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Evaluation of Port Logistics Efficiency and Analysis of Influencing Factors

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Abstract

This paper constructs a port logistics input-output index system of Chongqing port, and analyzes the port logistics efficiency and influencing factors of Chongqing port using DEA-BCC and Tobit models. The results show that the overall port logistics efficiency of Chongqing port shows an incremental increase due to the continuous improvement of pure technical efficiency and scale efficiency. Port logistics efficiency has reached DEA effective and accompanied by fluctuation in recent years. The study shows that port city GDP negatively affects technical efficiency and scale efficiency. Unit port berth output positively affects technical efficiency and pure technical efficiency. The level of urbanization positively affects technical efficiency and scale efficiency, while population size positively affects scale efficiency only. Road freight volume and rail freight volume do not have an impact on port logistics efficiency.

Keywords: port logistics, logistics efficiency, influence factors

1. Introduction

With the advent of economic globalization, port has become a key factor restricting regional economic development. As an important link in the supply chain logistics network system, port logistics occupies an extremely important position in the process of global material circulation and turnover. In recent years, the overall pattern of China's ports has become more and more mature, and the level of informatization and intelligence has been continuously improved. However, there are still some problems in logistics efficiency. Port logistics efficiency has become one of the main factors restricting the operation and development of port enterprises and regional economy. Therefore, this study takes Chongqing port as an example, evaluates and analyzes its port logistics efficiency, and puts forward relevant development suggestions.

Scholars at home and abroad have conducted a lot of relevant studies on port logistics efficiency. The commonly used analysis methods are data envelopment analysis (DEA) and related improved models based on DEA. In DEA, the unit or organization to be evaluated is called decision unit (DMU). DEA is to construct data envelopment curve by selecting multiple input and output data of decision-making unit, using linear programming and taking the optimal input and output as the production frontier. At present, a large number of research literature mainly studies the port logistics efficiency from the perspective of port operation enterprises and the input-output of the port itself. Port operating companies were studied such as Yuxin Cui who selected 13 listed port companies to conduct a comprehensive evaluation of their logistics operation efficiency. (Cui, Y.-X., Hua, M.-X., & Li, R.-M., 2021) Dan Liu used the Windows network DEA model to study the total operating efficiency of 15 listed Chinese ports from 2015-2019. (Cao, X.-Y., Zheng, Y.-D., & Liu, X.-Y., 2021) Feng Feng used the SBM-DEA model to measure the operational efficiency of 17 listed Chinese ports from 2010-2015 and proposed related development strategies (Feng, F., Chen, L., & Huang, H., 2017). The port's own input-output research such as Yan Zheng used DEA model to evaluate the efficiency of Lianyungang's logistics data for the last decade from 2008-2017. (Zheng, Y., & Xu, M.-X., 2020) Wen Qin analyzed the efficiency of Zhuhai port logistics industry and its influencing factors from 2007 to 2016 by constructing the input-output index system of Zhuhai port logistics industry. (Qin, W., 2018) Diansheng Li introduced the DEA quadratic relative evaluation model to port logistics efficiency measurement and conducted empirical simulations on 13 ports in China. (Li, D.-S., & Zhang, S.-Z., 2013) Taking Liaoning province as an example, Tan Li analyzed the port logistics

efficiency of Liaoning province from 2001 to 2009 based on the port logistics efficiency index system, and the results showed that the port logistics efficiency of Liaoning province was high. (Li, T., Wang, L., & Wang, Y., 2012)

In summary, the main research on port logistics efficiency uses DEA models and related improvement models. Therefore, this paper applies the DEA-BCC model to study the logistics efficiency of Chongqing port on the basis of the previous research. The data used in this paper is the logistics data of Chongqing Port from 2010 to 2020. The study also uses the Tobit model to analyze the influencing factors affecting the logistics efficiency of Chongqing port, and proposes relevant development strategies and references for the development and construction of Chongqing port.

