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Research on the Efficiency of Ocean Shipping Enterprises Based on DEA

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ABSTRACT

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This paper uses the data envelopment analysis (DEA) method to evaluate the total factor productivity of China's listed ocean shipping enterprises in 2016-2018. The results show that in recent years, the total factor productivity of these enterprises is in a good level in the transportation industry; the main reasons for the inefficiency of the ocean shipping enterprises are low technical inefficiency and management efficiency, and the technical and management level should be enhanced. In addition, China's ocean shipping enterprises should further control their investment and strengthen cost management. Finally, this paper proposes the reform direction of state-owned enterprises such as increasing R&D investment, improving corporate governance, reforming the assessment system, and performing market-oriented reforms.

ADDITIONAL INDEX WORDS: *DEA, technical efficiency, management efficiency, state-owned ocean shipping enterprises.*

INTRODUCTION

Scarcity and efficiency are two major themes in economics research. Samuelson once suggested that efficiency is the most effective use of social resources to meet human aspirations and needs. In welfare economics, "Pareto optimality" is often used to measure the optimal allocation of resources (Liu *et al*., 2015). The so-called "Pareto optimality" refers to the allocation of resources in an economic system, in which the benefit obtained by some people can be improved without impairing the welfare of anyone else, if no other allocation method is available. Enterprises also face these two major themes of scarcity and efficiency. In economics, the production function is used to study the production activities of enterprises. The total factor productivity of an enterprise is reflected in technical efficiency (TE) and scale efficiency (SE). TE in the economic sense refers to the relationship between input and output, that is, the maximization of output under a given cost or the minimization of input cost under a given output. SE also plays an important role in the enterprise production process, and the "scale effective" means a state in which the input amount is between increment and decrement in returns to scale (the optimal state of "constant returns to scale").

According to Battese and Coelli, (1988), the measurement methods of production efficiency mainly include Soro residual method, index method, data envelopment analysis method (DEA) and stochastic frontier analysis (SFA). The first and fourth methods are parameter methods, and the second and third methods are non-parametric methods. China's ocean shipping enterprises are dominated by state-owned enterprises. For a long time, the problem of low production efficiency in the state-owned enterprises has been the focus of the theoretical circles (Jefferson, 1992; Liu *et al*., 2002; Zheng, 2003). For this problem, there are different explanations. Kornai, (1986) and Lin, (2004) believed that the soft budget constraint generated by state-owned property rights would lead to low production efficiency; Zhang, (1999) studied the efficiency of state-owned enterprises from the perspective of agency theory, and considered that serious problems in the agency chain of public ownership economy led to the inefficiency; more scholars have discussed the reasons for the enterprises inefficiency from the perspective of corporate governance, including manager compensation arrangements, independent director system, shareholding of major shareholders, background characteristics of management, management shareholding and performance evaluation system, (Li, 2007; Richardson, 2006; Stern, 2004; Yan, 2016).

In view of the availability and objectivity of the data, this paper uses the data envelopment analysis (DEA) method for enterprise efficiency evaluation. DEA is a new performance evaluation method proposed by a well-known operational researcher A. Chanes, W.W. Cooper and E. Rhodes in 1978, which uses linear programming ideas to evaluate the relative efficiency of similar sectors. Later, Charnes, Coopers, (1985), Wei *et al*., (1987) further deepened and improved the DEA method. Currently, the DEA method has been widely used in the efficiency evaluation of finance, education, health, agriculture, transportation and other industries (Charnes, 1989; Ding, 2011; Ji, 2016; Qu, 2011; Yang, 2012). But there has been no evaluation about the ocean shipping enterprises by the scholars. In view of this, on the basis of previous studies, this paper uses the DEA method to evaluate the efficiency of China's ocean shipping enterprises, and explore the factors affecting the efficiency of enterprises and the path of improvement (Crilley *et al*., 2012).

