Port system evolution in Chinese coastal regions: A provincial perspective

Abstract

Against the background of provincial port integration in China, provincial port groups have become critical market players in the port industry. It has become necessary to review the evolution of the port system in Chinese coastal regions from a provincial perspective. This paper investigates the evolution of the Chinese port system by treating eleven coastal provinces as the units of analysis. The port system is categorized into four segments according to cargo type, namely, containers, solid bulk cargo, general cargo and liquid bulk cargo. Multiple methods are applied to study the port system from the perspectives of market shares, cargo concentrations, the port hierarchy and port specialization. The findings suggest that no province holds a leading market position in all cargo sectors, and interprovincial port competition remains intense. The degree of specialization in the provincial port systems is generally moderate, though Hebei Province is an exception with a high level of port specialization due to its special geographical location. This paper also elaborates on several policy implications for provincial port groups.

Keywords: Port system evolution; Port integration; Port hierarchy; Port specialization; Provincial perspective

1. Introduction

Currently, the global port industry has witnessed a wave of cooperation among ports in various forms (Notteboom et al., 2018). As one of the main strategic port governance tools (Zhang et al., 2019) and the most far-reaching form of port cooperation with mergers and acquisitions (Shinohara and Saika, 2018), port integration is expected to eliminate overcapacity and decrease inter-port competition, especially among ports in proximity to each other (Notteboom and Yang, 2017; Wu and Yang, 2018; Yang et al., 2019; Chen et al., 2020). According to Brooks et al. (2017), port mergers and acquisitions have emerged in several countries such as Canada, France, Belgium, Portugal and Italy. Among them, Italy is a representative where 15 regional port system authorities are newly established to integrate the previous 24 local port authorities with broader geographical scopes (Parola et al., 2017). Generally speaking, the port merger process is often characterized by complexity because of the possible reconfiguration of port governance structure (Ferretti et al., 2018).

It is worth pointing out that the regional integration of port entities (e.g., port authorities, port operators) has a significant impact on the structure of transport activities in a given region because of a shared long-term vision, combined planning and a value chain approach (Mclaughlin and Fearon, 2013). With cooperation among the adjacent ports becoming increasingly closer under port integration schemes, port competition is likely to evolve from the inter-port (i.e., intercity) level to a much broader level with a larger geographical scope (Zheng et al., 2020). In the work of Zheng et al. (2020), Chinese port competition is found to develop from the inter-port level to the interprovincial level due to provincial port integration. In this context, the port system is expected to change accordingly because the market players in the system have changed from numerous local port companies to a limited number of provincial port groups (Feng et al., 2019). More specifically, in China, provincial port groups (see Table 1) have been newly established as integrators in many coastal provinces to merge local port companies and coordinate their businesses (Huo et al., 2018). The creation of provincial port groups, to a great extent, is closely related to the development of Chinese port governance. In the past decade, the evolution of port governance in China has been greatly influenced by institutional layering processes, in which new rules, procedures or structures are added to existing institutions by degrees (Notteboom and Yang, 2017). In practice, the Ministry of Transport (MOT) issued the "*Guideline for promoting the transformation and upgrading of ports*" to encourage port enterprises to utilize capital resources for mergers with the aim of achieving regional port integration (MOT, 2014). Inspired by this guideline, some provinces began to implement the mergers among local port companies. Particularly, the establishment of Zhejiang Provincial Seaport Investment & Operation Group was officially acknowledged and advocated by the MOT as the national show case (MOT, 2017), which significantly promoted the popularity of "provincial port group" model nationwide.

These provincial port groups actually manage the main ports in their provinces, including seaports and inland ports. Compared with local port companies, port groups at the provincial level are controlled by the provincial governments or by mega state-owned companies held by the central government, which have many port assets, a high level of bargaining power and strong investment capacities (Chen et al., 2020). Moreover, Chinese provincial port groups are required to play proactive roles in upgrading the local port industry and providing efficient and effective port services for local economic development (MOT, 2017).

Table 1. Provincial port groups in Chinese coastal provinces

Province	Provincial port group	Year of establishment	Main ports in the port group
Guangxi	Beibu Gulf Port Group Co., Ltd.	2007	Fangchenggang Port; Beihai Port; Qinzhou Port
Hebei	Hebei Port Group Co., Ltd.	2009	Qinhuangdao Port; Tangshan Port; Huanghua Port
Zhejiang	Zhejiang Provincial Seaport Investment & Operation Group Co. Ltd.	2015	Ningbo Zhoushan Port; Jiaxing Port; Wenzhou Port; Taizhou Port; Yiwu Port
Jiangsu	Jiangsu Port Group Co., Ltd.	2017	Nanjing Port; Suzhou Port; Nantong Port; Zhenjiang Port; Lianyungang Port
Hainan	Hainan Harbor & Shipping Holding Co., Ltd.	2018	Xiuying Port; Yangpu Port; Macun Port; Xinhai Port
Liaoning	Liaoning Port Group Co., Ltd.	2018	Dalian Port; Yingkou Port; Dandong Port
Shangdong	Shangdong Port Group Co., Ltd.	2019	Qingdao Port; Rizhou Port; Yantai Port; DongYing Port; Weifang Port; Binzhou Port
Fujian	Fujian Port Group Co., Ltd.	2020	Fuzhou Port; Xiamen Port; Quanzhou Port; Ningde Port; Putian Port

Note: Shanghai and Tianjin are not listed in the table because these two cities are provincial-level municipalities and their local port companies (i.e., Shanghai International Port Group Co., Ltd. and Tianjin Port Group Co., Ltd.) have been provincial port groups since their early establishment in the era of port devolution. Guangzhou is also not listed because that province has not yet established a provincial port group.
Source: Authors' own compilation.

Notably, in the research field of port geography, the previous literature on port system evolution has mainly focused on the development of port system from the perspective of individual ports with specific geographical scopes (e.g., Gouvernal et al., 2005; Wilmsmeier and Monios, 2013; Liu et al., 2013; Wilmsmeier and Monios, 2016; Monios et al., 2019; Nguyen et al., 2020).

However, with the rise of port integration and of regional port entities worldwide, it has become both interesting and necessary to review the port system evolution from a broader perspective by treating a port range covering several neighboring ports, rather than an individual port, as the particular unit of analysis. In so doing, policy and decision makers can make more effective policies regarding port management, which can better facilitate regional economic development. In addition, these regional port integrator companies can gain a deeper understanding of their market positions in the port system and adopt more suitable business strategies.

This paper focuses on the evolution of the port system in Chinese coastal regions from a provincial perspective because most Chinese coastal provinces have completed their port integration and have established provincial port groups to be unified port operators in their jurisdictions (e.g., Huo et al., 2018; Wu and Yang, 2018; Chen et al., 2020). A total of eleven coastal provinces in mainland China are treated as the basic units of analysis shown in Fig. 1. To comprehensively investigate the Chinese coastal port system, the evolution of market shares, cargo concentrations, the port hierarchy and port specialization are analyzed through multiple quantitative approaches. To understand the coastal port system in terms of cargo variety, the port system is categorized into four subsystems according to cargo type (i.e., containers, solid bulk cargo, general cargo and liquid bulk cargo).

