EVOLUTION OF HIERARCHICAL STRUCTURE AND SPATIAL PATTERN OF COASTAL CITIES IN CHINA – BASED ON THE DATA OF DISTRIBUTION OF MARINE-RELATED ENTERPRISES

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ABSTRACT

In this paper, a comprehensive research of the evolution of the hierarchical structure and spatial pattern of coastal cities in China was conducted based on the data of distribution of the headquarters and subsidiaries of marine-related enterprises in 1995, 2005 and 2015 using the city network research method proposed by Taylor. The results of the empirical research showed: China's coastal city network had an obvious hierarchical characteristics of "national coastal city-regional coastal city-sub-regional coastal city-local coastal city", in the 20 years of development process, the hierarchies of coastal cities in China showed a hierarchical progressive evolution; in past 20 years, the spatial pattern and network structure of coastal cities in China tended to be complete, and the city network was more uniform, forming a "three tiers and three urban agglomerations" network structure; the strength of connection among the cities was obviously strengthened, and the efficiency of urban spatial connection was improved overall.

Keywords: Hierarchical structure; Spatial pattern; City network

INTRODUCTION

At the beginning of this century, the United Nations proposed "The 21st century is the century of ocean", believing that the ocean is the main field of international competition of the 21st century[1]. Later, China introduced the Outline of the National Planning for Development of Ocean Economy in 2003 and the "Twelfth Five-Year Plan" for National Marine Economic Development in 2012, regarding the marine economy as a new economic growth point[2]. Meanwhile, taking the coastal city carrying the marine economic activities as the regional development priority, China formulated the Development Plan for the Blue Economic Zone in Shandong Peninsula, Development Plan for the Blue Economic Experimental Zone in Fujian Strait and other national strategies to promote the development of coastal cities. In recent years, the coastal cities in China have achieved rapid development with the help of excellent geographical environment[3-5], policy support[6-8], market factors[9, 10] and FDI[11, 12], and complex and diverse changes have taken place in urban spatial pattern, gradually forming an urban system of perfect structure and reasonable hierarchy.

The rapid development of coastal cities in China continuously drives relevant academic research, and issues such as economic disparities of coastal cities[13-15] and economic structures of coastal cities[16-18] have become research hotspots, and certain research achievements have been made on mutual actions between coastal cities and tourism[19-21], population[22, 23] and so on. However, there have been few literatures on the development of coastal cities based on marine economy, this may because few statistics on marine economy lead to difficulty in quantitative measuring

as marine economy is a new economic form. Therefore, to study the influence of China's marine economic development on coastal cities, this paper studied the hierarchical structure and spatial pattern of coastal cities in China using the micro-main body of marine economic activities-marine-related enterprise. Studying China's coastal city network based on the distribution of marine-related enterprises has its rationality. From the perspective of the dynamic mechanism of the formation of city network, enterprise is one of the important driving forces of the formation of city network[24], besides, Taylor pointed out that infrastructures in a city, such as road, airport and railway, do not constitute a real city network, which in fact is formed by connecting enterprises' strategies[25]; under the condition of market economy, the marine-related enterprise is the micro-main body of marine economic activities, and the connection among marine-related enterprises in different cities influences and even decides the connection among cities and spatial pattern. From the perspective of spatial position, the business activities of marine-related enterprises have distinctive geographical characteristics, thus its spatial distribution and hierarchy can reflect the hierarchical structure of the city to a certain extent.

Based on this, a comprehensive research of the evolution of the hierarchical structure and spatial pattern of coastal cities in China was conducted based on the data of distribution of the headquarters and subsidiaries of marine-related enterprises. With coastal cities in 1995, 2005 and 2015 being taken as the research object, firstly, China's coastal city networks in different years were respectively constructed using the city network research method proposed by Taylor; secondly, the relative network connection rates of coastal cities were calculated, based on which the urban hierarchies were classified and the evolution was analyzed; thirdly, the evolution of the spatial pattern of coastal cities was analyzed; finally, pertinent policies and suggestions were put forward on the basis of empirical analysis.

marine-related enterprises meeting the standards in 1995, 2005 and 2015 were determined, for example, a total of 64 marine-related enterprises meeting the standards in 2015 were selected, including 11 marine fisheries, 2 offshore oil and gas industries, 4 sea salt industries, 5 marine chemical industries, 14 marine communications and transportation industries, 17 marine equipment manufacture industries, 4 marine biopharmaceutics industries and 7 coastal tourism industries.

