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Analysis on the Features of Chinese Dry Ports: Ownership, Customs Service, Rail Service and Regional Competition

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Abstract:

In recent years, many regions including China have witnessed fast growth of dry ports. Unlike in the other regions of the world, the amount of cargos handled by most dry ports in China is not in compliance with the significant amount of resources invested, but the reasons behind have not been discussed before. After a brief review on the development pattern of Chinese dry ports, certain dry port functions like customs clearance and rail connection, dry port ownership structure, and inter-competition among dry ports are identified as the unique factors which distinguish Chinese dry ports from others and affect their performance. We investigate the relationship between these factors and the efficiency of Chinese dry ports with a two-stage approach based on a panel data collected from eight dry ports affiliated to the port of Ningbo, China, covering the 2011-2016 period. In the first stage, Data Envelopment Analysis (DEA) is used to measure these dry ports' technical efficiency. In the second stage, Tobit regression analysis is applied to explore the relationship between efficiency and the above mentioned factors. Several insightful findings are observed, further leading to useful managerial insights.

Keywords: Dry port development; Efficiency evaluation; Data Envelopment Analysis (DEA); Tobit regression

1. INTRODUCTION

Globalization boosts freight volumes at global, regional, and local levels, and also brings challenges to seaports and their inland transport network. Many seaports have to face increased capacity shortage within the seaports and congestion on the roads near the seaport area (Wan et al., 2013), which in turn lengthen transport times. With road being the main inland transportation mode, negative environmental effect of shipping activities is exacerbated. Such challenges may be tackled with inland logistics platforms that can divert pressure away from seaport by receiving cargo and vehicles, offering short-term storage, handling and consolidating cargoes, and providing clean and rapid transport to seaport (Crainic et al., 2015). Dry ports, as the important nodes in transportation network, have been put into practice to provide those functions. As defined by Roso and Lévêque (2002), a dry port is "an inland intermodal terminal directly connected to a seaport, with high-capacity traffic modes, preferably rail, where customers can leave and/or collect their goods in intermodal loading units, as if directly to the seaport." Mode shift from road to rail makes the transport network more environmental-friendly, reduces transport costs, and allows a more efficient transfer of cargos between inland cities and seaport. The implementation of dry ports helps to relieve the pressure faced by seaports and the whole transport network.

Dry ports can also provide value-added services to cargos, such as warehousing, packing, cleaning and fumigation, customs clearance, and consignment consolidation (UNCTAD, 1991). All these benefits have encouraged countries with or without seaports to set up dry ports ever since the concept was brought forward, in order to achieve environmental and economic sustainability of relevant logistics activities. Many dry ports are city-based and invested by local governments, since they are considered to be economic growth poles (Beresford et al., 2012). Rail operators and private companies may also invest in dry ports, yet seaports normally do not participate in the investment (Roso and Lumsden, 2010).

Dry ports have appeared in China since the beginning of 2000s and experienced a fast development in the following 15 years. However, it is noticed that dry ports in China do not fit the aforementioned definition in several aspects. For example, many dry ports have not been connected by rail and some of them even have no function of customs clearance (Zeng et al., 2013). The ownership structure of Chinese dry ports is relatively simple, since in most of the cases, a dry port is invested by a certain seaport for the purpose of relieving operational burden at the capacity constrained seaport and capturing cargos from the hinterland. Also, the density of dry ports is very high and the competition could be extremely fierce among them.

Although some existing literature has reviewed the motivations, challenges, opportunities, and development paths of dry ports in China (Beresford et al., 2012; Zeng et al., 2013), the impact of the aforementioned features on efficiency of Chinese dry ports has not been discussed before. Motivated by this phenomenon, the paper aims to verify if these features lead to inefficiency of a sample of dry ports. Concretely, this paper will explore answers for the following specific questions: a) How do efficiency levels change among a sample of Chinese dry ports over the past years? b) Which entity should dominate dry port investment and operation: local government or seaport? c) How does the usage of rail service affect dry port efficiency? d) How does the availability of customs clearance function contribute to the efficiency of dry port? e) How does competition among dry ports (inter-competition) impact dry port efficiency?

In order to achieve the study objective, a two-stage analysis approach is proposed in this paper. In the first stage, Data Envelopment Analysis (DEA) is applied to evaluate technical efficiency among a sample of dry ports. In the second stage, Tobit regression analysis is implemented to explore the correlations of various factors mentioned above and DEA scores obtained in the first stage. The study is based on a panel data with eight dry ports covering the period of 2011-2016. All the eight dry ports are invested and operated partially by Ningbo Port Corporation, which is now the third largest seaport in the world in term of total container throughput.

The empirical results revealed that customs clearance function impacts dry port efficiency in a negative way in China. The reliance of rail service improves the efficiency of a dry port only if the dry port is distant from its affiliated seaport. Regarding the effect of ownership structure, we observed that too much involvement of seaport in dry port investment will bring negative influence on the efficiency of dry port. However, the negative influence is moderated by the size. In addition, inter-competition is proved to contribute to dry port efficiency. This study helps to improve the understanding on the development of dry ports in China and provide decision support for policy makers and relevant dry port stakeholders to improve their service quality, future investment plans and resource allocation.

The paper is organized as follows. Section 2 reviews the features of Chinese dry ports, using dry ports of other regions as a benchmark. Some hypotheses regarding how various features affect the efficiency of dry port are proposed. Section 3 describes the methodology and data which are used to test these hypotheses. Section 4 discusses the results. Section 5 draws the conclusion and provides the policy and managerial implications.

2. THE FEATURES OF CHINESE DRY PORTS

In this section, we summarize the features of Chinese dry ports from three aspects: basic functions, ownership structure and inter-competition status. For each aspect, we compare the difference between China and other regions. Based on the comparison and previous literature, we propose four hypotheses regarding how these features will affect efficiency for testing.

2.1 Dry port functions

UNCTAD (1991) identified the basic functions of dry ports as follows: receipt and dispatch of cargo, truck operations, loading/unloading of cargo/containers to and from trains, customs clearance, gate checks and security, storage of cargos and containers, container repair, information flow and communications, record keeping and data storage, billing and cash collection.