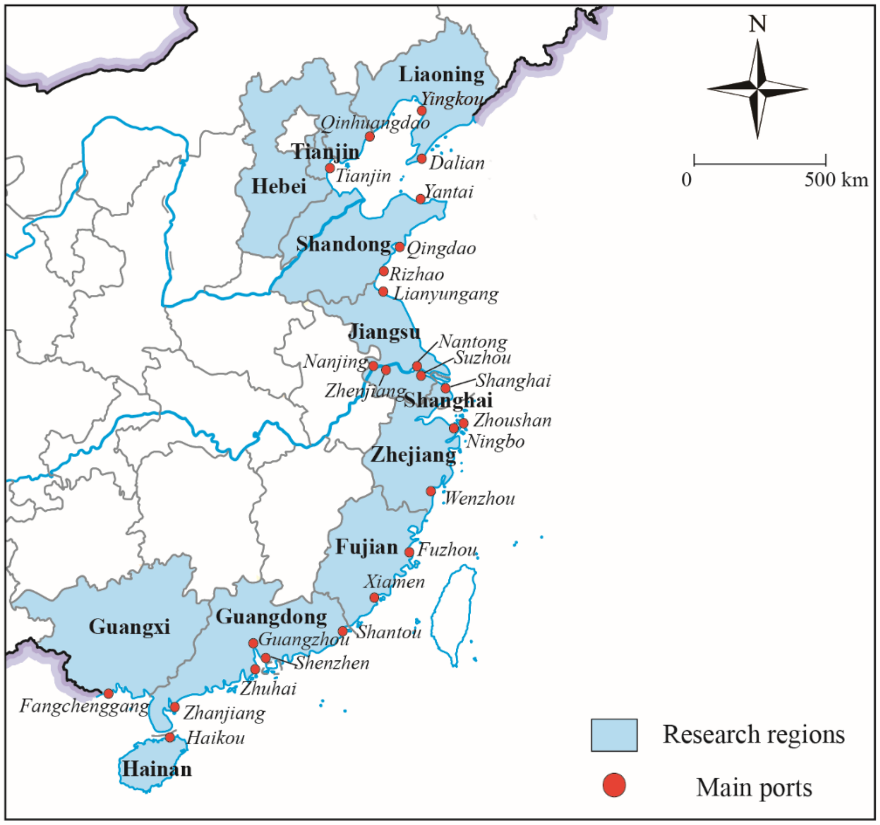

Fig. 1. Coastal provinces in mainland China

The remainder of this paper is organized as follows: Section 2 presents a brief review of the existing literature on port system evolution. Section 3 describes the methodological approaches and data collection. The results of the analysis of the port system evolution from a provincial perspective are presented in Section 4. Section 5 discusses the policy implications for Chinese provincial port groups that can be derived from our analysis. Section 6 concludes the paper.

2. Literature review

Port evolution, including port system development, is an important research theme in port geography studies (Ng et al., 2014). There are a number of classic research tracks in this field, such as Taaffe et al. (1963) on the six-phased development of a port transport network, Bird (1963) on the Anyport model, Hayuth (1981) on port system de-concentration, Notteboom and Rodrigue (2005) on port regionalization and Rodrigue and Notteboom (2010) on foreland-based regionalization. These remarkable conceptual models of port development and port system development have been widely adopted, with the necessary adjustments for different geographical scales, to investigate port evolution all over the world (Yang et al., 2017).

Among the numerous studies on port system evolution, with geographical scales ranging from regional to national and even global, most studies take individual ports as their basic units of analysis. For example, Gouvernal et al. (2005) investigate the dynamics of change in the container port system in the western Mediterranean by focusing on the eight largest ports in the region. Wilmsmeier and Monios (2013) present developments in specific top and secondary container ports in the UK to analyze the evolution of container port system. A potential deconcentration is identified within the UK container port system. Wilmsmeier and Monios (2016) highlight the developments in the main Latin American ports to illustrate the trends in the evolution of port systems. Liu et al. (2013) argue that the container port system in the Pearl River Delta is undergoing regionalization with specialization by illustrating the relationships among ports of Hong Kong, Shenzhen and Guangzhou. Monios et al. (2019) select several ports in different port ranges as illustrative cases to explain the dynamics behind the emergence of second-tier hubs. It should be noted that the work of Wilmsmeier et al. (2014) provides striking research on port system evolution; the authors choose sub-regions of a port system rather than individual ports as their units of analysis. Specifically, the Latin American and Caribbean port system is categorized into eight subsystems. This study by Wilmsmeier et al. (2014) clearly shows that it is necessary and feasible to enlarge the geographical scales of the basic units of analysis when conducting comparative research on different port ranges. The works of Notteboom (2006; 2010) on the European container port system also manifest that a port system can be divided into several port ranges in light of geographical characteristics, ports of call of liner services and the hinterland capture area. In China, besides the divisions according to the provincial jurisdictions, the coastal ports in the port system are grouped to form five port ranges across provinces, namely the Bohai Rim, Yangtze River Delta, Southeast coast, Pearl River Delta and Southwest coast (MOT, 2006).

With regard to the types of cargo handled in ports, a majority of the existing port system evolution studies focus on container traffic (e.g., Gouvernal et al., 2005; Notteboom, 2010; Wilmsmeier and Monios, 2013, 2016; Wilmsmeier et al., 2014; Monios et al., 2019). This is mainly because of the substantial development in container transportation since the 1980s (Liu et al., 2013). Port systems for the other types of cargo remain comparatively under-researched. In recent years, inspired by studies on container port systems, a few studies have begun to explore the development pattern of bulk port systems. For instance, Lee et al. (2014) point out that the bulk port system in the west coast of Korea has experienced de-concentration. Wang and Ducruet (2014) analyze coal traffic in the Chinese port system and argue that the spatial distribution of coal-exporting ports is characterized by the dominance of ports in North China, while the distribution of coal-importing ports is widespread and includs most main ports along the Chinese coast. Wang et al. (2018a) builds on Wang and Ducruet (2014) and reveals the spatial evolution of the Chinese coal port system. The authors articulate that the spatial pattern has changed from "south input and north output" to "all input and north output". Yang et al. (2017) determine the evolutionary path of the Yangtze River bulk port system's spatial structure by dividing its development process into five stages with different characteristics. In addition to these studies on container and bulk port systems, there are still few studies on port systems for general cargo and liquid bulk cargo.

Regarding the analysis and display of the evolution of port systems, a number of data analysis techniques have been developed and adopted by port geographers due to their various research objectives. Of these techniques, the use of market shares based on port throughput is a simple but useful technique to show the development of ports (e.g., Notteboom, 2010; Wilmsmeier et al., 2014; Wilmsmeier and Monios, 2016). Related to market shares, ranking ports according to throughput or growth rates can also be used to illustrate the development of the port system (Monios et al., 2019). Notably, cargo concentration and de-concentration, as important indicators of port competition levels, are widely studied in the relevant literature (e.g., Notteboom, 2010; Li et al., 2012; Notteboom et al., 2020). There are several methods for measuring cargo concentration or de-concentration in the port domain such as the Herfindahl–Hirschman index, the Gini coefficient, the Lorenz curve, and the concentration ratio (Notteboom, 2006; Nguyen et al., 2020). As a means to assess the port competitiveness, productivity or efficiency changes in the ports in a port system have attracted some research interest. Data Envelopment Analysis (DEA) is generally used for port productivity/efficiency measurements (Cullinane et al., 2005; Medal-Bartual et al., 2016; Nguyen et al., 2020). Port specialization has been measured for ports as a means to improve port competitiveness and reduce inter-port competition within the port system (Ducruet et al., 2010; Wang et al, 2018b). In addition, to gain a deeper understanding of the port hierarchy in a port system, the rank-size rule has been recently introduced in port studies to investigate the rank-size distribution of large, medium and small ports with various cargo throughput scales in a port system (Sun et al., 2016; Chen et al., 2019).

In summary, we can identify two research gaps associated with port system evolution. First, few studies have reviewed the port system evolution from a broader perspective by enlarging the geographical scales of the basic units of analysis beyond individual ports. Second, few studies have focused on port systems for general cargo and liquid bulk cargo. Following the previous literature, we also find that the evolution of the port system can be quantitatively evaluated by measuring market shares, cargo concentrations, the port hierarchy and port specialization. Therefore, against the background of increasing port integration at the provincial level in China, the current paper conducts a study on port system evolution in Chinese coastal regions from a provincial perspective by dividing the overall system into four subsystems (i.e., port systems for containers, solid bulk cargo, general cargo and liquid bulk cargo) and measuring multiple aspects (i.e., market shares, cargo concentrations, the port hierarchy and port specialization) of the system.

