Analysis of Operation Efficiency of Major Ports in China Based on Super-Sbm Model

Ang Li[1,*], Chujue Wang[2]

[1]China Institute of Water Resources and Hydropower Research, Beijing, 100038, China

[2]Business School, Hohai University, Jinling North Road No. 200, Changzhou, 213002, China

[*]Corresponding author: liang@iwhr.com

Keywords: Port, Operational efficiency, Super-sbm model, Malmquist index

Abstract: as an important window of China's foreign economy, whether the port can achieve efficient operation has always been a highly concerned issue for the government and enterprises. To solve this problem, based on the traditional DEA model, this paper proposes a Super-SBM model considering the unexpected output such as environmental pollution. This model can reflect the importance of controlling the unexpected output by restricting the weight of different types of output. Finally, taking the major port enterprises in China as an example, this paper applies the model proposed in this paper to objectively evaluate the operation efficiency of major ports in China, and provides relevant improvement suggestions.

1. Introduction

Ports are an important window for countries to develop and contact with foreign countries. The strategic concept of building “New Silk Road Economic Belt” and “21st Century Maritime Silk Road” proposed by General Secretary Xi Jinping not only provides broad prospects for economic development of countries and regions along the route, but also brings historical opportunities and challenges to the development of China's coastal ports. With the continuous advancement of economic globalization, the economic and cultural exchanges among various countries are deepening, and the economic and trade exchanges among countries are also becoming more and more frequent. The status of port competition is becoming more and more important. Therefore, it is of great economic and strategic significance to effectively analyze and evaluate the operation efficiency of port listed companies and provide feasible suggestions for improving the operation performance and international competitiveness of port enterprises.

Data envelopment analysis (DEA) is an effective method commonly used to study port efficiency, and relevant scholars have made useful exploration. For example, Abranedo Rosas et al. [1] used the traditional DEA method to measure the operation efficiency of 29 Mexican coastal ports. Tongzon et al. [2] based on DEA model, compared and analyzed the efficiency of 4 container ports in Australia and 12 other container ports in the world. Seth et al. [3] applied the window DEA model to evaluate the efficiency changes of 15 U.S. container ports. Bray et al. [4] applied fuzzy DEA model to evaluate the efficiency of a group of international container ports selected by them. Lin et al. [5] developed an inverse data envelopment analysis (IDEA) model and used the model to empirically test the statistical data of 16 major ports in China under China's 13th five-year plan. Lee et al. assessed the environmental efficiency of port cities based on slacks based data envelopment analysis (SBM-DEA). Based on the existing literature, this paper uses Super-SBM model to evaluate and analyze the operation efficiency of China's major port enterprises.

2. Models and Indicators

The specific form of Super-SBM model considering relaxation variables is as follows:

$$\rho = \min \frac{\frac{1}{m}\sum_{i=1}^{m} \overline{x}_i / x_{i0}}{\frac{1}{s_1+s_2}\left(\sum_{r=1}^{s_1} \overline{y}_r^g / y_{r0}^g + \sum_{j=1}^{s_2} \overline{y}_j^b / y_{j0}^b\right)}$$

$$s.t.\ x_0 = X\lambda + S^-,\ y_0^g = Y^g\lambda - S^g,\ y_0^b = Y^b\lambda + S^b$$

$$\overline{x} \geq \sum_{j=1,\neq 0}^{n} \lambda_j x_j,\ \overline{y}^g \leq \sum_{j=1,\neq 0}^{n} \lambda_j y_j^g,\ \overline{y}^b \leq \sum_{j=1,\neq 0}^{n} \lambda_j y_j^b$$

$$\overline{x} \geq x_0,\ \overline{y}^g \leq y_0^g,\ \overline{y}^b \geq y_0^b$$

$$\sum_{j=1,\neq 0}^{n} \lambda_j = 1,\ S^- \geq 0,\ S^g \geq 0,\ S^b \geq 0,\ \overline{y}^g \geq 0,\ \lambda \geq 0$$

Among ρ is the target ecological efficiency value;x,y^g and y^b are input, expected output and unexpected output respectively;m,S_1 and S_2 are the number of input, expected output and unexpected output indicators respectively; Vectors S^-,S^g and S^b are input slack, expected output slack and unexpected output slack respectively; λ is the weight vector.