After the marine-related enterprises meeting the standards in 1995, 2005 and 2015 were determined, the city where the marine-related enterprise was located was assigned with different score in light of the importance of marine-related enterprise, of which, the city where the headquarter of marine-related enterprise was located was assigned with 3 scores, and the city where the subsidiary of marine-related enterprise was located was assigned with 2 scores, and the city where the office of marine-related enterprise was located was assigned with 1 score, if the city had no branch of marine-related enterprise, it was assigned with 0 score. Considering that some cities were assigned with lower scores in the scoring of coastal cities in China by using the above method, thus, the cities assigned with 3 scores or above were selected in this paper[1].

As can be seen from Table 1, the 17 cities in 1995 selected included two categories, the first category was city with the high administrative rank, such as capital, municipality and capital city of coastal province, the second category was developed coastal city. The 11 new cities in 2005 were mostly coastal cities, where marine-related enterprises gradually emerged and formed connections among cities thanks to their geographical advantage of being by the sea. The 13 new cities in 2015 first included inland cities, such as Jinan and Taizhou, presenting sea-land connection development.

Tab. 1. Major coastal cities in China in 1995, 2005 and 2015.

Cities in 1995	Dalian	Beijing	Tianjin	Qingdao	Yantai	Nanjing	Nantong	Suzhou	Shanghai
	Xiamen	Ningbo	Fuzhou	Hangzhou	Zhuhai	Shenzhen	Guangzhou	Shantou	
New cities in 2005	Dandong	Weihai	Rizhao	Dongying	Wuxi	Wenzhou	Zhoushan	Foshan	Zhanjiang
	Huludao	Lianyungang							
New cities in 2015	Yingkou	Weifang	Ji'nan	Binzhou	Taizhou	Zhenjiang	Xuzhou	Changzhou	
	Ningde	Zhongshan	Huizhou	Maoming	Suqian				

DATA AND RESEARCH METHODS

RESEARCH OBJECTS AND DATA PROCESSING

The marine-related enterprise to be selected in this paper must meet two standards, the first standard was that it must have a standard enterprise website containing information about the location and scale of its subsidiaries or offices; the second standard was that it must have subsidiary or office in at least two coastal cities. By querying the websites of all marine-related enterprises, China Marine Statistical Yearbook, statistical yearbooks and statistical bulletins of relevant provinces or cities, relevant bulletins released by the State Oceanic Administration and so on, the

RESEARCH METHODS

In this paper, first, the value matrix for the distribution of marine-related enterprise in coastal city was constructed using the GaWC network method[25], then, the connection matrix about coastal cities was obtained, based on which China's coastal city network was constructed. According to the information about the distribution of marine-related enterprises, the city where the headquarter of marine-related enterprise was located was assigned with 3 scores, and the

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[1] A few cities, such as Beijing, Jinan and Nanjing, are not cities by the sea, but they have high administrative ranks and marine-related enterprise headquarters. To reflect the relationship among coastal cities more comprehensively and objectively, these cities were classified as coastal cities in this paper.

city where the subsidiary of marine-related enterprise was located was assigned with 2 scores, and the city where the office of marine-related enterprise was located was assigned with 1 score, and the value matrix V between coastal city and marine-related enterprise was constructed:

$$V = \begin{pmatrix} V_{11} & V_{12} & \cdots & V_{1n} & \cdots & V_{1t} \\ V_{21} & V_{22} & \cdots & V_{2n} & \cdots & V_{2t} \\ \vdots & \vdots & \ddots & \vdots & \ddots & \vdots \\ V_{m1} & V_{m2} & \cdots & V_{mn} & \cdots & V_{mt} \\ \vdots & \vdots & \ddots & \vdots & \ddots & \vdots \\ V_{s1} & V_{s2} & \cdots & V_{sn} & \cdots & V_{st} \end{pmatrix} \quad V_{mn} = \begin{cases} 3 & \text{city m has the headquarter} \\ 2 & \text{city m has the subsidiary} \\ 1 & \text{city m has the office} \\ 0 & \text{otherwise} \end{cases} \quad (1)$$

