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The Relative Efficiency of Container Terminals in Small and Medium-Sized Ports in China

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Abstract

The promotion of domestic consumption in China will gradually ramp up the small and medium-sized port container industry, and this will require greater port efficiency and an updated development strategy. The aim of this paper is to evaluate operational and productivity efficiency change in 21 coastal small and medium sized-port container terminals in China. The first step was carried out using data envelopment analysis (DEA) and the Malmquist productivity index (MPI), and the factors affecting productivity efficiency change were then estimated and quantified using Tobit regression. The empirical results indicate that the most efficient terminals are the Rizhao and Lianyungang port terminals. Furthermore, the terminals that hold a share of more than 50% of Chinese state-owned shipping line show the highest increase in productivity efficiency change. Lastly, the results indicate manpower structure; Chinese state-owned shipping line shareholding; registered capital; and shipping routes have positive effect and the factor, number of terminal operators, have a negative correlation.

Key Words : Small and Medium-sized Port (SMP), Data Envelopment Analysis (DEA), Malmquist Productivity Index (MPI), Tobit Regression

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I. Introduction

During the Chinese "two meeting" between the National People's Congress and the Chinese People's Political Consultative Conference, Premier Wen clearly stated in the "Government Work Report" that China should make a strong commitment to domestic demand expansion as its long-term strategy for economic development. The focus of economic growth in China should also shift from its current export and investment-led growth model to a consumption-based model. The domestic demand-led economic development model will not just change the economy but will also affect supply structures in China and promote the development of China's domestic container shipping ports.

In the domestic trade container transportation business, the domestic trade waterway dispatching system cannot depend completely on big ports. The system needs small and medium-sized ports (SMPs) as feeder ports to supply large regional hub ports and therefore meet demands for multi-level port layouts. As a key element of China's waterway transportation industry, SMPs play an important role in economic development, alleviate pressure on waterway transportation, and aid the development of port cities.

Many studies have already been done on port efficiency, most of which are based on hub ports or full ports in a region. However, few studies have investigated SMPs as a target for analyzing efficiency. This study aims to analyze port operation efficiency in China and focus on SMPs using the DEA and Tobit methods. Data regarding the relative operating efficiency of each SMP can be used to formulate suggestions regarding the improvement of port management and to assist departments in making decisions for enhancing the efficiency.

II. Literature Review

1. Port Efficiency Evaluation Using DEA-Malmquist

The DEA model is commonly used to examine the efficiency of ports and has been the subject of many research studies estimating port efficiency (Al-Eraqi et al., 2008; Khin and Yang, 2010; Wu and Goh, 2010; Hung et al., 2010). However, this model can only examine the relative efficiency of targets. To overcome this disadvantage, more and more researchers are using DEA-Malmquist both to estimate efficiency and to evaluate changes in efficiency over time.

Yuen et al. (2013) used DEA-Malmquist models to estimate the efficiency of 21 major container terminals in China and neighboring countries. Li et al. (2013) proposed the three-stage DEA model to evaluate comprehensive efficiency, pure technical efficiency, and scale efficiency. Barros (2012) used DEA-Malmquist models to evaluate efficiency and productivity efficiency changes in seaports located in Angola, Nigeria, and Mozambique from 2004 to 2010. So et al. (2007) used DEA-CCR (Charnes, Cooper and Rhodes) and DEA-BCC (Banker, Charnes, and Cooper) models to measure the operational efficiency of 19 major container ports in Northeast China. Schøyen and Odeck (2013) used DEA models to evaluate the relative efficiency of 24 container ports between 2002 and 2008, including ports in Norway, all of the Nordic countries, and the United Kingdom. Wilmsmeier et al. (2013) used the Malmquist TFP index to analyze and compare port productivity and efficiency evolution for 20 terminals in 10 countries in Latin America, the Caribbean, and Spain for the period from 2005 to 2011. Fu et al. (2009) applied the DEA-based Malmquist productivity index to measure the operating efficiencies of 10 leading container ports in China from 2001 to 2006.

2. Tobit Regression

Tobit regression is widely used to evaluate productivity efficiency change and to determine the reasons for gains. This method can quantify the effects of independent variables on the dependent variable.

