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The Effects of Seaport-Inland Port Dyads on Container Seaport Hinterland Delimitation

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ABSTRACT

The emerging seaport-inland port dyad contributes greatly to the development of seaport hinterlands. However, little research has examined its influence on container hinterland delimitation. This paper used an improved radiation model to study the effects of seaport-inland port dyads on the container seaport hinterland delimitation in the context of a Chinese multi-port system. The radiation of each seaport was estimated to track changes in the seaport superior hinterlands and hinterland ratings and discover the patterns of the effects. The results show that the formation of dyads expands the scope of superior hinterlands and improves the hinterland ratings of seaports. The provinces close to inland ports and far from seaports were significantly affected and the same inland port influenced seaports differently. These results demonstrate that establishing a seaport-inland port dyad is a good way to compete with other seaports for larger market shares. These different effects can serve as a guideline for seaport authorities to choose suitable dyads to achieve their hinterland targets.

KEYWORDS

hinterland; inland ports; seaport-inland port dyad; radiation model.

1. INTRODUCTION

Inland ports usually enhance the connection between seaports and inland areas. With the continuing development of the inland port, a cooperation partnership between some seaports and inland ports has formed. This forms the seaport-inland port dyad. In a dyad, a seaport and an inland port are two nodes in a transport network, with a rail transport link connecting them [1]. These dyads realise a win-win situation for inland ports and seaports in which an inland port can be enlarged by getting support from seaports [2] while also facilitating cargo aggregation for seaports [3], providing multimodal transportation services by using transport corridors.

The seaport-inland port dyad can be categorised into two types based on two different kinds of connection as shown in *Figures 1 and 2*. The first type is a private dyad that connects a seaport with its privately-operated inland port. This type of inland port refers to an inland port run by port authorities, operators in port or ocean carriers [1]. Therefore, the transport corridors in the first dyad only serve this seaport and provinces around inland ports. The second type is a public dyad that connects a seaport and a shared port. This type of inland port tends to be run by the market, government and together with multiple seaports [2]. For example, a famous public inland port, the Xi'an International Inland Port, located in the Shanxi province of China, acts as a shared port and connects with multiple ports including Tianjin Port, Lianyungang Port, Shanghai Port, Qingdao Port and Shenzhen Port [4].

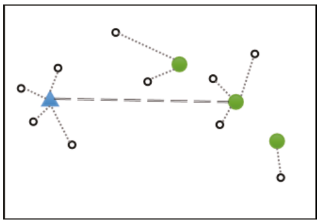

Figure 1 – The schematic diagram of a private dyad

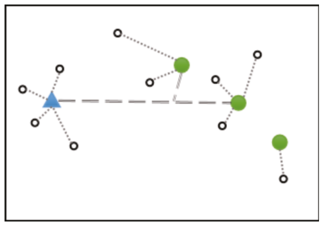

Figure 2 – The schematic diagram of public dyads

Considering the construction expenses, cooperating with public inland ports for seaports is seen as more cost-effective than building a new private inland port. Therefore, most seaports prefer cooperating with public inland ports. However, it is not an easy task for port authorities to choose a suitable inland port to cooperate with because dyad redundancy may cause a waste of resources. In this regard, several key problems that port authorities are concerned about remain underexplored: what changes occurred in the seaport's hinterlands after collaborating with inland ports? Is forming dyads beneficial for seaports to compete for a larger part of the market than conventional models? If this action is not beneficial, what are the changes in the influence of seaports on provinces after forming dyads?

Although the changes these dyads create on seaport hinterlands have been analysed qualitatively in academic literature (e.g. enlarging the scope of hinterlands), few studies have measured the effects quantitatively. A model that can quantitatively capture the effects of dyads on the seaport hinterlands is needed. To fill this research gap, in this paper we intend to measure hinterland delimitation and provide guidance for seaports to make feasible hinterland strategies. Instead of the traditional gravity models, we propose an improved radiation model that considers the impact of all provinces within a radius of the distance from the seaport to the hinterland. Using the data from a multi-port system in China, we demonstrate the differences in hinterlands after considering inland ports and compare these hinterlands with the traditional situations. Based on the radiation results of seaports, we identify the superior hinterlands of seaports. The superior hinterland of a seaport is a new concept we proposed, which is the seaport that holds the most significant market share in these regions. This term focuses more on the superior position of the seaport and is more appropriate to show a hinterland with multiple competing seaports than regular hinterlands. To study the changes in the hinterlands of seaports, we further analyse the radiation of a particular seaport in different provinces and observe seaport hinterland ratings (weaker radiation, weak radiation, strong radiation and stronger radiation). To the best of our knowledge, this was the first detailed analysis of China's multi-port system under this dyad, in which we discussed the changes and came up with some strategies which may help seaports make smart decisions.

This paper contributes to the existing literature to better understand the influences of seaport-inland port dyads on seaport hinterlands quantitatively. The radiation model we proposed in this paper is perhaps the first endeavour in this regard to solve the delimitation of port hinterlands. The evaluation of the influences derived from the partial dyads could help seaports to compare the benefits caused by different dyads. For a long-term perspective, the changing patterns as summarised in this paper could guide seaport authorities to make hinterland strategies, such as investments in inland ports and/or the layout of hinterland networks.

The rest of the paper is organised as follows. Section 2 provides a literature review of seaport-inland port dyads and effects on hinterlands, and the studies done on hinterland delimitation and methods. Section 3 contains the analytical steps of the methodology. The case study is presented in Section 4, and Section 5 summarises and concludes the paper.

