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A Study on Operational Efficiency Analysis on the Value of Chinese Shipping Companies

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Abstract : *Shipping companies are key components of the logistics industry, which is extremely significant in enhancing the country's comprehensive national power and promoting global trade development. In the context of the implementation of the new development pattern strategy in China and the impact of the global novel coronavirus (COVID-19), this paper takes 22 Chinese shipping listed companies as the research object and analyses the operational efficiency of them from 2011 to 2020 based on the Super-SBM DEA Model and Window DEA Model. Factors affecting the efficiency are further analyzed with the Tobit model. The research conclude that the operational efficiency of Chinese shipping companies as a whole shows a steady increase from 2011 to 2020. Although most of them are in a relatively effective operation state, fewer are absolutely effective companies. Besides efficiency among companies differs obviously, which indicates the potential of further improvement and promotion. What's more, factors such as current economic development level, enterprise size, human resources quality and enterprise turnover speed have significant positive correlation to the operation efficiency of Chinese shipping listed companies, which is significant to improve the operation efficiency of Chinese shipping companies.*

Key Words : *DEA model, Super-SBM DEA, Tobit model, Shipping companies, Operational efficiency*

1. Introduction

The center of the logistics industry, shipping companies play an important role in linking industrial and supply chains. The rapid development of Chinese shipping companies has contributed greatly to the development of international trade and the progress of China's social economy. However, after the world financial crisis in 2008, China's shipping industry were trapped in development trough, and the revenue and profit of many shipping companies fell to varying degrees, and as a result some even withdrew from the shipping market (i.e., Hainan Pan Ocean Shipping Co., Ltd. went bankrupt in 2013; Nanjing Tanker Corporation was reorganized in bankruptcy in 2014; Windland Shipping Company went bankrupt in 2016). Moreover, after the outbreak of the novel coronavirus epidemic in 2019, China's production and trade activities were affected to varying degrees, and its maritime market and shipping companies were affected and hindered, entering the adjustment phase (Liu et al., 2021). In addition, with the slump in the development of Chinese shipping companies and the impact of the pandemic, the shipping safety of Chinese shipping companies will also be affected to a certain extent, which is detrimental to the development of shipping companies and the shipping market.(Sun, ZhiJian., 2021) Therefore, in response to China's economic development dilemma and the impact of the epidemic, the Chinese government proposed a strategy to strengthen the construction of a new development pattern with the domestic grand cycle as the mainstay and the dual domestic and international cycles promoting each other in 2020, providing directions for China's economic development in the coming period (Lv, JiaChen., 2021).

Meanwhile, China's shipping market will inevitably enter a new stage of development, presenting Chinese shipping companies with new opportunities and challenges. Pursuing economies of scale, lowering average costs, rationally allocation resources, and improving operational efficiency have become important means to solve the development dilemma and ensure the safety of Chinese shipping companies. However, Chinese shipping companies still face problem such as backward management methods, low operational efficiency and unsound management of shipping network operations, which seriously restrict the transformation and development of Chinese shipping enterprises.

Therefore, based on the Super-SBM DEA Model and Window DEA Model, this study selected 22 shipping listed companies in

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China as research samples and scientifically evaluates their operational efficiency from 2011 to 2020. Based on this, the Tobit model is used to investigate the factors influencing the operational efficency of Chinese shipping companies listed on the stock exchange. This has positive implications for Chinese shipping listed companies to improve their operational efficiency and enhance their management capabilities and competitiveness. Moreover, the rational allocation of resources and profit enhancement brought about by the improvement in operational efficiency will also provide strong support for the safe operation of China's shipping industry.

2. Literature review

2.1 Data Environment Analysis (DEA)

The operational efficiency of an enterprise is an important indicator for measuring its operational status, which is prmainly calculated by the input-output ratio to evaluate the resource utilization rate and the overall operation status(Pang, 2006). Farrell first introduced the concepts of technical efficiency (TE) and the efficiency production function in 1957, which pioneered modern efficiency measurement methods (Farrell, 1957). At present, the methods used to study enterprise efficiency at home and abroad include indicator analysis, data envelopment analysis (DEA), and stochastic frontier approach (SFA) (Na and Chen, 2017).

Among them, Data Envelopment Analysis(DEA) is a unique tool for evaluating the relative effectiveness of work performance of the same type of organization (or project) based on linear programming and is a non-parametric efficiency measurement method. An organization whose performance is measured using the DEA method is called a decision-making unit (DMU).

FSA is a parametric analysis method, whereas DEA is a nonparametric efficiency measure. It has been widely used, extended and refined since its introduction in 1978 by renowned operations research scientists Charnes, Cooper and Rhodes. Decision Making Units (DMUs) are organizations whose performance is measured using DEA. The effectiveness of a DMU is determined by whether it is on the production frontier, which means that only the production mix that falls on the production frontier a technically efficient. Accordingly, it has the advantage of being applicable to multiple-input and multiple- output situations. It neither requires prior estimation of the specific form of the production function nor gauging the data and setting weights, and has been widly used in the efficiency evaluation of various industries (Wang and Yang, 2010).