Choi (2011) proposed that strategic alliances and self-created demand will have a more positive effect than investment in infrastructure on improving port efficiency using the Tobit regression model. Han and Jang (2009) used the Tobit regression model to evaluate the determinants of cargo volume inflow in the major sea ports of Korea based on independent variables (number of manufacturers, number of firms in supportive and relative industries, number of berths, berth depth, and port software with services) and dependent variable net inflow volumes. Luo et al. (2013) used the Tobit regression model to examine the environmental factors influencing eight Chinese container ports' efficiency using DEA output and input variables, a Gulf Regional Development Plan (GRDP) of the hinterland, and the hinterland population as independent variables. The ports' efficiency was used as a dependent variable to quantify the independent variables. Zhang (2009) chose the Tobit regression model to evaluate the determinants of China's main seaport container terminal efficiency, using port size, ownership structure, the economics of port networks, port globalization, service level, years, and other dummy variables as independent variables. Mo and Lee (2010) applied the Tobit regression model to evaluate the effect of the explanatory variable on container terminal efficiency, and the results show that container cranes and container yards have a positive effect on container terminal efficiency. In this paper, Tobit regression will be used to quantify the effects of various influencing factors on port terminal productivity efficiency.

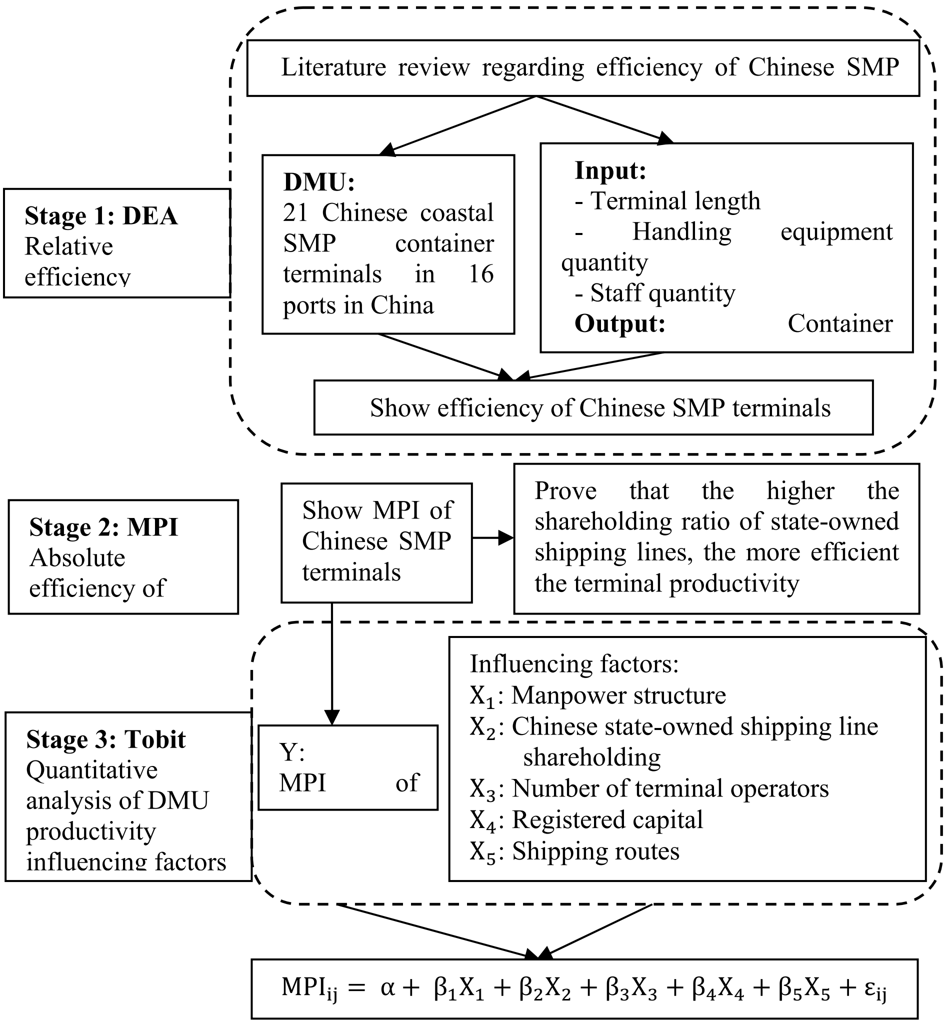
III. Methodology

The core framework of this paper is shown in Figure 1. In stage 1, the DEA method is employed to measure the relative efficiency of 21 SMP terminals from 2008 to 2012 using input variables (terminal length, handling equipment quantity, and staff quantity) and output variable container throughput. In the next stage, MPIs are applied to examine productivity efficiency change in selected container terminals, and the results indicate that a higher shareholding ratio of state-owned shipping lines can lead to more efficient terminal productivity change. The third stage employs the Tobit regression model to estimate and quantify the factors influencing SMP terminal productivity. The influencing factors are manpower structure, Chinese state-owned shipping line shareholding, number of terminal operators, registered capital and shipping routes.