The aggregated score of marine-related enterprises in city m was $V_m = \sum_{n=1}^{t} V_{mn}$, the cities assigned with 3 scores or above were selected. As the city is the carrier of the enterprise, and the connection among enterprises in two cities constitutes the connection among the cities, so the degree of connection between two cities is the accumulated connection among marine-related enterprises shared by the two cities. The connection value generated from marine-related enterprise n between city α and city β was defined as $R_{\alpha\beta,n} = V_{\alpha n} \times V_{\beta n}$, and the total connection value between city α and city β was defined as $R_{\alpha\beta} = \sum V_{\alpha n} \times V_{\beta n}$. Based on this, the incidence matrix $R_{s \times s}$ among s cities was constructed, and the city network was obtained using ArcGIS software. The total connection value of city network was defined as $T = \sum_{\alpha=1}^{s} \sum_{\beta=1}^{s} R_{\alpha\beta}$, and the connection value between city α and all the other cities was defined as $T_\alpha = \sum_{\beta=1} R_{\alpha\beta}$, and the network connection rate of city α was defined as $t_\alpha = \frac{T_\alpha}{T}$, and the relative network connection rate $pt_a = \frac{T_a}{T_\gamma}$ was obtained with city γ with the highest network connection rate as the benchmark.

CALCULATED RESULTS AND ANALYSIS

EVOLUTION OF THE HIERARCHICAL STRUCTURE OF COASTAL CITIES IN CHINA

The relative network connection rates[2] of coastal cities in China in 1995, 2005 and 2015 were calculated based on the relative network connection rate, and the results are shown in Table 2.

The relative network connection rate of city node can reflect the status and influence of the city in the network, the more

important the city, the higher the relative network connection rate[26]. The cities were clustered using the K-Cluster module of SPSS, and the cities with similar relative network connection rates were classified as a group, thus the coastal cities in China were divided into national coastal city, regional coastal city, sub-regional coastal city and local coastal city according to their importance in the network. Taking 2015 for example, Figure 1 was made.
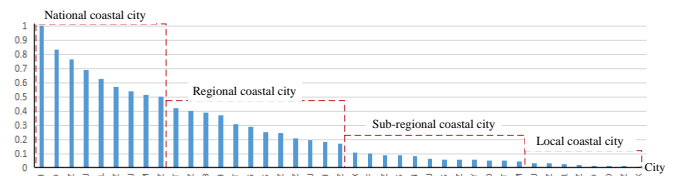

Fig. 1. Ordering and classification of relative network connection rates of coastal city nodes in China in 2015.

As can be seen from Figure 1, the higher the relative network connection rate of a city, the greater the role and influence of the city in China's marine economic development. By clustering, 41 coastal cities in 2015 were divided into 4 groups: the first group was national coastal city, including 9 cities of Shanghai, Qingdao, Shenzhen, Tianjin, Dalian, Guangzhou, Beijing, Xiamen and Suzhou, these cities were the hubs of connection among coastal city networks, and had great influence and competitiveness; the second group was regional coastal city, including 12 cities of Yantai, Hangzhou, Ningbo, Weihai, Nantong, Lianyungang, Zhoushan, Fuzhou, Taizhou, Nanjing, Zhuhai and Wenzhou, these cities were the priorities of regional connection, and had strong radiation depth and breadth for the other coastal cities; the third group was sub-regional coastal city, including 12 cities of Wuxi, Weifang, Rizhao, Zhongshan, Jinan, Zhanjiang, Foshan, Huizhou, Dongying, Ningde, Shantou and Maoming, these cities enjoyed rapid marine economic development, with increasing strength; the fourth group was local coastal city, including 8 cities of Zhenjiang, Xuzhou, Suqian, Binzhou, Dandong, Huludao, Changzhou and Yingkou, these cities were new cities of developing the marine economy.

Tab. 2. Network connection rates of coastal cities in China in different years.

City	1995	2005	2015	City	1995	2005	2015	City	2005	2015	City	2015
Shanghai	1	1	1	Fuzhou	0.24	0.24	0.24	Lianyungang	0.21	0.29	Jinan	0.09
Beijing	0.62	0.67	0.74	Hangzhou	0.36	0.46	0.40	Dandong	0.02	0.02	Binzhou	0.03
Tianjin	0.60	0.61	0.69	Suzhou	0.38	0.48	0.50	Huludao	0.02	0.02	Taizhou	0.21
Shenzhen	0.53	0.53	0.76	Ningbo	0.31	0.41	0.39	Weihai	0.39	0.37	Zhenjiang	0.04
Qingdao	0.43	0.53	0.73	Yantai	0.17	0.47	0.42	Rizhao	0.09	0.19	Xuzhou	0.04
Dalian	0.40	0.43	0.63	Zhuhai	0.18	0.18	0.18	Dongying	0.05	0.16	Changzhou	0.02
Nanjing	0.39	0.29	0.39	Shantou	0.04	0.12	0.05	Zhanjiang	0.09	0.17	Suqian	0.03
Guangzhou	0.46	0.46	0.57	Wenzhou	—	0.17	0.17	Wuxi	0.11	0.11	Ningde	0.05
Xiamen	0.41	0.51	0.52	Zhoushan	—	0.25	0.25	Yingkou	—	0.01	Zhongshan	0.09
Nantong	0.29	0.35	0.31	Foshan	—	0.04	0.06	Weifang	—	0.11	Huizhou	0.06
											Maoming	0.05