Among these functions, the rail connection between dry port and seaport is crucial (Roso and Lévêque, 2002). This is because the congestion on the road and at the seaport gates can be relieved as road transport is substituted by rail transport. Furthermore, total CO_2 emissions during transportation decreases, considering that rail transport emits less CO_2 than road transport. Meanwhile, economies of scale are possible to be achieved by using rails, which has a larger capacity than road transport (Lättilä et al., 2013). Reliable rail shuttle service to the seaport also allows a seamless hinterland access. As an evidence, dry port Azuqueca de Henares in Spain offers daily rail connections to the seaports of Barcelona, Bilbao and Santander and attracts a large number of cargos from hinterland (Roso and Lumsden, 2010). Given the positive effect of rail connection, the following hypothesis can be proposed:

Hypothesis 1: The efficiency of dry ports with more convenient rail service to seaport is higher than the dry ports with less convenient rail service.

In China, some dry ports have direct rail access to seaports. Shanghai Railway Administration started sea-rail intermodal transportation between dry port Bengbu and port of Shanghai in 2013. Three shuttle trains are operated every week. The transportation time between the port of Shanghai and Bengbu is reduced by 50 hours and transport cost per twenty-foot equivalent unit (TEU) is reduced by 40% (Su and Xue, 2013). However, most dry ports in China are not connected with seaports by direct shuttle trains. City of Xi'an in Shannxi Province relies heavily on rail transport, 75% of exports from Shannxi Province are transported to major sea hubs by intermodal transport including train, but there is still no direct regular train service connecting dry port Xi'an and seaports (Beresford et al., 2012). Lacking direct rail connection results in long transport time and high transport cost and discourages shippers to import or export cargos through dry ports.

Moreover, customs clearance is recognized as one of the core functions for a dry port (Beresford et al., 2012). With customs clearance service, the qualified enterprises can enjoy the preferential policy as a one-stop process, from declaration and inspection to authorizing the release of import and export cargo at dry port, and thus facilitate the transportation. Almost all the dry ports studied in the literature provide customs-related services. For instance, Matsapha, a dry port in Swaziland in South Africa, performs customs clearance for faster throughput (Roso and Lumsden, 2010). Cikarang dry port in Indonesia is able to handle all documentation work for customs. The customs clearance function enables the seaports to restructure their supply chain locally and hence shorten lead times (Beresford et al., 2012). In light of this, we have the second hypothesis:

Hypothesis 2: Provision of customs clearance function in a dry port improves the dry port's efficiency.

In China, customs clearance function is usually realized through the agreement signed by customs authority and dry port operators, with provincial and municipal government playing an active role in strengthening relevant relations. However, not all the dry ports are endowed with the function, nor the function works well at some dry ports due to institutional and practical limitations. For example, the customs regulations at dry port Shijiazhuang require shippers to declare cargos at their dry port warehouses and finish the rest of the customs procedure, such as release consignments, at the seaport (Beresford et al., 2012). Unlike the true one-stop service that requires all the customs-related procedures completed at the dry port, the customs arrangement in Shijiazhuang causes shippers extra costs and time and thus makes it less attractive to use dry port. The design of efficient monitoring and regulation processes is still required (Zeng et al., 2013).

2.2 Dry port ownership

Owners of a dry port can be real estate developers, rail operators, terminal operators, freight forwarders and local authorities (Rodrigue et al., 2010; Roso and Lumsden, 2010). Many dry ports in North America follow the landlord model where a real estate promoter cooperates with a rail operator to build logistics activities at the rail terminal and obtain revenues (Rodrigue et al., 2010). The developers of dry ports in Europe are more diversified. Dry port Venlo in the Netherlands is invested by the main terminal operator at the port of Rotterdam. Swedish dry ports are owned either entirely by a municipality or jointly by a municipality and commercial entities such as rail operators or shippers. An African dry port tends to apply state ownership (Roso and Lumsden, 2010). Although the India government welcomes foreign corporations to invest in Indian dry port, subsidies and preferential policies are provided to support state-owned dry port corporations in improving their efficiency and service to compete with these foreign corporations (Ng and Gujar, 2009).

Public sectors, i.e., local governments in certain hinterland region, want to develop dry ports to promote regional economic development. Private promoters and seaports, on the other hand, regard developing dry port as a chance to develop business or expand market. The potential conflicts of interest require a leverage among actors (Rodrigue et al., 2010). The appropriate ownership structure for dry ports has not been studied to our knowledge. However, in seaport sector, Monios and Wilmsmeier (2012) suggested that a close operational relationship between inland terminal and seaport terminal operator should be established, in order to attract cargo flows to the seaport. Tongzon and Heng (2005) agreed that less government-controlled ownership is positively related to seaport efficiency. These findings may imply that dry ports heavily invested by seaports can be more efficient, and the following hypothesis is formulated:

Hypothesis 3: More involvement of seaport in the ownership structure of dry port leads to higher efficiency.

Figure 1 shows the distribution of Chinese dry ports and their affiliated seaports. Different from dry ports in other regions, Chinese dry ports are rarely fully owned by private sectors, since the role of private companies in the dry port sector is not clearly defined by laws (Beresford et al., 2012). Usually, a Chinese dry port is jointly invested by one single seaport and local companies owned, at least partially, by the local government (Zeng et al., 2013). Seaports have been broadly and deeply involved in dry port investment and operation because they think the dry port can help them to capture hinterland cargo of certain region. It remains a question who should dominate ownership structure, the seaport or the government.