3. Methodology and data

3.1. Market share

Market share is a popular concept in business practice and is generally considered a measure of the consumer preferences for a product relative to other similar products. In the port geography literature, the market shares of various ports or regions in a port system are often calculated according to their port throughputs and are used to show the spatial distribution of cargo (see e.g., Wilmsmeier et al., 2014; Notteboom et al., 2020).

$$\mathrm{MS_{ij}} = \frac{\mathrm{X_{ij}}}{\sum_{j=1}^{n} \mathrm{X_{ij}}} \times 100\% \tag{1}$$

where $\mathrm{MS_{ij}}$ denotes the market share of province j in cargo type segment i. n is the total number of provinces studied. In our paper, $\mathrm{n} = 11$. $\mathrm{X_{ij}}$ is the total port throughput for cargo type i in province j. A higher market share usually means a larger proportion of total port throughput in the port system and a strong barrier to entry for other competitors.

3.2. Herfindahl–Hirschman Index (HHI)

The HHI is widely used to quantitatively measure the level of market concentration in a specific industry. In the field of port studies, the HHI is a popular method for identifying the level of market concentration in the port industry (e.g., Notteboom, 1997; Notteboom, 2010; Twrdy and Batista, 2013; Nguyen et al., 2020). In this paper, the HHI is measured as:

$$\mathrm{HHI_i} = \sum_{j=1}^{n} \left(\frac{\mathrm{X_{ij}}}{\sum_{j=1}^{n} \mathrm{X_{ij}}} \right)^2 \text{ and } \frac{1}{\mathrm{n}} \leq \mathrm{HHI_i} \leq 1 \tag{2}$$

where $\mathrm{HHI_i}$ is the HHI index for cargo type i in the port system. n is the total number of provinces studied. In our study, $\mathrm{n} = 11$. $\mathrm{X_{ij}}$ denotes the total port throughput for cargo type i in province j.

A high HHI value represents a high degree of concentration and vice versa (Rhoades, 1993). According to Notteboom et al. (2016), if the HHI value is between 0.15 and 0.25, the market is moderately concentrated. Note that an HHI value exceeding 0.25 means a high concentration.

3.3. Rank-size rule regression

Port hierarchy is one of important research issues associated with port systems (Ng et al., 2014), which is closely related to the rank-size distribution of large, medium and small ports with various cargo throughput scales in a port system (Laxe et al., 2012). As one of the most striking empirical regularities in geographical economics, the rank-size rule is broadly used in the research field of city size distributions, describing a unique rank-size relationship between a city's population and its rank (Giesen and Südekum, 2011; Arshad et al., 2018). The rank-size rule was first identified by Auerbach (1913), who showed that the city sizes obey a Pareto distribution. The idea of the rank-size rule was further refined and popularized by Zipf (1949) and later became commonly known as Zipf's law when the Pareto exponent equals 1 (Fang et al., 2017). It is widely accepted that conformity with Zipf's law implies an optimal allocation of resources, and deviations from Zipf's law indicate non-optimal allocations due to over- or under-agglomeration (Wan et al., 2020). Recently, the rank-size rule has been introduced into port studies to investigate the rank-size distribution of a port system (i.e., the port hierarchy) based on port throughputs (e.g., Sun et al., 2016; Chen et al., 2019). In this study, the rule is expressed as follows:

$$\ln \mathrm{P_k} = \ln \mathrm{C} - \alpha \ln \mathrm{k} \tag{3}$$

where the logarithm of the k-th ranked province's port throughput $\mathrm{P_k}$ is regressed on the logarithm of the rank k ($\mathrm{k} = 1,2,\cdots \mathrm{N}$). The rank k is determined by the volume of the province's port throughput. C represents the theoretical port throughput of the primary province in the port system, which is a constant. α is referred to as Pareto exponent, also called the Zipf exponent. When α equals 1 (i.e., $\alpha = 1$), Zipf's law is followed perfectly, which means that an ideal optimal distribution in the port system exists. When α is greater than 1 (i.e., $\alpha > 1$), it indicates that the port system is characterized by a power-law distribution. Specifically, the port throughputs of the high-ranked provinces account for the majority of the total port throughput, while the proportion of the middle- and low-ranked provinces' port throughputs is small. The larger α is, the more dominant the role that high-ranked provinces play in the port system. When α is between 0 and 1 (i.e., $0 < \alpha < 1$), the rank-size distribution of the port system is a normal distribution. In such a situation, the middle- and low-ranked provinces' port throughputs account for a large proportion of the total port throughput, and the volume of port throughputs in the high-ranked provinces is not notably large. The smaller α is, the more even the distribution of total port throughput among provinces. Empirically speaking, when α is in the range of [0.8, 1.2], it can be argued that Zipf's law basically holds (Gabaix and Ioannides, 2004).

3.4. Port Specialization Index (PSI)

Port specialization is considered to be a good way to reduce fierce inter-port competition (Zhuang et al., 2014). The quantification of the degree of port specialization has been widely explored by port geography scholars (e.g., Rimmer, 1966; Ducruet et al., 2010; Wang et al, 2018b). However, a universally accepted mathematical formula for calculating port specialization degree does not exist. In this paper, we adopt the PSI that was developed by Wang et al. (2018b) to identify the degree of port specialization, because the PSI is very useful for horizontal comparison across Chinese coastal provinces. The PSI is measured as:

$$\mathrm{PSI_i} = \frac{\mathrm{n_i}}{\mathrm{n_i}-1} \times \sum_{\mathrm{j}=1}^{\mathrm{n_i}} \left(\mathrm{t_{ij}} - \bar{\mathrm{t}}\right)^2 \text{ and } \bar{\mathrm{t}} = \frac{\sum_{\mathrm{j}=1}^{\mathrm{n_i}} \mathrm{t_{ij}}}{\mathrm{n_i}} \tag{4}$$

where $\mathrm{PSI_i}$ is the PSI of province i. $\mathrm{n_i}$ is the total number of cargo types in province i. $\mathrm{t_{ij}}$ denotes the proportion of port throughput of cargo type j to the total port throughput of province i. The value of the PSI is between 0 and 1. A high PSI value means a high degree of port specialization focusing on a specific cargo type.

3.5. Data collection

According to the "*Rules for the Comprehensive Statistical Report of Ports*" (MOT, 2010), port throughput can be divided into five main types of cargo throughput, namely, containers, solid bulk cargo (e.g., coal, iron ore, bulk grain), liquid bulk cargo (e.g., crude oil, refined oil, liquefied natural gas), general cargo (e.g., timber, bagged cement) and automobiles carried by Ro-Ro ships. According to the China Port Yearbook 2019 (China Ports and Harbors Association, 2020), the port throughput of autos carried by Ro-Ro ships accounts for only 5% of the total port throughput in the Chinese coastal region. Due to this small proportion, we exclude autos carried by Ro-Ro ships from our analysis. Therefore, only solid bulk cargo, liquid bulk cargo, general cargo and containers are the main cargo types analyzed in this paper. It is worth mentioning that we include the port throughput of autos carried by Ro-Ro ships in the analysis of port specialization because doing so ensures the accuracy of the PSI calculation by taking all main cargo types into consideration.

Regarding the data used in our analysis, we collect the port throughput data for the mentioned main cargo types in Chinese coastal provinces from the China Port Yearbooks (2008-2019).