2. Research Model and Index System Construction

2.1 DEA-BCC

Data envelopment analysis (DEA) evaluates the multi-input and multi-output efficiency of decision units from the input and output perspectives, which does not require artificial weighting assumptions and avoids the influence of subjective factors. The most typical computational models in the DEA approach are the CCR model with constant returns to scale and the BCC model with variable returns to scale. In this study, according to the actual port logistics operation characteristics, the BCC model with variable scale payoff is chosen to measure the logistics efficiency of the port, and the specific DEA-BCC model is as follows.

$$D(BCC)\begin{cases}\min\theta \\ \sum_{j=1}^{n} x_j\lambda_j + S^- = \theta x_p \\ \sum_{j=1}^{n} y_j\lambda_j - S^+ = y_p \\ \sum_{j=1}^{n} \lambda_j = 1 \\ \lambda_j \geq 0,\ j = 1,\cdots,n \\ S^- \geq 0, S^+ \geq 0\end{cases}$$

Where, θ is the comprehensive technical efficiency value of the decision-making unit. λ_j is the unit combination coefficient, which can connect each effective point to form an effective front. x_j, y_j represents the input and output of the decision-making unit respectively. x_p, y_p represents the input and output of the decision-making unit respectively. n represents the number of decision-making units. S^-, S^+ represents the redundancy of input and the deficiency of output respectively. If $\theta = 1, S^- = S^+ = 0$, it indicates that the input-output efficiency is optimal, and the decision-making unit is DEA effective. If $\theta = 1, S^+ \neq 0$ or $S^- \neq 0$, it indicates that the input-output efficiency is close to the optimal, and the decision-making unit is weak DEA effective. If $\theta < 1$, it indicates that the input-output efficiency is not optimal, and the decision-making unit is non DEA effective.

2.2 Tobit

Tobit regression model was first proposed by Tobit, which is more suitable to deal with the related problems limited by explanatory variables. The results of DEA reflect only the logistics efficiency of the decision unit, which cannot reflect the influencing factors of logistics efficiency. Since the DEA efficiency values are taken in the range of 0-1, the explanatory variables are restricted and meet the requirements of Tobit regression model. The Tobit regression model is as follows.

$$y_j = \begin{cases} y^* = \beta x_j + u_j + \varepsilon_j & y^* > 0 \\ 0 & y^* \leq 0 \end{cases}$$

Where, j=1,2,3⋯n represents the decision-making unit. y_j is the explained variable and x_j is the explanatory variable. β is the regression coefficient, u_j is the constant term and ε_j is the error term, $\varepsilon_j \sim N(0, \sigma^2)$.

2.3 Selection and Construction of Index System

This study is based on the actual operation process of the port and the availability of data. In accordance with the principle of "low input, high output", the study selects the amount of investment in port and navigation infrastructure, the length of production quayside and the number of production quayside berths as input indicators, and the amount of port cargo throughput and port operating profit as output indicators, as shown in Table 1.

Table 1. Evaluation index system of port logistics efficiency

Indicator category	Indicator name	Indicator code
Input Indicator	Number of berths at production Wharf	X_1
	Length of production wharf shoreline	X_2
	Investment in port and shipping infrastructure	X_3
Output indicators	Port cargo volume	Y_1
	Port operating profit	Y_2

3. Analysis of Empirical Results

3.1 Analysis on Logistics Efficiency of Chongqing Port

Taking Chongqing port as an example, this research studies the efficiency and influencing factors of port logistics. Firstly, DEA-BCC model is used to analyze the relevant evaluation index data of Chongqing port from 2010 to 2020, relevant data are shown in Table 2.

Table 2. Relevant index data

Year	Y_1	Y_2	X_1	X_2	X_3
2010	9668.42	6669.41	853.00	73008.00	309960.00
2011	11605.67	10800.00	880.00	73938.00	369429.00
2012	12502.40	8746.21	1241.00	94554.00	281915.00
2013	13676.00	13500.00	869.00	73204.00	306000.00
2014	14664.78	14100.00	664.00	70501.00	248000.00
2015	15680.00	11900.00	812.00	69984.00	224830.00
2016	17372.00	13600.00	811.00	70667.00	273720.00
2017	19722.00	66500.00	741.00	67000.00	336727.00
2018	20444.00	22600.00	664.00	63760.00	342858.00
2019	17125.00	18000.00	632.00	61659.00	220000.00
2020	16497.00	16400.00	610.00	59411.00	279148.00

The study uses DEAP 2.1 software to analyze the above data, and the results of the analysis include port logistics technical efficiency, pure technical efficiency, and scale efficiency. Pure technical efficiency refers to the output capacity that can be achieved with a certain input capacity, and scale efficiency reflects the scale of development of the port over the years. Technical efficiency can be expressed by the product of pure technical efficiency and scale efficiency. The results are shown in Table 3.