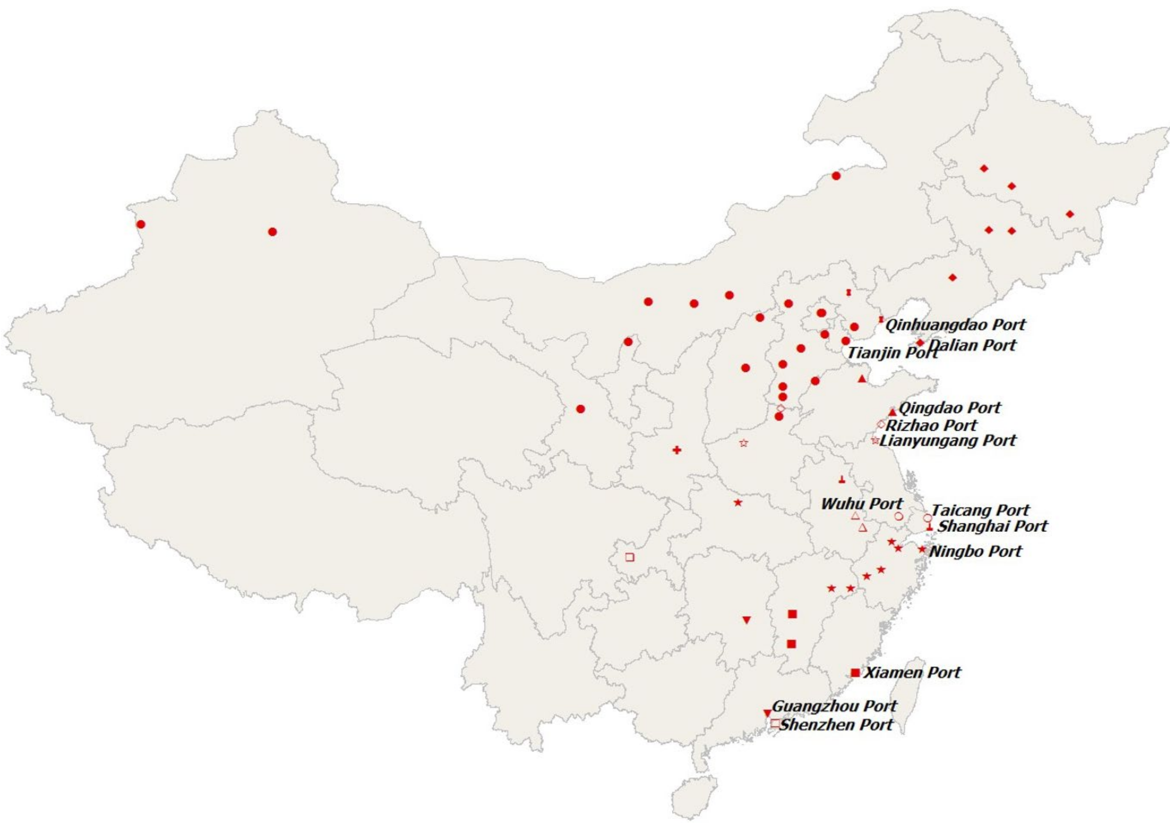

Figure 1 Dry ports and their affiliated seaports in China

Note: Each seaport and its dry ports are indicated by the same mark. Marks without name labels indicate dry ports.
Source: Authors' own composition

2.3 Dry port inter-competition

Competition provides incentives for firms to improve efficiency (Oliveira and Cariou, 2015). Empirical studies on seaports in the United States find that competition between seaports is associated with high efficiency (Wan et al., 2014). Hence, we bring forward the last hypothesis:

Hypothesis 4: Inter-competition produces higher dry port efficiency.

In recent years, building dry ports becomes a "fashion" in China. As depicted in Figure 1, more than thirty dry ports have been established. Most of them are concentrated in the central and eastern regions. The density of dry ports became very high. For example, four dry ports have been built in Henan Province and they are invested by different seaports. Fierce competition among seaports is then presented among their dry ports. Unlike seaports that face both intra- and inter-port competition, dry ports merely compete with other dry ports in the same region.

3. METHODOLOGY

The production frontier based methods have been extensively used in industrial/organizational contexts for efficiency or performance measurement over the past several decades (Cullinane et al., 2006). DEA is one of the most applied methods in this respect. This non-parametric method was first put forward by Charnes et al. (1978) to measure technical efficiency when decision making units (DMUs) have multiple inputs and outputs. Numerous empirical studies used this method to measure seaport efficiency or performance (e.g., Tongzon and Heng, 2005; Barros and Managi, 2008; Bergantino and Musso, 2011; Niavis and Tsekeris, 2012; Yuen et al., 2013; Wanke, 2013; Oliveira and Cariou, 2015). The method has also been applied in dry port efficiency evaluation (e.g. Haralambides et al., 2011; Haralambides and Gujar, 2012) and inland waterway container terminals (Wiegmans and Witte, 2017). CCR model and BCC model are two models used for DEA analysis. The former assumes that the production process yields constant returns to scale and the latter assumes that the production process yields variable returns to scale (Charnes et al., 1978; Banker et al., 1984).

In some studies, DEA is followed by a regression analysis to estimate the impact of environmental factors on efficiency scores. Banker and Natarajan (2008) found that a two-stage approach, comprising DEA in the first stage and an ordinary least squares, maximum likelihood or even a Tobit model in the second stage, outperforms parametric methods in terms of estimating the impacts of contextual variables. Windle and Dresner (1995) suggested that combining DEA with Tobit regression is an efficient tool when dependent variable is in the range of (0, 1]. A number of studies (e.g. Turner et al., 2004; Wan et al., 2014; Ding et al., 2015) combined DEA with Tobit regression to explore factors influencing infrastructure productivity of seaports or container terminals. This two-stage approach has not been applied in dry port efficiency study yet. In this paper, following Windle and Dresner (1995), we apply the standard two-stage approach.

3.1 Stage 1 - efficiency evaluation with DEA

In the first stage, an output-oriented DEA model is applied. Unlike the input-oriented approach, the output-oriented approach maximizes outputs given fixed inputs. This approach is more suitable for our study, since inputs for dry ports do not vary very frequently, but outputs may change frequently. Both CCR and BCC models are used for comparison. DEA scores generated from our model fall in the range of (0, 1] and a score equal to 1 indicates being efficient.

In measuring seaport efficiency, we should first identify dry ports' outputs and inputs. The output is in most cases measured by physical quantity of cargo handled, such as total throughput in tons or in TEUs. TEU can be considered as the output unit for dry ports as containers are the major cargos of dry ports. To reflect the multi-output nature and operational characteristics of dry ports, we further identify four types of services provided at dry ports, i.e. comprehensive services, container management services, transport services and freight forwarding services. Each service type is considered as one output. To run a dry port, various inputs are required. In this paper, we use the area of a dry port, including handling and storage areas, to measure the land input. The amount of fixed asset and current asset are used to measure the capital input.

3.2 Stage 2 - Tobit regression

Tobit regression (Tobin, 1958) is a censored regression. It supposes that the true dependent variable, i.e. efficiency score in this paper, is an unobservable (latent) variable. However, we can observe DEA scores which are bounded above at 1. When the true efficiency score is above 1, it is censored to the case where the DEA score equals to 1. In particular, as the true efficiency score is denoted DEA_{kt}^{*} for dry port *k* in year *t*, the observable DEA efficiency score is defined as follows:

$$DEA_{kt} = \begin{cases} DEA_{kt}^{*} & if\ DEA_{kt}^{*} < 1 \\ 1 & otherwise \end{cases} \quad (1)$$

In a random-effects Tobit model[1], the latent variable, DEA_{kt}^{*}, has a linear relationship with a set of explanatory variables and can be written into the following equation:

$$DEA_{kt}^{*} = \beta_0 + \sum_i \beta_i x_{kti} + \omega_{kt} \quad (2)$$

where *i* indicates the repressors, x_{kti} represents the environmental variables that impact dry port efficiency, and $\omega_{kt} = u_k + \varepsilon_{kt}$, in which u_k is the random effect at the dry port level and ε_{kt} is the error term.