With the gradual maturity and increasing improvement of the DEA method, numerous scholars have adopted the DEA model to study the efficiency of transportion and logistics companies. Among them, research on the efficiency of shipping companies using the DEA model in Western countries such as Europe and the United States began earlier. Schinnar (1980) used DEA to study third-party logistics companies and employed efficiency as the basis for supplier selection. Tongzon (2001) used the DEA model to evaluate the efficiency of the operations of 16 ports in China and verified the feasibility of the DEA method in the evaluation of port operation efficiency. Min (2006) improved input-output indicators by selecting input-output indicators such as accounts receivable, employee compensation, fixed assets, operating expenses, and operating income to evaluate the efficiency of six logistics companies in the US. Hamdan (2008) used the DEA method to evaluate the efficiency of 19 warehouses of logistics companies in the country and made recommendations and targets for improvement. Hung et al. (2010) evaluated the operational efficiency of major container ports in Asia, measured the rankings and pointed out directions for improvement based on an analysis of the advantages of the DEA method. Odeck et al. (2012) further used the Tobit model to analyze in depth the factors affecting the efficiency of the factors and make recommendations based on the evaluation of the operational efficiency of ports using the DEA method.

Research on Chinese scholars applying the DEA method specifically for the efficiency analysis of shipping listed companies started late, and the number of papers available was limited A total of 14 journal papers and 65 master's and doctoral dissertations were retrieved by entering both shipping and DEA keywords in the Chinese paper search website (CNKI). However, their limitations are representative of recent studies. Chen et al. (2004) used 15 Chinese ports in 2002 as a research sample and studied input redundancy and output deficiency by applying the data envelopment analysis method to analyze the operational efficiency of the sample companies. Kuang (2007) applied the Super-CCR DEA model to evaluate the operating efficiency of 13 Chinese listed port companies from 2004 to 2005 and studied the trend in their efficiency changes. Zhong (2011) evaluated the efficiency of Chinese listed logistics companies by applying a three-stage DEA model to address the problems of insufficient service innovation and low efficiency of logistics services and concluded that increasing the size of companies would improve efficiency. Li et al. (2015) used at three-stage DEA model to measure the operational efficiency of China's coastal container terminals and concluded that scale efficiency was the main reason for differences in operational efficiency of terminal companies. Chu et al. (2020) used the Malmquist DEA model to measure the operational efficiency of 12 listed logistics companies in China and applied the Tobit model to explore key influencing factors. It was concluded that the operational efficiency of most of the listed logistics companies in China was on the rise mainly due to technological progress. Gao et al. (2020) measured the overall efficiency and influencing factors of 13 listed shipping companies in China from 2010-2018 using the improved BBC DEA model and Tobit model and concluded that overcapacity and personnel redundancy had a greater hindering effect on the development of shipping.

2.2 DEA application studies in shipping and port industry

Many syudies on the efficiency of shipping companies have been conducted in the relevant research literature, but they have shortcoming in terms of the efficiency of Chinese shipping listed companies. First, some studies adopt traditional DEA models (BBC or CCR) when analyzing the efficiency of shipping companies, failing to fully consider the problem of slack improvement in input and output variable, often resulting in the calculation results being out of line with reality. Second, although some studies have considered the problem of variable slack improvement that has adopted SBM-DEA models, they can only distinguish the effectiveness and ineffectiveness of decision units and cannot continue to compare and rank multiple decision units with an efficiency value of 1. Third, while some studies used the Super-SBM DEA model to evaluate the efficiency of shipping enterprises and solved the problem of slack improvement and the efficiency of multiple decision units equsl to one, the majority of these studies only calculated the cross-sectional efficiency value, or static effciency value, and did not consider the dynamic efficiency value. Fourth, some studies did not consider the restricted nature of the dependent variable whose efficiency value is greater than one in the analysis of efficiency influencing factors, and often used general regression models for regression analysis, which biased the regression results. In summary, previous studies on the efficiency of Chinese shipping companies have not yet been able to simultaneously solve the problems of variable relaxation improvement, multiple decision units with efficiency values equal to one, a lack of dynamic comparability of efficiency values and restricted efficiency values of the dependent variable.

Therefore, considering the limitations and shortcomings of previous studies, this study uses a combination of the Super-SBM DEA model and Window DEA model to calculate the efficiency values of 22 listed shipping companies in China. The method first calculates static efficiency values according to the Super-SBM DEA model, which solves the problems of variable relaxation improvement and multiple decision units with efficiency values equal to one. Then dynamic efficiency is further calculated based on efficiency solves the problem of lack of time series comparability. In addition, based on dynamic efficiency values, this study further selects the Tobit model to analyze the factors affecting the operational efficiency of Chinese shipping companies. All of the above can compensate for the limitations of previous studies.