Malmquist index believes that the change of productivity comes from the change of technology and technical efficiency (the change of technology comes from the movement of production frontier, and the change of technical efficiency comes from the change of distance between production frontier and actual output). Both of them can be calculated by distance function. The change of productivity is to use the distance function to calculate the input-output change relationship from the base period t to the period t+1. The specific expression of Malmquist index is as follows:

$$TPF = \left[\frac{D^t(x_{t+1}, y_{t+1})}{D^t(x_t, y_t)} \times \frac{D^{t+1}(x_{t+1}, y_{t+1})}{D^{t+1}(x_t, y_t)}\right]^{1/2}$$

$$= \frac{D^{t+1}(x_{t+1}, y_{t+1})}{D^t(x_t, y_t)} \times \left[\frac{D^t(x_{t+1}, y_{t+1})}{D^{t+1}(x_{t+1}, y_{t+1})} \times \frac{D^t(x_t, y_t)}{D^{t+1}(x_t, y_t)}\right]^{1/2}$$

The index system constructed in this paper is shown in Table 1:

Table 1 Operational Efficiency Evaluation Index System

Category	Index	Dimension
Investment	Operating costs	RMB/100mn
	Fixed assets	RMB/100mn
Produce	Number of employees	People
	Business income	RMB/100mn
	Net profit	RMB/100mn

3. Empirical Results

According to the above principles, DEA solver Pro 13.1 is used to calculate the data from 2016 to 2020 year by year, and the calculation results of operation efficiency are obtained, as shown in Table 2.

Table 2: Operational Efficiency Values from 2016 to 2020

Operational efficiency	2016	2017	2018	2019	2020	Mean value	Ranking
Yantian Port	4.12	3.33	1.96	1.45	1.44	2.46	2
Zhuhai Port	0.20	0.22	0.42	0.71	0.48	0.41	12
Beibu Gulf port	0.43	0.40	0.51	0.72	0.65	0.54	9
Investment port	1.04	1.03	0.99	1.44	1.08	1.12	5
Nanjing Port	0.27	1.04	1.01	1.05	1.22	0.92	7
Rizhao Port	0.16	0.22	0.38	0.36	0.37	0.30	13
Shanggang group	2.01	2.45	2.19	1.59	1.77	2.00	4
Jinzhou Port	7.54	0.21	1.11	1.22	1.14	2.24	3
Chongqing Port	0.18	1.24	1.30	0.30	1.05	0.81	8
Tianjin Port	1.02	0.32	0.29	0.32	0.37	0.46	11
Tangshan port	1.20	1.15	0.73	0.85	0.95	0.98	6
Lianyungang	5.60	5.34	5.29	5.26	5.16	5.33	1
Ningbo Port	0.57	0.41	0.45	0.52	0.50	0.49	10
Average value	1.87	1.33	1.28	1.21	1.24	1.39	

It can be seen from the results in Table 2 that a total of 5 port enterprises have achieved the optimal efficiency, while the operating efficiency of other ports is not ideal. From the perspective of all major ports, the operating efficiency of each port varies greatly, and the polarization phenomenon is serious. Lianyungang has the highest comprehensive operating efficiency within the study range, with an average efficiency of 5.33, and Rizhao has the lowest comprehensive operating efficiency, with an average efficiency of only 0.3. From the perspective of individual enterprises, the top five are Lianyungang, Yantian port, Jinzhou port, Shangang group and investment promotion port. The last three are Tianjin port, Zhuhai port and Rizhao port. Among them, Rizhao Port has the worst performance and needs to focus on efficiency improvement.

Table 3 Annual Average Malmquist Index of Port Enterprises and Its Decomposition

Decision making unit	Comprehensive technical efficiency	Technical progress	Pure technical efficiency	Scale efficiency	Operational efficiency
Yantian Port	1.000	0.726	1.000	1.000	0.726
Zhuhai Port	1.009	0.941	1.045	0.966	0.950
Beibu Gulf port	1.034	0.982	1.026	1.008	1.015
Investment port	1.000	0.924	1.000	1.000	0.924
Nanjing Port	1.006	0.996	1.000	1.006	1.001
Rizhao Port	1.055	0.981	1.031	1.023	1.034
Shanggang group	1.000	1.000	1.000	1.000	1.000
Jinzhou Port	1.094	0.984	1.047	1.044	1.077
Chongqing Port	1.072	0.957	1.071	1.001	1.026
Tianjin Port	0.996	1.002	0.997	0.999	0.998
Tangshan port	0.995	0.962	1.000	0.995	0.957
Lianyungang	1.028	0.987	1.012	1.015	1.015
Ningbo Port	1.007	0.986	0.993	1.014	0.993
Average value	1.023	0.956	1.017	1.005	0.978