Various environmental factors have been discussed in the literature, including population (Barros and Managi, 2008; Bergantino and Musso, 2011; Niavis and Tsekeris, 2012; Yuen et al., 2013; Wan et al., 2014; Oliveira and Cariou, 2015), GDP (Barros and Managi, 2008; Bergantino and Musso, 2011; Niavis and Tsekeris, 2012; Yuen et al., 2013), scale (Turner et al., 2004; Tongzon and Heng, 2005; Wan et al., 2014), number of terminal operators (Wan et al., 2014; Ding et al., 2015), and number of Class I railroads serving seaport (Turner et al., 2004; Wan et al., 2014). Among these widely-discussed factors, we select *GDP per capita* of the dry port's city and *Large scale* as environmental variables for the second stage regression on dry port efficiency. Similar to the case of seaports, an increase in economic activities (measured by *GDP per capita*) in the city boosts transport demand for the dry port. In addition, based on the discussion in Section 2, factors relevant to the characteristics and special features of Chinese dry ports are the main interest of the regression analysis. These factors include, *Reliance of rail* service between seaport and dry port, *Customs function, Seaport ownership,* regional *Competition*, and so on.

3.3 Data and variable construction

[1] We mainly present results for random effect model, because according to Greene (2004), estimations of fixed effects (or dummy variables) tend to be biased with Tobit regression. However, as part of the robustness check, we also estimated fixed-effect Tobit models based on a semiparametric method proposed by Honoré (1992) and pooled regressions. Similar results are obtained which proved the robustness of the result. The results of fixed-effect Tobit regressions and pooled regressions are demonstrated in Appendix.

The analysis is implemented with panel data of eight dry ports invested and operated by Ningbo Port Corporation. The data covers a six-year period from 2011 to 2016. However, two dry ports in the sample, Yiwu and Xiangyang, did not exist until 2013 and dry port Xiaoshan just commenced operation in 2012. Therefore, in total we have 43 observations and each observation is a (dry port, year) pair. The basic information of the eight dry ports is listed in Table 1.

Table 1 List of dry ports studied

Dry ports	Start year	Capacity (TEU/year)	Road Distance to Ningbo (km)	Location	Shareholders other than Port of Ningbo
Yingtan	2011	50000	600	Jiangxi	Local government-owned enterprise, 61.369%
Shangrao	2011	50000	500	Jiangxi	Local government-owned enterprise, 50%
Quzhou	2011	100000	400	Zhejiang	Local enterprise, 60%
Jinhua	2011	30000	260	Zhejiang	Local government-owned enterprises, 76.92%
Yiwu	2013	600000	236	Zhejiang	Local government-owned enterprise, 65%
Shaoxing	2011	40000	145	Zhejiang	Local government-owned enterprises, 95%
Xiaoshan	2012	60000	175	Zhejiang	Local government-owned enterprise, 65%
Xiangyang	2013	30000	1300	Hubei	Rail corportation,100%

Sources: collected and summarized by authors

For dry port efficiency analysis with DEA in the first stage, three inputs and four outputs are summarized in Table 2. All data comes from annual reports of these dry port companies provided by Ningbo Port Corporation.

Table 2 Summary for variables in DEA analysis

Variable		Number of DMUs	Mean	Maximum	Minimum	Standard deviation
Inputs	Dry port area (m^2)	43	31314	90000	10000	24341
	Current assets (thousand RMB)	43	12068	79450	182	20717
	Fixed assets (thousand RMB)	43	16546	39528	0.461[a]	13531
Outputs	Comprehensive services throughput (TEUs)	43	8492	69855	0	17358
	Container management services throughput (TEUs)	43	19782	82840	0	22494
	Transport services throughput (TEUs)	43	11721	64477	0	14498
	Freight forwarding services throughput (TEUs)	43	4455	57622	0	10425

a. Dry port Xiangyang utilizes the infrastructure and equipment belonging to the local railway station, and thus its fixed assets investment is close to 0.

Data used to construct explanatory variables of Tobit regression analysis are collected from several sources, such as Annual Economic Reports published by local governments, Annual Reports of dry ports provided by Ningbo Port Corporation. The explanatory variables are summarized in Table 3.

Table 3 Summary for variables in Tobit regression analysis

Variable	Total DMUs	Mean	Maximum	Minimum	Standard deviation
Economic status (ln *GDP per capita*)	43	10.957	11.872	9.681	0.543
Large scale (Dummy)	43	0.163	1	0	0.374
Service (No.)	43	5.465	11	2	2.394
Long haul (Dummy)	43	0.233	1	0	0.427
Reliance of rail (%)	43	0.151	0.594	0	0.179
Customs function (Dummy)	43	0.512	1	0	0.506
Seaport ownership (%)	43	0.295	0.5	0	0.165
Competition (No.)	43	7.395	11	2	2.352

The detailed explanation of these explanatory variables are as follows:

Economic status: Economic growth is crucial for dry port development. Well-developed local economy can guarantee strong transport demand (Bergantino and Musso, 2011). We use *GDP (nominal) per capita* at the city level to capture the local market potential related to each dry port.

Large scale: Returns to scale refers to disproportionally faster increase in outputs as the production scale (i.e. inputs) increases. It is a possible reason for difference in efficiency (Turner et al., 2004). Larger dry ports may be more efficient than smaller ones and result in higher efficiency scores. The scale of the seaport can be measured by its container throughput (Rodrigue and Notteboom, 2012). In our study, we follow the method proposed by Wan et al. (2014) and use a dummy variable *Large scale* to distinguish small and large dry ports. Dry port with annual total container throughput (across all four types of outputs) over 45,000 TEU, which is the average level of all DMUs, is considered as a large dry port. The value of the variable *Large scale* is 1 if the dry port is considered as a large dry port; otherwise it is 0.

Service: A dry port can offer a great variety of services. According to the statistics report of the sample dry ports, the four types of services provided at dry ports, namely comprehensive services, container management services, transport services and freight forwarding services, can be further divided into 14 sub-categories, which are transhipment, inspection, packing and unpacking, consolidation, container maintenance, fumigation, weighing, bonded service, empty container management, sea-rail intermodal transport, road transport, drop and pull transport, customs clearance and road transport forwarding service. When various types of services can be found at one stop, the clustering effect may make the dry port more attractive compared to those with only a few limited services. However, when these services do not share inputs while each requires some fixed inputs, inputs increase as the number of services increases, consequently, the diseconomies of scope yields and the efficiency may become low. For example, sea-rail intermodal transport and road transport are not very likely to share inputs, while all of them require investment on special equipment to make the services available even at a low demand. Therefore, providing these two services simultaneously may lead to low efficiency of the dry port. Hence the effect of having more service sub-categories on dry port efficiency is not clear. The variable *Service* is constructed to capture this effect and it is equal to the number of service sub-categories offered by each dry port. Thus, at most a dry port in our sample can offer 14 different services.