1. DEA-Malmquist

In recent years, there have been a number of studies investigating port efficiency, many of which used DEA to analyze port industries (Cullinane and Wang, 2006). DEA is a nonparametric method for evaluating the efficiency of a Decision Making Unit (DMU), which is structured directly from the sample data by applying a linear or non-linear programming method. It is non-parametric because it requires no assumption regarding the shape or parameters of the underlying production function. The CCR and BCC models are the most widely applied DEA models.

<Figure 1> Core framework of the research



The Malmquist productivity index (MPI) was first presented by Malmquist (1953) and subsequently expanded by Fare et al. (1994) as a DEA-based MPI that measures productivity efficiency change over time. The index can be divided into two parts, one measuring changes in technical efficiency and the other, changes in the technology changes. For the purposes of this paper and taking account of the accessible resources, DEA-Malmquist is used as the preferred analysis method.

2. Tobit Regression

The Tobit model is subject to constraints in terms of the dependent variable. Windle and Dresner (1995) found that DEA used in conjunction with Tobit regression may be as useful as total factor productivity (TFP) for evaluating productivity and determining the reasons for gains.

The Tobin's (1958) model can be outlined as follows:

$$Y_i^* = \alpha + \beta_j X_i + \varepsilon_i,\ i = 1,2, \dots \dots, n \tag{1}$$

where X_i is a vector of explanatory variables including ownership, α and β_j are vectors of correlation coefficients, and the random error term is captured by ε_i. The Tobit model can be represented as (1) together with the following equation:

$$Y_i = \begin{cases} Y_i^* & \text{if } Y_i^* > 0 \\ 0 & \text{if } Y_i^* \leq 0 \end{cases} \tag{2}$$

Equation (2) is therefore a two-sided censored Tobit model. The independent variable X_i takes the actual observations and Y_i^* can only be observed in a restricted manner. When $Y_i^* > 0$, the limit values are observed in order to take the actual observations. when $Y_i^* < 0$, the limited observations are intercepted to 0.

IV. Empirical Analysis

1. Selection of SMPs in China

Different countries have different understandings and definitions of SMPs. Mitchel (1970) noted in early 1970 that there were three groups of Irish ports termed large, medium-sized, and small. According to the classification standards of that time, large ports handled cargo of over 1,000,000 tons annually; medium-sized ports handled cargo between 150,000 and 1,000,000 tons annually, while small ports handled cargo of under 150,000 tons annually. Lin and Notteboom (2013) defined some typical characteristics when describing the profile of SMPs in China. In terms of port size, ports with an annual cargo throughput of less than 300 million tons are defined as SMPs. Most SMPs play an indispensable role in the development of multiport gateway regions around the world, and they are necessary in order to improve the competitiveness of such regions and to strengthen their role in facilitating network-based supply chains. According to the typical characteristics of SMPs, we selected 21 terminals in 16 coastal SMPs as the DMUs in this paper, as shown in Table 1.

<Table 1> Selection of SMPs in China in 2012

Ports	Throughput (million tons)	Container terminal
Yingkou	301	-Yingkou new century container terminal Co., Ltd. (YKNCCT) -Yingkou container terminal Co., Ltd. (YKCT)
Jinzhou	74	-Jinzhou New Century terminal Co., Ltd (JNCT)
Qinhuangdao	271	-Qinhuangdao new port container Co., Ltd. (QNPC)
Yantai	203	-Container company of Yantai port holding Co., Ltd. (YTCT) -DP world Yantai -Yantai rising dragon international container terminal Co., Ltd. (YRDICT)
Rizhao	281	-Rizhao and Qingdao container terminal Co., Ltd. (RQCT)
Lianyungang	174	-Lianyungang new oriental international Wharf Co., Ltd. (INOCT)
Wenzhou	70	-Wenzhou Jinyang container terminal Co., Ltd. (WJYCT)
Fuzhou	114	-Fuzhou Qingzhou container terminal Co., Ltd. (FQCT) -Fuzhou international container terminal Co., Ltd. (FICT)
Quanzhou	104	-Quanzhou pacific container terminal Co., Ltd. (QPCT)
Humen	84	-PSA Dongguan container terminal Co., Ltd. (PSA DGCT)
Zhongshan	23	-Zhongshan port & shipping enterprise group Co., Ltd. (ZPSEG) -Zhongshan port international container terminal Co., Ltd. (ZICT)
Zhuhai	77	-Zhuhai international container terminal (Jiuzhou) Co., Ltd. (ZJCT)
Zhanjiang	171	-Zhanjiang port China shipping container terminal Co., Ltd. (ZCSCT)
Qinzhou	56	-Qinzhou port group Co., Ltd. (QZPG)
Fangcheng	101	-Fangcheng container terminal Co., Ltd. (FCCT)
Haikou	72	-Haikou harbour container terminal Co., Ltd. (HHCT)

2. DEA Application

The relative efficiency of 21 SMP terminals between 2008 and 2012 was estimated using DEA based on input variables (terminal length, handling equipment quantity, and staff quantity) and output variable container throughput. The results are shown in Table 2.