3. Research Methodology

3.1 DEA method

3.1.1 Super-SBM DEA

The DEA analysis method contains various models, of which the CCR and BBC models are applied earlier and are more basic. The traditional CCR and BBC models use radial distance functions, which cannot measure all slack variables and therefore have shortcomings in efficiency assessment. In 2001, Kaoru proposed the SBM model, which differs from the traditional radial model in that it incorporates the slack variables directly into the objective function, thereby addressing of input and output slackness. In addition, the CCR and BBC models may also have multiple decision units with the same technical efficiency value of one in the process of efficiency evaluation, making it impossible to rank multiple technically efficient units. Therefore, in 1993, Andersen and Peterson proposed the super-efficiency DEA model (Super-efficiency Data Envelopment Analysis), which effectively solved the problem of ranking efficient decision units with technical efficiency values of one.

Further, Tone(2001) combined the advantages of the SBM DEA and Super DEA models and proposed the Super-SBM DEA model. This model solves both the problem of ranking effective units and the problem of non-radial relaxation improvement and is a highly applicable efficiency evaluation model.

Suppose there are n decision units ($DMU_{j,}j = 1,2,\ldots,n$), each decision unit has m inputs ($x_{i,}i = 1,2,\ldots,m$) and s outputs ($y_{r,}r = 1,2,\ldots,s$), x_{ij} is the i input of the j DMU, y_{rj} is the r output of the j DMU, and λ_j is the weight of the j decision unit. Then the Super-SBM DEA model is as follows:

$$
\begin{aligned}
Min\theta &= \frac{\frac{1}{m}\sum_{i=1}^{m}\frac{\bar{x}_i}{x_{i0}}}{\frac{1}{s}\sum_{r=1}^{s}\frac{\bar{y}_r}{y_{ro}}} \\
s.t.\ \bar{x} &\geq \sum_{j=1,\neq o}^{n} \lambda_j x_j \\
\bar{y} &\leq \sum_{j=1,\neq o}^{n} \lambda_j y_j \\
\sum_{j=1,\neq o}^{n} \lambda_j &= 1 \\
\bar{x} \geq x_o \ and\ \bar{y} &\leq y_o \\
\bar{y} \geq 0, \lambda &\geq 0
\end{aligned}
\tag{1}
$$

In this model Θ is the efficiency value. Hence, a larger value of Θ indicates higher efficiency.

3.1.2 DEA-window

Wang and Feng (2013) pointed out that since DEA models analyze efficiency values by constructing production frontiers and the frontiers are different in different periods, the cross-period DEA efficiency is not comparable. There are two international methods to solve the above problem: the Malmquist index method, which is further decomposed into two parts by Caves et al: technical change and efficiency change. Banker et al. (1994) further decomposes technological change into two components: scale efficiency change and pure technical efficiency change. The second method is the window DEA analysis model, which compares individual decision units with a frontier surface consisting of a fixed-width window, achieving comparability of the efficiency of all decision units over a time series (Charnes et al., 1985). According to Heshmati (2010), the Malmquist index method does not truly reflect the level of technological progress, therefore, the calculated efficiency values may be biased. This study employs the window DEA model to assess intermporal operating efficiency based on this research findings. According to Banker R D et al. (1994), to balance the credibility and stability of the efficiency measure, an appropriate window width can be selected as d=3 or d=4. This study chooses a window width of d=3 and the detailed model is as follows.

The hypothesis is that there are a total of T periods of panel data (t=1,2,3⋯,T) and n DMUs, (j=1,2,3⋯,N), in which d=3, which means a window covers three adjacent time periods, thus there will be w=T-d+1=T-2windows (w=1,2,3⋯,T-2). In addition, because every widow contains 3×N DMUs, the total number of DMUs becomes (T-2)×3×N, Details are as follows. The specific distribution is shown in Table 1:

Table 1. Distribution of windows and DMU

Window 1			Window 2			Window 3		
1	2	3	2	3	4	3	4	5
DMU1,11	DMU1,12	DMU1,13	DMU2,12	DMU2,13	DMU2,14	DMU3,13	DMU3,14	DMU3,15
DMU1,21	DMU1,22	DMU1,23	DMU2,22	DMU2,23	DMU2,24	DMU3,23	DMU3,24	DMU3,25
DMU1,31	DMU1,32	DMU1,33	DMU2,32	DMU2,33	DMU2,34	DMU3,33	DMU3,34	DMU3,35
DMU1,41	DMU1,42	DMU1,43	DMU2,42	DMU2,43	DMU2,44	DMU3,43	DMU3,44	DMU3,45
DMU1,51	DMU1,52	DMU1,53	DMU2,52	DMU2,53	DMU2,54	DMU3,53	DMU3,54	DMU3,55
…	…	…	…	…	…	…	…	…
DMU1,j1	DMU1,j2	DMU1,j3	DMU2,j2	DMU2,j3	DMU2,j4	DMU3,j3	DMU3,j4	DMU3,j5
…	…	…	…	…	…	…	…	…
DMU1,N1	DMU1,N2	DMU1,N3	DMU2,N2	DMU2,N3	DMU2,N4	DMU3,N3	DMU3,N4	DMU3,N5