Long haul: Long distance results in high transport cost and thus high export cost to the shippers in the deep hinterland. In order to establish close connection to seaports, a fast, convenient, yet environmental-friendly transport corridor is required. Consequently, cities distant from seaports favour the construction of dry ports. The dummy variable, *Long haul*, is used to indicate long distance between the seaport and the dry port. We set the threshold of *Long haul* as 500 *km* in accordance with the concept of a distant dry port (FDT, 2007). If the road distance between the seaport and the dry port is over 500 *km*, the dry port is identified as a relatively faraway dry port and *Long haul* equals to 1; otherwise the value is 0.

Reliance of rail: It is noted that *Reliance of rail* in some literature is denoted by the frequency of rail shuttle service between the dry port and seaport. However, in our case, dry port Quzhou and dry port Yingtan have no fixed rail service timetable, but only provide random service that depends on the number of accumulated containers. Thus, we use the ratio of annual TEUs carried by sea-rail intermodal mode to total container throughput across four different services as a proxy of rail service level of the dry port. Castillo-Manzano et al. (2013) apply the same variable to approximate the frequency and number of port-to-rail intermodal connections.

Customs function: Since the customs clearance service is not available or functioning smoothly at all dry ports, *Customs function* may not positively associate with dry port efficiency in China. *Customs function* is defined as a dummy variable where the value of the variable is 1 if the dry port can offer customs clearance service and 0 otherwise.

Seaport ownership: The variable is measured by percentage of shares owned by the seaport. Among the eight dry ports investigated, except for dry port Xiangyang, all the others are operated by the joint-venture between Ningbo Port Corporation and local enterprises (government-owned). Additionally, the ownership structure of those dry ports was determined before the construction of those dry ports and has been unchanged since then and during the sampling period, so there is no endogeneity between efficiency score and *Seaport ownership*.

Competition: We assume that competition exists within a radius of 400 *km* of the dry port in concern.[2] Dry ports located in this area are considered as the competitors and more competitors

[2] We test a few thresholds, i.e. 300 *km*, 400 *km*, 500 *km* and 600 *km* and find 400 *km* generate the highest significant level in the regression.

lead to fiercer competition. Number of rival dry ports within the 400 *km* radius is taken as proxy of *Competition*.

4. EMPIRICAL RESULTS AND DISCUSSION

4.1 Efficiency analysis

The average DEA scores and scores of individual dry ports with CCR model and BCC model are shown in Figure 2, Table 4 and Table 5 respectively. In Figure 2, CRS stands for scores from CCR model and VRS stands for scores from BCC model. The results show that the overall efficiency of dry ports varies over time without a stable increasing trend. Concretely, the efficiency scores increased steadily before 2014, and then decreased from 2014 to 2016. The reason lies on the decline of container throughput during the two years. The dry ports did not follow the same pattern as their adherent stakeholder, the port of Ningbo, whose throughput has maintained a significant growth since 2008.

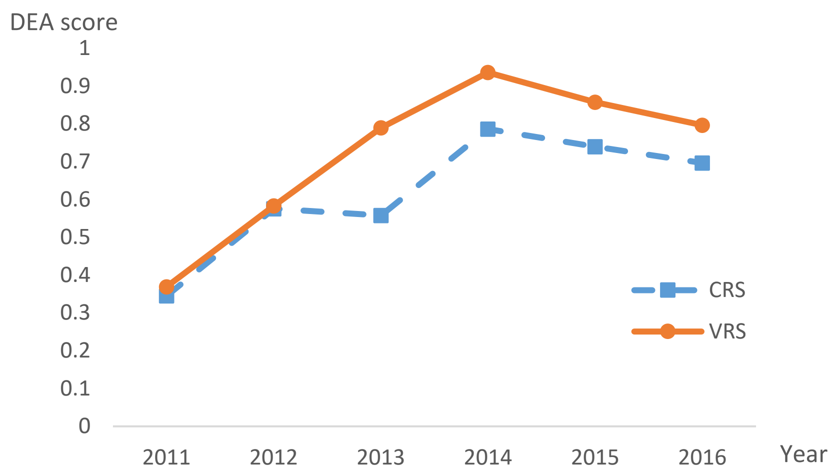

Figure 2 Average DEA scores from CCR and BCC models

In Table 4, the average efficiency score over all dry ports and years from CCR model is 0.64. Only 26% of dry ports are identified as relatively efficient. The average efficiency score over all dry ports and years from BCC model is 0.75 with 46% of dry ports identified as relatively efficient in Table 5. In summary, less than 50% of the dry ports are recognized as efficient from both models. The result implies that the most of dry ports of the port of Ningbo are not efficient. There has been a tendency of imbalance in efficiency scores. As shown in Table 4 and Table 5, some dry ports experienced continuous increasing of container throughput, namely the output in DEA model, yet some others, i.e. Yingtan, Quzhou and Jinhua, yielded declining volumes. These dry ports reported exceptionally low efficiency scores after 2014 and consequently dragged down the average efficiency level.

Table 4 DEA scores assuming constant return to scale (CCR model)

	2011	2012	2013	2014	2015	2016	Average
Yingtan	0.079	0.073	0.548	0.745	0.648	0.34	0.406
Shangrao	0.385	0.294	0.417	0.86	0.965	1	0.654
Quzhou	0.276	0.363	0.315	0.494	0.342	0.558	0.391
Jinhua	0.437	1	1	0.966	0.525	0.308	0.706
Yiwu	-	-	0.764	1	0.638	1	0.851
Shaoxing	0.548	0.721	0.838	1	0.988	1	0.849
Xiaoshan	-	1	0.289	0.225	0.813	0.368	0.539
Xiangyang	-	-	0.288	1	1	1	0.822

Table 5 DEA scores assuming variable return to scale (BCC model)