2. LITERATURE REVIEW

2.1 Studies of seaport-inland port dyads and effects on hinterlands

Studies find that inland ports contribute to disburden seaport storage capacities [5], promote the growth of city-port container volumes [6], and enhance seaports' competitiveness [7]. Therefore, some experts point out that enhancing the connection between seaports and inland ports could be a promising strategy for seaports to exploit new markets, such as cooperating with existing inland ports or establishing new ones [8–9]. Bask et al. [1] proposed a conception of seaport-inland port dyads to describe this kind of connection between seaports and inland ports. In addition, they cited two cases from Finland and Sweden to illustrate the development of seaport-inland port dyads. It was the first time that inland ports and seaports were discussed as integral rather than separate entities.

Studies further surveyed some dyad cases to investigate the dynamics of seaport-inland port dyads. Roso et al. [10] interviewed three seaport-inland port dyads to collect the services provided by inland ports in dyads. The results showed that three inland ports in dyads attracted more freight and created more considerable customer value by transit. Santos & Soares [11] focused on analysing seaport-inland port dyads in the Portuguese range, noting that several dyads were in operation or under formation. They argued that seaport authorities should, as far as practicable, support the development of transport corridors and inland ports. These studies show that prompting the formation of seaport-inland port dyads is beneficial for seaports. However, blindly pursuing a closer relationship between the seaport and inland port and forming dyads seems unwise. A two-period game was proposed by Wang et al. [12–13] to help seaport and inland port authorities to manage risk in seaport-inland port systems. They noted that seaports should be examined more carefully to establish the link between seaports and inland ports.

Although existing literature highlights the benefits of seaport-inland port dyads and the importance of establishing suitable ones, only few studies quantitatively investigate the influence of existing dyads on seaport hinterlands. Therefore, this paper intends to study the detailed changes in seaport hinterlands after considering dyads in a Chinese multi-port system and help seaport authorities in choosing suitable inland ports to cooperate with.

2.2 Studies of hinterland delimitation and research models

Researchers have widely discussed the definition and division of economic hinterlands in the process of port regionalisation to analyse port and regional economy. Feng [14] indicated that port hinterlands can be classified into direct and indirect hinterlands based on the port's influential scope. Rodrigue et al. [15] and Santos et al. [16] endorsed a classification of monopoly hinterlands and competitive hinterlands. A port's hinterland is not a static concept but rather a dynamic one [17]. New trends showed that the share of monopolistic hinterlands of ports is shrinking, and the areas for competition are increasing [18]. Hence, gaining more market shares in hinterlands to face the fierce competition has been one of the most important tasks of seaports. The present paper aims to identify container seaport hinterlands that occupy a superior position than others in a province.

Traditional methods of dividing the economic hinterland of ports include the layers method, pivot and ligament method [19]. These methods usually consider only one element, which cannot reflect the complexity of hinterlands, especially competitive ones. The multi-factor complex division method has recently received attention. The method considers the mutual attraction of seaports and provinces (e.g. gravity model, Huff model) [20, 21] or considers the choice of transportation paths [16, 22]. Although these methods consider more factors than traditional ones, some factors, like inland ports, are not well considered. In addition, research about the influence of other seaports and provinces in hinterland delimitation remains scarce.

The radiation model offers an alternative way of identifying seaport hinterlands. It was initially proposed by Simini [23] to simulate human mobility. In this model, Simini argues that people in the same travel distance have equal mobility possibilities. Therefore, it focuses more on the overall influence of provinces within a same travel distance and is confirmed superior to the gravity model. The model has been widely applied, e.g. in population movement, information flow [23, 24] and highway freight traffic prediction [25]. Because of the similarity between cargo transport and people's movement, this model is also helpful in analysing hinterland delimitation. However, the basic radiation model only considers two factors in analysis, which may fail to capture the objective complexity in this paper. Therefore, we needed to improve it according to certain situations.

3. METHODOLOGY

To determine the scopes of seaport hinterlands, we first identify the influencing factors of seaport radiations to improve the radiation model. In this section, we will explain the detailed calculation of our model parameters.

3.1 Influencing factors of seaport radiation

The strength of seaport radiation depends on the influential strength of seaports and provinces and is affected by many factors. Typically, provinces with greater influences have more demand for cargo transportation, while ports with greater influences have greater freight transportation capability. Therefore, knowing how to measure the influence strength of these two factors is crucial.

To comprehensively evaluate provincial influences, we define three components: infrastructure construction, overall economic strength and logistics development [20, 26–36]. The first two reflect the effects of cities [36, 27]. The last one is vital as our focus is on the flow of goods between provinces and seaports. Therefore, in this part we select the variable of accessibility of the province. It relates to network performance [37] and is one of the most important variables to measure the connection ability between provinces and seaports. The measure of accessibility adopted in this paper was the negative value of total transportation cost from each origin of cargo (load centre) to each container seaport [16]. For each of the three components, we select specific variables based on the existing literature. A list of selected variables is presented in *Table 1*.

Table 1 – Province influence evaluation system

Measure aspects	Specific variables
Infrastructure construction (y_1–y_4)	Land area y_1 Province investment in fixed assets y_2 Province highway mileage y_3 Province railway mileage y_4
Overall economic strength (y_5–y_{17})	Gross regional product (GDP) y_5 Per capita GDP y_6 Per unit area of gross regional product y_7 Total retail sales of consumer goods y_8 General local fiscal budget revenue y_9 Total population y_{10} Registered jobless population y_{11} Population per unit area y_{12} Proportion of the second industrial product y_{13} Second industry output value y_{14} Proportion of the tertiary industrial product y_{15} Tertiary industry output value y_{16} Per capita disposable income y_{17}
Logistics development (y_{18}–y_{25})	Freight tonne-kilometres y_{18} Foreign trade throughput y_{19} Road freight traffic y_{20} Total assets of industrial enterprises above designated size y_{21} Import value of commodities by place of destination and export Value of commodities by place of origin in China y_{22} Number of employees in transportation, storage, post, and Telecommunications y_{23} Accessibility y_{24} Port influence strength (if any) y_{25}

The evaluation of port influence strength largely depends on practical consideration as previous studies usually consider the cargo throughput of seaports only [20, 26–36]. For a seaport, we select two components: seaport infrastructure capacity and infrastructure availability. Seaport infrastructure capacity contains four specific variables to measure the cargo handling ability of a port, while infrastructure availability uses five sets of actual data to capture the port's impacts. The evaluation of inland ports is similar to that of seaports since few studies evaluated the impact of inland ports. A specific port evaluation system is established (*Table 2*).