4. Results of analysis

4.1. Evolution of market shares

The Chinese port system has witnessed dramatic growth in the past four decades under the umbrella of a booming economy (Notteboom and Yang, 2017). Fig. 2 provides the evolution of the port throughput for the four main cargo types from 2007 to 2018 for the eleven Chinese coastal provinces. Although the average year-on-year growth rate in the study period was over 7%, it is very obvious that the growth was already relatively weak between 2014 and 2018, especially in 2015, and the total port throughput of the main cargo types in coastal provinces increased by only 1.37% relative to that in 2014. This observation indicates to a great extent, that the Chinese port system has evolved into a new development phase characterized by slow throughput growth.

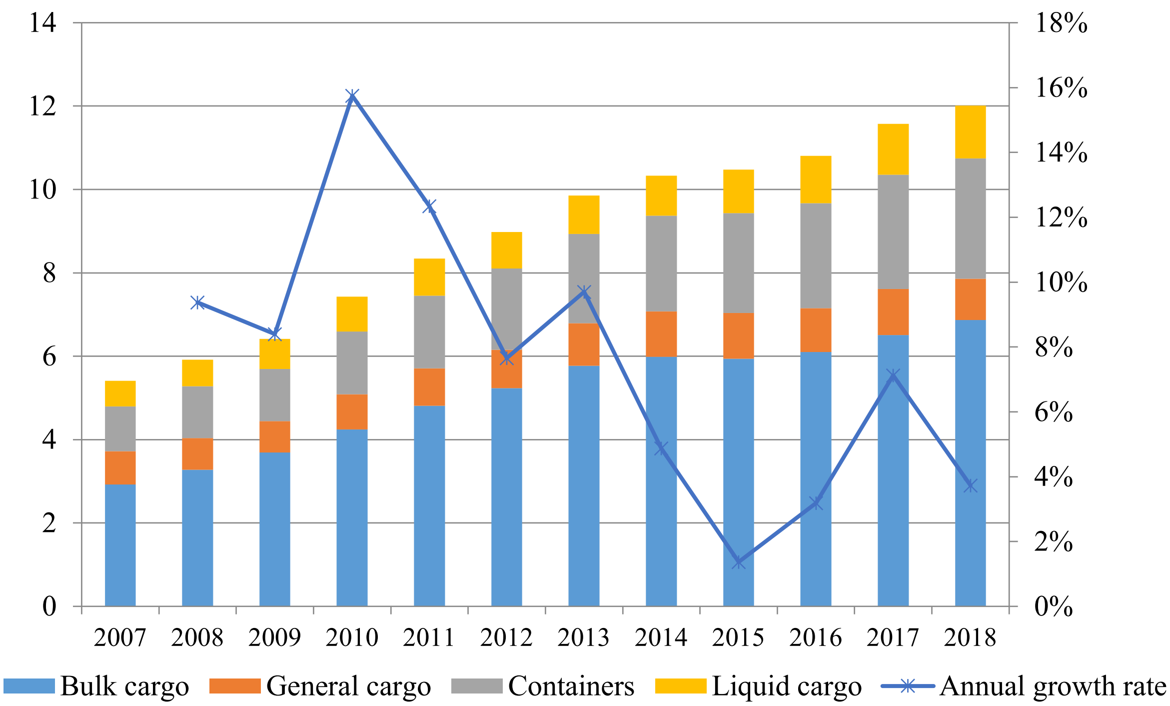

Fig. 2. Total port throughput of the main cargo types in Chinese coastal provinces (billion tons)

In terms of the breakdown of port throughput, solid bulk cargo throughput has continuously accounted for over half of the total port throughput (see Fig. 2). This is because China, as the world's manufacturing center, imports massive amounts of bulk raw material from other counties every year. For example, over 1 billion tons of iron ore were imported into China in 2018, which accounted for 71% of the global maritime iron ore trade (UNCTAD, 2019). The proportion of container throughput in total port throughput is the second highest, which is attributable to the large scale of containerized trade. According to the MOT (2019), the container throughput of Chinese seaports was over 222 million TEUs in 2018. Compared with the throughputs of solid bulk cargo and containers, the liquid bulk cargo throughput and general cargo throughput make up relatively small shares of total port throughput. Since 2016, the throughput of liquid bulk cargo has exceeded that of general cargo because of the stable development of the liquid chemical industry across the Chinese coastal regions in recent years.

To further illustrate the spatial distribution of cargo across the Chinese coastal regions from a provincial perspective, column charts (see Fig. 3) present the market shares of each coastal province in specific cargo segments over the years. It is easy to see that the spatial distributions of the throughputs differ significantly across the main cargo market segments. Specifically, some provinces account for a large proportion of the total throughput in one cargo sector, while their market shares in other sectors are quite low. Moreover, some provinces have continuously increased their market shares in one or more sectors, while others have gradually lost their market shares to different degrees. For instance, Shanghai has always held a leading market position with massive container throughput volumes, but its market shares in the bulk, general and liquid bulk cargo segments are considerably low. What is more critical for Shanghai is that its market shares in all segments have declined to an extent. Between 2007 and 2018 (the study period), Shanghai's market share fell from 23% to 17% in the container sector, from 7% to 3% in the solid bulk cargo sector, from 11% to 5% in the general cargo sector and from 5% to 3% in the liquid bulk cargo sector. Another example is Jiangsu Province, which has had excellent market performance in the solid bulk, general and liquid bulk cargo sectors. In particular, Jiangsu Province consistently accounts for more than 30% of the total general cargo throughput every year, which absolutely ensures its prime position in the market. However, Jiangsu performs poorly in the container sector, with market shares of less than 10%. Hebei Province is another striking example; it accounts for nearly 15% of the total solid bulk cargo throughput in the Chinese coastal regions, consistently ranking third after only Jiangsu and Zhejiang, whereas it only accounts for a small proportion of the market in the other three cargo segments. It is also worth mentioning the significant increase of Shandong's market share climbing from 10% to 20% between 2007 and 2018 in the liquid bulk cargo sector, which is greatly dependent on the rapid development of petrochemical industry in the province. According to the data disclosed by People's Daily Net (2020), the output value of Shandong's chemical enterprises above designated size accounted for 17% of national total value in 2019, maintaining the first place in the country.