	2011	2012	2013	2014	2015	2016	Average
Yingtan	0.113	0.08	0.675	0.997	1	0.459	0.554
Shangrao	0.419	0.296	0.417	1	0.967	1	0.683
Quzhou	0.309	0.397	0.331	0.521	0.365	0.593	0.419
Jinhua	0.449	1	1	0.97	0.533	0.714	0.778
Yiwu	-	-	1	1	1	1	1.000
Shaoxing	0.556	0.727	0.891	1	0.992	1	0.861
Xiaoshan	-	1	1	0.999	1	0.603	0.920
Xiangyang	-	-	1	1	1	1	1.000

On average, Yiwu, Shaoxing and Xiangyang are more efficient than the other dry ports, with average efficiency scores over 0.8 in both CCR and BCC models. Compared to the constant inputs, Yiwu's outputs increased dramatically. Yiwu is famous for its advanced commodity wholesale market. Foreign trade in the city of Yiwu is strongly supported by exporting a great quantity of goods for daily use such as clothes and small kitchen appliances, and it drives the increase of container throughput. According to the annual reports of dry port Yiwu, its container throughput increased twice from 2011 to 2016. This is different from the case of Xiangyang. Xiangyang has less container throughput compared to the other dry ports. For example, it only handled 5,517 containers in 2016 compared to 33,071 containers handled by Yiwu. Xiangyang was developed into a dry port from a local railway freight yard, which brought advantage of convenient rail service. Moreover, the amount of fixed capital investment in infrastructure and equipment was very low since the dry port was operated based on the rail freight yard. The small amount of inputs was fully utilized at Xiangyang and ultimately produced high efficiency scores. Xiangyang is the only dry port which consistently improved its relative efficiency scores over the past six years. As for Shaoxing, its container throughput increased steadily since 2011, while it input the least current assets in comparison with the other dry ports and finally achieved relatively higher efficiency scores.

The relative efficiency of Quzhou is rated the least among all the dry ports with an average score around 0.40, which is mainly due to its low resource utilization. For instance, in 2014, the total assets input and dry port area of Quzhou were three times more than Yiwu, yet the containers went through Quzhou was only 44% of the throughput of Yiwu. In addition, the outputs of Yingtan, Jinhua and Xiaoshan presented a dramatic decrease in recent two or three years, resulting in lower efficiency scores. For example, the container throughput of Yingtan dropped by 33.2% in 2016, similar to the case of Jinhua. At Xiaoshan, excess handling and storage area in comparison with the other dry ports resulted in low utilization of inputs.

4.2 Tobit regression results

In this section, Tobit model is employed to test the proposed hypotheses. We estimate three Tobit models. The first model is set as the benchmark model in which possible moderating effects of certain variables are not considered. Rail transport is usually adopted to serve cities far from the seaports (Roso et al., 2008). Generally, the competitiveness of shuttle trains against trucks increases with distance. Thus, we replace the dummy variable *Long haul* with an interactive term *Reliance of rail* × *Long haul* in the second model. We further explore the difference of seaport ownership effect in small and large dry ports in the third model. We replace the dummy variable *Large scale* with *Seaport ownership* × *Large scale* in the third model.

Regression results of three models are shown in Table 6, Table 7 and Table 8 respectively. The signs of estimated coefficients of explanatory variables are consistent in the three models, implying that the estimations of these indicators are robust. Dry port efficiency is positively correlated with *Economic status*. It is consistent with experience at seaports (Bergantino and Musso, 2011). The positive coefficient of *Large scale* suggests that the size of dry port also plays a positive role in improving efficiency, which is consistent with the finding of Turner et al. (2004), Niavis and Tsekeris (2012), and Wan et al. (2014) for seaport industry. The negative coefficient of service suggests that dry ports providing more services are less efficient, which proves that economies of scope does not yield among the services. As the coefficient of *Long haul* tends to be positive, it suggests that when the dry port is far from the seaport, it is more efficient.

Table 6 Regression results on DEA scores of benchmark model

Explanatory variables	**CRS as dependent variables**		**VRS as dependent variables**	
	Coefficient and significant level	**Standard error**	**Coefficient and significant level**	**Standard error**
Economic status	0.2427*	0.1262	0.3700***	0.1315
Large scale	0.3498***	0.1031	0.4472***	0.1063
Service	-0.0503**	0.0220	-0.0715***	0.0233
Long haul	0.7836***	0.2887	0.7197**	0.3009
Reliance of rail	-0.0595	0.3803	0.2327	0.3790
Customs function	-0.7620***	0.2879	-0.7021**	0.3052
Seaport ownership	-5.1991***	1.3738	-3.7681***	1.4681
Competition	0.2815***	0.0809	0.1769**	0.0872
Constant	-2.1583	1.5934	-3.0067*	1.6520
Observations (N)	43		43	
Wald chi2	34.76		46.16	
Log likelihood	-12.744026		-11.703904	

***significant level 1%, ** significant level 5%, * significant level 10%.

Table 7 Regression results of model showing distance difference on rail service

Explanatory variables	CRS as dependent variables		VRS as dependent variables	
	Coefficient and significant level	Standard error	Coefficient and significant level	Standard error
Economic status	0.2855**	0.1198	0.4180***	0.1161
Large scale	0.3152***	0.0948	0.3981***	0.0880
Service	-0.0265	0.0206	-0.0478**	0.0192
Reliance of rail	-0.5685	0.4158	-0.4408	0.3716
Customs function	-0.4295***	0.1627	-0.5150***	0.1694
Seaport ownership	-3.5429***	0.8053	-2.8516***	0.8201
Competition	0.2777***	0.0649	0.2226***	0.0636
Reliance of rail × Long haul	3.1297***	0.8683	3.8960***	0.9561
Constant	-3.2998**	1.5628	-4.3028***	1.5178
Observations (N)	43		43	
Wald chi2	43.50		66.00	
Log likelihood	-10.441894		-5.7503879	

***significant level 1%, ** significant level 5%, * significant level 10%.

Table 8 Regression results of model showing scale difference on seaport ownership

Explanatory variables	CRS as dependent variables		VRS as dependent variables	
	Coefficient and significant level	Standard error	Coefficient and significant level	Standard error
Economic status	0.2854**	0.1353	0.4313***	0.1423
Service	-0.0296	0.0236	-0.0447*	0.0258
Long haul	0.7503**	0.2987	0.7014**	0.3190
Reliance of rail	-0.1755	0.3900	0.0924	0.3992
Customs function	-0.7224**	0.2986	-0.6666**	0.3254
Seaport ownership	-5.3342***	1.4267	-4.0337***	1.5566
Competition	0.2797***	0.0839	0.1794*	0.0923
Seaport ownership × Large scale	0.8804***	0.3128	1.1632***	0.3337
Constant	-2.6465	1.7147	-3.7136**	1.7958
Observations (N)	43		43	
Wald chi2	30.31		39.24	
Log likelihood	-14.277928		-13.871934	

