[8] shaob Wang, "Spatial structure and evolution of China's coastal container port system," *Economic Geography*, vol. 36, no. 8, pp. 93–98, 2016.

[9] X. Dong, R. Wang, and Z. Han, "Analysis of spatial structure evolution of port hinterland system: a case study of Dalian Port Liaoning economic hinterland system," *Economic Geography*, vol. 30, no. 11, pp. 1761–1766, 2010.

[10] L. Jiang, S. Wang, and Z. Liu, "Study on spatial structure and regional role of port city zone in Liaoning Province," *Regional Research and Development*, vol. 29, no. 3, pp. 25–30, 2010.

[11] X. Zou, S. Somenahalli, and D. Scrafton, "Evaluation and analysis of urban logistics competitiveness and spatial evolution," *International Journal of Logistics Research and Applications*, vol. 23, no. 5, 2020.

[12] M. Zhao, W. Wu, and M. Zhang, "The spatial and temporal evolution of Chinese coastal rural logistics: fractal development and empirical simulation," *Journal of Coastal Research*, vol. 98, no. 1, 2019.

[13] P. W. de Langen, H. Sornn-Friese, and J. Hallworth, "The role of port development companies in transitioning the port business ecosystem; the case of port of Amsterdam's circular activities," *Sustainability*, vol. 12, no. 11, 2020.

[14] Y. Luo and B. Peng, "Coordinated development of port logistics and regional economy: measurement of correlation and spatial difference—an Empirical Study Based on Guangdong Province," *Journal of Chongqing Jiaotong University (Social Science Edition)*, vol. 16, no. 2, pp. 43–49, 2016.

[15] X. Gong and F. Zammori, "Coupling coordinated development model of urban-rural logistics and empirical study," *Mathematical Problems in Engineering*, vol. 2019, Article ID 9026795, 12 pages, 2019.

[16] Y. Su, Q. Jin, P. Yang, Q. Jiang, and G.-W. Weber, "A supply chain-logistics super-network equilibrium model for urban logistics facility network optimization," *Mathematical Problems in Engineering*, vol. 2019, Article ID 5375282, 12 pages, 2019.

[17] M. He, L. Zeng, X. Wu, and J. Luo, "The spatial and temporal evolution of logistics enterprises in the Yangtze River Delta," *Sustainability*, vol. 11, no. 19, 2019.

[18] W. Xu and Y. Xu, "Comprehensive strength evaluation of China's coastal ports and evolution of main port hinterland space," *Economic Geography*, vol. 38, no. 5, pp. 26–35, 2018.

[19] L.-Z. Cong, D. Zhang, M.-L. Wang, H.-F. Xu, and L. Li, "The role of ports in the economic development of port cities: panel evidence from China," *Transport Policy*, vol. 90, pp. 13–21, 2020.