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The development modes of inland ports: Theoretical models and the Chinese cases

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Abstract: This paper examines the development modes of inland ports based on the economic models and the Chinese empirical cases. After reviewing the recent policies in China, four modes, i.e., the government-driven mode, the seaport-driven, the market-driven mode and the corridor-effect mode, are established to describe the development of Chinese inland ports from the perspective of the driving forces. Moreover, we setup an economic model to compare them and conclude that (1) the seaport-driven mode promotes the larger inland port than the corridor-effect mode and the market-driven mode; (2) if the marginal capacity investment cost is low or the efficiency of the inland port is high enough, the corridor-effect mode leads to higher social welfare than the market-driven mode and the seaport-driven mode; (3) whether the government-driven mode promotes the larger inland port and higher social welfare than the other modes depends on the positive externality from the inland port to the social welfare; (4) The "Go west" policy and the Belt and Road Initiative (B&R) promote the inland port capacity under all modes. Whether the Free Trade Zone (FTZ) and the port integration promote the inland port capacity depends on the port efficiency improvement after the implementation of these policies.

Keywords: Inland port; Development mode; B&R; FTZ; Port integration; Economic model

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1. Introduction

Inland ports[1] in China have experienced fast growth since the emergence of the first inland port in 2002. Among the top 100 ports throughout the world (including the seaports and river ports) in 2019, there were three Chinese inland ports (Lloyd 's List, 2020): Suzhou Port (rank No. 31), Foshan Port (ranked No. 46) and Nanjing Port (ranked No. 53). The container throughput of the Suzhou Port reached 6.27 million TEUs in 2019. As the important nodes in transport and logistics networks, the inland ports provide important functions to guarantee the seamless connections between the inland areas and the international transport. In China, the inland ports not only behave as the extensions of the coastal ports or logistics network, but also (in some cases, e.g., Xi'an) are the engines of the social and economic development or the local regions.

According to Witte et al. (2019), an inland port has the following characteristics: the agglomeration of freight facilities in an inland area, direct connection to the seaport(s) and leaving/picking up standardized units to/from the seaport(s). Although there is no consensus on the research areas of inland port, Witte et al. (2017) propose an integrated analysis framework to include the infrastructure (positions of inland ports in supply chains and their functions), the spatial structure (the port-city relationship), the governance structure (the actors and different governance modes) and the spatial proximity (the spatial relationship between inland ports). Among these dimensions, the research on development modes of inland ports is an important area (the detailed literature review can be found in the next section).

Although the rapid development of Chinese inland ports has attracted much attention in the academic studies (e.g., Beresford et al., 2012; Monios and Wang, 2013; Zeng et al., 2013 and Notteboom and Yang, 2017), there are still some research questions which are not solved satisfactorily as follows: (i) Are there any specific development modes for the Chinese inland ports? (ii) What are the impacts of the latest policies in China on the development of its inland ports? (iii) How to compare the different inland port development modes from the perspectives of the port itself and the social welfare quantitatively, especially using the economic models?

In order to answer these questions, this paper reviews the latest policies which have the direct impacts on the Chinese inland ports. Specifically, we focus on the following four policies: the "Go west" policy, the Belt and Road Initiative (B&R), the Free Trade Zone (FTZ) and the port integration. We analyze the opportunities arising from these policies and comment their impacts on the development of Chinese inland ports. Moreover, we propose four modes to describe the development of Chinese inland ports, i.e., the government-driven mode, the seaport-driven mode, the market-driven mode and the corridor-effect mode. Based on the qualitative analysis, we setup an economic model to compare them from the perspectives of the inland ports themselves and the social welfare. Finally, we discuss the policy implications for inland port governance in China. Specifically, we focus on the governments' functions, the competition and cooperation relationships between the inland ports and the port-city interactions.

The rest of the paper is organized as follows. Section 2reviews the related literature. Section 3 analyzes the recent policies which have direct impacts on the Chinese inland ports. In Section 4, four modes are proposed to describe the development of the Chinese inland ports and an economic model is established to analyze these modes quantitatively. Section 5 makes some discussions on

[1]There are many terminologies in the literature with the similar meanings as inland port, e.g., dry port, inland terminal. In this paper, we use the definition proposed in the review paper by (Witte et al., 2019) and uniformly use the "inland port" to represent all these facilities.

the policy implications and concludes the paper.

2. Literature Review

There are many studies addressing the topic of inland ports in the past 25 years. Readers are referred to the review of Witte et al. (2019). In this section, we conduct a literature review from the following perspectives: the inland port development models, the inland port governance, and the studies on the inland ports in China.

There are rich studies on the inland port development models. Witte et al. (2019) point out that there are three stages, where the inland ports have been studied from “the valued components of the transport/logistics/supply chain system (follower)” to “the important components of the regional system (leader)”. Different models are used to describe the inland port development. In the early stage, the models treat inland ports as the nodes in transport and supply chain networks. The researches focus on the functions of inland ports to alleviate congestion at seaports and to replace some seaports’ operations. The port regionalization model (Notteboom and Rodrigue, 2005) is a typical and most influential one. In the diversification stage, models go beyond the port regionalization and diversify to various subjects. Among them, the containerization (Notteboom, 2010) and terminalization of supply chains (Rodrigue and Notteboom, 2009) are the representatives. In the contextualization stage, the Outside-In and Inside-Out (Wilmsmeier et al., 2011; Monios and Wilmsmeier, 2012, 2013; Monios and Wang, 2013) are the most applied. Also there are some trends to describe the inland port development from other perspectives, e.g., from an integrated spatial perspective (Debrie and Raimbault, 2016) and from the evolutionary and institutional economics perspective (Notteboom et al., 2017).

There are limited studies on inland port governance. Rodrigue et al. (2010) conduct case studies in inland ports from Europe and North America to summarize the main actors (public authorities and operators) and their functions (land use, transport and logistics) of inland ports. They point out that focus of the inland port governance is the coordination of the relationship among the different actors. Moreover, they emphasize two public goals for the inland port governance, attracting logistics activities to develop the local economy and reducing traffic congestion and reorganizing freight distribution to better fit local characteristics. Witte et al. (2014) address that the port-city challenges is the focus of the inland port governance. Witte et al. (2016) examine governance strategies in inland ports along the Rhine-Alpine Corridor. They state that two balances (port vs. urban development and public vs. private involvement) need to be considered in the inland port governance. Moreover, they point out that the cooperation transgressing the local level and the institutional boundaries of the inland port authorities and cities is important. The spatial and institutional differences between port cities are the key issues in inland port governance.

There are some empirical studies on the inland ports in China. Beresford et al. (2012) study three cases including Shijiazhuang Port, Xi’an Port and Kunming Port. They illustrate three inland port development modes in China, i.e., the seaport-based mode, the city-based mode and the border inland port mode. They draw a comparison on these modes in terms of cooperation, operators, policies, functions and competitors. They point out the lack of institutional coordination is the main challenge for Chinese inland ports. Monios and Wang (2013) use a sample of 18 Chinese inland ports in three port clusters to establish two conceptual models to characterize the inland ports in China, i.e., inside-out and outside-in. Zeng et al. (2013) analyze the motivations, challenges and opportunities of the Chinese inland ports. Chang et al. (2019) use a two-stage DEA model to investigate the relationships between the efficiencies of the Chinese inland ports and the following factors, i.e., customs clearance, rail connection, ownership structure and inter-competition among inland ports.

Comparing to the existing literature, this paper aims to contribute to the inland port research in the following ways.

(1) We propose three modes to describe the inland port development from the perspective of driving forces. Although there are various inland port development models in the existing literature, we analyze the inland ports from the different perspectives. For instance, the port regionalization model (Notteboom and Rodrigue, 2005) examines the functions of inland ports to alleviate congestion at seaports and replace some seaports' operations. Wilmsmeier et al. (2011) and Monios and Wang (2013) propose two models, i.e., the Outside-In model and the Inside-Out model, which emphasize the relationship between inland ports and coastal ports. Beresford et al. (2012)'s seaport-based model, the city-based model and the border inland port model by focus on spatial bases of inland ports. Our models investigate the origins and driving forces of inland port development (i.e., the government-driven, the seaport-driven, the market-driven and the corridor-effect mode). Therefore, our models provide a new perspective to investigate inland ports.

(2) We establish a theoretical economic model to examine and compare four modes of inland port development. Most literature investigates inland ports using the qualitative analysis or empirical studies, while we setup an economic model to quantitatively describe and compare these modes from the perspectives of the inland port capacity and social welfare. Moreover, we incorporate the impacts of the recent policies ("Go west", B&R, FTZ and port integration) in our economic models. Our economic model and the related conclusions can be the first step to study inland ports quantitatively.