…	Window T-3			Window T-2		
	T-3	T-2	T-1	T-2	T-1	T
…	DMU(T-3),1(T-3)	DMU(T-3),1(T-2)	DMU(T-3),1(T-1)	DMU(T-2),1(T-2)	DMU(T-2),1(T-1)	DMU(T-2),1T
…	DMU(T-3),2(T-3)	DMU(T-3),2(T-2)	DMU(T-3),2(T-1)	DMU(T-2),2(T-2)	DMU(T-2),2(T-1)	DMU(T-2),2T
…	DMU(T-3),3(T-3)	DMU(T-3),3(T-2)	DMU(T-3),3(T-1)	DMU(T-2),3(T-2)	DMU(T-2),3(T-1)	DMU(T-2),3T
…	DMU(T-3),4(T-3)	DMU(T-3),4(T-2)	DMU(T-3),4(T-1)	DMU(T-2),4(T-2)	DMU(T-2),4(T-1)	DMU(T-2),4T
…	DMU(T-3),5(T-3)	DMU(T-3),5(T-2)	DMU(T-3),5(T-1)	DMU(T-2),5(T-2)	DMU(T-2),5(T-1)	DMU(T-2),5T
…	…	…	…	…	…	…
…	DMU(T-3),j(T-3)	DMU(T-3),j(T-2)	DMU(T-3),j(T-1)	DMU(T-2),j(T-2)	DMU(T-2),j(T-1)	DMU(T-2),jT
…	…	…	…	…	…	…
…	DMU(T-3),N(T-3)	DMU(T-3),N(T-2)	DMU(T-3),N(T-1)	DMU(T-2),N(T-2)	DMU(T-2),N(T-1)	DMU(T-2),NT

In this table, represents the efficiency value of at time *t*. Further collation of the above results gives the distribution of efficiency values for at different points in each window, as shown in the following Table 2.

Table 2. Distribution of across windows (j=1,2,3...,N)

	1	2	3	4	5	…	T-3	T-2	T-1	T
Window 1	E1,j1	E1,j2	E1,j3							
Window 2		E2,j2	E2,j3	E2,j4						
Window 3			E3,j3	E3,j4	E3,j5					
Window 4				E4,j4	E4,j5					
Window 5					E5,j5					
…						…				
Window T-5							E(T-5), j(T-3)			
Window T-4							E(T-4), j(T-3)	E(T-4), j(T-2)		
Window T-3							E(T-3), j(T-3)	E(T-3), j(T-2)	E(T-3), j(T-1)	
Window T-2								E(T-2), j(T-2)	E(T-2), j(T-1)	E(T-2), jT

In this table, Ew,jt represents the efficiency value of DMU_j at time t. Further collation of the above results gives the distribution of efficiency values for DMU_j at different points in each window, as shown in the following table.

Further, after the efficiency values are arranged at different points in all windows, the different efficiency values obtained at each point in time are averaged to obtain a comparable time-series efficiency value for different periods. The specific distribution is shown in Table 3.

Table 3. Efficiency values after moving average of efficiency values

	t=1	t=2	t=3	...	t=T-2	t=T-1	t=T
Average	E1,j1	(E1,j2+E2,j2)/2	(E1,j3+E2,j3+E3,j3)/3	...	[E(T-4),j(t-2)+E(T-3),j(t-2)+E(T-2),j(t-2)]/3	[E(T-3),j(T-1)+E(T-2),j(T-1)]/2	E(T-2), jT

3.1.3 Tobit regression analysis

The efficiency values calculated based on the Super-SBM DEA model and the Window DEA model are both greater than zero and are semi-truncated data; therefore, if ordinary least squares (OLS) are used to analyze the efficiency influences, the parameters tend to be biased or inconsistent estimates cannot be obtained. By contrast, the Tobit model (restricted dependent variable model) is suitable for situations in which the dependent variable is restricted. Therefore, this study uses a Tobit regression model to address the semi-truncation of the efficiency value data and conduct a study of factors influencing efficiency. The Tobit model is expressed as follows:

Assuming that the explanatory variable is y_i, the minimum level is y_0 and the explanatory variable is x_i, a linear regression model can be established as follows:

$$y_i = \begin{cases} y_t^*, y_t^* > 0 \\ 0, y_t^* \leq 0 \end{cases} \tag{2}$$

$$y_i^* = \alpha + \beta_j \chi_i + \epsilon_{i,} i = 1,2 \ldots n$$

In this model, y_i is the vector of the restricted dependent variables (vector of efficiency values), which is the actual observed value when $y_i^* > 0$. The dependent variables were truncated to zero when $y_i^* \leq 0$, $\chi_i$is the vector of independent variables (vector of efficiency influences) which is the actual observed value and is not restricted; α is the intercept; β_j is the regression vector of dependent variables; and the randomness error is $\epsilon_i \sim N(0, \sigma^2)$.

3.2 Selection of indicators

3.2.1 Selection of input-output indicators

According to the characteristics of the DEA model, this study regards shipping companies as a type of business organization that uses labor and capital factors to provide shipping services and then obtain income and profit. Based on this understanding, this study considers the characteristics of shipping companies and the availability of data, sets the input indicators of the efficiency model from the two aspects of labor and capital factors and sets the output indicators from two aspects of profitability and customer service satisfaction based on relevant studies (Table 4). The specific input and output indicators are listed in Table 5.