Table 3. Evaluation results of logistics efficiency of Chongqing port

Year	crste	vrste	scale	
2010	0.451	0.826	0.546	irs
2011	0.504	0.804	0.627	irs
2012	0.570	0.780	0.730	irs
2013	0.639	0.825	0.774	irs
2014	0.799	0.944	0.846	irs
2015	0.896	0.979	0.916	irs
2016	0.863	0.872	0.990	irs
2017	1.000	1.000	1.000	——
2018	1.000	1.000	1.000	——
2019	1.000	1.000	1.000	——
2020	0.917	1.000	0.917	irs
average value	0.785	0.912	0.850	

According to Table 3, it can be seen that each efficiency value has been in an increasing trend, reaching the optimal in 2017 and continuing to be optimal for three years, which indicates that the port of Chongqing has been in a state of rapid development. The construction and operation management of the port are also improving continuously. From the viewpoint of technical efficiency, the technical efficiency of port logistics in Chongqing port reached an effective value of 1 in the three years of 2017, 2018 and 2019, indicating that the logistics efficiency of Chongqing port reached the optimum in these three years, with reasonable resource utilization, scientific management methods, and the amount of input and output in line with the development requirements. The technical efficiency of the port for the remaining 8 years is less than 1, which is not DEA effective, indicating that there are unreasonable allocations of port resources, each production resource factor is not fully utilized, and there are redundant inputs or insufficient outputs. Technical efficiency grew faster during 2010-2020, with an overall technical efficiency average of 78.5% and a 21.5% opportunity for improvement. In terms of pure technical efficiency, the efficiency values reach 1 for both 2017-2020, indicating that the management approach of Chongqing port tends to be scientific and effective in recent years, leading to the optimal operational efficiency of the port. The other years did not reach the effective value of 1, indicating that in the past the port may have wasted or misallocated resources due to redundant inputs or insufficient outputs, resulting in inefficient port operations. In terms of scale efficiency, the efficiency value reached 1 in 2017-2019, indicating that the returns to scale remain stable and optimal, and that the port can obtain considerable output as long as it maintains its current scale and allocates resources rationally. The overall upward trend in returns to scale from 2010-2016 indicates that Chongqing port is aware of the imbalance between resource inputs and outputs and has been taking measures to improve the rationality of resource allocation.

3.2 Analysis on Influencing Factors of Logistics Efficiency in Chongqing port

The factors influencing port logistics efficiency are complex and diverse. To further understand the factors affecting the logistics efficiency of Chongqing port, this study draws on the research results of other scholars as well as considers the factors covering the port's own internal factors and external socio-economic factors. Subject to the availability of data, this study takes the calculation results of DEA-BCC as the explanatory variables, and port city GDP(X_4), output per unit of port berth(X_5), urbanization level(X_6), population size(X_7)and road and railroad freight volume(X_8) as the explanatory variables to explore the factors affecting the logistics efficiency of Chongqing port.

Table 4. Tobit regression analysis results

	crste			vrste			scale		
	ratio	z value	p value	ratio	z value	p value	ratio	z value	p value
X_4	-0.000	-2.487	0.013	-0.000	-1.012	0.312	-0.000	-2.937	0.003
X_5	0.016	3.002	0.003	0.012	3.317	0.001	0.005	1.179	0.238
X_6	0.123	2.512	0.012	0.045	1.323	0.186	0.106	2.620	0.009
X_7	0.001	0.521	0.602	-0.002	-1.680	0.093	0.003	2.431	0.015
X_8	-0.000	-0.308	0.758	-0.000	-0.314	0.753	0.000	0.061	0.952

According to Table 4, the Tobit regression model of Chongqing port logistics efficiency is as follows.