(3) For the perspective of inland port governance, we consider a new factor, i.e., the port integration and its impacts on the competition and cooperation among the inland ports. Witte et al. (2019) point out that competition between different regional inland ports could be a research focus from the institutional dimension. Our paper makes an attempt on this side based on the Chinese cases.

3. Latest policies and their impacts on the inland ports in China

In this section, we briefly review some policies which have strong relationships with the inland port development in China. Specifically, we study the "Go west" policy, the B&R, the FTZ and the port integration. These policies have profound impacts on inland ports in China, which will be discussed in details and be incorporated into the economic model in Section 4.

3.1 "Go west" policy

Compared to the rapid development of coastal provinces, the economic development in Chinese western provinces lagged behind, and the gap between the western areas and the coastal areas has been enlarged since the 1990s. In order to balance the disparity between the two areas in terms of economic and social development, Chinese central government initiated the "Go west" policy to promote local economies in western provinces. One of the important outcomes of the "Go west" policy was the moving of the manufacturing industries to the western provinces. We use Chongqing as an example to show that its throughput has gained significant increment in the recent 17 years (see Figure 1), partially due to the "Go west" policy. With the support of the "Go west" policy, Chongqing has been achieving the double-digit GDP annual growth rates since 2003, with the only two exceptions being 2009 (9%) and 2018 (6%) (Bao et al., 2019). Meanwhile, the average annual growth rate of its port throughputs at the same period (2003-2018) is 12.8% (tjj.cq.gov.cn). The correlation between the GDP and the port throughputs of Chongqing at this period is 0.996. These data provides a strong support that Chongqing's throughput increment is partially resulted from the "Go west" policy.

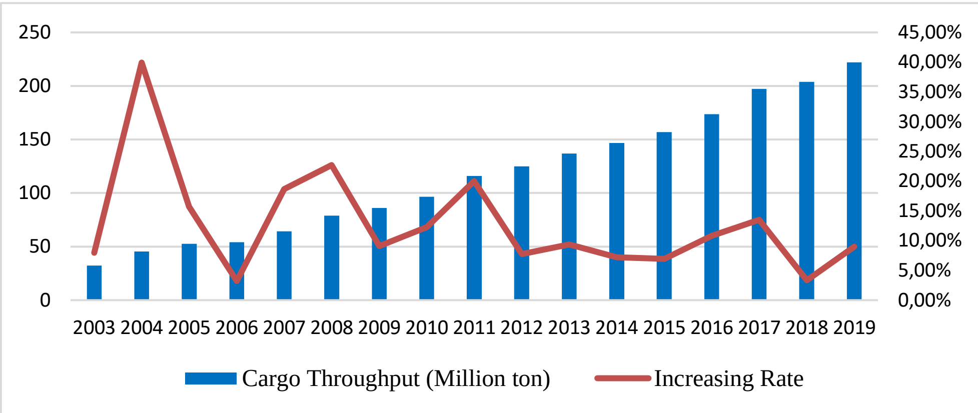

Figure 1 Development of the Port of Chongqing

Source: http://tjj.cq.gov.cn

In China, the nationwide industrial transfer has been promoted by the "Go west" policy. Many manufacturers in the east part of China have moved their factories to the central or western provinces aiming at lowering labor and land costs. Under this background, some central or western inland cities have grown to be the manufacturing sites with enormous import and export demand, which further requires a more advanced inland transport system.

3.2 B&R

The B&R was launched in 2013 to foster the economic cooperation and infrastructure investments from Western Pacific to the Baltic Sea and the inland Asia areas. It has the culture/historical, geo-economic and geo-political nature (Notteboom and Yang, 2017). Along the B&R paths, there are two streams of ports in China which benefit from the B&R: the ports in the Southeast and South coastal areas (e.g., Fuzhou Port, Guangzhou Port and Haikou Port), and the inland ports (e.g., Chongqing Port, Chengdu Port and Xi'an Port) in western provinces. In order to support the B&R, especially the land-based Silk Road Economic Belt (the Belt), the China Railway Express (CRE) project and the Multimodal Transport Demonstration Project (MTDP) were promoted. Since the first launching of CRE on March 19th, 2011, there are more than 1000 CREs from China to European countries.[2] Now there are 61 routes from 38 cities in China to 36 cities in 13 European countries. Meanwhile, to improve the multimodal transport system, ministries including Ministry of Transport (MOT), National Development and Reform

[2]The 1000th CRE (train X8024) was launched on May 13th, 2017, from Yiwu to Madrid.

Commission (NDRC), Ministry of Diploma (MOD) and General Administration of Railways (GAR) published policies to support MTDP (see Table 1). Among the Chinese inland ports, 19 of them were chosen as the construction demonstrations in the MTDP.

To better implement the B&R and make sure that the central and western provinces are well connected to the eastern developed regions and the other countries, the central and local governments pay great attention on the development of inland transport infrastructure. According to the "Three-year (2016-2018) Action Plan for the Major National Transport Infrastructure Projects" (a policy supplement to the B&R), a majority of these projects are conducted in the central and western part of China, which significantly improve the accessibility of those land-locked regions. The improved inland transport infrastructure brings the cargoes and new business opportunities to the inland ports in China. Without B&R, the products to the eastern and middle European regions would choose the sea routes and arrive at the coastal ports, which need to spend much time. Meanwhile, the raw material transportation costs from the regions along the B&R routes are reduced because of the transport infrastructure improvement. Therefore, the B&R is another impetus for the development of the Chinese inland ports, by reducing the transportation costs.

3.3 FTZ

Since the first FTZ was launched in Shanghai in September 2013, there have been 18 FTZs in China. New economic policies and governance reforms are tested in these FTZs, which introduce the greater degree of openness related to foreign investments and the international trade. Specifically, the inland customs clearance policy[3] is one of the most important policies. Under this policy, the import and export cargo inspection processes are simplified and the “single window” and “one stop” clearance service are provided. “Single window” service means the activities including cargo declaration, manifest declaration, vessel declaration, enterprise qualification, certificate of production, permit application, taxpaying, query and export tax rebate can be combined and provided in one custom working window. The ports (both inland ports and coastal ports) can offer shippers or consignees a “one stop” clearance service through customs declaration, inspection, cargo space booking and other relevant services. Eligible shippers or consignees can declare their cargoes to any of the local customs and apply for cargo inspection. The customs in the coastal ports and inland ports will realize the “information sharing” and “mutual recognition of inspections”. All these new policies related to the customs and FTZs can attract more cargo and services to inland ports whose efficiencies and competitiveness are greatly improved[4].

[3]This policy is mainly used in the FTZs now and will be promoted to all Chinese customs in 2020. See http://www.bjkab.gov.cn/myDoInfo/front/article/1482114117424777.html.

[4]Some studies provide the similar statements as ours. E.g., in the review paper of Wan et al. (2018), they summarize the impacts of the FTZ and the increase of the efficiency in inspection and customs clearance on a port’s inland terminal. They point out that these policies have the equivalent effects as the increase in the corridor capacity, which can increase the inland port efficiency finally.

Table1 Policies related to the multimodal transport in China since 2016

Plan and policy	Government ministries	Implementation time
The construction and development plan for CREs (2016-2020)	NDRC	Oct. 19, 2016
The multimodal system construction for the ports in the Yangtze economic belt in the 13^{th} five-year plan	NDRC, MOT, GAR	Dec. 7, 2016
The logistics corridor construction plan (2016-2020)	NDRC, MOT	Dec. 7, 2016
The notification for the promotion of multimodal transport	18 ministries and departments including NDRC and MOD	Jan. 4, 2017
The port corridor system construction plan in the 13^{th} five-year plan	MOT, GAR	Feb. 12, 2017
The development plan of the railway multimodal transport in the 13^{th} five-year plan	NDRC, MOT, GAR	Apr. 19, 2017

Sources: multiple sources including
http://zizhan.mot.gov.cn/zfxxgk/bnssj/dlyss/201701/t20170104_2149676.html,
http://www.ndrc.gov.cn/gzdt/201705/W020170512615532307335.pdf
http://www.askci.com/news/chanye/20161017/16423170328.shtml
http://www.ndrc.gov.cn/zcfb/zcfbtz/201612/W020161226327540701292.pdf
http://zizhan.mot.gov.cn/zfxxgk/bnssj/zhghs/201701/P020170103622520522947.pdf
http://www.gov.cn/xinwen/2017-02/23/content_5170277.htm

3.4 Port integration

After the decentralization reform of the Chinese port governance system in 2001, severe competition and excessive capacities appeared with the fast development among the Chinese ports (Cullinance and Wang, 2007). In order to avoid destructive port competition, port cooperation and integration become more and more popular in China's port industry. Now many ports along the coastal areas and Yangtze River get involved in the integration trend, where most integration is formed in the provincial bases.