Table 4. Previous studies on input and output indicators

Scholars	Input indicators	Output indicators
Liu Jiliang (2004)	Net fixed assets, overheads, number of employees and main operating costs	Net profit, main operating income, earnings per share and total profits and taxes
Zhong Zuchang (2011)	Fixed assets, employee wages, operating costs	Prime operating revenue
Li Xiaomei and Bai Xuefei (2011)	Total assets, operating costs	Operating income, net profit, earnings per share
Gao Tao et al. (2020)	Total assets, number of employees, net increase in cash and cash equivalents	Operating income, net profit
Omrani and Keshavarz (2016)	Ship Finance, Ship Manning, Technical Provision, Technical Repairs	Container Service, Passenger Service, Selling Agent
Chao (2018)	Expense, Number of employees, Product lifting	Revenue
Venkadasalam (2020)	Staff cost including director's remuneration, Fixed assets, Shareholder's equity	ROA, ROA, Revenue
Kim, Byung Cheol (2015)	Number of employees, Total assets, operating costs	Operating income, net profit

Table 5. Table of input and output indicators

Types	Name	Evaluation category	content	units
Input indicators	input1	Labor inputs	Number of employees	China Yuan (CNY)
	input2	Capital inputs	Net fixed assets	China Yuan (CNY)
	input3		Net increase in cash and cash equivalents	China Yuan (CNY)
Output indicators	output1	Profitability	Net profit	China Yuan (CNY)
	output2	Customer service satisfaction	Prime operating revenue	China Yuan (CNY)

The number of employees, net fixed assets, and net increases in cash and cash equivalents are all specific input indicators. The number of employees is the shipping company's manpower base for operating activities and provides labor support for the company. The net value of fixed assets is the material basis for the operation of shipping companies, and it can provide capital support. The net increase in cash and cash equivalents is the working capital that must be invested to carry out the operating activities, that ensure the normal production and operating activities of companies. Net profit is an important output indicator for measuring input factors such as abilities and operating capacity, whereas primary operating revenue is the output volume of the related business and is an important indicator of market share, reflecting customer satisfaction.

3.2.2 Selection of indexes of influencing factors

Many factors affect the operational efficiency of shipping companies and based on the research results of Li et al. (2016), Gong et al. (2019) and Gao et al. (2020), and on the availability and scientificity of data, this study selects the efficiency influencing factors from macro, meso, and micro perspectives. The details are listed in Table 6.

Table 6. Influencing factors for shipping listed companies

Perspectives	Name	Influencing Factors	Indicator Meaning	calculation or source
Macro	X1	LNGDP	Economic Development Dimension	National Bureau of Statistics of China
Meso	X2	LN Total import and export	Foreign trade level	National Bureau of Statistics of China
Micro	X3	LN Total corporate assets	Enterprise size level	CSMAR Database
	X4	The proportion of high-end talents in enterprises	Manpower Quality Level	Number of bachelor's degree or above/total number of employees
	X5	Total assets turnover ratio	Enterprise turnaround operational level	CSMAR Database

GDP reflects the overall economic development of a country and is the most important external macro environment for shipping companies' operating activities. Total import and export are important indicators that affect the business volume of shipping companies: the higher the indicator, the better the shipping demand in the shipping industry and the better the shipping business under the same conditions; the total assets of an enterprise reflects the scale of an enterprise; the larger the scale of an enterprise, the lower the operating cost of an enterprise; the percentage of top talents reflects the human capital of an enterprise; and the higher the indicator, the management and innovation ability of an enterprise, The higher the percentage of top talents reflects the enterprise's human capital, usually the higher the indicator indicates that the enterprise is better in management and innovation ability, which is an important influencing factor for the efficiency of the enterprise's opration; the total asset turnover ratio reflects the enterprise's ability to use assets, usually the higher the indicator indicates that the faster the enterprise's asset turnover, the more output is generated; The higer the indicator, the faster the assets are turned over and the more output is produced. The specific distribution is shown in Table 7.

Table 7. Descriptive statistics of influencing factors

Variable	Obs	Mean	Median	Std.Dev.	Min	Max
X1	220	13.49	13.48	0.24	13.10	13.83
X2	220	12.50	12.47	0.11	12.37	12.68
X3	220	23.17	23.24	1.31	20.07	25.77
X4	220	0.27	0.25	0.12	0.09	0.58
X5	220	0.44	0.31	0.38	0.09	1.72

The descriptive statistics results show that the mean value of LNGDP is 13.49, which is greater than its median value of 13.48, showing a right-skewed characteristic with a, standard deviation of 0.24, which is less volatile. The total LN import and export variable are similar to the LNGDP variable, which exhibits a right-skewed characteristic and is less volatile. The mean value of the total assets variable of LN firms is 23.17, which is smaller than its median value of 23.24, showing a left-skewed characteristic, and its standard deviation is 1.31, which is more volatile than the other indicators. In addition, the two indicators of top talent ratio and total asset turnover of companies also show a right skew and less volatility.