Table 2 – Port influence strength evaluation system

		Measure aspects	Specific variables
Port influence strength	Seaport	Infrastructure capacity (x_1–x_4)	Yard area x_1 Length of wharf x_2 Port comprehensive capacity x_3 Annual container passing capacity x_4
		Infrastructure availability (x_5–x_9)	Port cargo throughput x_5 Port container throughput x_6 Number of berths in production x_7 Number of berths in production in 10, 000-ton x_8 Length of production wharf x_9
	Inland port	Infrastructure capacity (x_{10}–x_{13})	Inland-port area x_{10} Total project investment x_{11} Planning construction area x_{12} Annual maximum passing capacity x_{13}
		Infrastructure availability (x_{14})	Inland-port throughput x_{14}

3.2 Radiation model of hinterland delimitation

After analysing the above critical influencing factors, this paper proposes an improved radiation model by adjusting the parameters, as shown in *Equation 1*:

$$F_{sp} = F_s \frac{(U_s + \mu \cdot U_k) \cdot U_p}{(U_s + O_{sp}) \cdot (U_s + U_p + O_{sp})} \tag{1}$$

where F_{sp} is the radiation strength of seaport s ($s \in S$) to province p ($p \in P$). F_s is the container throughput of seaport s. U_s is the port influence strength of seaport s, which is affected by multiple factors x_α ($x_\alpha \in X$), representing the comprehensive influence capacity of the seaport. It should be noted that when a seaport and an inland port are linked to each other, the comprehensive influence capacity of seaport s should also consider the combined strength of the inland port U_k in the radiation model. Therefore, we introduce a binary index μ for measuring the usage of seaport-inland port dyads (1 = using, 0 = not using). In practical cases, the total transport cost is a vital consideration for shippers to decide whether to use a seaport-inland port dyad or not. Therefore, the value of this index is calculated based on the path of the minimum transport cost.

U_p is the influence strength of province p, which is affected by multiple factors y_β ($y_\beta \in Y$), representing the comprehensive influence capacity of the province. O_{sp} is the total province influence strength in a circle with s as the origin and a radius based on the distance between province p and seaport s (excluding the source and destination provinces).

3.3 Calculation of model parameters

The determination of U_s, U_p and U_k is the first step of the calculation. After building province and port influential evaluation systems in Section 3.1, we use principal component analysis (PCA) to calculate port influence strength U_s and province influence strength U_p. Principal component analysis (PCA) is one of the most common methods for estimating pattern coefficients. It provides a mathematical solution to make the unobservable components expressed as functions of observable variables [39], which successfully forms a comprehensive parameter to represent a variety of variables [31, 25]. In this paper, we used the PCA of SPSS 20.0 to calculate the influence strength of provinces and ports.

O_{sp} is the sum of the influence strength in the circle with a radius r_{sp} which can be determined after obtaining the value of port influence strength. If a province p is a hinterland of a seaport s, then the provinces within the same distance to the seaport s possibly belong to their hinterlands as well. This parameter (O_{sp}) ensures that the radiation force of seaport s in nearby provinces is larger than that in distant provinces. *Figure 3* shows the framework of methodology in this paper.

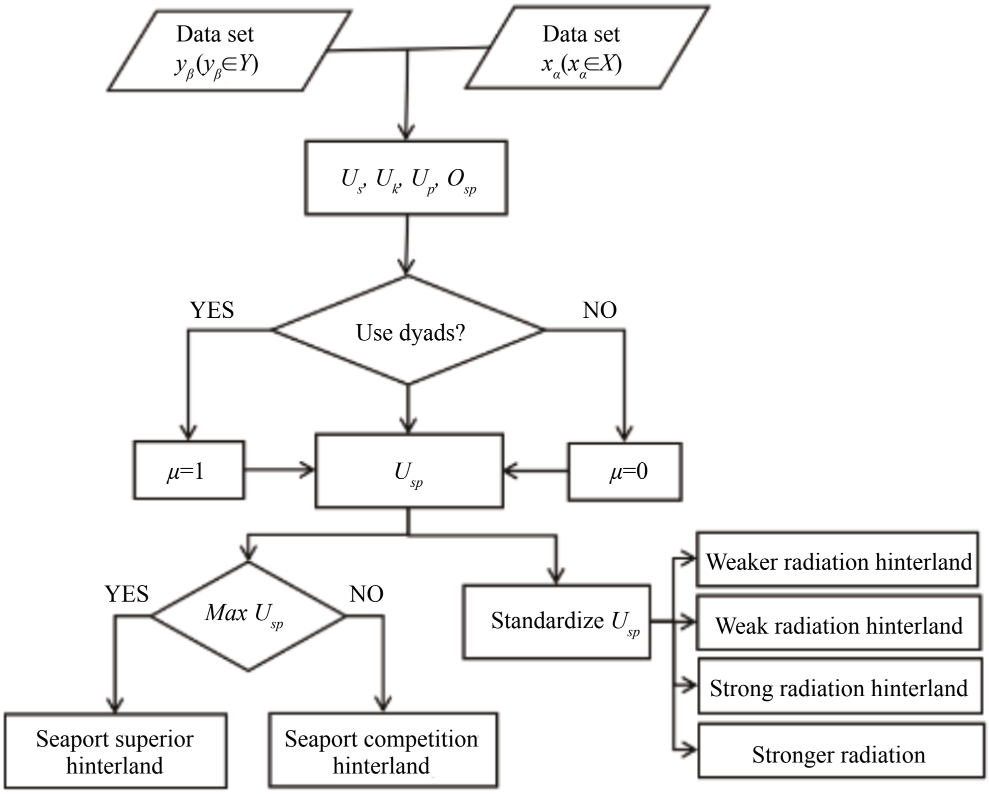

Figure 3 – Methodology for hinterland delimitation of this paper

4. CASE STUDY

In the case study section, we first introduce the object of study and the data sets of this paper. Based on calculations of the improved radiation model, an analysis of the superior hinterlands of multi-seaports and the hinterland rating of single seaports are discussed.