The port integration strategies have big impacts on the development of related inland ports. In some cases such as Guangxi and Hebei, the integration is mainly among coastal ports. This integration increases their market powers, redistributes their relationships with the corresponding inland ports and enhances the Outside-In modes. In other cases such as Zhejiang and Jiangsu, the integration includes inland ports (such as Yiwu in the Zhejiang Port Group and Suzhou and Nanjing in the Jiangsu Port Group), which upgrades the bargaining positions for key inland ports and causes the divergence of inland ports. Therefore the competition between inland ports is transferring from the individual level to the group level where the corresponding coastal ports are evolving. Although the impacts of the port integration to the inland port development are not clear currently, it will definitely cause some positive effects on the inland port development. Specifically, the inland ports' efficiencies can be improved by the cooperation promoted by the port integration. It is worthy point out that our analysis on the impact of port integration to the inland port efficiency is consistent with the existing studies (e.g., Wan et al., 2018)[5].

The "Go west" and B&R policies generally trigger the institutional reforms in many aspects, such as the customs management (e.g., the FTZ policies) and port administration (e.g., the port integration policies). To a great extent, those institutional reforms make it much easier for inland importers and exporters to arrange international trade and transport for their cargos. Therefore, the FTZ and port integration policies improve the efficiencies of the inland ports.

4. Inland port development modes

In this section, we first develop four modes from the perspective of key drivers behind the inland port development processes, i.e., the government-driven mode, the market-driven mode, the corridor-effect mode and the seaport-driven mode. Since the seaport-driven mode has been extensively studied in the related literature (e.g., Monios and Wang, 2013; Witte et al., 2019), we do not examine it in details. The other three modes are specifically explored with four cases, i.e., Xi'an inland Port, Chongqing Port, Yiwu Port and Horgos Port, where Chongqing port and Yiwu port belong to the market-driven mode. Figure 2 shows the specific geographical positions of these four inland ports in China. Following the summaries of the development modes of inland ports, an economic model is set up to compare these modes from the perspectives of port capacity and the social welfare.

Figure 2 The geographical positions of the four inland ports in China

[5]Other papers, e.g., Alvarez-SanJaime et al. (2015), also discuss the similar issue. They point out that the integration of a seaport and an inland transporter may cause the congestion in the seaport to increase and thereby reduce its efficiency. However, their definition of integration (the integration of a seaport and an inland transporter) is different with ours (the integration of a seaport and an inland port). Moreover, the reasons are different. In Alvarez-SanJaime et al. (2015), the seaport undertakes a vertical integration pricing strategy (i.e., letting the per unit distance price in the inland transport be 0) to increases its throughput, which causes more congestion and lower efficiency. Note that the lower efficiency in their paper is caused by the increase of the port throughput and the marginal congestion cost is unchanged. In our paper, the improvement of the inland port efficiency is caused by the reduction of the marginal congestion cost because of the port integration policies. Therefore, the conclusion in Alvarez-SanJaime et al. (2015) is not contradictory with our analysis.

4.1 The inland port development modes

4.1.1 Government-driven mode

Governments, especially local governments, generally play an active role in the inland port establishment and operation for the development of inland ports in China (Beresford et al., 2012). Chinese inland ports are likely to be considered as "growth poles" in local economy. Because they can behave as the logistics clusters and even potential industry agglomerations, inland ports are strongly supported by local governments. The Inside-Out development mode was proposed by Wilmsmeier et al. (2011) and applied in China by Monios and Wang (2013), which significantly shows the local governments' strong motivations to promote the development of inland ports for the purpose of improving local economic competitiveness. Moreover, a regulatory governmental organization usually named as "administration of district" is established to take the responsibility of basic issues of an inland port, such as site layout planning, infrastructure and superstructure (Monios and Wang, 2013). Among the three groups of Chinese inland ports by Beresford et al. (2012), the city-based inland port is particularly driven by local governments. Specifically, the city-based inland port is generally accepted by the local government as a strategy for the regional economy development serving local trade and attracting additional manufacturing-related investments (Beresford et al., 2012). This paper highlights the active roles of governments in the development of Chinese inland ports. In order to further elaborate these roles, we propose a government-driven mode illustrated in Figure 3. In recent years, the B&R and the FTZ strategy have greatly enhanced the governments' leading positions in steering the development of the Chinese inland ports in recent years. Driven by these macro policies, the central government and the local governments provide the sufficient financial funds for the infrastructure construction of the inland ports. The well-constructed inland ports are expected to fuel the growth of the economy by smoothing connections between the inland areas and the coastal regions.

The government-driven mode describes a situation where governments deeply participate in the development process of an inland port by comprehensive means such as direct investments, the incentive policies and the administrative devolution. The main reason why governments adopt this approach is that an inland port can function as a logistics hub to facilitate the domestic and/or international trade and materialize regional economic agglomerations. A distinct characteristic of government-driven mode is the interactive relationship between the central government and local governments. Local governments need to ask for preferential policies that can only be granted by the central government, such as export tax rebate and special customs supervision. Conversely, the central government needs local governments to implement national strategies and steer the development of local economy. The competition among local governments in China is fierce. Therefore, the relationship between the central government and local governments, to a certain extent, is unequal. Moreover, the governments support the development of inland ports mainly because the social logistics costs of inland cities can be reduced if the well-developed inland ports can provide the good logistics services. Moreover, the transportation industry that is related to inland ports can absorb a lot of social labor, which also meets the governments' objectives and benefits.

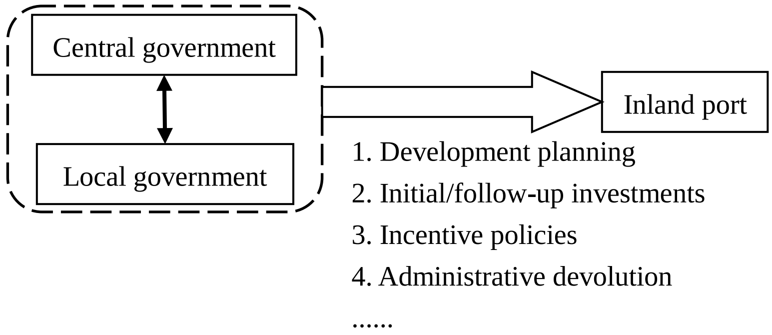

Figure 3 The government-driven mode

A critical case of the government-driven mode is the rapid growth of Xi'an inland port in Shaanxi province. Xi'an inland port refers to Xi'an International Trade and Logistics Park (XITLP) which has been a component of China (Shaanxi) Pilot FTZ since August 2016. Beresford et al. (2012) present some information including the main objectives, the investment structure and preferential policies about XITLP. Xi'an municipal government was the most important promoter of XITLP, and has directly, especially at the early stage, invested in land, infrastructure and basic facilities (Beresford et al., 2012). Meanwhile, great efforts have been made by municipal government to elicit private and foreign investment into the inland port. Because the improvement in the convenience of customs clearance operation is essential to the development of Chinese inland ports (Monios and Wang, 2013), XITLP has gained significant support from Shaanxi provincial government to apply to General Administration of Customs for being special supervision area. As a core part of China (Shaanxi) Pilot Free Trade Zone approved by the State Council in August 2016, XITLP has further upgraded its capacity of bonded processing, logistics and service. Except for the customs service, intermodal transport infrastructure is the other concern for inland ports (Monios and Wang, 2013), particularly for those located more than 1000 km away from seaports. Thanks to Xi'an Railway Container Center Station (XRCCS) which was launched in July 2010, XITLP considerably improves its capacity for intermodal transport. According to the long-term plan, the container throughput of XRCCS will reach 3.1 million TEUs in 2025. The project XRCCS was planned by former Ministry of Railway and invested by CRIntermodal, a holding subsidiary of state-owned China Railway Company. The national leading group for B&R promotion has listed Xi'an as one of inland main cargo source places and key railway nodes of CREs. According to the National Development Plan of CREs (2016-2020), more investments will be collected for the construction and improvement of the key railway nodes in B&R. It is worth highlighting that the CRE operating between Xi'an and Europe/Central Asia achieved great success in the past few years from the perspective of cargo volume. As shown in Table 2, the increasing cargo volumes indicate that XITLP begins to have an emerging logistics corridor by railway to Europe directly, which replies less on traditional routes (from seaports to

Europe by ship). Compared with traditional routes, the logistics corridor by railway has an advantage of transit time. However, the disadvantage is the transport cost. At the current stage, Shaanxi provincial government and Xi'an municipal government provide financial subsidies to CRE operator and shippers to attract cargos and maintain the stability of scheduled operations. Nearly 0.6 million RMB was granted by local government to CREs from Xi'an to Europe/Central Asia. Without subsidies from local government, it will be very hard for CREs to be profitable.