The final efficiency impact regression model constructed is specified as follows:

$$Y = \beta 0 + \beta 1X1 + \beta 2X2 + \beta 3X3 + \beta 4X4 + \beta 5X5 + e \quad (3)$$

where $\beta 0$ is a constant term: $\beta 1$, $\beta 2$, $\beta 3$, $\beta 4$, and $\beta 5$ are estimated parameters: X1- X5 represent LNGDP, LN total import and export, Ln total enterprise assets, enterprise top talent share and total asset turnover, respectively; and ε is a random disturbance term.

4. Efficiency evaluation and analysis of empirical results

4.1 Data description

Most of the listed companies in China have adopted the strategy of diversified operation in their development strategy, which makes the main business of listed companies gradually diversify. Chinese shipping listed companies are also in line with this status quo, that is, the business of Chinese shipping listed companies is also expanding continuously, and most of them show the characteristics of comprehensive management. Therefore, based on the realistic operating situation of shipping companies and date availability, this study identifies listed companies whose shipping business is their main business as Chinese listed shipping companies. Accordingly, according to the Guideline on Industry Classification of Listed Companies published by the Securities and Futures Commission and the information on listed companies published by the China Securities Regulatory Commission, there are 33 listed companies in China with shipping business as their main business until 2020, after excluding 11 of them with short establishment time and incomplete data, there are 22 companies left. These 22 listed companies have shipping businesses as their main business. For better analysis, this paper divides the selected 22 listed companies into two categories according to whether their main business involves port business or not, among which 12 companies are involved in the port business group while 10 companies are not. In addition, the relevant data of the 22 listed shipping companies from 2011 to 2020 selected in this study mainly come from the data published by the CSMAR Database, the CNINFO website, and the annual reports of shipping listed companies.

4.2 Analysis of efficiency evaluation results

Based on the Super-SBM DEA and Window DEA models mentioned previously, this study selects an output-oriented perspective and uses MAXDEA software to perform the calculations. The specific process is as follows: (1) divide the sample into eight windows according to the window width equal to 3, and fill 22 DMUs into different windows to obtain 8×2×22=352 DMUs; (2) for each window, use the Super-SBM model to calculate the efficiency value of DMUs in the window; (3) after collating the above efficiency results and obtaining the distribution of efficiency values of 22 DMUs at different points in each window, the different efficiency values obtained at each time point are averaged; and (4) the averaged efficiency values of each DMU are integrated to obtain the distribution of efficiency values of 22 Chinese shipping listed companies from 2011 to 2020 which are comparable in time series. The final calculation results are listed in Table 8.

Table 8. Technical efficiency values of shipping companies (2011 to 2020)

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Zhuhai Port Co., Ltd	0.59	0.76	0.91	0.90	0.87	0.81	0.84	0.84	0.86	0.80
Chang Jiang Shipping Group Phoenix Co., Ltd	0.46	0.53	0.80	1.08	1.09	2.47	2.58	1.09	0.99	0.96
Beibu gulf port(CNBBW)	0.86	0.97	0.87	0.89	0.78	0.84	0.88	0.97	0.95	0.95
Xiamen Port Development Co., Ltd	0.81	1.01	1.01	1.11	1.37	1.02	1.10	1.53	1.91	2.32
China Merchants Port Group Co., Ltd	1.15	1.18	1.17	1.10	1.13	1.12	1.06	1.01	0.94	0.93
Nanjing Port Co., Ltd	0.84	0.87	0.78	0.84	0.85	1.07	1.15	1.14	1.17	1.16
Hainan Strait Shipping Co., Ltd	1.41	1.03	0.99	0.78	0.84	0.92	0.96	0.97	0.94	0.96
RizhaoPort Co., Ltd	0.75	0.78	0.79	0.79	0.69	0.66	0.75	0.86	0.84	0.81
Shanghai International Port Group Co.,Ltd	1.23	0.93	0.98	1.03	1.01	0.99	1.10	1.11	1.12	1.14
Cosco Shipping Energy Transportation Co., Ltd	0.74	0.71	0.67	0.68	1.11	1.22	0.93	0.81	0.85	0.98
Jinzhou Port Co., Ltd	0.88	0.74	0.78	0.79	0.75	0.70	0.84	0.97	0.99	0.96
Chongqing Port Co., Ltd	0.65	0.69	0.73	0.77	0.75	0.74	0.93	0.96	0.81	0.79
Cosco Shipping Specialized Carriers Co., Ltd	0.70	0.79	0.73	0.74	0.75	0.65	0.77	1.05	0.81	0.81
Huaihe Energy (Group) Co., Ltd	2.19	2.80	2.63	2.17	0.86	0.75	0.78	0.80	0.88	0.94
Tianjin Port Co., Ltd	0.97	0.94	0.97	0.98	1.05	0.98	0.85	0.84	0.85	0.86
Ningbo Marine Co., Ltd	0.81	0.72	0.78	0.78	0.82	0.85	0.90	0.99	0.97	0.93
Tangshan Port Group Co., Ltd	0.78	1.13	1.19	1.15	1.06	1.10	1.12	0.93	0.97	0.97
Jiangsu Lianyungang Port Co., Ltd	0.74	0.83	0.87	0.85	0.71	0.73	0.71	0.74	0.77	0.75
Ningbo Zhoushan Port Co., Ltd	0.89	0.89	0.90	0.90	0.90	0.83	0.83	0.87	0.88	0.87
Cosco Shipping Development Co., Ltd	0.89	1.01	0.92	0.97	1.36	0.77	0.84	0.90	0.92	0.96
Liaoning Port Co.,Ltd	0.71	0.72	0.76	0.74	0.79	0.88	0.74	0.81	0.88	0.90
COSCO Shipping Holdings Co., Ltd	0.73	0.76	0.75	0.81	0.85	1.56	1.40	1.31	1.43	1.51
Average	0.90	0.94	0.95	0.95	0.93	0.99	1.00	0.98	0.99	1.01

