ISSN: 2688-8645

Evaluation of the Efficiency of Container Terminal Collection and Distribution System in Hub Port based on DEA Model

Qicheng Cai[1]

[1]School of Transport and Communications, Shanghai Maritime University, Shanghai, China.

Abstract

As the forerunner of regional economic development, the study of the technical efficiency of the port, especially the efficiency of the collection and distribution system of the container hub port, is of great significance. This paper uses the DEA-BCC model to take the hub port container terminal collection and distribution system as a whole, conducts data analysis and comparative research on the technical efficiency of major domestic large hub port container terminals, and draws a conclusion: the hub port container terminal as a whole In a state where the overall efficiency value is constantly increasing, the return to scale is increasing, and the development prospects are good, there are also individual terminals that need to further improve their management methods and expand or reduce the port scale to match output and input. Finally, combined with the literature, several feasible suggestions are put forward for improving the collection and distribution efficiency of container terminals in hub ports.

Keywords

Hub port container terminal; DEA-BCC model; collection and distribution system; efficiency.

1. Introduction

In modern times, the process of economic globalization is accelerating, and all countries hope to enhance their own international competitiveness. As a hub of water and land transportation, if multiple modes of transportation are compared to blood vessels, then ports are the heart of regulating and dredging blood vessel functions. The port itself continuously fulfills transportation functions such as storage, transit, processing, and circulation. Not only that, but as an important basic economic facility, the port can promote the development of the inland economy while simultaneously promoting industry, commerce, and agriculture in the surrounding areas. So it can be said that the port is an important link in the economic network. China has a coastline of more than 18,000 kilometers, and there is great potential for the development of various ports.

For the port, the transportation hub, the development of the collection and distribution system is very important. As an important foundation to ensure the survival and development of ports, it has a very crucial role in guiding and converging economic development. Of course, different countries have different requirements for product transactions, which requires a more efficient, more complete and more advanced collection and distribution system to meet different needs. Through the improvement of infrastructure and the rational allocation of existing resources, the interconnection of the five modes of transportation, namely waterway, highway, railway, aviation and pipeline, to further form a complete collection and distribution system is the first task of the current port collection and distribution development.

Any modern container port must have a complete and unblocked collection and distribution system in order to become an important water and land transportation hub in the integrated transportation network. With the expansion of international trade worldwide, the diversified

ISSN: 2688-8645

development of port logistics services, with unimpeded collection and distribution networks, can directly lead to the development of port throughput in the region, which will increase the loading and unloading speed of the terminal, strengthen the turnover of vehicles and ships, Ensuring the delivery of goods on time and shortening the circulation time of goods are of great significance and effect. Developed countries and regions attach great importance to the establishment of a collection and distribution system with ports as the hub. Singapore, Rotterdam, Hong Kong and other ports have good collection and distribution networks to always maintain the leading position of port cargo throughput in the world. The specific characteristics of the collection and distribution transportation system of each port, such as the number of collection and distribution lines, the composition of transportation methods, and the geographical distribution, mainly depend on the scale, direction, distance and structure of cargo types of transportation links between the ports and the hinterland. Generally, ports with large scale, multiple directions, long or long transport distances, and more complex cargo types often have more lines in the collection and distribution system, and the structure and distribution pattern of transport modes are more complex; vice versa . From the perspective of development trends, the collection and distribution systems of general large or larger ports should be developed in the direction of multi-channel, multi-directional and multi-modal transportation according to local conditions. However, for most port countries, the collection and distribution of container ports is still a relatively weak link, and an efficient collection and distribution network has not yet been formed, and there are relatively few theoretical studies in this area.

2. Problem Description and Research Status

2.1. Section Headings

2.1.1. Sub-section Headings

With the continuous development of economic globalization, the volume of international trade has also increased. Ports have become a key hub and node in international cargo transportation, and are an indispensable part of multimodal transportation. Its operational efficiency is essential to the overall international logistics and transportation efficiency. Many scholars have conducted research on the operating efficiency of port container terminals, as follows:

Domestic scholars Ding Caihong and Tao Yonghong [1] mainly studied the production efficiency of large-scale ports in Jiangsu Province. The main method they used was the three-stage DEA model, and they made certain findings after empirical research. They found that most ports in Jiangsu Province have good development prospects, but there is still a certain degree of poor port efficiency, and it is necessary to further improve the adaptability of the port itself to the environment. The scholar Nie Jingli [2] conducted research and analysis on Shenzhen Port through the BBC model and found that the DMU of Shenzhen Port is effective, indicating that the input and output of Shenzhen Port under the BBC model are balanced and reasonable, which has certain reference value. Sui Xiaoyan and Jiang Guiyan [3] adopted the DEA model and took most major coastal ports in China as the evaluation objects. The time interval was selected from 2009 to 2014 for five years. The DEA-CA-MI method was used to evaluate the production efficiency of the sample ports. Three different evaluations found the common characteristics of China's coastal ports. They found that the average improvement in port efficiency became lower and lower as the port size increased. Liu Nan, Ju Shuimu, Dong Jian [4] From the perspective of supply chain, by choosing a reasonable method and a suitable index system, the collection and distribution system as a whole uses the DEA model to study its efficiency, and found that most of the port containers The technical efficiency and scale efficiency of the terminal collection and distribution system are low, and the pure technical efficiency is relatively high. Li Guizhi[5] conducted research and analysis on the distribution and nature of ports in Liaoning Province, and evaluated the two major ports through expert survey method and analytic hierarchy process, and found that the level of collection and distribution of Dalian Port is slightly higher than Yingkou Port.

Lu Bo and Wang Shouyang [6] used three derivative models of DEA-CCR, DEA-BBC, and DEA-Super-Efficiency to study China and South Korea respectively, focusing on their 31 different levels of but all major container terminals. After precise calculations, a certain conclusion is reached. Whether it is a container terminal in China or South Korea, the utilization rate of resources has not reached perfection. While maintaining the port's current resource and equipment input, the output is using a certain method. It can be further improved by nearly 1.3 times. Among them, the overall efficiency of China's container terminals is higher than that of South Korea's container terminals; and South Korea, as a large port country, is better than China in the use of resources, which is worth learning from China. Chen Rong and Li Ling [7] used the interval analytic hierarchy process, and after using the cross-efficiency DEA-IAHP model method to analyze the efficiency of the port, they used the super-efficiency method SUPER-DEA to carry out the analysis in ports with higher efficiency values. Shi Lingling[8] analyzed Ningbo Port through data envelopment analysis, compared Ningbo Port with other ports, and established a comprehensive index system for evaluating port efficiency. Li Gongming[9] analyzed the efficiency of Tianjin Port through the improved DEA model.

Although there are precedents that consider the collection and distribution system as a whole to study efficiency through the DEA model, it does not emphasize the direction of the collection and distribution system when selecting input and output variables. This article gives priority to the selection of output variables Two methods of collection and distribution: sea-rail combined transportation and water-to-water transshipment were developed. The efficiency level was obtained by studying the input-output ratio of container terminals in different hub ports.

3. Efficiency Evaluation Method and Evaluation Index System

The key to the efficiency evaluation of the port container terminal collection and distribution system is to select a suitable evaluation method and determine a reasonable evaluation index. At present, the efficiency evaluation methods of ports, especially container terminals, mainly include: stochastic frontier analysis (SFA), data envelopment analysis (DEA), multiple linear regression analysis, total factor productivity (TFP), etc. From the perspective of frequency of use, SFA and DEA is the most common.

3.1. Evaluation Method

This article chooses the non-parametric method, and mainly uses the DEA-BCC model for research and analysis. DEA (Data Envelopment Analysis) is called Data Envelopment Analysis. As a mathematical method, it is based on relative efficiency and uses linear programming to measure the scores of multiple evaluation decision-making units based on multiple input and multiple output indicators. The evaluation and decision-making unit here refers to setting the efficiency measurement object into an independent unit that can be measured and evaluated. DMU can be any department or unit with measurable input and output (or input and output), such as manufacturers, schools, hospitals, project implementation units, or individuals. The pure technical efficiency BCC-DEA evaluation model can be obtained as 1:

$$\min \theta - \varepsilon \sum (s^{+} + s^{-})$$

$$s.t. \sum_{j=1}^{n} \lambda_j x_{ij} + s_i^{-} = \theta x_{ik}$$

$$\sum_{j=1}^{n} \lambda_j y_{rj} - s_r^+ = y_{rk} \tag{1}$$

$$\sum_{j=1}^{n} \lambda_j = 1$$

$$\lambda \geq 0; s^- \geq 0; s^+ \geq 0;$$

$$i = 1, 2, \ldots, m; r = 1, 2, \ldots q; j = 1, 2, \ldots, n$$

In the formula, n represents the number of decision-making units DMU, m and q respectively represent the number of input variables and output variables, and respectively represent the slack variables corresponding to input and output, and x and y represent input and output elements, respectively. In this paper, x represents the length of berths, the number of berths and the water depth of the channel, and y represents the throughput of containers and cargoes, and represents the comprehensive efficiency value of the research decision-making unit, where the comprehensive efficiency value = pure technical efficiency value × scale efficiency value.

The relationship between technical efficiency (TE) and pure technical efficiency (PE) and scale efficiency (SE) obtained by the BCC model is PE=TE/SE. Therefore, the BCC model can be used to analyze the three efficiencies of container terminal operations in the hub port, so as to find out the reasons for the low efficiency of invalid decision-making units and analyze the degree of efficiency between units.

3.2. Evaluation Model Construction

The main basic ideas of DEA evaluation model are as follows:

(1) First, the DEA model needs to determine the object of evaluation: for each different input unit and output unit, they will be given a collective name, which is called DMU (Decision Making Unit). Evaluation group

(2) Determine the effective frontier of production: Calculate and analyze the ratio of input to output, and use the weight of the DMU composed of each input and output as a variable for calculation;

(3) Determining the effectiveness and judging whether a decision-making unit is DEA effective is essentially judging whether the decision-making unit falls on the production frontier of the possible set of production.

The final model used in this article is through the Charness-Cooper transformation and dual programming theory and introduces slack variables s+, s- and non-Archimedean infinitesimals. There are three kinds of results that can be obtained by such a DMU model, and these three kinds of results can respectively show the efficiency status of the evaluated DMU: valid or invalid. DEA is effectively divided into two situations: one is called strong efficiency, which refers to a special state in the production process. In this state, if the output is guaranteed to be consistent, then the quantity of any input is It cannot be reduced, unless the quantity of output is fundamentally reduced, or the quantity of another input is directly increased; there is also a special state that cannot intentionally increase any output unless the quantity of inputs is fundamentally increased or reduced The quantity of another output. In the DEA model, the criterion for judging whether it is in a special state, that is, whether it is strong and effective, is θ=1, and the slack variables are all 0. The other is weakly effective, which means that the number of inputs cannot be reduced in equal proportions unless the number of outputs is reduced; the number of outputs cannot be increased in equal proportions unless the number of inputs is increased. The criterion for judging whether it is weakly effective is whether θ is equal to 1, and there is no need to consider the problem of slack variables. From the above DEA model, we can get three efficiency values, namely comprehensive technical efficiency, pure technical efficiency and scale efficiency, in which comprehensive technical efficiency = pure technical efficiency × scale efficiency.

3.3. Evaluation Index

According to previous literature studies, there are two main methods for selecting port input and output indicators, namely indirect method and direct method. The indirect method uses the financial data of listed port companies as input-output indicators to indirectly evaluate port efficiency. The direct method mainly believes that ports are producers of services, so it directly and clearly uses various port infrastructures as inputs and throughput and other indicators as outputs. The indirect method and the direct method have their own advantages and disadvantages in port performance evaluation. The direct method is very appropriate for the DEA model, because the direct method can analyze complex production relations with multiple inputs and multiple outputs. The indicators selected by the direct method can intuitively reflect the relative efficiency of the DMU.

In the current literature using the DEA method to study port technical efficiency, the selection of port input indicators and output indicators is shown in Table 1:

Table 1. Relevant research on port technical efficiency measurement indicators

Related research	Investment index	Output index
Caihong Ding [1] (2018)	Berth throughput capacity	Cargo throughput
	Main fairway depth	Foreign trade throughput
	Storage area	Container throughput
	Pile field accumulation	Mechanical efficiency
	Number of production berths	Annual operational days
Jingna Nie [2] (2018)	Number of berths	Container throughput
	Berth length	
	Quay lenth	
Xiaoyan Sui [3] (2018)	Number of berths	Cargo throughput
	Berth length	Container throughput
Lingling SHI [7] (2012)	Quay lenth	Annual throughput
	Number of berths	
	Number of suspension bridge	
	Number of RTG	
	Fairway length	