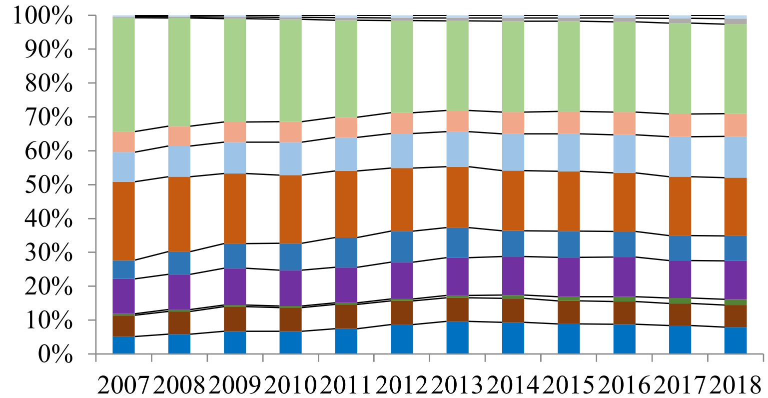

Fig. 3a Market shares in the container sector

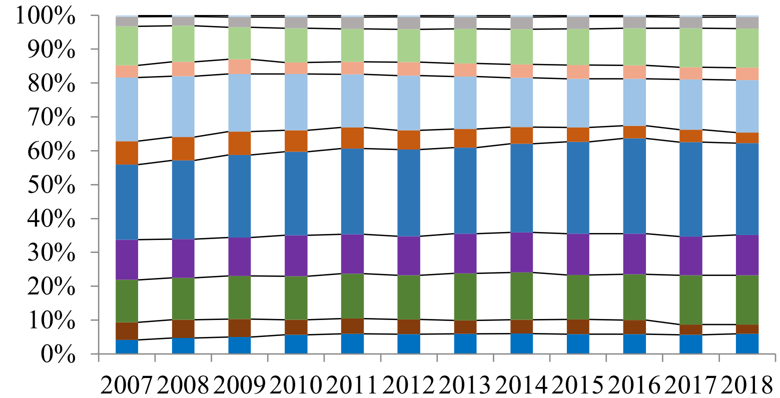

Fig. 3b Market shares in the solid bulk cargo sector

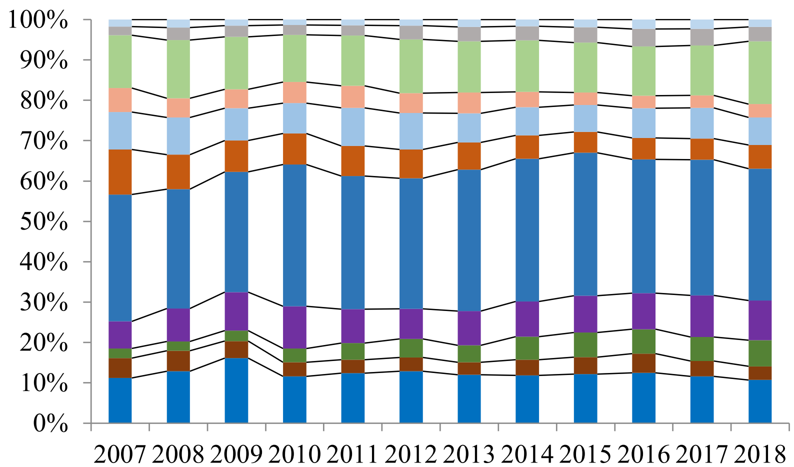

Fig. 3c Market shares in the general cargo sector

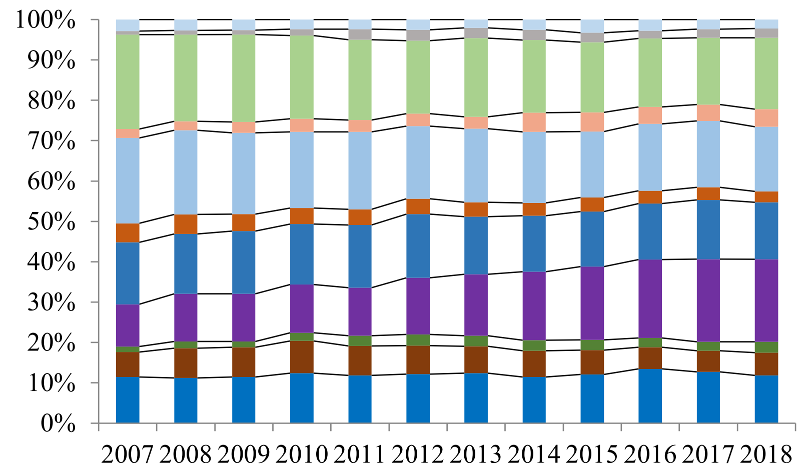

Fig. 3d Market shares in the liquid bulk cargo sector

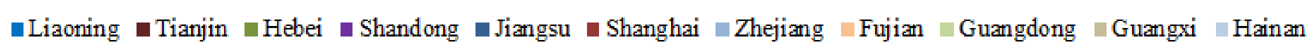

Fig. 3. Market shares of the coastal provinces in specific cargo segments

4.2. Evolution of cargo concentration

As a widely used indicator for displaying the level of market concentration, the HHI for the port throughput of the four main cargo types is measured for the Chinese coastal provinces (see Fig. 4). Fig. 4 shows that in general, the cargo concentrations are quite low, ranging between 0.13 and 0.2, which indicates a rather competitive port market in China.

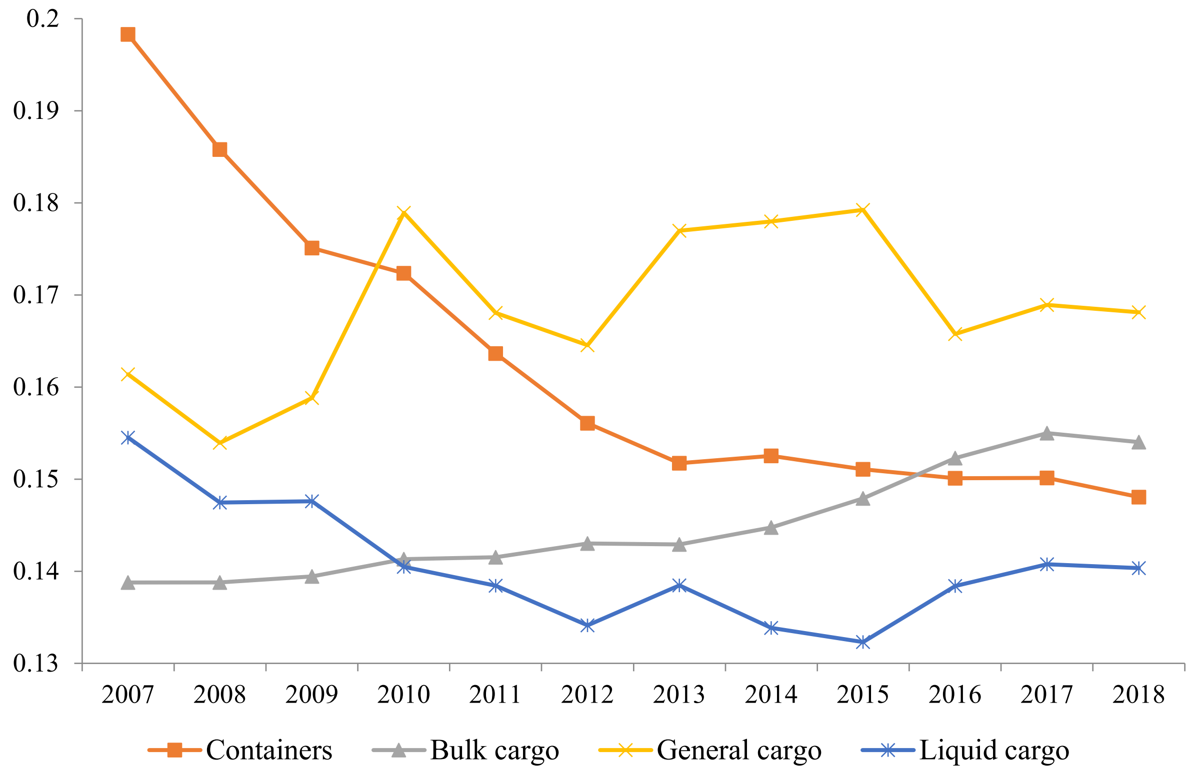

Fig. 4. HHI for eleven Chinese coastal provinces in different cargo segments

As Fig. 4 shows, it is obvious that the HHIs differ considerably across the different cargo market segments. More specifically, the HHI of the total container throughput for Chinese coastal provinces has continuously and obviously declined, which denotes to a great extent that the Chinese coastal region has experienced a steady trend towards cargo de-concentration. The HHI has been below 0.15 since 2012, indicating that the interprovincial competition among coastal provinces in the container sector is quite fierce and has a low level of market concentration.

Compared to that of container market, in the solid bulk cargo sector, the HHI increased modestly from less than 0.14 to more than 0.15, which indicates that the bulk market underwent a phase of moderate concentration during the study period. The slight increase in the HHI is closely related to the growing market shares of the top-ranked provinces. Fig. 3b shows that the combined market share of the top four provinces in the system increased from 65% to 69% between 2007 and 2018.

The market concentration level for general cargo fluctuates within a relatively stable range from approximately 0.16 to 0.18. It is easy to see that the average HHI for general cargo throughput was slightly higher than the average HHI for the port throughputs of the other cargo types in our study period. Compared with the low cargo concentrations in other sectors, the market concentration in the general cargo sector is moderate.