***significant level 1%, ** significant level 5%, * significant level 10%.

Although rail link is believed as a crucial element for dry port operation, the coefficient of *Reliance of rail* is not statistically significant in all the three models. This is consistent with Castillo-Manzano et al. (2013)'s empirical finding that the usage of rail has no statistically significant relationship with Spanish seaports' ability to attract hinterland cargos. However, this result may not serve as a sufficient evidence to reject Hypothesis 1 for two reasons. First, the cargo rail system in China is featured with insufficient capacity, significant congestion, and inefficiency due to monopoly. Those disadvantages reduce the competitiveness of rail mode (Rimmer and Comtois, 2009). Second, most of the sample dry ports are close to the port of Ningbo, considering the loading and uploading time, *Reliance of rail* becomes less important. Thus, in the second model (Table 7), we added interaction term, *Reliance of rail* × *Long haul*, to examine how the impact of rail service on dry port efficiency differs between dry ports with different distances to seaport. The results in Table 7 indicate that the interaction term has a statistically significant and positive coefficient. This implies that *Reliance of rail* contributes to the efficiency only when the distance between the dry port and the port of Ningbo is larger than 500 *km*. The empirical results support the argument that rail mode has an edge over road mode considering long-haul transportation and Hypothesis 1 is partially supported.

It is surprising that the impact of *Customs function* on dry port efficiency is negative. This rejects Hypothesis 2 which declares that customs clearance function simplifies the time-consuming procedure taking place in seaport and should be a selling point for dry ports. The reason may be that the customs clearance function has not been implemented smoothly in China. As a fact, not all shippers in the hinterland can enjoy the simplified one-stop service of the *Customs function*. Only the enterprises that have high credit ratings (i.e. AA or A) can apply for the service. As a result, less than 5% of the enterprise users of dry ports are benefited from the *Customs function*. On the other hand, according to our interview with the dry port operators, the procedure of *Customs function* is not really streamlined at many dry ports due to complicated paperwork, and this makes the usage of dry port less attractive to cargo owners and logistics providers.

Seaport ownership also exerts a negative influence on dry port efficiency, and therefore Hypothesis 3 is rejected in our case. This implies that *Seaport ownership* of dry ports may have some negative impact on dry ports. The result might be explained by the failure to align the incentives of seaports and dry ports. As a dry port may only account for a small share of a seaport's total investment and business – for instance, the investment on dry port Xiaoshan in 2012 and 2013 both accounted for less than 1% of Ningbo Port Corporation's total investment amount in the same year (NPC, 2012; NPC, 2013) – a seaport tends to put more weight on its seaport operation and is willing to sacrifice some efficiency at the dry ports to increase the cargo volume for the seaport. In other word, the seaport is motivated to act in its own best interests, which might be contrary to the expectation of the dry port and the local government. If the seaport owns the asset at the dry port and such ownership reflects the claim to residual rights (Grossman and Hart, 1986), i.e. the authority to make decisions with respect to the assets upon contingencies unspecified in the contract, it will obtain a better bargaining position (threaten point) when uncontracted issues arise. For instance, a seaport might be reluctant to use sea-rail intermodal transport mode since it owns a trucking company itself. Furthermore, it may prevent its dry ports from serving other competing seaports with spare capacity. Such decision may be beneficial for the seaport but may be costly to the dry ports if the throughput cannot be guaranteed. According to the property rights theory of the firm, the importance of each party's investment incentive determines asset ownership (Gibbons, 2005). Thus, allocating the property rights to the seaport may reduce the local government's investment incentives. In the case of dry ports, the local government's investment may be more important (or at least not less important) since it can influence the availability of the rail linkage, coordination from local industry players as well as various regulatory and policy supports, which are the uncontractable specific assets and essential in the context of mainland China. In light of this, from dry ports' point of view, it might be more efficient for the local government to lead the ownership structure.

The third model further explores the difference of impacts of *Seaport ownership* on dry port efficiency considering different size (*Large scale*) of dry ports (Table 8). The coefficient of the interaction term turns to be significantly positive. This implies that the scale of the dry port moderates the negative influence of seaport ownership. There are two possible reasons: (1) large dry ports require substantial capital investment which may not be available from local government and thus more incentive should be given to the seaport; and (2) the seaport cares about the well-being of large dry ports more than small dry ports as more investment is involved in large dry ports for the same level of ownership share.

Finally, fierce *Competition* exerts a significant and positive effect on dry port efficiency, verifying Hypothesis 4. The results are in line with results of port industry from Wan et al. (2014) and airport sector from Adler and Liebert (2014).

5. CONCLUDING REMARKS AND IMPLICATIONS

Compared to the large body of literature of seaport efficiency analysis, few attentions have been paid to the dry port sector. Although numerous dry ports have been established in China in the past decade, the efficiency of these dry ports, which is defined as the ability to produce outputs using inputs, seems not so satisfying. Dry ports in China are different from those in other regions with regard to functional fulfilment, ownership structure and inter-competition status. This paper evaluates efficiency of eight Chinese dry ports affiliated to the port of Ningbo and examines how these features associate with the differentiation of efficiency among the sampled dry ports.

It is found that the average efficiency of dry ports invested by Ningbo Port Corporation experienced an increase since 2011, followed by a decline since 2014. The efficiency scores vary among dry ports. The high efficiency of dry ports can be explained by rational utilization of local transport resources and stable increase of outputs. By conducting Tobit regression model, we find that *Reliance of rail* is not significantly correlated with dry port efficiency, which is not in alignment with dry port's definition, nor experiences from other countries. However, further analysis discovers that when the dry port is far from the seaport, its efficiency does improve with high *Reliance of rail*. *Customs function* impedes dry port efficiency, which is a surprising result yet reveals the problem of policy implementation in China. As for ownership structure, increasing the shares held by seaport implies lower dry port efficiency. Nevertheless, this phenomenon is relieved when the dry port handles large number of containers. Furthermore, fierce inter-competition is positively related to dry port efficiency, this is consistent with the existing result in seaport sector.