Therefore, this article refers to the experience of the past literature, chooses the direct method, and selects three from various input variables from the perspective of the level of the collection and distribution system. They are the number of berths, the length of berths, and the annual container throughput. It is an input variable; two of the different output variables are selected, namely the sea-rail combined transport box and the water-to-water transfer box as output variables for research. As shown in the following Table 2:

ISSN: 2688-8645

Table 2. Selection of indicators and units for measuring port technical efficiency

	Index	Mersuring Unit
Input indicators	Number of berths	
	Berth length	Meter
	Container throughput	10 Thousand TEU
Output indicators	Sea-rail combined container throughput	TEU
	Water-water transfer container throughput	TEU

These five variables are the five variables that have the greatest influence on the efficiency of the hub port container terminal obtained through factor analysis in the literature and consider the five variables of the collection and distribution system. This paper mainly selects ten ports including Yingkou Port, Tianjin Port, Shekou Port, Lianyungang Port, Shanghai Port, Ningbo Zhoushan Port, Jiangyin Port, Guangzhou Port, Yantian Port and Wuhan Port for analysis. The initial data of the above port are as follows:

Table 3. 2018 Raw data of each port

2018					
Port	Number of berths	Length of berths	Container throughput	Sea-rail combined throughput	Water-water transfer throughput
Yingkou Port	4	1260	275.24	35.45	10.28
Tianjin Port	14	4594	890.73	0.03	29.44
Shekou Port	9	3440	562.03	0.08	237.53
Lianyungang Port	9	2884	472.72	0.74	0.87
Shanghai Port	45	8996	4201.01	0.46	1612.66
Ningbo Zhoushan Port	23	7948	2087.31	22.5	399.37
Jiangyin Port	2	667	182.66	4.06	49.35
Guangzhou Port	20	3206	1683.22	0.29	1023.88
Yantian Port	20	7382	1316	14.5	207.2
Wuhan Port	4	131	86.9	1.7	35.3

4. Empirical Research

4.1. BCC Model Calculation Results

As shown in the following Table 4:

Table 4. 2018 calculation results for each port

Port	**TE**	**PE**	**SE**	**RE**
Yingkou Port	1.000	1.000	1.000	-
Tianjin Port	0.055	0.178	0.306	irs
Shekou Port	0.695	0.761	0.914	irs
Lianyungang Port	0.014	0.308	0.047	irs
Shanghai Port	0.700	1.000	0.700	drs
Ningbo Zhoushan Port	0.444	0.459	0.966	drs
Jiangyin Port	0.699	1.000	0.699	irs
Guangzhou Port	1.000	1.000	1.000	-
Yantian Port	0.339	0.345	0.982	irs
Wuhan Port	1.000	1.000	1.000	-

4.2. BCC Result Analysis

For the DEA-BCC model, it can be seen from Table 4 that for relatively large ports such as Shanghai Port and Ningbo Zhoushan Port, the return to scale is diminishing. The reason should be that the sea-rail intermodal container and water container throughput are The proportion of water transfer containers is not that high. This may be caused by various reasons. Perhaps in the future, we can see that large ports focus on the development of collection and distribution systems, especially sea-rail combined transport, which can further improve its technical efficiency. Of course, in terms of collection and distribution, Shanghai Port's water and water transfer tanks are at a very high level. Its excellent services and economic transfer costs continue to attract international ships and cargo to transit through Shanghai. For smaller hub ports, such as Tianjin Port, Shekou Port, Lianyungang Port, Jiangyin Port, and Yantian Port, their overall efficiency value does not reach 1, indicating that the overall efficiency of these ports is invalid for DEA, indicating that these ports The input elements are not fully utilized, and their input and output are not optimized, and further improvement is needed. In 2016, the pure technical efficiency of Jiangyin Port reached 1, but the scale efficiency did not reach 1, indicating that although the port's management system is good, the port scale cannot keep up with the port's overall efficiency, so the overall efficiency of Jiangyin Port is not DEA is effective, so the port scale needs to be expanded. For Yingkou Port, Guangzhou Port and Wuhan Port, their overall efficiency value has reached 1, and they need to be maintained or further developed. The sea-rail intermodal transportation system of many ports still needs further strengthening and improvement. Many ports can strive to improve their own operational service levels while investing resources, so that the development scale of the port container collection and distribution system matches the output capacity to improve overall efficiency. As for the efficiency of the port itself, there are the following suggestions.