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Table 1. *Summary of enterprise input-output indicators.*

Indicator type	indicator selection	Indicator sign	Definition of Indicator
Input Indicators	Fixed asset	FA	Depreciation of fixed assets in the current period (unit: 100 million yuan)
	Raw materials	TE	Cash paid for goods and services + change in notes payable + change in accounts payable - change in advance payment (unit: RMB 100 million)
	Labour	LE	Cash paid to and for employees in the current period + Changes in the amount of payroll payable (unit: RMB 100 million)
	Period charge	FE	Other cash paid related to operating activities (unit: RMB 100 million)
Output Indicators	Operating income	RV	Operating income (unit: RMB 100 million)

THEORETICAL ANALYSIS AND RESEARCH DESIGN

Data Envelopment Analysis Model

DEA is a linear programming analysis method mainly used to evaluate the production efficiency of homogeneous units with multiple inputs and multiple outputs (Lv *et al*., 2016). The basic idea is: with each evaluated unit as a decision unit (DMU), many DMUs constitute the evaluated total; then, through comprehensive analysis for the ratio of input and output, the weight of each input and output indicator of DMU is taken as the variable to perform simulation and determine the effective production frontier surface; finally, according to the distance between each DMU and the effective production frontier surface, it evaluate whether each DMU is effective for DEA (Li *et al*., 2016). In this paper, it's assumed that there are K state-owned enterprises, and each state-owned enterprise is a decision-making unit, including l types of input factors x_{jl} $(l = 1, \ldots, L)$ and m types of output $y_{jm}(m = 1, \ldots, M)$. Besides, assuming that the sum of convexity, cone and inefficiency for the enterprise $n(n = 1, \ldots, K)$ is the smallest, then the DEA model of constant returns to scale (CRS) can be expressed by the following model:

$$\begin{cases} \min\left[\theta - \varepsilon\left(e_1^T s^- + e_2^T s^+\right)\right] \\ s.t. \sum_{j=1}^{k} x_{jl}\lambda_j + s^- = \theta x_l^n \quad l = 1, 2, \ldots, L \\ \sum_{j=1}^{k} y_{jm}\lambda_j - s^+ = y_m^n \, m = 1, 2, \ldots, M \quad n = 1, 2, \ldots, K \\ \lambda \geq 0 \end{cases} \tag{1}$$

where, $\theta(0 < \theta \leq 1)$ is the value of the objective function. A larger value of θ indicates a higher overall efficiency level of the enterprise. At $\theta = 1$, it means that the enterprise is effective in CRS and is at the optimal production frontier, i.e., the output efficiency is maximized at a certain input level.

If a constraint $\sum_{j=1}^{k} \lambda_j = 1$ is introduced, equation (1) can be transformed into a DEA model of variable returns to scale (VRS). The VRS model decomposes the overall efficiency into TE and SE, and it is equal to the product of the two efficiencies. The efficiency index $(\theta_b, 0 < \theta_b \leq 1, \theta_b \geq \theta)$ obtained by the VRS model represents the pure technical efficiency (PTE) index. SE can be calculated by the equation $SE = \frac{\theta}{\theta_b}(0 < SE \leq 1)$. Similarly, the closer the value of θ_b and $SE$is to 1, the higher the level of PTE and scale efficiency the enterprise has. When the above two index values are equal to 1, the enterprise obtains the optimal PTE and scale efficiency. According to the DEA model, the overall efficiency index indicates the allocation, utilization and scale benefits of the input factors in the enterprise, the PTE indicates the allocation and utilization of the input factors for the enterprise, and the scale efficiency indicates the scale economy of the enterprise.

Indicator Selection and Data Sources

The production function of an enterprise can be regarded as a model of input and output, and the input factors include capital, labour, land, and so on (Cai *et al*., 2017; Xu *et al*., 2018). The inputs and outputs of economics exist in various physical forms, and they can also be monetized. Using financial indicators, we can approximate the input and output of the enterprise in the current period. The operating income, operating profit, net profit, etc. in the financial indicators can represent accounting output. In contrast, the DEA model emphasizes the actual output of the enterprise, including both the realized output such as operating income and the unrealized output (inventory). In view of the particularity of the shipping industry, this paper selects operating income to represent output. The input of the enterprise can be divided into fixed input and variable input. In this paper, the depreciation of fixed assets accrued in the current period was selected as the fixed investment, and the variable input includes raw materials, labour costs and other expenses. The specific indicators are defined in Table 1.