From the empirical findings, we can draw some managerial implications and policy suggestion for both dry port operators and public authorities, to improve efficiency of dry ports. For decision-makers at seaports, the managerial implication includes:

i. When a seaport decides to invest in a dry port, several factors need to be taken into account. First, having multiple dry ports within a catchment area may enhance competition among dry ports and hence improve their efficiency. Second, having a majority share of a dry port and use it as a tool to acquire hinterland cargo seems to have some negative impacts on dry port efficiency. Seaport managers should bear in mind that too much control on a dry port might reduce the incentives of other local investors or stakeholders, including the local government, to contribute to the dry port business. Third, considering dry ports' efficiency along, investing in large dry ports is proved to be favourable rather than investing in small dry ports. An asset-light strategy should be considered when investing in small dry ports.

ii. Rail service appears to be an unnecessary element to encourage dry port efficiency if the dry port is near to seaport and the rail services are not provided with desired quality. However, it becomes necessary when the dry port is located far away from the seaport. The provision of good freight rail services may be partially influenced by the ownership of dry port assets as local governments play a key role in land provision and rail infrastructure development.

iii. When a seaport holds a large share of its dry ports, the gain of seaport may build upon the efficiency loss of the dry ports. Therefore, a joint performance assessment including both the seaport and its dry ports might be necessary. That is, efficiency of entire chains should be considered rather than individual nodes. Understanding the whole picture will help seaports make better decision on the level of integration with dry ports.

For local governments or other local investors of dry ports, the policy implications can be summarized as:

iv. Although the involvement of seaport may reduce the financial burden of local governments in developing dry ports, the current development pattern that seaports initialize and dominate dry port investment seems to move to the opposite of the local governments' expectation. In order to facilitate the export of local productions, the local dominated model seems to be an effective strategy. A successful example is the dry port Xi'an, which obtains initial investment from local government and private enterprises, and cooperates with multiple seaports by signing cooperation agreement (Beresford et al., 2012).

v. For Chinese dry ports, the customs clearance service does not function well and in many cases the so-called one-stop process cannot be effectively implemented. Relevant policies should be formulated to reduce redundant operations and paperwork, in order to fully exploit the advantage of one-stop process.

vi. When a local government considers a layout plan of dry ports in certain region, building one single dominant dry port may not be an optimal strategy. A well-distributed layout of a couple of dry ports can stimulate higher efficiency because of competition.

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APPENDIX

Table A Regression results using fixed-effect (FE) model and pooled model

Explanatory variables	Model (1)				Model (2)				Model (3)			
	CRS		VRS		CRS		VRS		CRS		VRS	
	FE	Pooled	FE	Pooled	FE	Pooled	FE	Pooled	FE	Pooled	FE	Pooled
Economic status	0.2287 (0.2522)	0.2427* (0.1262)	0.1193 (0.1991)	0.3700*** (0.1315)	0.7336*** (0.1879)	0.2855** (0.1198)	0.5814*** (0.0638)	0.4180*** (0.1161)	0.2219 (0.3727)	0.2854** (0.1353)	0.0993 (0.3402)	0.4313*** (0.1423)
Large scale	0.3185* (0.1630)	0.3498*** (0.1031)	0.2525* (0.1346)	0.4472*** (0.1063)	0.5105*** (0.0914)	0.3152*** (0.0948)	0.4482*** (0.0681)	0.3981*** (0.0880)	-	-	-	-
Service	-0.0456** (0.0192)	-0.0503** (0.0220)	-0.0458*** (0.0138)	-0.0715*** (0.0233)	-0.0104 (0.0102)	-0.0265 (0.0206)	-0.0232*** (0.0079)	-0.0478** (0.0192)	-0.0253** (0.0127)	-0.0296 (0.0236)	-0.0304*** (0.0094)	-0.0447* (0.0258)
Long haul	0.6909 (0.4956)	0.7836*** (0.2887)	0.2450 (0.3856)	0.7197** (0.3009)	-	-	-	-	0.6077 (0.6369)	0.7503** (0.2987)	0.1737 (0.5212)	0.7014** (0.3190)
Reliance of rail	-0.0087 (0.3885)	-0.0595 (0.3803)	-0.0689 (0.3034)	0.2327 (0.3790)	0.0087 (0.2687)	-0.5685 (0.4258)	-0.0093* (0.2681)	-0.4408 (0.3716)	-0.2085 (0.4323)	-0.1755 (0.3900)	-0.2540 (0.3832)	0.0924 (0.3992)
Customs function	-0.6407* (0.3764)	-0.7620** (0.2879)	-0.2633 (0.2156)	-0.7021** (0.3052)	-0.4611*** (0.1712)	-0.4295** (0.1627)	-0.3052*** (0.0839)	-0.5150*** (0.1694)	-0.5723 (0.4322)	-0.7224** (0.2986)	-0.2095 (0.2724)	-0.6666*** (0.3254)
Seaport ownership	-4.4701** (2.0802)	-5.1991*** (1.3738)	-1.7971 (1.4391)	-3.7681** (1.4681)	-3.6999*** (0.9262)	-3.5429*** (0.8053)	-2.0960*** (0.6522)	-2.8516*** (0.8201)	-4.3980* (2.5338)	-5.3342*** (1.4267)	-1.7161 (1.8738)	-4.0337** (1.5566)
Competition	0.2522* (0.1414)	0.2815*** (0.0809)	0.0726 (0.1087)	0.1769** (0.0872)	0.3892*** (0.0911)	0.2777*** (0.0649)	0.2307*** (0.0446)	0.2226*** (0.0636)	0.2349 (0.1722)	0.2797*** (0.0839)	0.0562 (0.1403)	0.1794* (0.0923)
Reliance of rail ×Long haul	-	-	-	-	4.7623*** (1.0873)	3.1297*** (0.8683)	3.3388*** (0.5049)	3.8960*** (0.9561)	-	-	-	-
Seaport ownership × Large scale	-	-	-	-	-	-	-	-	0.7540 (0.6657)	0.8804*** (0.3128)	0.5690 (0.6069)	1.1632*** (0.3337)

Constant	-	-2.1583 (1.5934)	-	-3.0067* (1.6520)	-	-3.2998** (1.5628)	-	-4.3028*** (1.5178)	-	-2.6465 (1.7147)	-	-3.7136** (1.7958)
Observations (N)	43	43	43	43	43	43	43	43	43	43	43	43
LR chi2	119.39	27.01	130.44	36.53	558.74	31.61	298.11	48.44	117.46	23.94	304.83	32.20
Prob > chi2	0.000	0.0007	0.000	0.000	0.000	0.0001	0.000	0.0000	0.000	0.0023	0.000	0.0001

***significant level 1%，** significant level 5%，* significant level 10%，parenthesis denotes the standard error

Model (1): Benchmark model;

Model (2): Model showing distance difference on rail service;

Model (3): Model showing scale difference on seaport ownership.