4.1 Data

In this study, we used data from Chinese ports. The geographic scope and detailed ports are presented in *Figure 4* and *Table 3*. The first two public inland ports with the largest cargo volumes were chosen and labelled by X and Y rather than their commercial names. Then we selected seven among the top 20 international seaports in terms of container throughput (2019) and are distributed geographically along the coastal cities of China, labelled from A to G. These seaports have already been working with the two inland ports or planning to do so soon. Ports C and D, F and G are geographically close, and the hinterlands of these ports may overlap, which represents the potential competition between ports. *Table 4* shows the data sources of related variables.

Figure 4 – The objects and geographic scope of this study

Table 3 – The research object sets of this study

Objects	Commercial name	labels
Inland ports	Chengdu Inland Port	X
	Xi'an Inland Port	Y
Seaports	Tianjin Port	A
	Lianyungang Port	B
	Shanghai Port	C
	Ningbo-Zhoushan Port	D
	Xiamen Port	E
	Shenzhen Port	F
	Guangzhou Port	G

Table 4 – The data sources of related variables

Variables	Data sources
y_1~y_2, y_6	Official websites and Annual Statistical Reports of provincial governments
y_3~y_5, y_8~y_{23}	Official website of the National Statistics Office (http://www.stats.gov.cn/tjsj/)
y_{24}	Technical Standards for Highway Engineering JTGB01-2014/2003, International Container Car Transportation Rules, Railway freight rate rules, Regulations on Collection of Port Charges of China, He et al [40] (Respectively container transport speed; inland transit and car transport prices; rail freight prices; loading and unloading charges for seaports)
y_2, y_7	Calculated by the authors
x_1~x_3, x_7~x_9, x_{13}	China Port Yearbook (2016-2018), China Statistical Yearbook (2019), seaport official website (e.g. http://www.lygport.com.cn/, https://www.nbport.com.cn/gfww/), National Statistics Office; Seaport Bond Annual Report (Lianyungang Port)
x_5~x_6	Official website of the Ministry of Transport of China (http://www.mot.gov.cn)
x_{10}, x_{12}~x_{13}	Official website of inland port (https://www.caexp.net, http://cdirs.cdiport.com/)
x_{11}, x_{14}	Related press releases on inland ports

4.2 Seaport superior hinterland

In this paper, we obtained the superior hinterlands of seaports using the improved radiation model. Without considering inland ports, *Figure 5* depicts the superior hinterlands of seaports A through G. When inland ports are considered, the layout of the superior hinterlands of seaports changes, as shown in *Figure 6*.

The results in *Figure 5* can be divided into three parts. The first part includes seaports B, D and E. These seaports have weaker influence strengths compared to other seaports and they only dominate the provinces where they are located. Seaports A and C make up the second group, having a larger scale of hinterlands than the former ones. The two seaports hold most of China due to their strong influence strengths and have a large container throughput, indicating a large number of sailing routes and high sailing frequency.

The last part is more complex than the other two in terms of the fierce competition between seaports F and G. In this part, F occupies more provinces than G, such as Guangdong, Jiangxi, Hunan and so on. This does not mean that G has no market share in these locations, but that G may not have a significant edge over F in these provinces. Interestingly, seaport G wins more market shares in two inland provinces (Sichuan and

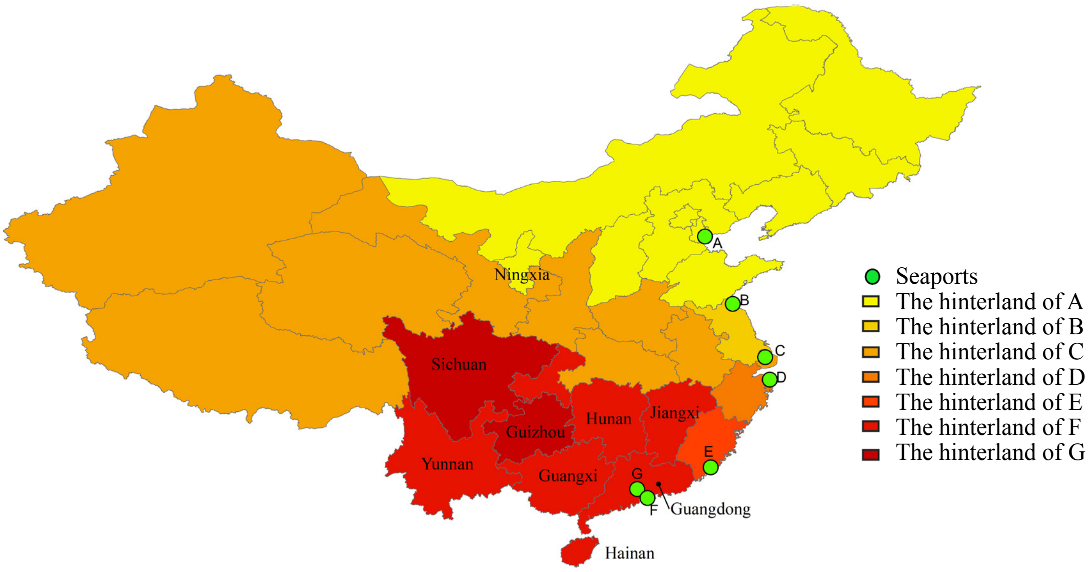

Figure 5 – Superior hinterlands of seaports (inland ports unconsidered)