Table 2 Cargo volumes of CRexpress (Chang'an) between Xi'an and Europe/Central Asia

Year(s)	Trains	Thousand tons
Nov. 2013 ~ Dec. 2015	142	202
2016	151	226
2017	194	232
2018	1235	1202
2019	2133	1800

Source: multiple sources including
http://itl.xa.gov.cn/zsyz/tzdsj/5de72a72fd8508098d157f41.html
http://itl.xa.gov.cn/xwzx/spjj/5e6c33e5f99d655333b3d202.html
http://itl.xa.gov.cn/xwzx/zyxw/5eba1926f99d65761335c17e.html

As an institution-driven facility (Beresford et al., 2012), the development of XITLP is greatly embedded in the institutional context that is jointly created by local and central governments. The interactive relationship between local governments and the central government is crucial for XITLP, which means the continuing investment and incentive policies. Although the investment and business participation from private and foreign sectors are also important for the sustainable development of XITLP, the leading role of governments is more fundamental. Recently, a distinct change of XITLP that can be observed is the rise of CRexpress (Chang'an) between Xi'an and Europe/Central Asia due to the B&R and FTZ. The emerging logistics corridor by railway to Europe is likely to make XITLP more independent from seaports, which may reshape the international logistics system of West China.

4.1.2 Market-driven mode

The growth of inland container market drives the development of inland ports (Korovyakovsky and Panova, 2011). Based on the three tier system (Wakeman, 2008), Rodrigue et al. (2010) point out that the freight flows from commercial and manufacturing sectors are closely linked with inland ports. Here, it is necessary to manifest that freight flows in commercial and manufacturing sectors are generally transported as container cargos. Economies of scale can be achieved by the concentration and consolidation of freight traffic (Roso and Lumsden, 2009). Commercial and manufacturing sectors have strong motivations to reduce their logistic costs via logistics clusters. In China, although governments have been prone to active involvement of operational matters in economic domain (Beresford et al., 2012), no one can deny that market mechanism plays an important role in shaping the logistics system. In this section, a market-driven mode (Figure 4) is developed to explain the reason why some Chinese inland ports can gain rapid growth without too much participation of governments. After a brief conceptual elaboration, the mode is applied to two critical cases respectively.

The market-driven mode includes two scenarios, namely manufacturing-driven and trade-driven. In the manufacturing-driven scenario, the development of an inland port is largely dependent on the scale of local manufacturing industry. Generally, the manufacturing centers cluster in Chinese eastern coastal areas where logistics system is mainly built surrounding the seaport. Notably, the imbalanced spatial development of China's economy leads to the industrial transfer from East China to the central and western regions (Xu, 2016). The main economic forces behind the industrial transfer are labor force cost advantage and the vast domestic market in central and western China. As mentioned in Section 3.1, the "Go west" policy has promoted the nationwide industrial transfer by providing incentives such as tax concessions for the manufacturers to move their factories from the coastal areas to the inland regions. Driven by the large-scale industrial transfer, some inland cities have grown up rapidly to be manufacturing centers. The logistics demand of these centers increases very fast. Inland ports develop fast as a facility that can provide effective intermodal transport and comprehensive logistics services. In the trade-driven scenario, an inland port is located in an inland trade-based city where large-scale wholesale trade is dominant. In order to enhance business competitiveness, traders intend to improve global customers' satisfaction by ensuring customer responsive and agile supply chain management. Timely delivery is essential. For customs, clearance is the core function of inland ports (Beresford et al., 2012). The international trade between inland traders and their oversea customers can benefit a lot from the streamlined customs operation of inland ports. The "single window" and the "one stop" clearance services promoted by the FTZ policy can greatly facilitate the international trade. Notably, the inland ports which are not far away from seaports can be synchronized with the seaport system and provide the inland traders more efficient logistics services. In such case, port integration between the inland ports and the seaports makes the regional transportation systems more competitive. In the following part of this subsection, the market-driven mode is applied to Chongqing Guoyuan Port (CGP) and Yiwu inland port (YIIP).

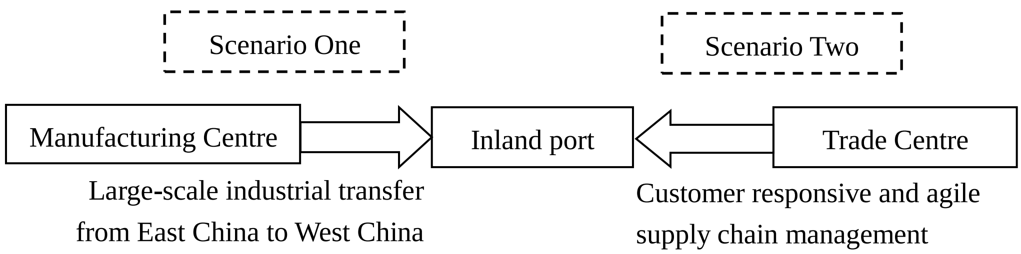

Figure 4 The market-driven mode

Chongqing, a province-level municipality in western China, is one of the largest inland cities undertaking the large-scale industrial transfer from East China. During 2014 to 2017, Chongqing introduced 2,152 industrial investment projects, and the total amount of contracted investment was nearly 1.8 trillion RMB. More than 60% of these projects were invested under the umbrella of industrial transfer. By tremendous investments, Chongqing is elevating its status in Chinese manufacturing domain and enhancing its position as a manufacturing center in western China. To better meet the logistics demand of manufacturing enterprises, Chongqing Guoyuan Port, as the largest Chinese inland hub port providing waterway/rail/road multimodal transport services, was built and officially put into operation in December 2013. A distinctive feature of CGP is that it is not a pure "dry port" but an inland port with waterway terminals along the Yangtze River. Therefore, CGP can make full advantages of waterway transport to lower logistics costs of manufacturing enterprises. Besides, the operation of CRE (Chongqing-Xinjiang-Europe, also known as Yuxinou) directly connects Chongqing with Europe by railway, which to a great extent differentiates CGP from other traditional inland waterway ports. Several information technology (IT) giants such as Hewlett-Packard (HP), Asus and Acer have transferred their manufacturing bases to Chongqing. CRE (Yuxinou) as an emerging transport option for goods exported to Europe has grown up fast as an emerging transport option for goods exported to Europe. Nowadays, IT companies are the main users of CRE (Yuxinou) which takes 13 to 16 days to reach Duisburg from Chongqing. This is shorter compared to the 36-day container ship transport time (China Daily, 2011).

Yiwu, an inland city located in eastern China, has the world's largest wholesale market of small wares. Yiwu is known as the "Commodity Capital" on the globe (China Daily, 2018). Driven by the logistics demand of international trade, YIIP was invested by Yiwu International Inland Port Group (YIIPG) and completed its first construction phase in October 2011. At present, YIIP acts as the main conduit for Yiwu's international trade. The logistics services that YIIP can provide include cargo consolidation, storage, distribution, freight forwarding, intermodal transfer (rail-road), and bonded warehouse, etc. It is worth mentioning that YIIP has a very close business relationship with seaport of Ningbo Zhoushan. The distance between YIIP and Ningbo Zhoushan port is just around 200 km. Ningbo Zhoushan port even considers YIIP as its extended gateway in the port hinterland. Note that the Outside-In mode (Wilmsmeier et al., 2011) and the seaport-based mode (Beresford et al., 2012) cannot fit Yiwu case precisely, because seaport of Ningbo Zhoushan does not play the leading role in the development of YIIP. Recently, under the background of regional port integration reform (Notteboom and Yang, 2017), YIIPG and Ningbo Zhoushan Port Group are merged into Zhejiang Provincial Seaport Group, which significantly enhances the synergy between two ports. To shorten the transit time of exported goods, YIIP also has introduced the operation of CRE (Yiwu-Xinjiang-Europe, also known as Yixinou) in recent years. Compared to the traditional maritime transport, the railway transport by CRE (Yixinou) can reduce transit time of nearly 20 days.

The cases of CGP and YIIP show the development of inland ports that are essentially boosted by the strong logistics demand of the hosting cities. Specifically, there are two types of those cities, namely manufacturing centers and trade centers. The development of inland ports in manufacturing centers greatly benefits from Chinese large-scale industrial transfer from eastern China to the central and western regions. While inland ports embedded in trade-based cities are driven by the traders' pursuit of customer responsive and agile supply chain management. It is useful to note that in the development process of these inland ports, governments still play an important role. However, unlike the government-driven mode, governments in the market-driven mode generally act as a facilitator rather than a direct participant.