5. Conclusion

This paper uses the DEA-BBC model to evaluate the efficiency of the container terminal collection and distribution system in a hub port. This article first introduces the research background and significance of research on container terminals in hub ports, and consults a large number of domestic and foreign research materials. Among the several methods of studying port efficiency, data envelopment analysis is selected. Subsequently, the DEA-BBC model was used to conduct an empirical analysis of the technical efficiency of the container terminal collection and distribution system of the hub port. At the same time, after comparing the empirical data results, a conclusion about the comprehensive efficiency value of the port was drawn, and the future port container The development of the terminal and the further improvement of the efficiency of the port container terminal put forward suggestions.

On the whole, the efficiency level of container terminals in various hub ports has a good development prospect, and the efficiency level continues to rise. However, it is not ruled out that some ports have unstable efficiency values and lower output levels than other ports. There are serious output. The problem of mismatch between investment and port scale requires further improvement. Due to the lack of knowledge of the author, this article still has certain unsolved problems. For example, if the port with a comprehensive efficiency value of 1 needs to be further separated, the MAXDEA software needs to be used for SUPER-EFFICIENCE-DEA analysis, and there are certain difficulties in the operation of the software At the same time, the selection of the parameter variable DMU was too difficult to find many data, so factor analysis was not used. The index system and total data are still the focus of research on port technical efficiency.

References

[1] Ding Caihong, Tao Yonghong. Research on the performance evaluation of large ports in Jiangsu Province from the strategic perspective of the Yangtze River Economic Belt——Based on the three-stage DEA model[J]. Journal of Jiangsu University of Science and Technology (Social Science Edition), 2018, 18(02): 101-108.

[2] Nie Jingli. Research on port efficiency of Shenzhen Port based on DEA model[J]. Comprehensive Transportation, 2018, 40(08): 114-118.

[3] Sui Xiaoyan, Jiang Guiyan, Cao Pengliang, Du Chuncheng. Evaluation of the operation efficiency of major coastal ports in China based on DEA-CA-MI[J]. Journal of Ningbo University (Science and Technology Edition), 2018, 31(01): 82-88.

[4] Liu Nan, Ju Shuimu, Dong Jian. Empirical research on the efficiency evaluation of port container terminal collection and transportation system from the perspective of supply chain[J]. Journal of Southeast University (Philosophy and Social Sciences Edition), 2013, 15(04): 28- 33+134.

[5] Li Guizhi. Evaluation of Liaoning Province's Port Collection and Distribution System[J]. Logistics Science and Technology, 2016, 39(04): 78-81.

[6] Lu Bo, Wang Shouyang. A comparative study on the operational efficiency of container terminals in China and South Korea [J]. Management Review, 2017, 29(05): 175-182.

[7] Chen Rong, Li Ling. Research on the Evaluation of Port Logistics Efficiency Based on Cross-Efficiency DEA-IAHP[J]. Journal of Nanyang Institute of Technology, 2018, 10(02): 13-18.

[8] Shi Lingling. Research on Ningbo Port Efficiency Evaluation Based on Data Envelopment Analysis [D]. Dalian Maritime University, 2012.

[9] Li Gongming. Research on Tianjin Port Operation Efficiency Based on Improved DEA [D]. Dalian Maritime University, 2017.

[10] Ai Yazhao, Zhou Kunxiao. Analysis of container port efficiency based on stochastic frontier analysis (SFA) method[J]. Journal of Shanghai Maritime University, 2015, 36(02): 31-35.

[11] Peter F. Wanke, Carlos Pestana Barros, Public-private partnerships and scale efficiency in Brazilian ports: Evidence from two-stage DEA analysis, Socio-Economic Planning Sciences, Volume 51, 2015, Pages 13-22, ISSN 0038-0121.

[12] Gabriel Figueiredo De Oliveira, Pierre Cariou, The impact of competition on container port (in)efficiency, Transportation Research Part A: Policy and Practice, Volume 78, 2015, Pages 124-133, ISSN 0965-8564.