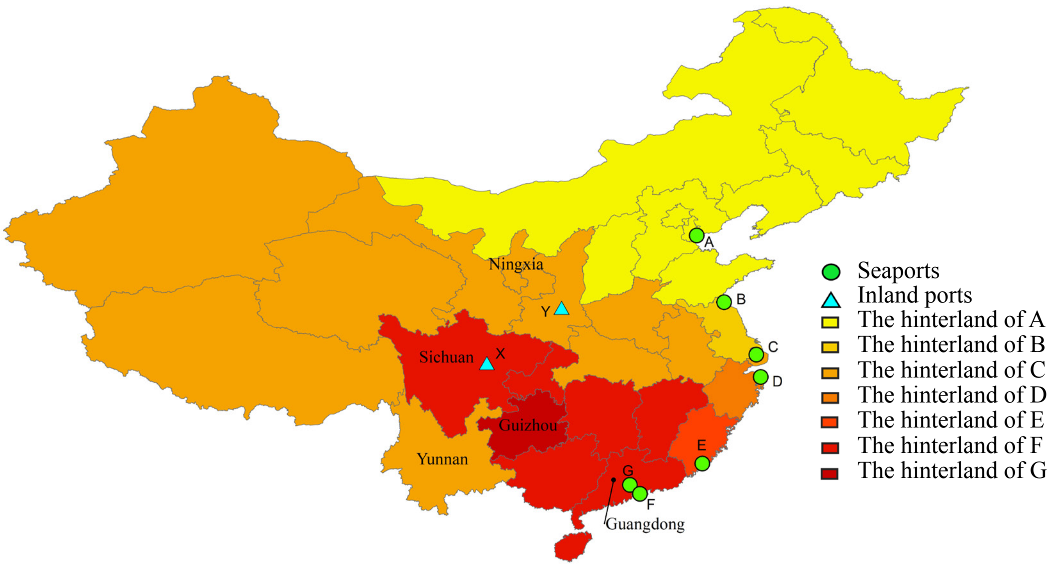

Figure 6 – Superior hinterland of seaports (inland ports considered)

Guizhou provinces) than F. We compared the radiation forces of the two seaports and found that this is due to the slight geographical advantage of G, which is closer to the two interior provinces. Therefore, Sichuan and Guizhou become competing hinterlands for seaports F and G. The two seaports' competitive powers, particularly in Sichuan province, are virtually comparable. It indicates that, when the distance between seaports and provinces is big, the competitive advantages of neighbouring seaports diminish.

Figure 6 shows the effects of seaport-inland port dyads on the superior hinterlands of seaports. The hinterlands of seaports B, D and E are the same as *Figure 1*. Aside from the three ports listed above, other seaports' hinterlands have seen minor changes. To begin with, seaport C increases the Ningxia and Yunnan provinces as its superior hinterlands, expand its scope of superior hinterlands. This suggests that seaport C has benefited by considering the inland ports and forming seaport C – inland port dyads. This action can boost its influence strength but also improve the targeted province's hinterland accessibility. It is also meaningful for the provinces, as a higher level of accessibility could facilitate the centralisation and frequency of freight transport by using the corridors between inland ports and seaports, reducing transport costs. Second, despite losing one piece of the hinterland (Yunnan province), seaport F gained Sichuan province from seaport G. In the previous analysis, we mentioned that seaport F and seaport G are quite competitive in Sichuan province without considering inland ports. The radiation of seaport G was slightly bigger than F. However, when we consider inland ports, the radiation of seaport F in Sichuan province surpassed that of G. This may be because F benefits more from the dyad than G in the radiation in Sichuan province. These differences show the different effects of the same inland port on the seaport hinterlands.

4.3 Seaport hinterland rating

As presented in Section 4.2, the superior hinterlands of seaports have not changed significantly. To study the changes in seaport hinterlands in more details, we further analysed the radiation changes of single seaports. Seaports F and E were chosen because G's superior hinterlands changed significantly whereas seaport E's superior hinterlands remained stable. According to the regular distribution, we set the radiation force of ports F and E to 0-1 and split them into four levels: weaker radiation, weak radiation, strong radiation and stronger radiation.

Figure 7 presents the hinterland rating of seaport F without considering inland ports. The classification is based on geographical distribution. The results show that the closer a province is to seaport F, the stronger F's radiation on the province. *Figure 8* presents the hinterland rating of seaport F when considering inland ports in container transportation. Compared with *Figure 6*, the range of strong and stronger radiation levels of seaport F expands greatly. Seaport F increases in Sichuan province as its superior hinterland (see *Figure 6*). In particular, the changes in the radiation of seaport F in Hebei, Sichuan and Henan provinces are ranked the first, third, and fifth in the top fifteen provinces for radiation growth of F when considering inland ports (see *Figure 9*). For seaports, the radiation growth indicates an increase in their market shares in these provinces. In turn, for the provinces, it shows that the connectivity between provinces and seaports has improved, and the convenience of import and export of goods is enhanced, which is good for revenue generation.