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[2] The number of coastal cities in 1995, 2005 and 2015 selected in this paper were 17, 28 and 41 respectively, thus some cities lacked relative network connection rate of 1995 or 2005.

According to the cluster analysis of coastal cities in 1995, 2005 and 2015, the hierarchical structures of coastal cities in

China were obtained. To directly reflect the characteristics and evolution of the hierarchical structures of coastal cities in China from 1995 to 2005 and to 2015, Table 3 and Figure 2 were made.

Tab. 3. Hierarchical structure of coastal cities in China in different years

| Year	City hierarchy	City name
1995	National Coastal Cities	Shanghai, Beijing, Tianjin, Shenzhen
	Regional coastal cities	Qingdao, Dalian, Nanjing, Guangzhou, Xiamen
	Sub-regional coastal cities	Nantong, Fuzhou, Hangzhou, Suzhou, Ningbo
	Local coastal cities	Yantai, Zhuhai, Shantou
2005	National Coastal Cities	Shanghai, Beijing, Tianjin, Qingdao, Shenzhen, Xiamen
	Regional coastal cities	Dalian, Yantai, Suzhou, Ningbo, Fuzhou, Nanjing
	Sub-regional coastal cities	Hangzhou, Nantong, Wenzhou, Zhoushan, Foshan, Zhuhai
	Local coastal cities	Dandong, Huludao, Weihai, Rizhao, Dongying, Lianyungang, Wuxi, Zhanjiang, Shantou
2015	National Coastal Cities	Shanghai, Beijing, Tianjin, Qingdao, Shenzhen, Xiamen, Dalian, Suzhou, Guangzhou
	Regional coastal cities	Yantai, Hangzhou, Ningbo, Weihai, Nantong, Lianyungang, Zhoushan, Fuzhou, Taizhou, Nanjing, Zhuhai, Wenzhou
	Sub-regional coastal cities	Wuxi, Weifang, Rizhao, Zhongshan, Ji'nan, Zhanjiang, Foshan, Huizhou, Dongying, Ningde, Shantou, Maoming
	Local coastal cities	Zhenjiang, Xuzhou, Suqian, Binzhou, Dandong, Huludao, Changzhou, Yingkou
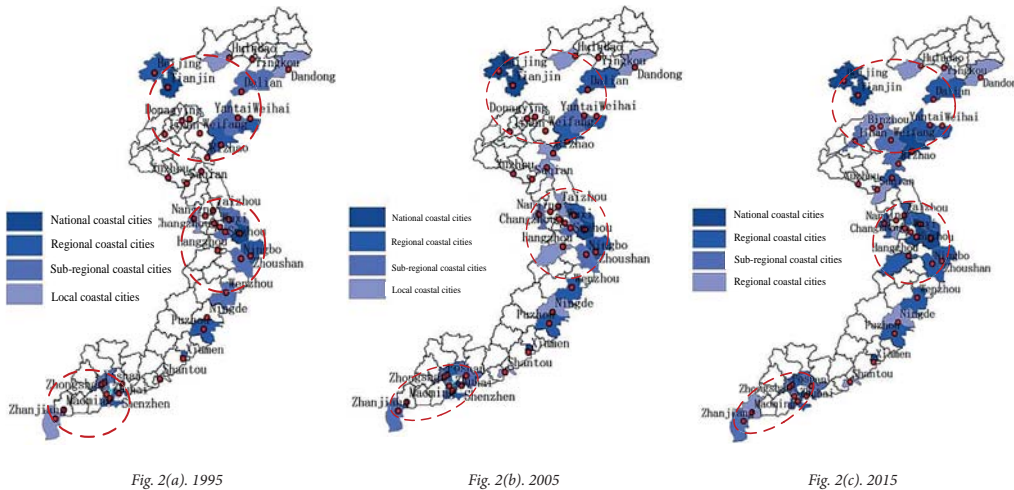
Fig. 2(a). 1995   Fig. 2(b). 2005   Fig. 2(c). 2015