Between 2008 and 2012, the CCR, BCC, and SE (scale efficiency) index of RQCT and INOCT were all valued at 1. Compared with other terminals, these two terminals have a reasonable input in terms of number of gantry cranes and quay length. Lianyungang is the starting point of the Trans China Railway (TCR) on the east coast of China, so its container volume is relatively large. It is also China's largest rail-sea transshipment port. In 2012, based on rail-sea intermodal transportation for containers, Lianyungang handled 303,000TEU, ranking it first in China. In addition, INOCT has partnered with the Ministry of Railways to open lines to Chengdu, Xi'an, Zhengzhou, Urumqi, and other domestic cities and international train lines in conjunction with Almaty and Moscow. Now INOCT has already been built under optimal conditions and is the largest container port between Shanghai port and Qingdao port. RQCT was founded on the basis of a 50% investment by both Rizhao port and Qingdao port, making each of those ports a 50% stakeholder. Thus, compared to other SMPs, RQCT benefits from the advanced operation management model of a large port. In addition, Rizhao port is making efforts to develop rail-sea containers (RSC) for intermodal transportation in a bid to occupy a more competitive position in the logistics system (Lin and Notteboom, 2013). In contrast, the CCR and SE efficiency of YRDICT is the lowest of all DMUs. SMPs have developed more rapidly in the Shandong peninsula in recent years. These ports transship cargoes from hub ports and generally complement or assist port functions. However, competition between SMPs is likely to become increasingly fierce because their hinterlands are relatively limited. A further finding was that port infrastructure is excessive relative to container handling capacity. Moreover, the efficiency indexes of two other container terminals in Yantai are both low due to a comparatively small container terminal scale and scattered resources. Thus, integrating resources to reduce the number of terminals can make port size bigger. The SE efficiency of YKNCCT was found to be higher than 0.85, except in 2008. Yingkou port's main demand is distributed in Guangdong and Shanghai, and this extended hinterland supports Yingkou port's cargo more than the port city itself does. In its distribution function, Yingkou port draws support from inland ports in Shenyang to expand its function in the logistics system as a whole and to increase intermodal transportation (Lin and Notteboom, 2013). As a result of labor costs increasing year on year in coastal regions, manufacturing plants have moved from coastal regions to inland regions. This means that rail-sea transport has become a niche market for SMPs and can now take on the transportation of cargo between coastal regions and inland regions. At Yingkou port, three newly opened rail-sea express lines operating in two-day shifts are run by COSCO. However, the efficiency index of YKNCCT is lower than that of RQCT and INOCT. This means that it is unclear whether the relationship between Dalian and Yingkou in the hub-and-spoke network is competitive or cooperative. In 2010, in order to compete with the adjacent port Yingkou, Dalian port acquired Lvshun port and the inland port of Shenyang. In 2012, Yingkou port took countermeasures such as acquiring Dandong Port and expanding its scale. To some extent, this competition may lead to overcapacity and become a vicious circle for both competitors when they seek economies of scale.