Similar to the container segment, the liquid bulk cargo sector has witnessed a modest trend towards cargo de-concentration. The HHI fell from 0.155 to 0.134 over the period 2007-2012. However, in recent years, the concentration level for liquid cargo throughput has been maintained at a stable level with the annual HHI fluctuating slightly around 0.135. This low level of concentration means that the liquid cargo market is competitive. According to Fig. 3d, there were five provinces (i.e., Liaoning, Shandong, Jiangsu, Zhejiang and Guangdong) that consistently occupied more than 10% of the total liquid cargo throughput.

4.3. Evolution of the port hierarchy

Fig. 5 presents the log-throughput versus log-rank plots for Chinese coastal provinces in the main cargo sectors, an application of the rank-size rule regression. The straight lines on the black points indicate Zipf's law, which means that the port system is characterized by a Pareto distribution. Strictly speaking, deviations from Zipf's law exist to different extents in each cargo segment as shown in Fig. 5, indicating a non-optimal allocation due to over- or under-agglomeration. What should be emphasized is that Zipf's law provides a theoretically optimal rank-size distribution in mathematics according to the volumes of the coastal provinces' port throughputs, without accounting for differences in the natural resources endowments or economic development levels of each province.

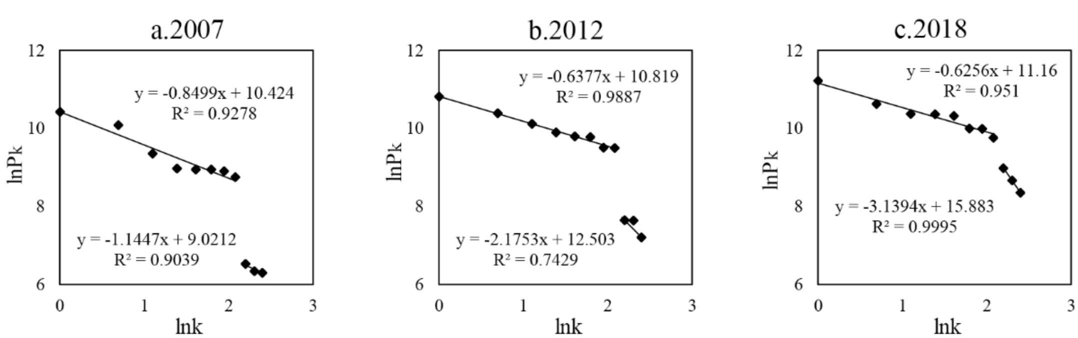

Fig. 5a. Rank-size distribution in the container sector

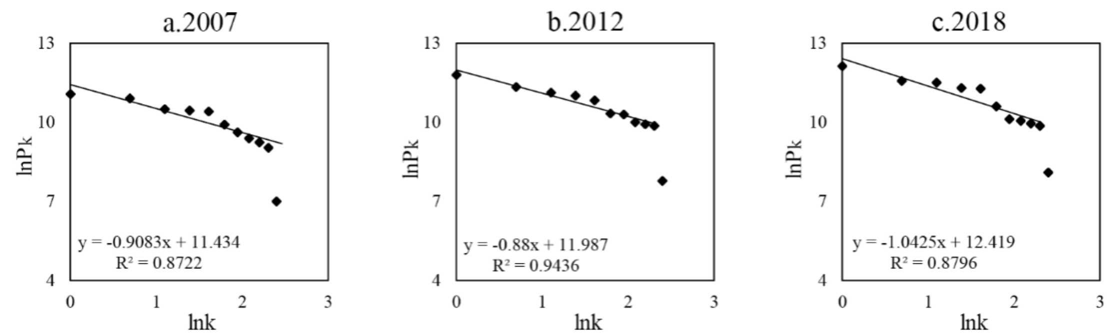

Fig. 5b. Rank-size distribution in the solid bulk cargo sector

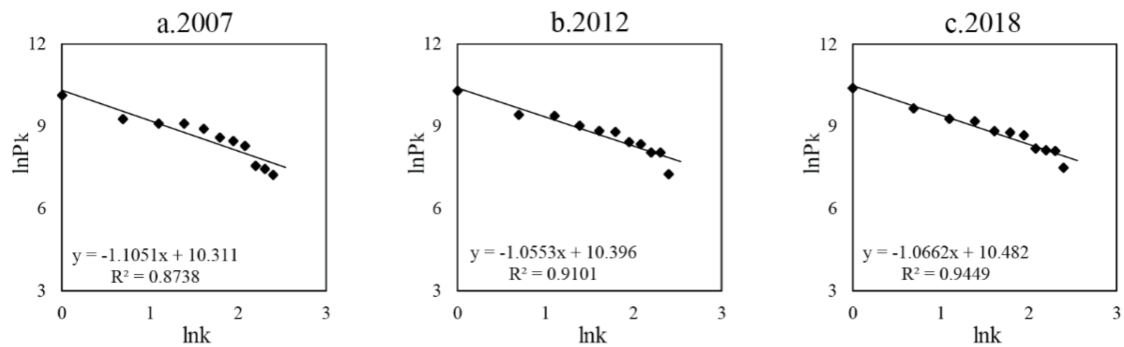

Fig. 5c. Rank-size distribution in the general cargo sector

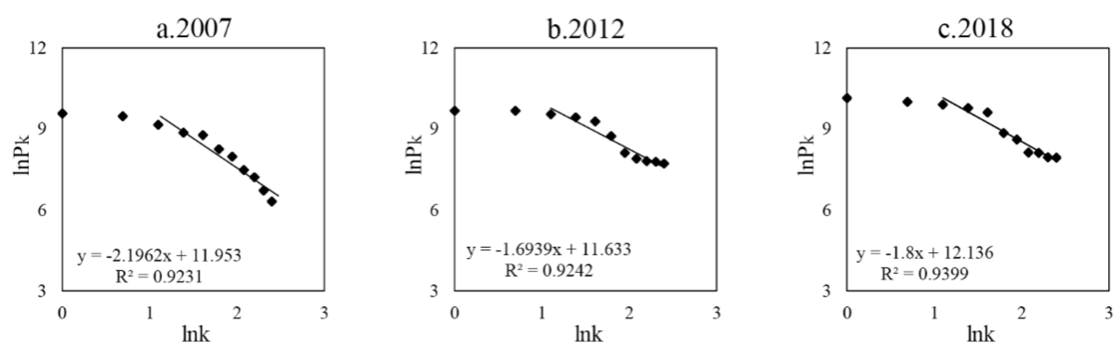

Fig. 5d. Rank-size distribution in the liquid cargo sector

Fig. 5. Rank-size distributions of the Chinese coastal provinces in specific cargo segments

Fig. 5 clearly shows that the rank-size distributions of the coastal provinces also differ significantly across cargo segments. Specifically, the container sector features a bi-fractal structure (see Fig. 5a). In detail, the rank-size distribution of the high- and middle-ranked provinces is distinct from that of the low-ranked provinces. This is mainly because the container throughput volumes in the low-ranked provinces (i.e., Hebei, Guangxi, Hainan) are much smaller than those of the high- and middle-ranked provinces.

In the solid bulk cargo sector, except for the lowest ranked province, the other provinces roughly conform to Zipf's law (see Fig. 5b). Notably, the lowest ranked province (i.e., Hainan Province) is very under-sized. There is a huge gap between Hainan's actual throughput and its theoretically optimal throughput in the sector. According to our data, Hainan's solid bulk cargo throughput accounts for less than 1% of the total solid bulk cargo throughput of Chinese coastal provinces.

Empirically speaking, Zipf's law basically holds for all provinces in the general cargo sector, where the Zipf exponent is nearly equal to one (see Fig. 5c). Therefore, the concentration ratio is almost equal to the dispersion ratio regarding the throughput distribution. This means that the throughput differences among the high-, middle- and low-ranked provinces are reasonably hierarchical.