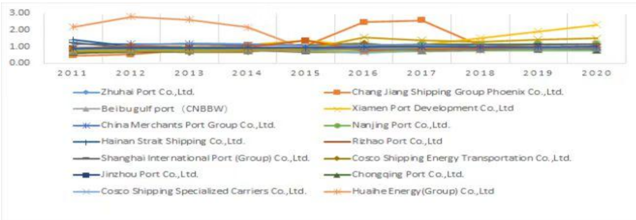

Fig. 1. Technical efficiency values of shipping companies (2011 to 2020).

The calculation results show that the average value of the technical efficiency of shipping companies in 2011-2020 shows a steady increase overall, and most shipping companies have higher efficiency values and better development. The percentages of companies operating effectively in 2011-2020 among all 22 sample companies are 18.18%, 22.27%, 18.18%, 27.27%, 36.36%, 31.82%, 31.82%, 31.82%, 18.18%, and 18.18%, respectively, indicating that there are still many Chinese listed shipping companies in ineffective operations and still need to continue improving. In terms of specific companies, Xiamen Port, COSCO Shipping, Nanjing Port, Shanghai Port Group, and Changhai Phoenix are in effective operation with high-efficiency values during the sample period. On the other hand, companies such as Lianyungang, Rizhao Port, COSCO Hitech, and Chongqing Gangjiu have average efficiency values between 0.75 and 0.80, but their overall efficiency ranking is lower, and there is a considerable gap between them and companies with excellent operational efficiency.

In general, the efficiency values of Chinese listed shipping companies in the sample period are generally high and the development momentum is good, but there are more relatively effective companies in the sample (0.90≤efficiency value <1.00) and fewer truly operationally effective companies. Therefore, the majority of Chinese listed shipping companies should actively rectify, strengthen the internal division of labor, and improve the management level so that the operational efficiency can be improved rapidly and has reached the effective operation status.

4.3 Tobit regression results for influencing factors

To further investigate the key factors influencing the operating efficiency of Chinese listed shipping enterprises, this study takes the comprehensive technical efficiency values derived from the first stage of DEA as the dependent variables (i.e., the explanatory variables) and the factors influencing the operating efficiency of shipping enterprises selected in Section 3 as the explanatory variables, and investigates the influence of each factor on the operating efficiency of enterprises.

The regression results are inaccurate and deviate from reality when the independent variables are highly correlated and exhibit multicollinearity. Therefore, in this study, correlation analysis (to judge the correlation) and variance inflation factor test (to judge the degree of multicollinearity) were conducted on the independent variables before the regression analysis, and the results are shown in Tables 9 and 10.

Table 9. Correlation analysis

	X1	X2	X3	X4	X5
X1	1				
X2	0.588	1			
X3	0.2056	0.1924	1		
X4	0.1198	0.1062	0.4592	1	
X5	-0.0414	-0.0201	-0.2429	-0.1524	1

Table 10. Variance inflation factor test

Variable	VIF	1/VIF
x1	4.77	0.20985
x2	4.74	0.210939
x3	1.36	0.735973
x4	1.27	0.786628
x5	1.07	0.937107
Mean VIF	2.64	

It can be seen that the correlation coefficients among the independent variable indicators, except for LNGDP and LN total imports and exports, are all below 0.5, and the correlations are low. Furthermore, the variance inflation test reveals that, despite indicators with high correlation, the test VIF values are all less than 10. As a result, it is possible to conclude that there is no significant multicollinearity among the selected independent variables, and the regression with the aforementioned indicators is valid.

To further study the key factors influencing the operating efficiency of Chinese listed shipping companies, this study used the comprehensive technical efficiency values derived from the first stage of DEA as the dependent variable (the explanatory variable) and the factors affecting the operating efficiency of shipping companies as the explanatory variables and studied the influence of each factor on the operating efficiency of the companies. Thus, StataMP-64 was used in this study to perform a Tobit regression on the operating efficiency of 22 listed Chinese shipping companies from 2011-2020, the results of which are shown in the Table 11 below.

Table 11. Tobit model regression results

Variable	Coefficient	Standard error	P value
X1	0.194*	0.233	0.045
X2	-0.516	0.508	0.309
X3	0.0625*	0.0354	0.077
X4	0.553*	0.321	0.076
X5	0.868***	0.106	0.000
C	2.859	3.84523	0.457
obs	220		
Wald chi2(5)	70.27		
Prob>chi2	0.0000		
Log likelihood	-111.48986		

Note: *** p<0.01, ** p<0.05, * p<0.1, indicate significant at the 5%, 1%, and 0.1% levels of significance, respectively, and C is a constant term.