<Table 2> Efficiency score of each DMU

DMU	2008			2009			2010			2011			2012		
	CCR	BCC	SE	CCR	BCC	SE	CCR	BCC	SE	CCR	BCC	SE	CCR	BCC	SE
YKNCCT	0.69	1.00	0.69	0.82	0.89	0.92	0.94	1.00	0.94	0.87	1.00	0.87	0.97	1.00	0.97
YKCT	0.64	0.86	0.74	1.00	1.00	1.00	0.79	1.00	0.79	0.65	1.00	0.65	0.84	1.00	0.84
JNCT	0.51	0.89	0.58	0.51	0.91	0.56	0.71	1.00	0.71	0.51	1.00	0.51	0.49	1.00	0.49
QNPC	0.32	0.57	0.57	0.24	0.67	0.36	0.25	0.78	0.33	0.27	0.80	0.34	0.21	0.72	0.29
YTCT	0.35	0.79	0.44	0.57	0.89	0.64	0.63	0.96	0.66	0.49	0.99	0.49	0.45	0.98	0.46
DPWorld Yantai	0.31	0.88	0.35	0.28	0.88	0.31	0.28	0.85	0.33	0.31	0.84	0.36	0.29	0.79	0.36
YRDICT	0.11	0.85	0.13	0.12	0.92	0.13	0.12	0.81	0.15	0.14	0.82	0.17	0.16	0.74	0.22
RQCT	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
INOCT	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
WJYCT	0.42	0.93	0.46	0.23	0.90	0.25	0.26	1.00	0.26	0.19	0.80	0.23	0.22	0.87	0.25
FQCT	0.52	0.94	0.55	0.47	1.00	0.47	0.46	1.00	0.46	0.40	1.00	0.40	0.39	0.99	0.39
FICT	0.27	0.68	0.40	0.30	0.74	0.41	0.36	0.64	0.56	0.28	0.63	0.44	0.23	0.62	0.38
QPCT	0.38	0.51	0.75	0.32	0.48	0.67	0.43	0.53	0.82	0.40	0.53	0.76	0.39	0.51	0.76
PSA DGCT	0.22	0.92	0.24	0.36	0.96	0.38	0.39	0.94	0.42	0.40	0.95	0.43	0.29	0.79	0.37
ZPSEG	0.47	0.57	0.82	0.43	0.58	0.74	0.40	0.57	0.71	0.38	0.57	0.66	0.35	0.56	0.63
ZICT	0.25	0.59	0.42	0.20	0.63	0.32	0.24	0.63	0.38	0.21	0.62	0.34	0.22	0.70	0.32
ZJCT	0.39	0.81	0.48	0.29	0.89	0.32	0.24	0.85	0.29	0.24	1.00	0.24	0.30	1.00	0.30
ZCSCT	0.24	0.79	0.31	0.21	1.00	0.21	0.28	1.00	0.28	0.27	1.00	0.27	0.23	1.00	0.23
QZPG	0.26	1.00	0.26	0.09	0.80	0.11	0.17	0.70	0.24	0.20	0.67	0.30	0.23	0.66	0.35
FCCT	0.21	1.00	0.21	0.21	1.00	0.21	0.23	1.00	0.23	0.21	1.00	0.21	0.20	1.00	0.20
HHCT	0.49	1.00	0.49	0.53	1.00	0.53	0.29	0.63	0.46	0.31	0.67	0.47	0.35	0.66	0.53

3. Malmquist Productivity Application

1) Malmquist Productivity Results

Showed in Table 3, as a whole, the total productivity of selected container terminals improved between 2008 and 2012, and the average value of the chained Malmquist productivity indices (MPI) was 1.479, representing a 47.9% improvement over 2008. Additionally, some container terminals showed a strong growth momentum, with eight exceeding the average MPI value. In particular, three of them increased in value once during the sample period, and there was only one container terminal with a value lower than 1. YRDICT showed the maximum productivity value between 2008 and 2012, with a value of 2.333. Conversely, WJYCT experienced the worst decline, at a rate of 15.3% over the sample period.

<Table 3> MPI of each SMP between 2008 and 2012

Port	DMU	DMU_No.	MPI	TECI	TCI
Yingkou	YKNCCT	DMU_1	2.032	1.397	1.454
	YKCT	DMU_2	1.971	1.318	1.496
Jinzhou	JNCT	DMU_3	1.449	0.964	1.503
Qinhuangdao	QNPC	DMU_4	1.008	0.640	1.576
Yantai	YTCT	DMU_5	1.854	1.285	1.443
	DP World Yantai	DMU_6	1.317	0.916	1.439
	YRDICT	DMU_7	2.333	1.470	1.586
Rizhao	RQCT	DMU_8	1.725	1.000	1.725
Lianyungang	INOCT	DMU_9	1.498	1.000	1.498
	WJYCT	DMU_10	0.847	0.516	1.643
Fuzhou	FQCT	DMU_11	1.022	0.750	1.363
	FICT	DMU_12	1.428	0.863	1.655
Quanzhou	QPCT	DMU_13	1.717	1.032	1.665
Humen	PSA DGCT	DMU_14	2.105	1.329	1.584
Zhongshan	ZPSEG	DMU_15	1.152	0.754	1.528
	ZICT	DMU_16	1.315	0.895	1.470
Zhuhai	ZJCT	DMU_17	1.206	0.755	1.597
Zhanjiang	ZCSCT	DMU_18	1.295	0.964	1.344
Qinzhou	QZPG	DMU_19	1.380	0.891	1.547
Fangcheng	FCCT	DMU_20	1.393	0.959	1.452
Haikou	HHCT	DMU_21	1.011	0.717	1.411
Average value			1.479	0.972	1.523

The mean value of the Technical Efficiency Change Index (TECI) was 0.972 between 2008 and 2012. The efficiency change indices of six terminals were greater in 2012 than in 2008, and two terminals had a value of 1. However, the efficiency change indices of the remaining 13 terminals showed a decline. The efficiency improvement of YRDICT was the most remarkable, increasing by 47.04% compared with 2008, but the efficiency of WJYCT increased by nearly 50% compared with 2008; the TECI value was 0.512 in 2012.