$$y_{\text{crste}} = -8.180 + 0.016X_5 + 0.123X_6 + 0.001X_7$$

$$y_{vrste} = 5.541 + 0.012X_5 + 0.045X_6 - 0.002X_7$$

$$y_{scale} = -15.689 + 0.005X_5 + 0.106X_6 - 0.003X_7$$

For technical efficiency, the regression coefficient value of X_4 is -0.000 and shows a significance at 0.05 level (z=-2.487, p=0.013<0.05), implying that port city GDP can have a significant negative relationship on technical efficiency. The value of the regression coefficient for X_5 is 0.016 and shows a significance at 0.01 level (z=3.002, p=0.003<0.01), implying that there is a significant positive relationship between the output per unit of port berth on technical efficiency. The regression coefficient value of X_6 is 0.123 and shows significance at 0.05 level (z=2.512, p=0.012<0.05), implying that the level of urbanization has a significant positive effect on technical efficiency. The regression coefficient value of X_7 is 0.001, but does not show significance (z=0.521, p=0.602>0.05), implying that population size does not affect technical efficiency. The regression coefficient value of X_8 is -0.000, but it does not show significance (z=-0.308, p=0.758>0.05), implying that the volume of road and rail freight does not have an impact relationship on technical efficiency. According to this logic, port city GDP does not have an impact on pure technical efficiency and has a significant negative impact on scale efficiency. Port berth output per unit has a significant positive effect on pure technical efficiency and no effect on scale efficiency. The level of urbanization does not affect the pure technical efficiency and has a significant positive effect on the scale efficiency. Population size does not have an impact on pure technical efficiency and has a significant positive impact on scale efficiency. The volume of freight transported by public railroads does not have an impact on pure technical efficiency and does not have an impact on scale efficiency.

4. Conclusions and Suggestions

This study used DEA-BCC model to analyze the port logistics efficiency for Chongqing port from 2010-2020. To further investigate the factors affecting the logistics efficiency of Chongqing port, the study used Tobit regression model to analyze the influencing factors of port logistics efficiency. It is found that the port logistics efficiency of Chongqing port has been improving year by year, and the logistics efficiency has reached its effective value in recent years. It indicates that Chongqing port has been improving its operation and management methods over the years, and the resource allocation mechanism has become more and more reasonable. Then the Tobit model is applied to analyze the influencing factors of port logistics efficiency. It is found that port city GDP has a negative effect on technical efficiency and scale efficiency, unit port berth output has a positive effect on technical efficiency and pure technical efficiency, urbanization level has a positive effect on technical efficiency and scale efficiency, population size only has a positive effect on scale efficiency, and road and rail freight volume does not have an influential relationship on any of the three types of efficiency values.

Based on the results of the above empirical study, in order for Chongqing port to better participate in the major strategy of "Upstream Yangtze River Shipping Center" construction, improve the port logistics efficiency of Chongqing port, and give full play to the value of Chongqing port's important geographical location, this paper proposes the following port construction recommendations.

(1) The city where the port is located should accelerate economic construction and achieve sustainable economic development. The city where the port is located should strengthen the development of pillar industries and encourage the landing and construction of new industries. The city should strengthen the momentum of advantageous industries, accelerate the process of transformation of old and new dynamic energy, and realize comprehensive, coordinated and sustainable economic development.

(2) Port construction should increase investment in science and technology and improve the level of port facilities and equipment intelligence. The development level of the port is reflected in the annual output per unit port berth, and the most basic thing that affects the output per unit port berth is the construction of port infrastructure equipment. In order to meet the requirements of the current business volume of Chongqing port for facilities and equipment, the port can increase the investment in science and technology and improve the intelligent level of port facilities and equipment, so as to improve the efficiency of port operations.

(3) The port should promote the cooperation between the port and the industry, academia and research institutions, and strengthen the quality training of practitioners. The improvement of practitioners' professionalism is related to the sustainable development of Chongqing Port. Port enterprises should strengthen the cooperation with industry, academia and research institutions, comprehensively carry out knowledge and skill training of practitioners and actively absorb professional talents. Port enterprises should also create a good learning environment for employees, provide learning opportunities and platforms, and build a management team with excellent professionalism.

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