According to the regression results, indicators of LNGDP, total LN imports and exports, total assets of LN companies, the proportion of high-end talents in companies, and the total asset turnover ratio passed the significance test, showing a significant influence on the efficiency value of shipping companies. The specific analysis results are as follows:

Firstly, LNGDP showed a significant promoting influence on the efficiency value of Chinese listed shipping companies at 10% level, and the analysis shows that the growth of Chinese GDP provides a good environment and foundation for the development and improvement of Chinese shipping market, promotes the healthy development of Chinese shipping companies, and is conducive to the efficiency enhancement of Chinese listed shipping companies; secondly, the total import and export of LN shows a shows an insignificant negative influence relationship, i.e. although the growth of China's total import and export will show a negative influence on the efficiency value of Chinese listed shipping companies (this negative influence is related to the intense competition and higher operating cost of shipping companies under the influence of the new crown epidemic), this influence is low and will not significantly reduce their operating efficiency; thirdly, LN total assets at the 10% level has a The significant promoting influence indicates that the expansion of the scale of Chinese listed shipping companies can bring benefits such as cost reduction and revenue increase to them, which in turn promotes the improvement of their operational efficiency; fourthly, the percentage of corporate top talents has a significant positive relationship with the efficiency value of Chinese listed shipping companies at the 10% level, indicating that in shipping companies, top talents, through their advantages in skills, technology and knowledge, play an important role in enterprise operation and enterprise management, which can enhance the competitive advantage of the enterprise and have a significant promoting effect on the efficiency value of the company; fifthly, the total asset turnover rate has a significant promoting effect on the efficiency value of Chinese shipping listed companies at 1% level, i.e. the total asset management level and total asset turnover speed of Chinese shipping listed companies have a significant promoting effect on their operation efficiency.

In general, factors such as economic development level, enterprise-scale size, human resource quality, and enterprise turnover speed have a significant influence on the operational efficiency of Chinese shipping listed companies and are important ways and means for Chinese shipping listed companies to improve their operational efficiency.

5. Conclusions and Recommendations

Based on Super-SBM DEA and Window DEA model, this paper evaluated the operating efficiency of 22 listed shipping companies in China from 2011 to 2020 and further regressed and analyzed the various influencing factors and degree of influence on the change of their operating efficiency based on Tobit model. The research results showed that:

(1) The overall operating efficiency of Chinese listed shipping companies is steadily increasing, and most listed shipping companies have high-efficiency values and are in a relatively effective development state.

(2) there are some differences in efficiency values among Chinese listed shipping companies, and companies like Xiamen Port, COSCO Shipping Holdings, Nanjing Port, Shanghai Port Group and Changjiang Phoenix have efficiency values greater than one and are in an effective operation state, which can serve as a model for other companies in an ineffective state.

(3) Tobit regression results show that factors such as the economic development level, development scale of shipping companies, personnel quality, and asset turnover are the main factors affecting the operational efficiency of Chinese listed shipping companies, and Chinese shipping listed companies should improve their operational efficiency through the above-mentioned methods.

In general, the proportion of shipping listed companies with effective operation in China is still not high, and most of them still have great room for efficiency improvement. Therefore, given the above research results, this study puts forward targeted countermeasures and suggestions to promote the operational efficiency of shipping listed companies in China.

First, we should follow the trend of regional economic development changes and change the enterprise development mode over time. The development of any enterprise is inseparable from the economic development of the region in which it is located. In the process of China's economic development gradually changing from labor-intensive to capital-intensive and technology-intensive, Chinese shipping listed companies should conform to the trend of regional economic development changes, timely change their development model, and constantly adapt to new changes in China's economic development. Second, the management level of shipping companies should be improved, and awareness of efficiency should be continuously strengthened. Since the reform and opening up, social and economic development in China has made great achievements, and Chinese shipping listed companies have also taken this opportunity to carry out rapid expansion and development; however, Chinese listed shipping companies tend to pay attention only to the speed of development, but neglect the quality of development, that is, the role of efficiency. Therefore, Chinese shipping listed companies should constantly improve their management level and strengthen their awareness of efficiency while attaching importance to the speed of development to achieve high-quality development of shipping companies. Once again, it accelerates scale development, optimizes the human capital structure, and enhances the speed of enterprise turnover operations. At the present stage, the size of enterprises, the quality of personnel, and the speed of enterprise turnover are the main factors affecting the operational efficiency of Chinese shipping listed companies. Therefore, Chinese shipping listed companies should start from the above angles, promote the development of enterprise scale, constantly optimize the structure of enterprise human capital, and accelerate enterprise turnover to improve the efficiency of their development.

In summary, Chinese shipping listed companies should pay attention to improving their operational efficiency and actively transform their development mode to continuously respond to the opportunities and challenges brought about by changes in the domestic and international environments.

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