The mean value of the Technical Change Index (TCI) was 1.523 between 2008 and 2012, and during this period, all of the ports' technical changes achieved high values. In 2012, 11 ports' technical changes increased by 50% compared with 2008, with RQCT having the most remarkable TCI value of 1.725. ZJCSCT experienced the lowest value, at 1.344, indicating that the reasons for productivity growth were based on an increase in technical changes but not technical efficiency. During this period, all of the terminals saw the benefits of technical change.

The results above prove that productivity efficiency change in SMPs involved in container operation is higher overall than that of large-sized ports. This correlates with the findings in the literature review regarding productivity growth, which show that SMPs are growing rapidly in terms of container operation.

2) Productivity Efficiency Changes in the Case of State Ownership Ratio Characteristics

In this chapter, we will try to ascertain how the ownership ratio of port authority and state-owned shipping lines can be made more efficient in container terminals using the MPI.

According to the shareholding ratio of state-owned shipping lines in selected port container terminals, this study divides the selected port container terminals into three categories: (i) non-state-owned shipping line shareholdings (0%); (ii) major non-state-owned shipping line shareholdings (1–49%); (iii) major state-owned shipping line shareholdings (≥ 50%) shown in Table 4.

Through analysis, we ascertained that container terminals with more than a 50% shareholding of state-owned shipping lines are ranked as the most efficient group when measured using all the MPIs, while container terminals with non-state-owned shipping line shareholdings are ranked as the least efficient. The major objective of state-owned shipping lines investing in operating container terminals is to connect major shipping lines and ports in order to form a controlled transport network system. This will in turn enhance the core competitiveness of their shipping business. Compared with container terminals where the port authority holds the major shares, state-owned shipping lines serve not just as port enterprises for providing stevedoring services, but also as terminal companies for the construction and operation of container terminals and related business; in other words, state-owned shipping lines are both operators and developers. To meet the needs of shipping business development, shipping lines are investing in constructing and operating the container terminals as ports of call on the main shipping lines. In this way, shipping lines may call more and more frequently at ports in which they have invested. If those ports are at the end of routes or are functioning as transfer ports, given their advantage of huge cargo sources, the volume of port containers will continue to increase. Yuen et al. (2013) also proved that state-owned shipping lines may promote cooperation between shipping lines and port authority and construct their own local operation and management systems.

<Table 4> SMP container terminal productivity by state-owned shipping line

Shipping line ownership	Descriptive statistic	Productivity efficiency change
Shipping line shareholding (0%)	**Mean**	**1.304**
	Standard deviation	0.359
	Geometric mean	1.262
Shipping line shareholding (1-49%)	**Mean**	**1.393**
	Standard deviation	0.453
	Geometric mean	1.343
Shipping line shareholding (≥ 50%)	**Mean**	**1.590**
	Standard deviation	0.257
	Geometric mean	1.574

4. Tobit Regression Application

1) Tobit Regression Variable And Parameter Setting

When the dependent variable is continuous but constrained by something, the ordinary least squares (OLS) method will calculate consistent estimates, but the Tobit regression model assumes truncated normal distribution in place of normal distribution and employs the maximum likelihood ratio estimation method. Since the MPI[1)] scores have lower and upper limits, there may be a truncated bias in the ordinary least squares (OLS) regression model. This is why we used the Tobit regression model (Tobin, 1958) rather than the OLS model.

With regard to the factor selection problem, this paper measures the factors impacting on productivity efficiency change in port terminals by considering the internal and relative factors of terminals. The factors influencing productivity efficiency that were chosen for Tobit regression are shown in Table 5 below.