Fig. 2. Hierarchical structures of coastal cities in China in different years

As can be seen from Table 3 and Figure 2, the coastal cities in China and their hierarchical structure had the following characteristics: (1) The hierarchical structure of coastal cities in China had a significant positive correlation with the urban administrative rank and the level of urban economic development. In the hierarchical structure of coastal cities in China, all the national coastal cities in China were municipalities or sub-provincial cities, especially capital Beijing, a city not by the sea, unexpectedly had many headquarters of marine-related enterprises, so it had an important influence on other coastal cities. The reason may be that these cities had higher administrative ranks and easier access to political, economic and social resources, so the marine-related enterprises were first established in these cities to expand the market radius and develop the marine economy by making use of the influence of these cities. (2) The hierarchical structures of coastal cities in China were closely related to geographical location. The marine economy had obvious geographical characteristics, the closer to the sea of a city, the more abundant marine resources the city had, the faster the marine economic development, and the

higher hierarchy of the city in the hierarchies of coastal cities. (3) The coastal city agglomerations in China can be divided into three major urban agglomerations overall, including the Circum-Bohai Sea Urban Agglomeration, Yangtze River Delta Urban Agglomeration and Pearl River Delta Urban Agglomeration, where the phenomenon of coastal city agglomeration was obvious.

The evolution of the hierarchical structure of coastal cities in China from 1995 to 2005 and to 2015 included: (1) The hierarchies of coastal cities in China presented a hierarchical progressive evolution. Driven by marine policy, China's marine economy developed rapidly, and the marine-related enterprises expanded rapidly relying on urban impact, and the coastal cities developed to a higher hierarchy, and the hierarchies of coastal cities in China showed a progressive rise process, in particular, the hierarchies of cities such as Yantai, Weihai, Lianyungang, Fuzhou, Foshan, Zhuhai and Zhanjiang rose obviously. From 1995 to 2005 and to 2015, the hierarchies of coastal cities in China presented a hierarchical progressive evolution, and the new cities of all hierarchies in 2005 and 2015 were mostly developed from the cities of lower hierarchies, for example, Zhuhai, just a local coastal city in 1995, rose to a sub-regional coastal city in 2005, and a regional coastal city in 2015. (2) The coastal city agglomerations in China formed a "three tiers and three urban agglomerations" network structure, the "three tiers" were Beijing, Shanghai and Shenzhen, and the "three urban agglomerations" were the Circum-Bohai Sea Urban Agglomeration, Yangtze River Delta Urban Agglomeration and Pearl River Delta Urban Agglomeration. From 1995 to 2005 and to 2015, in the 20 years of China's marine economic development, new coastal cities mainly emerged centering around the core cities of Beijing, Shanghai and Shenzhen, and the Circum-Bohai Sea Urban Agglomeration with Beijing as the center, Yangtze River Delta Urban Agglomeration with Shanghai as the center and Pearl River Delta Urban Agglomeration with Shenzhen as the center expanded continuously and their scales expanded gradually.

EVOLUTION OF THE SPATIAL PATTERN OF COASTAL CITIES IN CHINA

To analyze the association between the spatial patterns and coastal cities, the city network model was constructed using ArcGIS software according to the incidence matrix among coastal cities in China in 1995, 2005 and 2015, as shown in Figure 3.
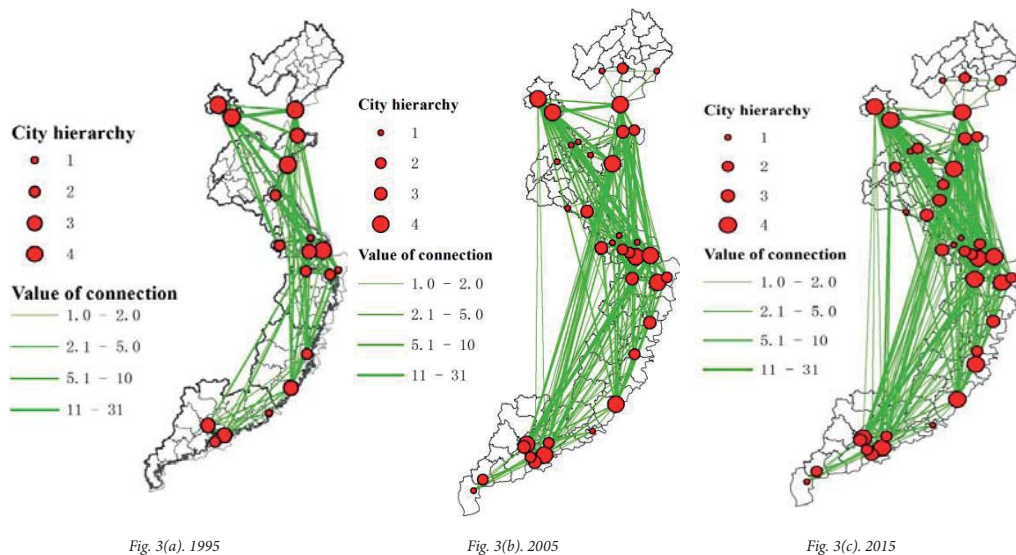