In addition to the changes in seaport F's radiation values, we also discovered that seaport F mostly increases radiation in provinces in or near the two inland ports. If a seaport wishes to expand its radiation force to specific areas, it might opt to build up or collaborate with inland ports that are close to the target provinces. This plan might enable the seaport to gain a competitive advantage in the target province, even surpassing rival seaports and claiming this province as its superior hinterland. It should be noted that this division of radiation force for a single seaport does not mean that the absolute ownership of seaport F in these provinces is the largest, but a close relationship between F and these provinces. Taking Hebei province as an example, even though the radiation force of F with the dyad developed increases by 236.08% compared to before, the province still belongs to seaport A's superior hinterlands, which is the closest seaport to Hebei. But this huge

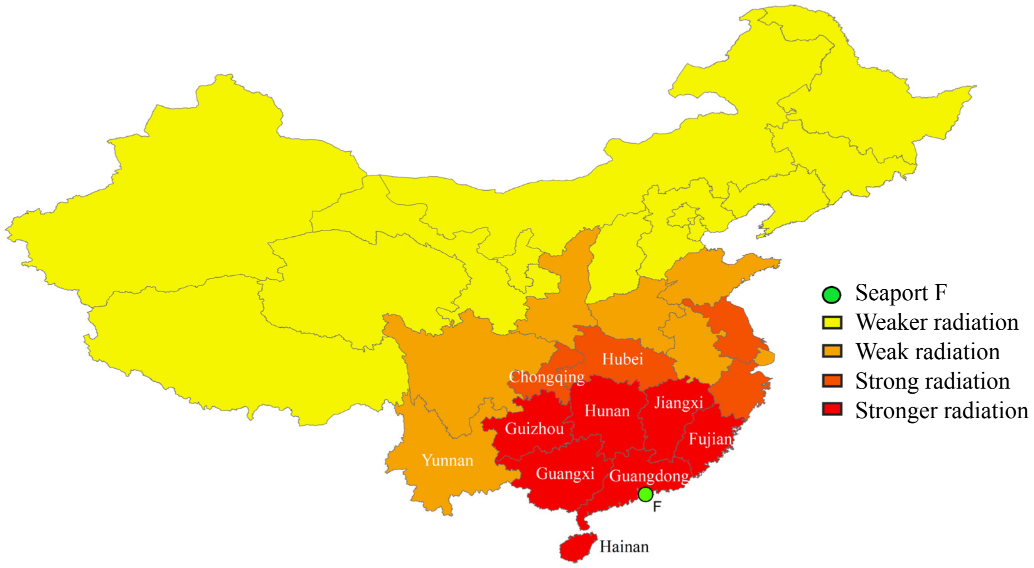

Figure 7 – Hinterland rating of seaport F (inland ports unconsidered)

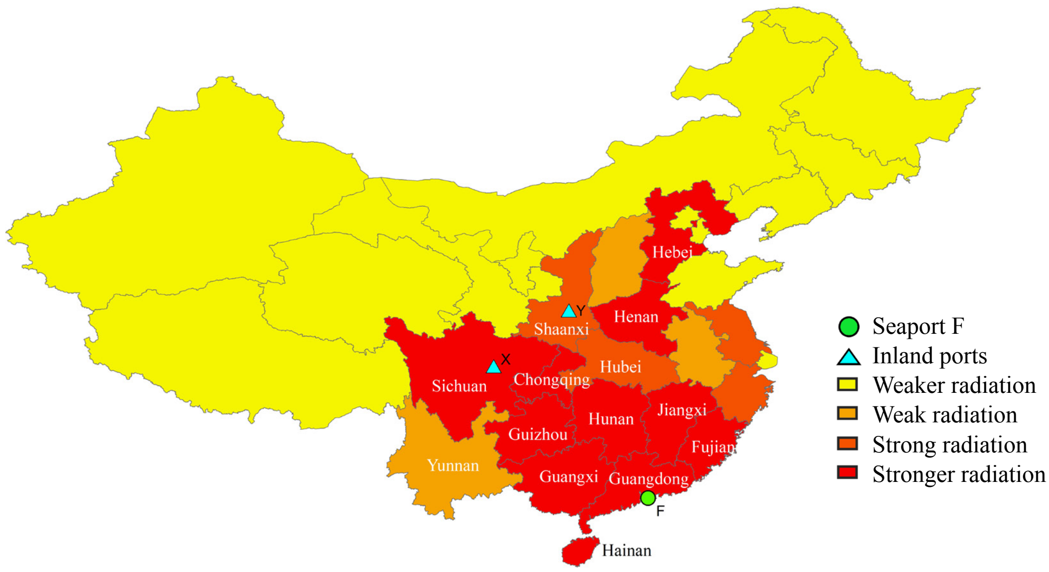

Figure 8 – Hinterland rating of seaports F (inland ports considered)

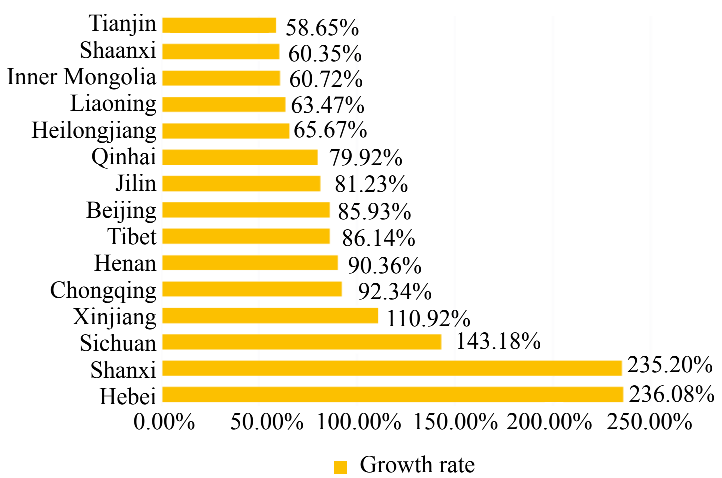

Figure 9 – Top fifteen provinces for radiation growth of F when considering inland ports

increase signalises that, although seaport F cannot compete for Hebei with A, the radiation growth when considering inland ports offers the possibility for F to gain more advantages in this competitive hinterland.

In the second part, we analysed the radiation of seaport E. This seaport appears to have nothing changed in the superior hinterland division (Section 4.2). However, when looking at the hinterland changes of this seaport alone, they are significant. *Figures 10 and 11* illustrate the hinterland rating of seaport E without and with inland ports, respectively.