<Table 5> Factors influencing productivity efficiency

Factor	Definition	Authors
Manps	Total number of employees with a bachelor degree or above.	Deng (2008) Liu (2008)
Shipold	How the terminal having a Chinese state-owned shipping line shareholding impacts on productivity efficiency change.	Long (2007) Zhang(2009) Luo et al. (2013) Yuen (2013) Song and Cui (2014)
Nopert	Number of terminal operators and how this impacts productivity efficiency change in terminals.	Han (2009) Mo and Lee (2010) Wang (2011)
Regicap	Registered capital in the early period of port terminal construction.	Mo (2008) Liu (2012)
Shipute	Number of shipping routes in each port terminal.	Pang (2006) Chio (2012)

1) Manpower structure: Port development depends on the presence of talent, and the effective management ability and competitiveness of the port are closely related to the level of education and knowledge of its human resources. This paper employed the variable percentage (manps) of a bachelor degree or above to reflect the education structure in each terminal.

1) MPI is chosen as the dependent variable rather than DEA scores to evaluate and quantify the factors that affect productivity changes in container terminals, because DEA scores are relative comparative values of DMUs but MPI can reflect the overall efficiency change in container terminals in the sample period, i.e., the productivity change in each container terminal.

2) Chinese state-owned shipping line shareholding: Section 4.3.2 demonstrated the impact of the shareholding ratios of state-owned shipping lines on productivity efficiency change. Tobit regression was employed again to argue whether this result is valid. Using dummy variables, terminals with Chinese state-owned shipping line shareholdings were marked "1" and those with none were marked "0". The variable is called shipold.

3) Number of terminal operators: Some port terminals are run independently by a single operator, while others are run by a number of operators together. In this paper, the number of terminal operators is a variable called nopert.

4) Registered capital: In the early period of port terminal construction, plenty of capital investment in the terminal can form a tangible and intangible capital operation system, optimize configurations to keep capital flowing, and ultimately realize maximum capital appreciation (Liu, 2012). Therefore, the registered capital of each port terminal is a variable called regicap.

5) Shipping routes: The number of shipping routes in the terminal represents the opening up of the entire hinterland; at the same time, the opening of new routes can increase the volume of the terminal. The number of shipping routes is a variable called shipute.

2) Tobit Regression Modeling and Results

In this paper, the Tobit regression model was used to examine and quantify the factors 1) Manps, 2) Shipold, 3) Nopert, 4) Regicap, and 5) Shipute which affect terminal productivity. Before regression analysis is conducted, correlation analysis should first be carried out to examine whether there is a strong linear relationship between each independent variable. Table 6 shows that the linear correlation between each variable is not strong, and all those values are lower than 0.5. Thus, the selected dependent variables can be employed in the Tobit regression model.

<Table 6> Multiple collinear relationship test

	Manps	*shipold*	*Nopert*	*Regicap*	*Shipute*
Manps	1				
shipold	-0.11781	1			
Nopert	0.223153	0.278351	1		
Regicap	0.152568	-0.30066	0.152201	1	
Shipute	0.075618	-0.00972	-0.22888	0.047112	1

The empirical model design is as follows :

$$MPI_{ij} = \alpha + \beta_1 manps_{ij} + \beta_2 shipold_{ij} + \beta_3 nopert_{ij} + \beta_4 regicap_{ij} + \beta_5 shipute_{ij} + \varepsilon_{ij}$$

MPI: Malmquist productivity index of 21 container terminals

α: constant

β: variable coefficient of the i^{th} independent variable

i: designated terminal name

j: designated year

ε_{ij}: random error

The MPIs of 21 container terminals are interpreted as a dependent variable to investigate the relationship between these factors and efficiency indices. When the regression coefficient is positive, there is a positive correlation between the independent variable and the efficiency indices. The greater the value of the independent variables, the more they impact the efficiency index.

According to the analysis results shown in Table 7, Regicap (0.1823), Shipold (0.1731), Shipute (0.0782) and Manps (0.0781) correlate positively with the terminals' productivity efficiency change. Conversely, Nopert (-0.0629) correlate negatively, thus limiting the improvements to the terminals' productivity efficiency change.

<Table 7> Results of the Tobit regression model

Criterion	Coefficient	Standard Error	Attribute
Regicap	0.1823277**	0.1314429	Registered capital (ten thousand RMB)
Shipold	0.1731650**	0.1418686	Chinese state-owned shipping line-1 If not-0
Shipute	0.0782272**	0.1275272	Number of shipping route
Manps	0.0781432*	0.1319377	Percentage of worker who have a bachelor degree or above
Nopert	-0.0628916**	0.1435328	Number of terminal operators
Constant	-0.0752801	0.1377574	-

Note: Statistically significant at α=0.05.