It can be seen from Table 3 that from 2016 to 2020, the operating efficiency (TFP) of all port enterprises increased by -2.2% annually. Among the 13 major port enterprises, 7 had positive growth rates and 5 had negative growth rates. From the decomposition of the average annual growth rate, the growth rates of comprehensive technical efficiency and scale efficiency are greater than 0, which are 0.7% and 1.4% respectively, and the growth rates of technological progress and pure technical efficiency are less than 0, which are -1.4% and -0.7% respectively. The results show that large-scale management is the main driving force for the improvement of operation efficiency of port enterprises during the study period, and technological progress is the main obstacle to the improvement of operation efficiency. From the point of view of port enterprises, the operating efficiency of Jinzhou port, Rizhao Port and Chongqing port increased significantly, by 7.7%, 3.4% and 2.6% respectively, significantly higher than the average level. Beibu Gulf port, Nanjing port, Shanggang group, Chongqing port and Lianyungang port have small changes in operating efficiency and stable performance. Other port enterprises showed an obvious downward trend in the study range, of which Yantian Port showed the most obvious decline, nearly 30%, indicating that there were serious business problems during the study period, and it was necessary to improve the technical management level and adjust the business strategy as soon as possible.

Table 4 Average Malmquist Index of Each Year and Its Decomposition

Particular year	Comprehensive technical efficiency	Technical progress	Pure technical efficiency	Scale efficiency	Operational efficiency
2016-2017	1.042	1.050	1.034	1.008	1.094
2017-2018	1.036	0.930	1.015	1.021	0.964
2018-2019	0.997	0.957	1.009	0.989	0.954
2019-2020	1.014	0.883	1.010	1.004	0.896

It can be seen from Table 4 that from 2016 to 2020, the operating efficiency of China's major port enterprises showed an overall upward trend, only slightly decreased in 2018-2019, and increased by 4.2% and 3.6% respectively in 2016-2017 and 2017-2018. From the factors influencing the changes of operational efficiency, the progress of scale efficiency and pure technical efficiency are the main driving forces for the rise of operational efficiency, with their contribution rates of 1% and 0.4% respectively. The upgrading of technology is a major problem that must be solved to further improve the operational efficiency of port enterprises.3 Conclusions and recommendations.

4. Conclusions and Recommendations

This paper applies Super-SBM model and Malmquist index to analyze the operation efficiency of major port enterprises in China. The results show that the operational efficiency of China's major port enterprises is quite different, and there is an obvious polarization phenomenon. In terms of geographical spatial distribution, the east coast is better than the inland, and the south is better than the north; From the development of the city, the more developed the urban economy is, the higher the operation efficiency of the port enterprises will be. From the perspective of the main influencing factors of port operation efficiency, the adoption of large-scale operation mode and the improvement of technical efficiency have significantly promoted the increase of port enterprise operation efficiency, while the issue of technology upgrading has restricted the further increase of operation efficiency.

In view of the research results of this paper and the existing problems of China's major port enterprises, this paper puts forward the following suggestions:

(1) Integrate wharf resources and realize specialized division of labor. On the one hand, make reasonable planning for the existing terminals and resources, integrate the infrastructure, and improve the distribution capacity; On the other hand, the existing multi-purpose and general-purpose wharves will be professionalized to improve their adaptability and handling efficiency according to the characteristics of cargo handling, so as to realize the specialization of port handling functions.

(2) Expand and strengthen the port value-added service business, and extend the port logistics chain service. Focusing on “large-scale operation, service and technological innovation, and expanding the market outside the port”, we will deeply cultivate port auxiliary services and port logistics business such as tugboat, foreign agent, tally, labor service, logistics warehousing, plane transportation, so as to improve the logistics service efficiency of port enterprises and enhance the income level of port enterprises.

(3) We will refine and optimize “port supply chain +” related businesses and provide efficient logistics services. With the help of modern science and technology and carriers such as mobile Internet and Internet of things, build a unified online service platform and offline integrated service

network of port supply chain to provide customers with fast, convenient and efficient services.

Acknowledgement

This research was supported by the Fundamental Research Funds for the Central Universities (Grant No. B210202158)

References

[1] Ablanedo-Rosas J H, Ruiz-Torres A J. International Journal of Shipping and Transport Logistics, International Journal of Shipping & Transport Logistics. 2009, 1(3):276-294.

[2] Tongzon J. Transportation Research Part A: Policy and Practice, Eastcambs.gov.uk, 2001, 35(2):107-122.

[3] Lee Y H. Guest Editorial: Smart logistics and global supply chain management, Maritime Economics & Logistics, 2016, 18(1):1-2.

[4] Bray S, Caggiani L, Ottomanelli M. Transportation Research Procedia, 2015, 5:186-200.

[5] Lin Y, Yan L, Wang Y. Performance Evaluation and Investment Analysis for Container Port Sustainable Development in China: An Inverse DEA Approach. Sustainability, 2019: 11,125.