The data used in this paper comes from the Wind financial database. According to the industry classification of Wind, there are 15 shipping enterprises listed in Shanghai and Shenzhen. Based on the requirements of research and design, (Peng *et al*., 2018) the sample range was extended to transport enterprises, and the number of sample enterprises reaches up to a total of 160 after eliminating the outliers. For comparison, the three major international shipping enterprises: Maersk, MSC and CMA-CGM were also added in the samples. Therefore, a total of 163 samples were obtained. Given that China's largest shipping company, China COSCO and China Shipping Group was merged in 2016, the time span of this study was 2016-2018 so as to illustrate the changing trend of business operations. In the DEA model, the input and output indicators are required to be isotropic, that is, with the input increasing, the output increases accordingly. Lang and Golden, (1989) mentioned that the input and output items must be selected in accordance with the Pearson correlation test to ensure the correlation between inputs and outputs. In this paper, the Pearson correlation analysis (Table 2) of the above data indicates that both input and output show a highly positive correlation, and the average correlation coefficient is above 0.7, which is consistent with the isotropic requirement of the DEA model.

Table 2. *Pearson correlation coefficient of input-output indicators.*

	Output	Raw materials	Labour	Period charge	Fixed asset
Output	1.0000				
Raw materials	0.9929	1.0000			
Labour	0.8595	0.8476	1.0000		
Period charge	0.8043	0.7831	0.8413	1.0000	
Fixed asset	0.7929	0.7927	0.9565	0.7917	1.0000

EFFICIENCY ANALYSIS OF OCEAN SHIPPING ENTERPRISES

This paper uses DEAP2.1 software to analyse the efficiency of China's ocean shipping enterprises through the VRS-based DEA model.

Analysis for the Efficiency of the Ocean Shipping Enterprise

The performance measurement models used in this paper measure the production efficiency of the enterprise in a production-oriented mode, that is, in the case of fixed input, the output is maximized. In order to explore enterprise efficiency from two aspects of resource management and output scale, this paper further decomposes the total efficiency of enterprises into pure technical efficiency and scale efficiency. Table 3 lists the input-output efficiency value of sample enterprises each year (Ling *et al*., 2014).

The economic efficiency evaluation of China's ocean shipping enterprises is as follows:

(1) In the past three years, the overall efficiency level of China's ocean shipping enterprises has been at a good level in the transportation industry. The last ranked Kingwin Logistics ranked 73rd among 160 sample companies. COSCO Shipping Holding Co., Ltd (COSCO) is China's largest ocean transportation enterprise, and its efficiency ranks first among 15 marine transportation enterprises. However, there is still certain gap from the top two international shipping companies and it has certain room for improvement. More local ocean shipping enterprises are less efficient, with the efficiency value less than 1. Therefore, it is necessary to carry out further enterprise reorganization by merger and acquisition for improving their efficiency.

Table 3. *Average efficiency of ocean shipping industry in 2016-2018.*

Rank	Company	total efficiency	technical efficiency	scale efficiency
1	MSC	1.4993	1.5002	0.9993
2	Maersk	1.369	1.4962	0.915
3	COSCO	1.2243	1.2787	0.9575
4	Air China	1.1677	1.192	0.9796
5	SF EXPRESS	1.1214	1.2613	0.8891
6	CMA-CGM	1.0438	1.0847	0.9623
7	CMES	1.0263	1.0713	0.958
8	COSCO Development	1.0099	1.0105	0.9994
9	COSCO Energy	1.0058	1.0161	0.99
10	Ningbo Marine	1	1	1
21	Shandong Marine	0.9002	0.9854	0.9136
24	De Bang	0.8897	0.9199	0.9671
30	Fujian GH	0.868	0.9338	0.9294
38	HNSS	0.8489	0.9621	0.8824
50	Bohai Ferry Group	0.824	0.8543	0.9645
66	CSC Phoenix	0.7675	0.7733	0.9925
Maximum value		1.4993	3.237	1.1316
Median value		0.83975	0.8894	0.95775
Minimum value		0.4969	0.6214	0.1853
Average value		0.8553	0.9615	0.9246

Table 4. *Improvement path of labour input in China ocean shipping enterprises (100 million yuan).*

	Original value	Improved value	Target value
COSCO	66.47	-43.7	28.77
CMES	4.84	0	4.84
COSCO Development	14.5	-1.84	12.66
COSCO Energy	7.09	0	7.09
Ningbo Marine	1.88	-0.68	1.2
Shandong Marine	8.33	-3.66	4.67
Fujian GH	0.96	0	0.96
HNSS	0.93	-0.33	0.6
CSC Phoenix	0.78	-0.1	0.68
Total	105.78	-50.31	61.47

(2) If economic efficiency is further decomposed into technical efficiency and scale efficiency, it can be seen that among the 15 ocean shipping enterprises, COSCO has the highest technical efficiency, which indicates its resource allocation level (technical level and management efficiency) is the highest. But, compared with the internationally leading ocean shipping companies, there are still large gaps, so it is necessary to further improve the technical and management level. In addition, the scale efficiency of COSCO is less than 1, and it is in the stage of diminishing returns to scale. Therefore, successfully surviving the merger & acquisition period is crucial. Similarly, the inefficiency of local ocean shipping enterprises is mainly caused by low technical efficiency (*Jiang et al*., 2018). Hence, it's the important path to increase the technical level, improve governance mechanisms, and promote efficiency by further enterprise reform.