The layout of *Figure 10* is similar to that of the hinterland of seaport F in *Figure 7*. However, the hinterland rating changes significantly considering inland ports. Similarly, we found that the radiation levels in the provinces of Sichuan, Chongqing and Henan increased. This means that both seaports E and F can enhance their radiation on the provinces by developing the seaport-inland port dyads. Especially for the radiation of seaport E in Henan and Sichuan provinces, the growth rate is as high as 592.19% and 441.23%, respectively. This growth happens because the seaport-inland port dyads change the path of cargo transportation from decentralised and small quantities to more centralised and larger amounts on the seaport-inland port corridors. However, such a significant increase in seaport radiation does not mean that the overall volume of freight increased so much in a short time. This is because the growth in freight volumes between the seaport and inland port is also related to the content of the services offered by the inland ports [6]. Moreover, the data shows that although the throughput of inland ports is growing every year, it is still far less than its annual maximum passing capacity. For example, the throughput of Xi'an inland port is 0.9 million TEUs, less than half of the designed capacity of 3.1 million TEUs [40–41].

Figure 12 shows the top fifteen provinces for E's radiation growth when considering inland ports. The provinces of Hebei and Hainan also have notable variances, as shown in *Figure 11*. These two locations likewise enhance the level of radiation intensity. However, Hebei and Hainan are neither located close to the inland ports nor are necessary to transship in inland ports in the cargo shipping process. Two possible reasons may be relevant to this abnormal phenomenon. On the one hand, inland ports raise the value of province influence strength (from 5.946 to 6.625), increasing the numerator in the calculation formula. On the other hand, when inland ports are ignored, the radiation of seaport E in these two provinces approaches the critical threshold. Inland ports contributed a small boost to the promotion of their radiation level.

For this paper, the sea-rail volumes and growth rates of seaport E in 2018, 2020 and 2022 [42–44] were collected and are shown in *Table 5*. Combining the results of this paper with the data collected, we find that under the influence of the seaport-inland port dyads, the attractiveness of seaport E to the hinterlands has increased, and the volume of sea-rail transport has increased tremendously, nearly doubling in five years. However, the share of sea-rail volume on annual container throughput is too small, lower than 1%. Moreover, the infrastructure capacities we collected in the data are greater than the needs. These result in a relatively slow growth in throughput in the actual situation of the seaport, which is less than expected.

Table 5 – The sea-rail volume and growth rate of seaport E

Year	Sea-rail volume	Year-on-year growth rate	Share of sea-rail in annual throughput
2018	31,600 TEU	33.43%	0.3%
2020	51,481 TEU	40.46%	0.4%
2022 (1-11M)	59,800 TEU	43.08%	0.5%

According to the results of seaport hinterland ratings, we argue that when inland ports are considered, the radiation of seaports tends to be strengthened. The growth rate of the seaport's radiation force varies from one province to another. These provinces, which have unique locations, grow larger than others. However, this growth reflects little in changing the seaport's superior hinterlands as the amount of freight transported by rail is small. In addition, the infrastructure is not well utilised, and some of the facilities are in a situation of inactivity. Therefore, we highly encourage seaports to determine the goal of forming seaport-inland port dyads in advance. For instance, for a seaport intending to achieve a higher market share in some provinces, a suitable location of inland ports can bring a big profit, which has been confirmed in the seaport hinterland rating.

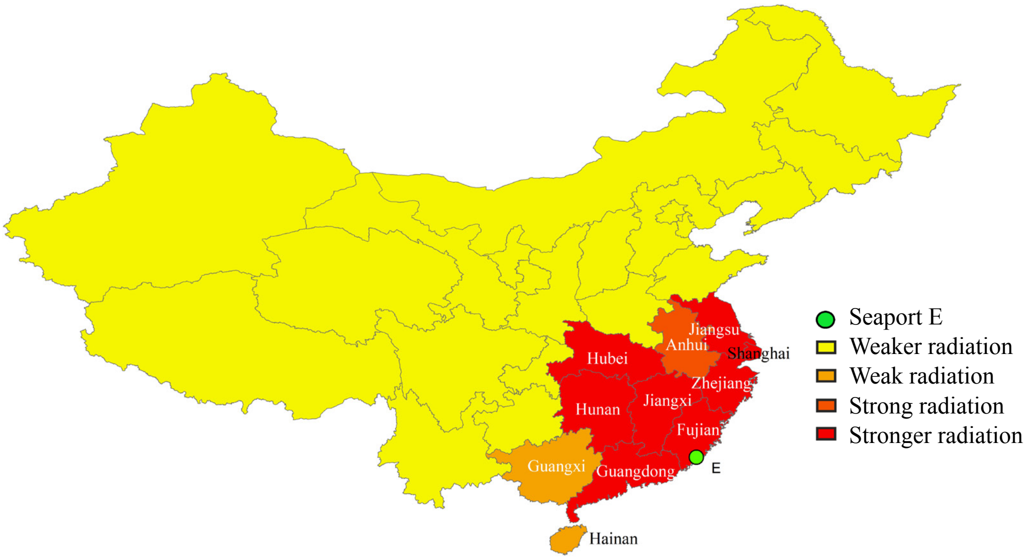

Figure 10 – Hinterland rating of seaport E (inland ports unconsidered)