4.1.3 Corridor-effect mode

Logistics corridors generally have spatial spillover effects to different degrees. In the existing literature, the corridors connecting inland ports and seaports in proximity have attracted considerable academic attentions (e.g. Notteboom and Rodrigue, 2005; Wilmsmeier et al., 2011;

Fraser and Notteboom, 2014). Because of the spatial spillover effects of corridors, the nodes along corridors potentially have opportunities to be regional load centers as inland ports. Recently, driven by the B&R, the railway corridors connecting vast inland China and Europe/Central Asia have developed rapidly. Therefore, the inland ports located along the border between China and the central Asian countries have good opportunities for the unprecedented development. In practice, the manufacturing and trade centers along corridors are more likely to develop their inland ports due to strong local logistics demand. However, some inland ports in China also have grown up without too much participation from the government or with the local logistics demand. Their success is highly dependent on the significant geographical positions they hold in corridors. To better explain the mechanism of formation of these inland ports, a corridor-effect mode (Figure 5) is developed and applied to a critical case. The mode describes a situation where the development of the inland port is mainly driven by large amounts of the goods in transit calling at the inland facility (i.e. the corridor effect). Generally, this kind of Chinese inland port is located at a key node, especially the gateway on the border, along corridors.

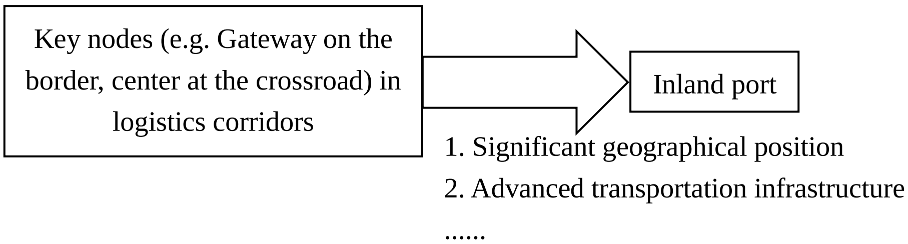

Figure 5 Corridor-effect mode

The critical case of the corridor-effect mode is Horgos inland port. Horgos is a border city located at the Chinese side of the China/Kazakhstan border, which was once a stop on the ancient Silk Road. At present, Horgos re-attracts great attention under the umbrella of the Silk Road Economic Belt. As one of the earliest opening-up entry/exit ports connecting China and Central Asia, Horgos has grown up to be the national first-class highway-based inland entry/exit port with the perfect conditions of transportation infrastructure and customs clearance in the vast western area of China. The inland port of Horgos is known as China-Kazakhstan Horgos Frontier International Cooperation Center (HFICC), which is the first cross-border international cooperation center jointly established by China and its neighboring countries. The HFICC consists of two components, namely a core area of 5.6 square kilometers and a supporting area covering of 9.73 square kilometers. In December 2012, the railway connecting Horgos and Aten Corey, Kazakhstan was officially completed, which meant a new Trans-Eurasian corridor was formed. Except for Alashankou, Horgos has been another main entry/exit port in the Trans-Eurasian corridors via Xinjiang. With the development of CRE, a large amount of goods is transported from inland China to Europe/Central Asia by rail. The freight trains calling at Horgos use HFICC to arrange transshipment because of the different width between the rails in China and Kazakhstan, to complete the necessary customs clearance at the border and to store cargos for a short period. According to Horgos Customs Authority, there are 662 freight trains calling at HFICC in the first half year of 2018, and nearly 60 thousand TEUs were correspondingly handled in HFICC.

4.1.4 Seaport-driven mode

This mode has been extensively studied (and with the different name as “the outside-in framework”) in the related literature, e.g., Monios and Wang (2013), Witte et al. (2019). In this mode, the development of the inland port is promoted by the related seaport to secure the latter’s hinterland control and relieve its congestion. The main function to invest and speed up the related inland port development is to improve the accessibility and operational performance of the seaport. The typical example of this mode is the ports of Qingdao and Weifang. The port integration strategies implemented by the seaports can exert significant impacts on the inland ports. The links between the inland ports and the seaports are closer in the operational and financial aspects, which can improve the performance of inland ports.

4.1.5 Summaries of the development modes of inland ports

The characteristics of the four modes are summarized in Table 3. Among the four modes discussed in the paper, two of them (i.e. government-driven mode and market-driven mode) can also be applied for other kinds of ports (including the seaports), because seaports share some common characteristics with inland ports. For example, many coastal cities' governments play active roles in the development of Chinese seaports and have made huge investment in the seaports infrastructure in the past decades to improve their capacities of servicing vast hinterland. Therefore, it is quite difficult to clearly distinguish the development modes of inland ports from the seaports. However, the corridor-effect mode and seaport-driven mode are unique for inland ports. Specifically, because of the spatial spillover effects of corridors, the transport nodes along the corridors potentially have opportunities to be the regional cargo centers as inland ports. Especially for those nodes, without strong local governments' investment support or local logistics demand, their success is highly dependent on the significant geographical positions they hold in the corridors, such as Horgos inland port which is presented as a critical case in our study. In the seaport-driven mode, the inland ports, to a certain extent, are affiliated to the seaports. Seaports take advantage of those inland ports as their extensions to service their hinterland.

Moreover, all the four modes contribute to the social welfare of the given region because they improve the condition and promote the function of the logistics infrastructure. The condition improvement and the function promotion can reduce the social costs of the economy development and thereby improve the social welfare. However, their magnitudes to the social welfare improvement are different and we will use the economic model in the next section to assess them.

Table 3 Characteristics of the four modes

Development mode	Main characteristics	Example
Government-driven mode	(1) Governments play active roles in the development of inland ports; (2) Interactive relationship between the central government and the local government; (3) Governments aim to improve social welfare by reducing social logistics costs.	Xi’an inland port
Market-driven mode	(1) Two sub-modes are included (the manufacturing-driven mode and the trade-driven mode); (2) The large-scale industrial transfer facilitates	Chongqing Guoyuan Port, Yiwu inland port

	the formation of the manufacturing-driven mode; (3) In the trade-driven mode, the inland ports are generally located in the inland trade-based cities where the large-scale wholesale trades are dominant.	
Corridor-effect mode	(1) The spatial spillover effects exist; (2) The development of the inland port is mainly driven by the large amounts of goods in the transit calling at the inland facility; (3) The inland ports are generally located at the gateways on the border, along the corridors.	Horgos inland port
Seaport-driven mode	(1) The development of the inland port is promoted by the related seaport; (2) The aim of developing inland ports is to improve the accessibility and operational performance of the seaport; (3) The links between the inland ports and the seaports are closer in the operational and financial aspects.	Weifang inland port

4.2 Theoretical analysis on the inland port development modes

4.2.1 Model setup

From Section 4.1 we know that the main difference of the modes is the player who leads the inland port development, i.e., the local government (the government-driven mode), the manufacture and the retailer (the market-driven mode), the inland transporter (the corridor-effect mode), and the seaport (the seaport-driven model). In this section, we setup an economic model to describe and compare these modes from the perspectives of the inland ports themselves and the social welfare.

A supply chain consists of a manufacturer, a retailer, an inland transporter, a seaport and an inland port. The retailer procures the products from the manufacturer and asks the transporter to deliver them through the inland port and the seaport. Let the retailer's profit as

$$\pi_R = (f - w - f_R)q \tag{1}$$

where f_R is the freight rate charged by the transporter and f and q are the product's price and demand, respectively. Because the products are transported through the inland port, q can be treated as the throughput of the inland port and the seaport. w is the wholesale price he paid to the manufacturer. The relationship between the price and the demand of the product can be expressed as:

$$P = A - bq \tag{2}$$

where A and b are the parameters to indicate the market scale and the demand sensitivity to the product's generalized price P. Here P takes the following form

$$P = f + \theta_C q / K_C + \theta_I q / K_I \tag{3}$$

where K_C and K_I are the capacities of the seaport and inland port, respectively. θ_C and θ_I

are the parameters to reflect the cargo delay costs in the seaport and inland port, respectively[6]. It is worthy pointing out that θ_C and θ_I can be the indicators to reflect the efficiencies of the two ports, with higher θ_C and θ_I indicating lower efficiencies. The linear demand function and the generalized price are commonly used in the maritime economics literature (e.g., see the review paper of Wan et al., 2018).[7] The manufacturer acquires his raw materials through the transporter using the seaport and the inland port. Let his profit as

$$\pi_M = (w - c - f_M)q \tag{4}$$

where c is his unit production cost and f_M is the freight rate charged by the transporter to deliver the raw material. The inland transporter's profit is

$$\pi_T = (f_R + f_M)q - (c_R + c_M + 2t_C)q \tag{5}$$

where c_R and c_M are the transportation cost to deliver the raw material and the product, respectively. t_C is the seaport charge. Meanwhile, the seaport's profit is

$$\pi_C = 2t_C q \tag{6}$$

In order to simplify the problem, we normalize the operation costs of the seaport and the inland port to 0.[8]

In the government-driven mode, the local government decides the inland port capacity to maximize his utility from the development of the inland port, i.e.,

$$U_G = uq \tag{7}$$

where u is the local government's unit utility from the inland port. A port's activities can bring the local society many benefits, including decreasing production and transportation costs, providing the function as a distribution center access to the retailers and manufacturers, developing port-related activities and promoting employment (Deng et al., 2013).Some of them can be treated as the local government's additional utility from the development of the inland port (e.g., port-related activities and employment promotion).