Fig. 3(a). 1995 *Fig. 3(b). 2005* *Fig. 3(c). 2015*

Fig. 3. Spatial patterns of coastal cities in China in different years

As can be intuitively seen from Figure 3, from 1995 to 2005 and to 2015, the strength of connection among coastal cities in China was gradually strengthened, and the density of city network gradually increased, and the urban spatial structure was becoming complete day by day. In 1995, the spatial pattern of coastal cities in China were not yet complete, and the strength of connection among coastal cities in China was weak. In 2005, the strength of connection among coastal cities in China was further strengthened, and the value of connection among some coastal cities was above 10, and the total value of connection among coastal city networks increased to 1,189, and the connection among coastal cities was closer, however, the strength of connection between new coastal cities and other cities was still low. In 2015, the spatial structure and network structure tended to be complete, the city network was more uniform, and the strength of connection among coastal cities in China was significantly strengthened, and the efficiency of urban spatial connection was improved overall.

CONCLUSIONS

In this paper, a comprehensive research of the evolution of the hierarchical structure and spatial pattern of coastal cities in China was conducted based on the data of distributions of the headquarters and subsidiaries of marine-related enterprises in 1995, 2005 and 2015 using the city network research method proposed by Taylor. According to the empirical research, the following conclusions were drawn: (1) China's coastal city network had an obvious hierarchical characteristics of "national coastal city-regional coastal city-sub-regional coastal city-local coastal city", in the 20 years of development process, the hierarchies of coastal cities in China showed a hierarchical progressive evolution. The high-hierarchy coastal cities were mostly municipalities or sub-provincial cities or seaside cities near the sea, these cities and their association constituted the basic framework of the spatial patterns of coastal cities in China. (2) In the 20 years of development process, the strength of connection among coastal cities in China was gradually strengthened, and the density of city network increased gradually, and the urban spatial structure was becoming complete day by day. The coastal city agglomerations in China formed a "three tiers and three urban agglomerations" network structure, the "three tiers" were Beijing, Shanghai and Shenzhen, and the "three urban agglomerations" were the Circum-Bohai Sea Urban Agglomeration, Yangtze River Delta Urban Agglomeration and Pearl River Delta Urban Agglomeration. (3) The structures of the three major coastal urban agglomerations became more complete, but there were differences in their internal and external spatial patterns. In the 20 years of development process, the association between the three major urban agglomerations and internal cities was strengthened, and the association among the three major urban agglomerations and external cities also became close gradually, and the connection among the cities became more direct and efficient. The Circum-Bohai Sea Urban Agglomeration had prominent internal connection while the Yangtze River Delta Urban Agglomeration had prominent external connection. Combined with the empirical analysis, this paper put forward the following policy recommendations.

In view of the obvious hierarchical structures of coastal cities in China, a long-term, overall planning based on China's overall marine economic development should be developed. Firstly, the government should attach importance to the construction of high-hierarchy coastal cities, cultivate and build the core coastal cities with competitive strength and influence, if the core coastal cities can not play their roles, the whole city network will be in a state of paralysis; secondly, form the urban agglomerations promoting China's marine economic development relying on the radiation and diffusion effects of high-hierarchy coastal cities to play the spatial polarization effect, so as to connect secondary development cities and promote China's marine economic

development; finally, give full play to the supporting roles of low-hierarchy coastal cities, avoid duplication of similar projects and industrial isomorphism, help them find their own positions in the industry, play their own advantages, and actively create a suitable external investment environment to strive to become a new coastal city with development potential.

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