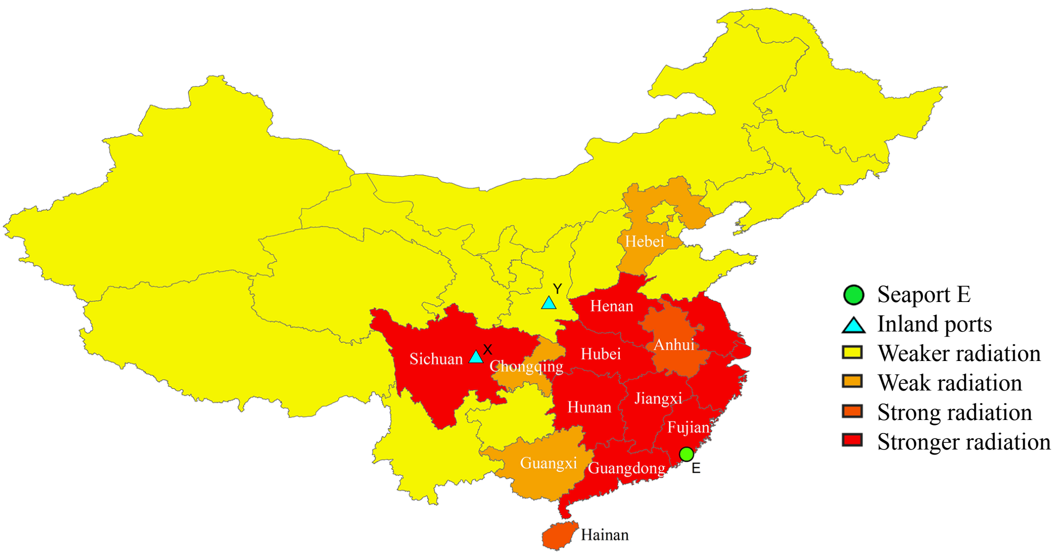

Figure 11 – Hinterland rating of seaports E (inland ports considered)

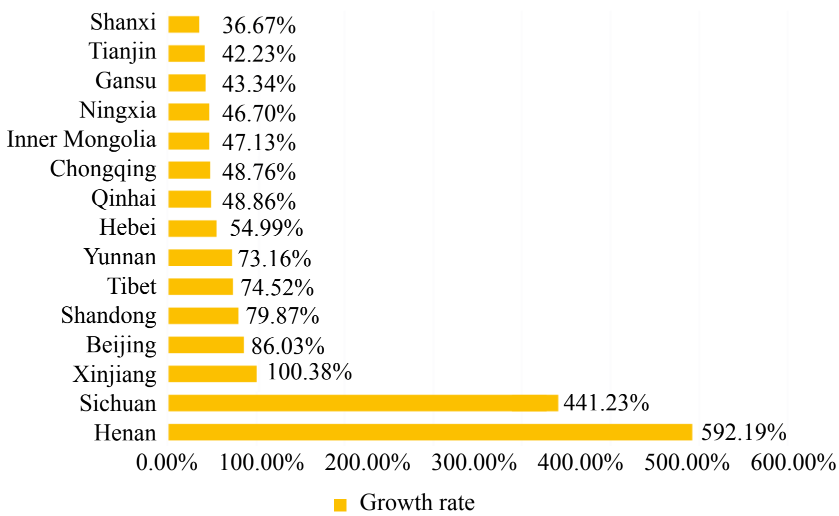

Figure 12 – Top fifteen provinces for radiation growth of E when considering inland ports

However, for seaports trying to hold a monopolistic position with respect to provinces, only choosing a suitable location is not enough. More considerations, like the influences of other seaports–inland port dyads, are essential. In this case, they need to further gain relative growth, like the results of larger superior hinterlands.

5. CONCLUSION

In this paper, we attempted to propose a radiation model to determine the scope of port hinterlands and then apply it in the context of multiple ports in China. The seaport superior hinterlands of seven seaports, as well as the seaport hinterland ratings of seaports F and E were further analysed. We found that the superior hinterlands of some seaports changed after forming seaport-inland port dyads. Interestingly, even though the superior hinterlands of some seaports did not change, their radiation force increased. The most influenced hinterland regions are the provinces located near inland ports and far from seaports. Through empirical study, we further proved that the proposed methodology is useful for seaports to evaluate their competitive strength and delimit hinterlands in different cases. According to the actual data, the seaport sea-rail volume which was affected by dyads maintained sustained growth. But the total volume occupied less than 1% of the annual seaport throughput and the use of infrastructure was unsaturated.

The findings of this study are expected to aid seaports in developing future hinterland strategies. Firstly, building up seaport-inland port dyads is an efficient way to increase hinterland scopes and fight for greater market shares in distant provinces with other seaports. In this situation, the cooperated inland ports located in or around the target provinces may obtain a better outcome. Secondly, the hinterland changes that each seaport receives through the same inland port are distinct. To achieve certain hinterland targets, seaports can compare the hinterland changes brought by different inland ports and then choose suitable inland ports to cooperate with. Lastly, compared to the present situation, the benefits of hinterland growth under the influence of the current dyads have not been fully realised. Perhaps it is more important to increase the utilisation of existing dyads than to create new ones. As for future work, different types of inland ports (public and private inland ports) should be considered, to further evaluate the influence of different dyads on specific seaports. In addition to that, studies may also investigate smaller units (i.e. cities) in the country.

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海港–陆港二元组对集装箱海港腹地划分的影响

摘要

新兴的海港–陆港二元组对海港腹地的发展有着重大贡献。然而，现有研究很少考察其对集装箱腹地划分的影响。本文采用改进辐射模型，研究在中国多港系统的背景下，海港–陆港二元组对集装箱海港腹地划分的影响。通过估算各海港的辐射力，探究海港优势腹地和腹地等级的变化，总结其影响规律。结果表明，二元组的形成实现了海港优势腹地的扩大和腹地等级的提高。靠近内陆港并且远离海港的省份受影

响程度明显。同一内陆港对不同海港的影响不同。这些结果表面，建立海港-内陆港二元组是海港与其他海港竞争更大市场份额的好方法。这些不同的影响可为海港当局选择合适的二元组以实现其腹地目标提供指导。

关键词
腹地；内陆港；海港-陆港二元组；辐射模型