Suppose the marginal capacity investment cost is η. Under the government-driven mode, the manufacturer-driven mode, the retailer-driven mode, the corridor-effect mode and the seaport-driven mode, the local government, the manufacturer, the retailer, the inland transporter and the seaport decide the inland port capacity to maximize their utility or profits, respectively.

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[6] In (3), the term $\theta_C q / K_C$ and the term $\theta_I q / K_I$ are the cargo delay costs in the coastal port and inland port, respectively. The delay cost should be positive, which leads to θ_C and θ_I being positive.

[7] The linear demand function is obtained from the utility-maximizing behavior consumers (or port users here) with quadratic additively separable utility function, which is commonly used in economics (Singh and Vives, 1984). Moreover, it enables us to obtain the closed form solutions which are easy to analyze. The form of the delay costs in (3) can satisfy the basic properties of the delay costs (Wan et al., 2018) and easy to solve.

[8] In our model, each player's decision variable is his charge. If the marginal operation costs of the seaport and the inland port are considered, we only need to add them to the optimal charges of each decision makers. Thus, their constant marginal operation costs have no substantial impacts on the results.

Furthermore, we define the social welfare function as

$$SW = Aq - bq^2/2 + uq - (c + c_M + c_R)q - q^2(\theta_C / K_C + \theta_I / K_I) - \eta K_I \tag{8}$$

which means that the social welfare consists of the consumer surplus ($Aq - bq^2/2$) plus the local government's additional utility, then minus the total operation costs related to the products (the manufacturing cost, the transport costs of the raw material and the products), the delay costs and the inland port construction costs.

Moreover, the impacts of the policy in Section 3 to the inland port development can be incorporated into our model as follows. The "go west" policy reduces the manufacturing costs (c). The B&R reduces the inland transportation costs (both c_M and c_R). The FTZ and port integration improve the inland port efficiency (reducing θ_I).

The game sequence among the players is described as follows: (i) The local government/manufacturer/retailer/inland transporter/seaport makes the decision on the inland port capacity, and undertakes its construction costs; (ii) The seaport decides on the charge to the inland transporter; (iii) The transporter decides on the freight rates of his services to the manufacturer and the retailer; (iv) The manufacturer decides on the wholesale price; (v) The retailer decides on the product price.

4.2.2 Comparisons on the inland port capacities under the different modes

Applying the backward induction, we obtain the optimal inland port capacities under different modes[9] as

$$K_G = \frac{\sqrt{(a - c - c_M - c_R)\theta_I \eta u} - 4\theta_I \eta}{4\eta(\theta_C / K_C + b)} \tag{9}$$

$$K_M = \frac{(a - c - c_M - c_R)\sqrt{2\theta_I \eta} - 16\theta_I \eta}{16\eta(\theta_C / K_C + b)} \tag{10}$$

$$K_R = \frac{(a - c - c_M - c_R)\sqrt{\theta_I \eta} - 16\theta_I \eta}{16\eta(\theta_C / K_C + b)} \tag{11}$$

$$K_T = \frac{(a - c - c_M - c_R)\sqrt{\theta_I \eta} - 8\theta_I \eta}{8\eta(\theta_C / K_C + b)} \tag{12}$$

$$K_C = \frac{(a - c - c_M - c_R)\sqrt{2\theta_I \eta} - 8\theta_I \eta}{8\eta(\theta_C / K_C + b)} \tag{13}$$

From (9) to (13) we find that the optimal inland port capacities under different modes are affected by the logistics services to the retailer and the manufacturer (i.e., c_M and c_R). We

[9]The detailed derivation process and the proofs of the following propositions and corollaries are presented in Appendix.

make the explanations as follows. Under the market-driven mode (either the manufacturer-driven or the retailer-driven), it is the manufacturer or the retailer who decide the inland port capacity to maximize their profit, respectively. From (1) and (4) we know that the logistics services to the retailer and the manufacturer (provided by the inland transporter to deliver the product and the raw material) affect the freight (i.e., f_R and f_M) and thereby their profits, which then affects their decisions on the inland port capacity. Under the corridor-effect mode, the logistics services to both the retailer and the manufacturer affect the inland transporter's profit directly (see (6)), which then affects its decision on the inland port capacity. Under the seaport-driven mode and the government-driven mode, the logistics services to both the retailer and the manufacturer affect the product demand and thereby the profits of the seaport and the government, respectively, which then affects their decisions on the inland port capacity. The impacts of the inland transport and logistics services on inland ports are common and extensively investigated by the related studies (e.g., Qiu and Lam, 2018; Tan et al., 2015, 2018).

Comparing the inland port capacity under the different modes, we have the following proposition.

Proposition 1.*If* $u \in ((a-c-c_M-c_R)/2, \infty)$, $K_G > K_C > K_T > K_M > K_R$ *; if* $u \in ((a-c-c_M-c_R)/4, (a-c-c_M-c_R)/2)$, $K_C > K_G > K_T > K_M > K_R$ *; if* $u \in ((a-c-c_M-c_R)/8, (a-c-c_M-c_R)/4)$, $K_C > K_T > K_G > K_M > K_R$ *; if* $u \in ((a-c-c_M-c_R)/16, (a-c-c_M-c_R)/8)$, $K_C > K_T > K_M > K_G > K_R$ *; if* $u \in (0, (a-c-c_M-c_R)/16)$, $K_C > K_T > K_M > K_R > K_G$.

The conclusions in Proposition 1 can be summarized in Figure 6, which tells us that the seaport has more incentive to promote the inland port capacity than the inland transporter, the manufacturer and the retailer. If the inland port is developed by the local government, his additional benefit from the inland port is the main factor to determine its capacity, with higher benefit leading to more inland port capacity under Mode G. The explanations on the comparison results of the inland port capacities under these modes are as follows. Larger port capacity can reduce the cargo delay cost and promote the demand, which is crucial to the profits or the benefits of all investors. The seaport and the inland transporter can get profits from the cargo demand twice, while the manufacturer and the retailer can only get by one time (comparing Eq. (1), Eq. (4) and Eq. (5), Eq. (6)). Thus, the seaport and the inland transporter have more incentive to promote larger inland port than the manufacturer and the retailer. Moreover, in our game structure, the action sequence (the seaport first, then the inland transporter, then the manufacturer and the retailer last) decides the earlier movers has more advantage and profit sharing in the whole supply chain than the later movers. Therefore, the earlier movers are more eager to promote the demand by increasing the inland port capacity than the later movers. For the local government, the unit utility from the inland port is crucial with larger utility leading more incentive to invest more on the inland port.

Next, we examine the impacts of the policies mentioned in Section 3 to the inland port capacity. We use Mode G, Mode T, Mode M, Mode R and Mode C to represent the government-driven mode, the corridor-effect mode, the market-driven mode (including the manufacture-driven mode and the retailer-driven mode), and the seaport-driven mode, respectively. The results can be summarized by the following corollary.

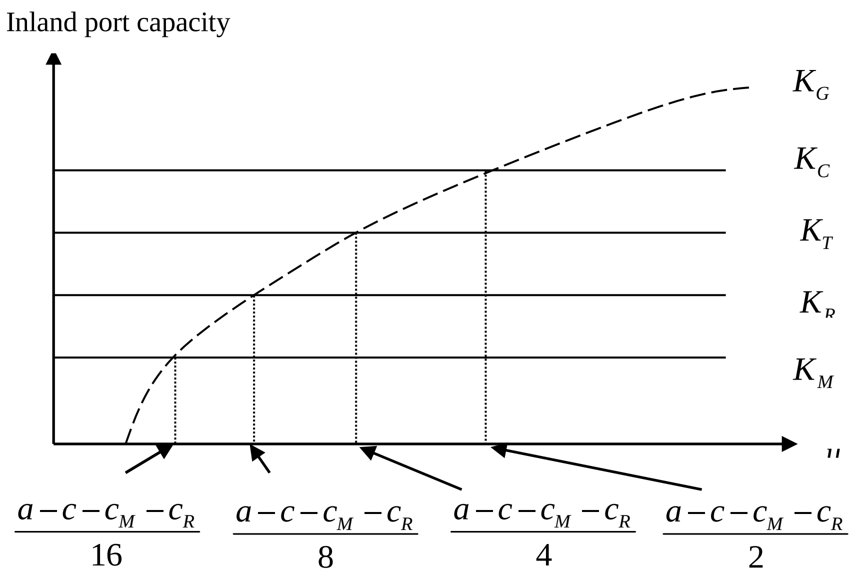

Figure 6 Comparisons of the inland port capacities under different modes

Corollary 1. *The "go west" policy and the BRI promote the inland port capacity under all modes. Whether the FTZ and the port integration promote the inland port capacity depends on the port efficiency improvement after the implementation of these policies. If* $\theta_I > u(a-c-c_M-c_R)/8\eta$*, the FTZ and the port integration promotes the inland port capacity under Mode G; If* $\theta_I > (a-c-c_M-c_R)^2/128\eta$*, the FTZ and the port integration promotes the inland port capacity under Mode C; If* $\theta_I > (a-c-c_M-c_R)^2/256\eta$*, the FTZ and the port integration promotes the inland port capacity under Mode T; If* $\theta_I > (a-c-c_M-c_R)^2/512\eta$*, the FTZ and the port integration promotes the inland port capacity under Mode M; If* $\theta_I > (a-c-c_M-c_R)^2/1024\eta$*, the FTZ and the port integration promotes the inland port capacity under Mode R.*