Regicap (0.1823) also has a positive effect on productivity efficiency. The port is a capital-intensive industry, and the more investment that is made in a port at the early stages, the bigger the size of the port, the port facility, manpower, services etc; in other words, the basic infrastructure will be relatively superior. Shippers are demonstrating a preference for selecting a complete infrastructure, good service, and more standard ports as transfer ports for cargo services. This means that more and more shipping carriers will call on those ports for cargo handling. Ports that have good loading and unloading facilities and distribution functions can avail of more trade business. Such ports will attract more people willing to invest, and this will in turn promote the economic development of the hinterland. The more registered capital there is, the bigger the space for capital operation will be. Capital operation not only allows a wide range of resources to be integrated, it can also address the mismatch of port structures, such as terminal leasing, joint management, and investment abroad (Liu, 2012).

Shipold (0.1731) is also an important factor that affects productivity efficiency improvement. The Tobit regression result shows that Chinese state-owned shipping line shareholdings increased by 1 and productivity efficiency can be improved by 0.21; this result matches the previous finding that more Chinese state-owned shipping line shareholdings means higher production efficiency. Long (2007) noted that shipping carriers are not just trying to develop their own fleets but also regard investment in ports as strategic positioning to ensure a smooth supply chain. Competitiveness in the shipping industry involves transferring control to the shipping node or port but not for the sole purpose of expanding the scale of the shipping fleet. In line with the growing domestic market, SMPs are becoming more important in terms of serving more cargoes. Attracting Chinese state-owned shipping lines that have huge capital and advanced management capability is becoming an important strategy for SMPs in enhancing the productivity efficiency of port terminals and increasing cargo volume. This will create a win-win effect for both the port and the shipping carriers.

Shipute has a positive effect (0.0782) on terminal productivity efficiency change. In recent years, the number of shipping routes has increased in line with the expansion of the domestic trade container market. The increase in shipping routes promotes the expansion of the hinterland

and extends the cargo channel, therefore increasing the volume of container terminals. As the port is an economic scale industry, large cargo volumes achieve greater efficiency (Pang, 2006).

Manps (0.0781) also has a positive effect on productivity efficiency, but its impact is not as influential as it was previously, compared with the three factors mentioned above. Through attracting the right port terminal management personnel, improving the structure of professional talent, and enhancing the efficiency of enterprise management, Chinese feeder ports' productivity efficiency can also be improved. With the advent of the knowledge economy, intellectual capital has become a fundamental factor in firm growth and competition, and it is now one of the most important and strategic resources for ports (Liu, 2008).

The negative factor is Nopert (-0.0629). Too many operators in the same terminal may lead to inefficient and time-consuming decision making due to the opposing interests and attitudes of each operator. In the event of irreconcilable differences between operators, the possibility of future cooperation may even be affected, resulting in a decline in production efficiency. Therefore, every terminal should employ a core decision-making operations manager.

V. Conclusion and Future Work

SMPs serve their regional economic center ports and provide hinterland cargo sources for hub ports. Labor should be divided rationally between SMPs and hub ports, making their respective advantages complementary to each other in order to promote the development of the regional economy. Previous research has mainly focused on hub port analysis. In an attempt to bridge this gap, the current paper estimates the operational and productivity efficiency changes in 21 coastal SMP terminals in China and also quantifies the factors that affect productivity efficiency change.

The results indicate that the most efficient terminals are Rizhao port and Lianyungang port. They also suggest that SMP terminals can improve their efficiency by cooperating with hub ports. As a result of such cooperation, transport networks can be established and hinterlands can be expanded. MPI tests have proved that terminals holding shares of over 50% of state-owned shipping lines show the highest increase in productivity. They also indicate that terminal efficiency correlates strongly with the presence of shipping carriers, especially Chinese shipping carriers who are very familiar with the Chinese market. In terms of factors that affect productivity efficiency change, the influence of the Shipute (0.0782) is obvious. Aside from the strategy of cooperation with hub ports, cooperation between SMPs is also an important way to enhance trade business by making full use of the 18,000 km north-south coastline, the 80,000 km Yangtze River main road, and 5000 km of the Pearl River Delta. The Nopert has negative influence to port, it's important to define who could be the core decision-making managers to joint operation and sale to port.

Therefore, in the tendency of increase input in ports, the main issue of SMPs is lack of cargo source. Attract effective shipping line (COSCO, China Shipping et al.) to invest and operate in SMPs is the strategy for (1) enhance the efficiency of terminal; (2) expand shipping route for increase cargo volume; (3) integrate number of shipping line for avoid excessive competition.

There has been little previous research on SMPs. Thus, there are many limitations in the selection of DMUs because there is no recognized definition of SPMs. Future research should focus on defining SPMs in multi-dimensional ways based on their differences from hub ports, for example, in terms of bulk/container cargo volume, hinterland scope, network condition, and information structure. *

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