In the liquid cargo sector, Zipf's law is to some extent applicable to the rank-size distribution of the coastal provinces. However, it is obvious that the actual port throughputs of the first- and second-ranked provinces are much smaller than the theoretical volumes required by Zipf's law (see Fig. 5d). Consequently, the throughput gap between these higher-ranked provinces and the lower-ranked provinces is narrow. Since conformity with Zipf's law implies an optimal allocation of resources, the under-throughput of the top-ranked provinces indicates a possible loss of agglomeration economies.

4.4. Evolution of port specialization

To evaluate the specialization level of the port system in each coastal province, PSIs are calculated and presented (see Fig. 6). One can observe that Hebei Province is unique in China, with considerably high PSI values over 0.7, which means that the degree of specialization in Hebei's port system is significant. In comparison, the PSIs of the other coastal provinces were generally below 0.5. Among these other provinces, Liaoning and Hainan had low degrees of port specialization degrees, with the PSI values less than 0.1, indicating that the throughputs of the main cargo types are balanced.

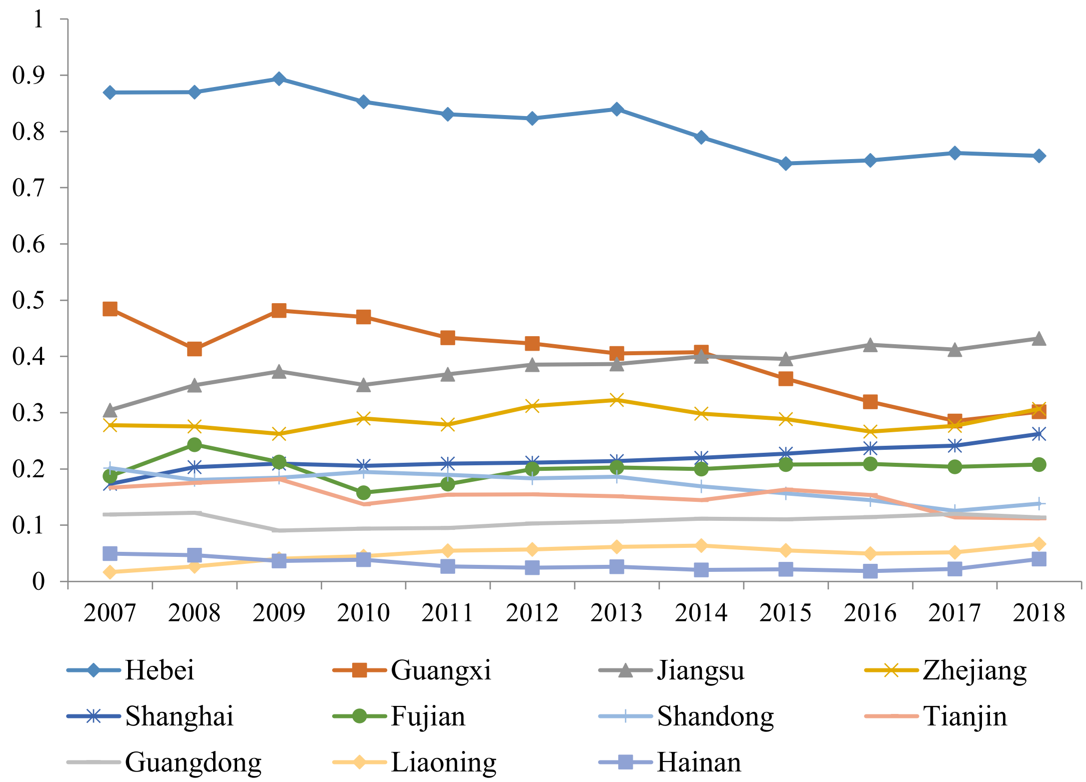

Fig. 6. The PSI of each Chinese coastal province (2007-2018)

The high degree of port specialization degree in Hebei is mainly because the three main seaports in Hebei (i.e., Qinhuangdao Port, Tangshan Port and Huanghua Port) are all major Chinese coal loading and unloading ports (Wang and Ducruet, 2014; Wang et al., 2018a). In particular, Qinhuangdao Port is the world's largest coal loading port. In 2018, the coal throughput in Qinhuangdao Port was over 200 million tons. In addition, Huanghua Port's coal throughput also exceeded 200 million tons, only slightly less than that of Qinhuangdao Port. From the perspective of transportation geography, it is worth noting that the coal transport corridors connecting Hebei's seaports and the major coalfields of three large coal producing provinces (i.e., Shanxi, Shaanxi, and Inner Mongolia) are short in terms of geographical distance and are already well developed with dedicated railway lines such as Da-Qin (Datong-Qinhuangdao), and Shen-Huang (Shenmu-Huanghua) (see Fig.7). In recent years, driven by the national strategy of coordinating the development of the Beijing-Tianjin-Hebei region, Hebei Province has tried to optimize its port system by developing port markets for other cargo types such as containers. For example, the container throughput in Hebei increased from 0.49 million TEUs in 2007 to 4.26 million TEUs in 2018. If measured by weight, the proportion of container throughput to Hebei's total throughput rose from 1.71% to 5% over the period studied. Hence, modest de-specialization is observed in Hebei.

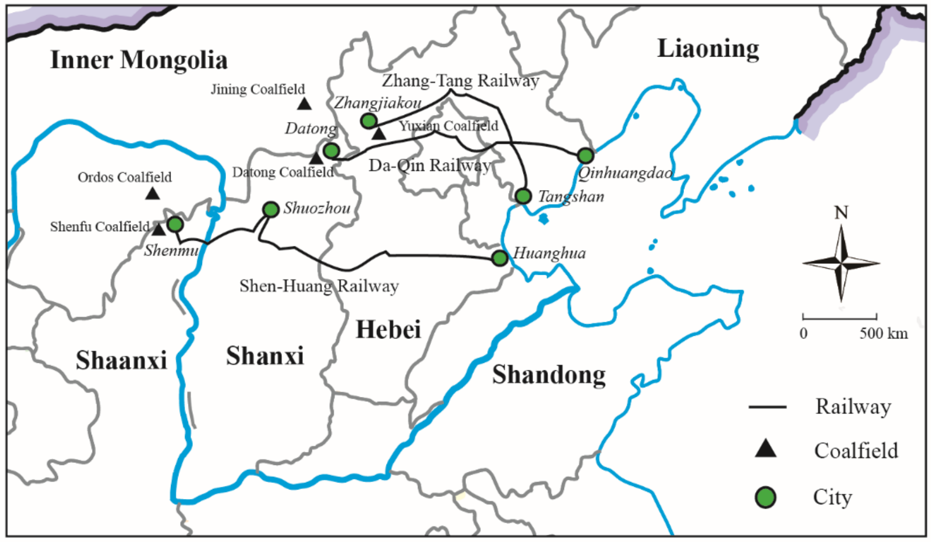

Fig. 7. Railway lines connecting Hebei's seaports and major inland coalfields

5. Discussion: policy implications for provincial port groups

In China, although the governance principles of port devolution laid down in the Port Law of 2004 are still standing (Notteboom and Yang, 2017) in the domain of port administrative management, port integration in recent years has actually led to port recentralization in the business field of port operation (Chen et al., 2020). With the rise of port integration, provincial port groups have become critical market players in the Chinese port industry. These port groups have substantial control over the main local port companies at the city level though equity transfer agreements under port integration schemes. Coordinating local port companies' businesses, reducing intense inter-port competition, developing the port industry and supporting local economic development in the provincial jurisdictions are important missions for provincial port groups. Accordingly, port competition has been found to evolve from the inter-port level to the interprovincial level (Zheng et al., 2020). Therefore, it is necessary for these port groups to gain an understanding of the evolution of the Chinese coastal port system from a provincial perspective, which is beneficial for the adoption of suitable business strategies for the future port development. Based on the above analysis of the evolution of market shares, cargo concentrations, the port hierarchy and port specialization in Section 4, several policy implications can be elaborated upon for Chinese provincial port groups.