Corollary 1 manifests that the "go west" policy and the B&R increase the demand of port service and speed up the development of the inland ports by reducing the manufacturing and transport costs. The impacts of the FTZ and port integration depend on the development modes and the port efficiency improvement after the policy implementation. The port efficiency improvement has two opposite effects on the capacity of the inland port. In one side, higher efficiency needs less port capacity because the cargo dwell time is reduced. On the other side, higher efficiency needs larger port capacity because the cargo demand is promoted by the lower delay costs. Only when the improvement of the port efficiency is significant enough, its cargo promotion effect exceeds its capacity reduction effect, the FTZ and port integration lead to larger inland port. The impacts of the FTZ and the port integration policies on the inland port capacity under different mode are summarized in Figure 7, which indicates that the impacts are determined by the inland port efficiency θ_I. From Corollary 1 and Figure 7 we know that Mode R has the lowest request on the port efficiency improvement after the policy implementation, while Mode C has the highest request, to lead to the positive impacts of the FTZ and port integration to the inland port development. The impacts under Mode G are related to unit utility from the inland port. These can be explained by the similar reasons as in Proposition 1.

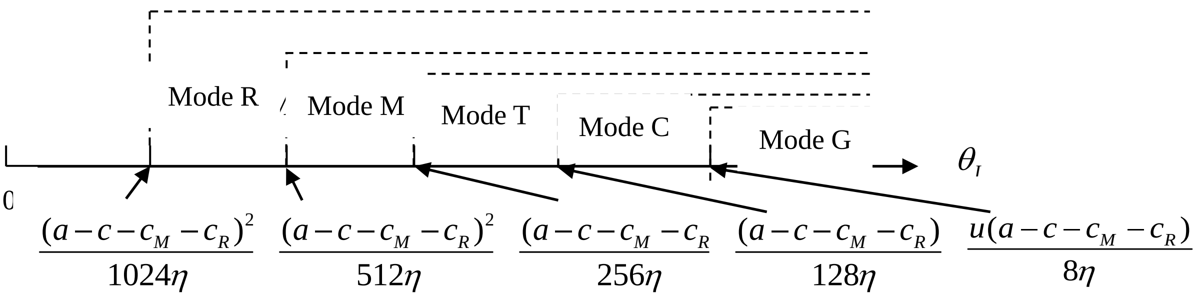

Figure 7 Impacts of the FTZ and the port integration policies
on the inland port capacity under different modes

4.2.3 Comparisons on the social welfare under the different modes

Next we calculate the social welfare under the different modes and obtain the following results.

$$SW_G = \frac{[\sqrt{(a-c-c_M-c_R)u}-4\sqrt{\theta_I\eta}]\{(a-c-c_M-c_R)[(30\theta_C/K_C+31b)+\sqrt{(a-c-c_M-c_R)u}-4b\sqrt{\theta_I\eta}]+32u(\theta_C/K_C+b)[\sqrt{(a-c-c_M-c_R)u}-4\sqrt{\theta_I\eta}]\}}{512u\sqrt{\theta_I\eta}(\theta_C/K_C+b)^2} \quad (14)$$

$$SW_M = \frac{[\sqrt{2}(a-c-c_M-c_R)-8\sqrt{\theta_I\eta}][\sqrt{2}(a-c-c_M-c_R)(30\theta_C/K_C+31b)+32(u-2\sqrt{\theta_I\eta})\theta_C/K_C+(32u-80\sqrt{\theta_I\eta})b]}{1024\sqrt{\theta_I\eta}(\theta_C/K_C+b)^2} \quad (15)$$

$$SW_T = \frac{(a-c-c_M-c_R-8\sqrt{\theta_I\eta})[(a-c-c_M-c_R)(30\theta_C/K_C+31b)+32(u-2\sqrt{\theta_I\eta})\theta_C/K_C+(32u-72\sqrt{\theta_I\eta})b]}{512\sqrt{\theta_I\eta}(\theta_C/K_C+b)^2} \quad (16)$$

$$SW_R = \frac{\begin{array}{l}(a-c-c_M-c_R-16\sqrt{\theta_I\eta})[(a-c-c_M-c_R)\\(30\theta_C/K_C+31b)+32(u-\sqrt{\theta_I\eta})\theta_C/K_C+(32u-48\sqrt{\theta_I\eta})b]\end{array}}{512\sqrt{\theta_I\eta}(\theta_C/K_C+b)^2} \tag{17}$$

$$SW_C = \frac{\begin{array}{l}[\sqrt{2}(a-c-c_M-c_R)-8\sqrt{\theta_I\eta}][\sqrt{2}(a-c-c_M-c_R)\\(30\theta_C/K_C+31b)+32(u-2\sqrt{\theta_I\eta})\theta_C/K_C+(32u-72\sqrt{\theta_I\eta})b]\end{array}}{1024\sqrt{\theta_I\eta}(\theta_C/K_C+b)^2} \tag{18}$$

Comparing the social welfare under the different modes, we have the following proposition.

Proposition 2. *If the marginal capacity investment cost is low enough, or the efficiency of the inland port is high enough, i.e.,* $\sqrt{\theta_I\eta}$ *is small enough, the following comparison conclusions can be obtained.*

(1) $SW_T > SW_R > SW_C > SW_M$;

(2) *The comparisons of* SW_G *and the others depend on* u. *Let* u_1, u_2, u_3 *and* u_4 *are the thresholds, and* $0 < u_1 < u_2 < u_3 < u_4$.

If $u \in (0, u_1)$, $SW_G > SW_T > SW_R > SW_C > SW_M$;

if $u \in (u_1, u_2)$, $SW_T > SW_G > SW_R > SW_C > SW_M$;

if $u \in (u_2, u_3)$, $SW_T > SW_R > SW_G > SW_C > SW_M$;

if $u \in (u_3, u_4)$, $SW_T > SW_R > SW_C > SW_G > SW_M$;

if $u \in (u_4, \infty)$, $SW_T > SW_R > SW_C > SW_M > SW_G$.

From the social welfare function (8) we know that it consists of five parts: the consumer surplus, the local government's utility, the cargo delay costs in the seaport and inland port, the costs of the manufacturer, retailer and inland transporter, and the inland port construction costs. When $\sqrt{\theta_I\eta}$ is small enough, the delay costs and the construction costs are low. Therefore, the social welfare is mainly determined by the other three parts, which are affected by the market demand q. This situation is very similar with a general supply chain, where the whole supply chain efficiency is better if the capacity is decided by the lower stream member, i.e., the member closer to the final customers (Belloni et al., 2017). In our supply chain, the retailer and the inland transporter are closer to the final consumers than the manufacturer and the seaport, respectively. This causes $SW_T > SW_C$ and $SW_R > SW_M$. On the other side, in our supply chain, the inland transporter and the seaport can benefit from the demand twice (their profits are based on the demand twice, see (5) and (6)), while the retailer and the manufacturer only benefit once. Thereby, the profits of the inland transporter and the seaport coincide with the social welfare more closely than the retailer and the manufacturer, respectively. This causes $SW_T > SW_R$ and $SW_C > SW_M$. These two factors (the parties' position in the supply chain and their relationship with the market demand) together determine the social welfare comparison results of the mode T, R, C and M. With the increase of the local benefit u , Mode G leads to the lower social welfare, compared to the other modes. This phenomenon of the excessive investment on the inland port made by the local government harms the whole social welfare is similar with the situation happened in the Chinese costal ports in 2000s (Xu and Chin, 2012).