Improvement Path of the Efficiency of Ocean Shipping Companies

Tables 4 to 6 list the original, improved, and target values of labour input, fixed asset investment, and other inputs for 12 representative ocean shipping enterprises in China (excluding data outliers). The total efficiency target value comes from the relevant value of the enterprise with similar effective produc-

Table 5. *Improvement path of fixed assets investment of China ocean shipping enterprises (100 million yuan).*

Fixed assets	Original value	Improved value	Target value
COSCO	59	27.74	86.74
CMES	26	22	48
COSCO Development	32.86	0	32.86
COSCO Energy	17.29	8.17	25.45
Ningbo Marine	10.33	20.23	30.56
Shandong Marine	8.87	-1.24	7.62
Fujian GH	6.99	-1.36	5.63
HNSS	7.02	2.44	9.46
CSC Phoenix	3.55	0	3.55
Total	171.91	77.98	249.87

Table 6. *Improvement path of other expenses in China ocean shipping enterprises (100 million yuan).*

Other expenses	Original value	Improved value	Target value
COSCO	66	-31	35
CMES	1.55	1.08	2.63
COSCO Development	10.58	-1.75	8.83
COSCO Energy	7.42	-2.39	5.03
Ningbo Marine	1.83	0	1.83
Shandong Marine	3.94	-0.72	3.22
Fujian GH	0.83	-0.07	0.76
HNSS	5.89	-2.73	3.16
CSC Phoenix	1.08	0.91	1.99
Total	99.12	-36.67	62.45

tion scale. The difference between the target value and the original value of the enterprise indicates the improvement space for the enterprise. Among them, the positive value represents the increase of relevant input, and the negative value represents the reduction of relevant input.

(1) Improved value of labour input

Table 4 shows that in terms of labour input, China's ocean shipping companies generally have excessive labour input, and need to control the size of employees and reduce labour costs.

(2) Improved value of fixed assets investment

Table 5 shows that from the perspective of fixed assets investment, China's ocean shipping companies need to scale up significantly and increase fixed asset investment. The scale of fixed assets investment in small ocean shipping companies is reasonable, mainly because of their single business type.

(3) Improved value of other expenses

Table 6 shows that China's ocean shipping companies need to further strengthen the management of the period expenses, especially for large state-owned ocean shipping enterprises. The period cost of COSCO is nearly double the total efficiency target value, among which the period cost of the China Merchant Energy Shipping is better controlled, reducing by 108 million yuan from the target value.

CONCLUSIONS AND IMPLICATIONS

This paper applies the DEA model to analyse the operating efficiency of listed enterprises in China's ocean shipping industry, and draws the following conclusions: (1) The overall efficiency level of China's ocean shipping enterprises is at a good level in the transportation industry, but compared with the internationally leading ocean shipping companies, there are still certain gaps, and it has certain room for improvement. (2) The main reasons for the inefficiency of China's ocean shipping enterprises are low technical efficiency and management efficiency, so it is necessary to further improve the technical and management level. (3) China's ocean shipping companies should further control their investment and strengthen cost management.

The analysis results above have important policy implications for China's ocean shipping enterprises in the future: First, a multi-level enterprise performance evaluation index system should be constructed in a phased and step-by-step manner, including financial indicators, and other indicators of corporate governance, technical efficiency, and environmental protection. Secondly, a fiscal and taxation policy system should be actively formulated to promote the technological advancement of ocean shipping companies, and improve the technical level of the enterprises through policies such as fiscal transfer payments, fund support, and tax incentives, thereby increasing total factor productivity. Slow development of technology is a major factor affecting total factor productivity. Finally, the market-oriented economic reforms should be deepened to improve market mechanisms, and promote the level of competition in various industries. Besides, it is necessary to gradually open state-owned monopoly industries, introduce private capital and competition mechanisms, and improve the operational efficiency of central enterprises.

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