First, from the analysis of the spatial throughput distributions in the main cargo segments, we can learn that the market performance of coastal provinces varies widely within a specific cargo market, and the performance of a specific province also differs greatly across different markets (see Section 4.1). This kind of heterogeneity might be caused by various factors, such as differences in economic development levels, natural resource endowments, geographical conditions and the effects of path dependence on port development. Our data clearly show that no province holds a prime position in all cargo sectors. In contrast, several provinces hold leading positions in one or two sectors. Take Shanghai as an example, driven by the national strategy of constructing the Shanghai international shipping center, Shanghai International Port Group (SIPG) has made full use of Shanghai's favorable geographical location as the main gateway to the Yangtze River and has placed great emphasis on container traffic (Veenstra and Notteboom, 2011; Wang and Ducruet, 2012). Due to the focus on the development of container terminals, SIPG has experienced declines in its market shares in the other cargo sectors.

Second, although the establishment of provincial port groups can mitigate inter-port competition in provincial jurisdictions to a great extent, port competition at the interprovincial level is still fierce, which is demonstrated by the low HHI values in our analysis (see Section 4.2). This finding can greatly clarify the concern that provincial port integration may lead to monopolies in the port industry (Zhang and Yin, 2018). For provincial port groups, determining how to compete with other port groups, especially neighboring port groups, is a major concern. For the nation, how to further coordinate the businesses of the provincial port groups is an important issue associated with regional coordinated development. In this context, port co-opetition (Song, 2003), a combination of competition and cooperation, can be observed in the Chinese coastal region. A representative example is the co-opetition among the three provincial port groups in the Yangtze River Delta, namely, SIPG, Zhejiang Provincial Seaport Investment & Operation Group (ZJ-PSIOG) and Jiangsu Port Group (JSPG). In order to compete with the leading market position that SIPG holds in the region and strengthen their attractiveness to local container cargo, both ZJ-PSIOG and JSPG have continued to increase their investment in container terminals. For instance, ZJ-PSIOG has enhanced the container handling capacity of Ningbo-Zhoushan port by implementing projects to expand container terminals. JSPG has begun to build a new container terminal in Tongzhou Bay, which is expected to have port capacities of over 15 million TEUs by 2025. Along with the competition, business cooperation is also emphasized by these port groups.

For example, ZJ-PSIOG and SIPG have reached a cooperative agreement on joint investments and operations in the Yangshan deep-water port. In 2018, ZJ-PSIOG added 5 billion yuan to SIPG's wholly owned subsidiary Shanghai Shengdong Container Terminal Co., Ltd. (SDCTC), which is the main operator in Yangshan port. After the capital increase, ZJ-PSIOG held 20% of SDCTC's overall shares; the remaining shares were still held by SIPG.

Third, from the view of the optimal port hierarchy (see Section 4.3), the rank-size distributions of the coastal provinces in the cargo segments need to be optimized, especially in the container, solid bulk cargo and liquid cargo sectors. Some provinces are under-sized, with huge gaps between their actual throughputs and theoretically optimal throughputs. According to Zipf's law, under-throughput indicates a possible loss of agglomeration economies. However, it should be noted that provincial under-throughput has many causes, such as under-developed economies, special industrial structures, unfavorable geographical locations and shortages of natural resources, which are difficult to change in the short or even long term. Compared to local port companies at the city level, provincial-level port groups in under-sized provinces are more motivated to improve their port capacities and achieve larger volumes of port throughput. This is mainly because provincial port groups in China are commonly entrusted by provincial governments with the development of the local port industry in their jurisdictions, and they have greater ability to gain financial and policy support from governments. Take Guangxi as an example, it is a typical under-sized coastal province with small port throughput volumes. In recent years, the Beibu Gulf Port Group (BGPG), the port integrator in Guangxi, has increased investment in the port infrastructure and corridors connecting the seaports and China's vast western inland regions. Benefitting from the implementation of the national strategy of developing new western land-sea corridors, the port hinterland of BGPG has expanded to Western China, and its throughput has grown rapidly, especially in the container sector. In 2019, BGPG's container throughput increased by 28.62% to over 4 million TEUs.

Fourth, the degree specialization in the Chinese provincial port systems is generally moderate except in Hebei Province, which has an obviously high level of specialization (see Section 4.4). According to our analysis, it is clear that the high level of port specialization in Hebei is closely related to its special geographical location. The case of Hebei is not universally representative. Most provinces have multi-functional port divisions with comprehensive capacities for various cargo segments. Note that keeping multi-functional port divisions does not mean that provincial port groups provide absolutely balanced port capacities across the different cargo sectors. In fact, it is critical for provincial port groups to achieve a careful balance between functional port divisions with a reasonable port layout. Take SIPG as an example, SIPG has not totally given up its market shares in other cargo segments, although it has placed significant emphasis on the container segment. This is mainly because provincial port groups take on the mission of providing essential port capacities to handle diversified cargo types with the aim of meeting the various transportation demands of local economic development.

6. Conclusion

Port system evolution has been widely addressed by researchers since the 2000s, though few studies have enlarged the geographical scales of their basic units of analysis from individual ports to sub-regions of a port system, or have focused on multiple cargo types rather than a specific cargo type. Against the background of provincial port integration in China and the potential consequent shift in port competition from the inter-port level to the interprovincial level, this paper reviews the evolution of the Chinese coastal port system in terms of four main cargo types (i.e., containers, solid bulk cargo, general cargo and liquid cargo) by analyzing four aspects associated with the port system (i.e., market shares, cargo concentrations, the port hierarchy and port specialization) from a provincial perspective. Moreover, several policy implications based on our analysis are elaborated upon for Chinese provincial port groups. Specifically, first, since a province is hard to hold leading positions in all cargo sectors, it is a wise option for provincial port groups to take comparative advantages by focusing on specific sectors. Second, port co-opetition can be adopted by provincial port groups as a business strategy to handle the relationship with other port groups, especially neighboring ones. Third, provincial port groups, in those under-sized provinces with small volumes of port throughput, should make full use of their abilities at the provincial level to facilitate local port development. Fourth, in order to better meet various demands of local economy regarding port services, provincial port groups should have multi-functional port capacities.

With regard to the international relevance of this paper in a general sense, it is mainly reflected in two aspects. First, using multiple methods to analyze the port system evolution from different perspectives can provide a comprehensive understanding of a port system. In this study, four quantitative approaches are utilized to investigate the evolution of market shares, cargo concentrations, the port hierarchy and port specialization in Chinese coastal port system.

Undoubtedly, these methods can also be adopted when analyzing other port systems. Due to the heterogeneity among port systems with different geographical characteristics, throughput volumes, hinterlands capture areas and port governance structures, the results from the quantitative analysis of this paper may not be exactly applicable to other port systems. However, they enable future comparative studies on port systems from different countries and regions by using same methods. Second, port integration with mergers has been observed in more and more countries worldwide. The formation and development of Chinese provincial port groups to a great extent show the feasibility of coordinating neighboring ports through mergers, which can hold lessons for other countries considering similar moves. From the current consequence of provincial port integration in China, it cannot be concluded that a provincial model is likely to lead to a more balanced and unconcentrated port system across all cargo sectors in a national scope, although the cargo concentrations are quite low. However, we can infer from our findings that port integration contributes to more reasonable multi-functional port divisions in a provincial scope.

Regarding a future research agenda, the following appear to be candidates: (1) New quantitative methods can be introduced to measure more aspects of a port system with the aim of gaining a much deeper understanding of port system evolution; (2) It is necessary to establish causality between port integration and evolutionary processes of a port system; (3) The impacts of port integration on regional and national port systems need to be investigated more profoundly; (4) Comparative studies should be conducted on port systems from different countries and regions, especially these places where port integration has risen.

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