Proposition 2 has good policy implications as follows. In port regulation studies, centralization and decentralization are two commonly-used modes (Zheng and Negenborn, 2014), with the central government caring about the whole social welfare and the local government paying attention to his benefits from the port development. Based on the conclusions of Proposition 2, we can find their impacts on the inland port development. If the local government regulates the inland port, the best mode for him is Mode G. If the central government regulates it, the best choice is the mode which can provide the maximum social welfare. We know that when the local benefit (from the inland port) is small, i.e., $u \in (0, u_1)$, the central government and the local government have the same preference on the choice of its development mode. However, with the increase of the local benefit, the local government's choice deviates from the central government's preference more and more. Therefore, when the inland port can bring large benefit to its local city, the policy makers need to pay attention to the local government's overinvestment incentive and the centralization regulation is recommended. Otherwise, the local government (or the decentralization mode) can play a leading role in the development of the inland port.

5. Discussions and conclusions

Chinese inland ports gained significant development during the past two decades. However, practitioners as well as policy makers are facing several challenges. After the discussions on the development modes of the inland ports and the related economic models, we examine their governance from the following perspectives: the involvement of the central government and local governments, the port-city relationship and challenges (both at the institution level and at the port industry level), and the coordination of the port groups.

(1) Besides the inland ports under the government-driven model, whose development is greatly dependent on the direct participation of local governments, governments' involvement, to a certain extent, is also observed in the development process of inland ports under the other two models, namely the market-driven model and the corridor-effect model. Governments' involvement, especially at the early stage, can substantially help improve inland ports in many aspects such as customs clearance and bonded warehouse functions. However, very few local governments have detailed spatial development plans for inland ports (Witte et al., 2019). Therefore, local governments should pay attention to the layout and master plans of inland ports

ensuring the synergy between inland ports and their hosting cities and regions. Meanwhile, the central government should take the responsibility of guiding local governments' efforts to develop inland ports. Nowadays, many inland ports in China are driven by national policies such as B&R and industrial transfer. If national policies are wrongly interpreted and not implemented well on local levels, which may result in the uncoordinated development or even malignant competition between inland ports (Bergqvist et al., 2010). Governments also need to deal well with their relationship with market and make full advantage of the market mechanism. Undoubtedly, the logistics demand from the market is the most critical driver for the sustainable development of inland ports in the long term. Moreover, when the inland port can bring large benefit to its local city, the local government's overinvestment incentive need to be concerned and the central government's involvement is crucial to the planning of the inland port development.

(2) From the perspective of port-city relationship, we mainly pay attention to the interests balance among the different stakeholders. With the development of inland ports, multi-dimensional inland port-city challenges emerge (Witte et al., 2014). In China, almost all inland ports are significantly embedded in their hosting cities regardless of main driving forces behind ports' development. The positive and negative externalities of inland ports co-exist and exert influence on cities' spatial, economic and institutional dimensions. In this circumstance, improving governance capacity of inland port is very important. Specifically, the holistic governance should be introduced to deal with the development issues of inland ports. The negative external effects such as air pollution and congestion need to be considered. Moreover, inland ports should adopt the stakeholder management strategy focusing on the balance of diversified interests. This will help inland ports coordinate their business partners such as shippers, freight forwarders and transport enterprises.

(3) From the perspective of cooperation, we mainly pay attention to the port coordination under the port integration strategy. In recent years, port integration arises as a national strategy to solve the over-capacity problem that Chinese seaports are facing on regional level (Notteboom and Yang, 2017). However, in some provinces undertaking port integration reform, such as Zhejiang and Jiangsu, inland ports are merged into the provincial seaport enterprise and become associated companies with municipal seaport enterprises. Consequently, the link between those inland ports and seaports could be closer in operational and financial aspects. At the current stage, the newly built provincial seaport enterprises just integrate inland ports located in coastal areas to enhance the hinterland for their seaports. With the expected evolution of Chinese seaport competition from inter-port level to inter-port cluster level, provincial seaport enterprises in coastal provinces are likely to follow Outside-In pattern to further enlarge their hinterland in vast central and western China regions. In that case, the port-hinterland transportation network, the ownership of inland port and regional layout of inland ports may be changed. Because provincial seaport enterprises could organize the freight flows from hinterland based on a more comprehensive view compared to former municipal seaport enterprises.

Further research can be considered as follows. Although the contributions of inland ports to the local economy are recognized, how to empirically quantify these contributions is a critical issue. As China has large samples of inland ports, future studies can use the ports to empirically assess their contributions to local economy. Moreover, there are some unsolved questions related to port integration between inland ports and seaports. For instance, how to maintain the sustainable coordination among these integrated ports? How to arrange the ownership structure and find the feasible benefit allocation schemes between them? These interesting topics are also the recommendations for further research.

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Appendix

The derivation of the optimal inland port capacities under the different modes

According to the backward induction, we first analyze the retailer's decision on the product price. Substituting (2) into (1) and maximizing π_R, we have

$$f = (A + w + f_R)/2 \tag{19}$$

Substituting (19) into (4) and maximizing π_M, we have

$$w = (A + c + f_M - f_R)/2 \tag{20}$$

Substituting (19) and (20) into (5) and maximizing π_T, we have

$$f_M = f_R = (A - c + c_M + c_R + 2t_C)/4 \tag{21}$$

Substituting (19), (20) and (21) into (6) and maximizing π_C, we have

$$t_C = (A - c - c_M - c_R)/4 \tag{22}$$

Substituting (19), (20), (21) and (22) into (7), π_R, π_M, π_T and π_C, and maximizing their utility or profits minus the inland port investment costs, we obtain K_G, K_R, K_M, K_T and K_C, respectively. □

Proof of Proposition 1

Comparing (10), (11), (12) and (13), we know that $K_C > K_T > K_M > K_R$. From (9) and (13), we have $K_G > K_C$ if $u > (a - c - c_M - c_R)/2$. From (9) and (12), we have $K_G > K_T$ if $u > (a - c - c_M - c_R)/4$. From (9) and (10), we have $K_G > K_M$ if $u > (a - c - c_M - c_R)/8$. From (9) and (11), we have $K_G > K_R$ if $u > (a - c - c_M - c_R)/16$. □

Proof of Corollary 1

From (9), (10), (11), (12) and (13), we have $\partial K_G / \partial c < 0$, $\partial K_C / \partial c < 0$, $\partial K_T / \partial c < 0$, $\partial K_M / \partial c < 0$, $\partial K_R / \partial c < 0$, $\partial K_G / \partial c_M < 0$, $\partial K_C / \partial c_M < 0$, $\partial K_T / \partial c_M < 0$,

$\partial K_M / \partial c_M < 0$, $\partial K_R / \partial c_M < 0$, $\partial K_G / \partial c_R < 0$, $\partial K_C / \partial c_R < 0$, $\partial K_T / \partial c_R < 0$, $\partial K_M / \partial c_R < 0$, $\partial K_R / \partial c_R < 0$. These prove the first part of this Corollary.

From (9), we have $\partial K_G / \partial \theta < 0$ if $\theta_I > u(a-c-c_M-c_R)/8\eta$. From (13), we have $\partial K_C / \partial \theta < 0$ if $\theta_I > (a-c-c_M-c_R)^2/128\eta$. From (12), we have $\partial K_T / \partial \theta < 0$ if $\theta_I > (a-c-c_M-c_R)^2/256\eta$. From (10), we have $\partial K_M / \partial \theta < 0$ if $\theta_I > (a-c-c_M-c_R)^2/512\eta$. From (11), we have $\partial K_R / \partial \theta < 0$ if $\theta_I > (a-c-c_M-c_R)^2/1024\eta$. These prove the second part of this Corollary. □

Proof of Proposition 2

Comparing (15), (16), (17) and (18), we know that $SW_T > SW_R > SW_C > SW_M$ when $\sqrt{\theta_I \eta}$ is small enough. After calculation we know that

$$\begin{aligned} SW_G - SW_T &= 2(a-c-c_M-c_R)[(a-c-c_M-c_R)(1-30\theta_C/K_C-31b) \\ &+32(1-u)(b+\theta_C/K_C)+(31b+30\theta_C/K_C)\sqrt{(a-c-c_M-c_R)/u}] \end{aligned}.$$

Moreover, $$\begin{aligned} &\partial(SW_G - SW_T)/\partial u = -(a-c-c_M-c_R)[64(b+\theta_C/K_C) \\ &+(31b+30\theta_C/K_C)\sqrt{(a-c-c_M-c_R)/u^3}]<0 \end{aligned}.$$

We know that $\lim_{u\to 0^+}(SW_G - SW_T) > 0$ and $\lim_{u\to +\infty}(SW_G - SW_T) < 0$. Therefore, we have $SW_G > SW_T$ when u is small enough. Similar logic can be applied to prove the comparisons of SW_G and SW_R, SW_G and SW_C, and SW_G and SW_M . □