https://doi.org/10.22306/al.v10i2.397 Received: 08 Mar. 2023; Revised: 10 Apr. 2023; Accepted: 09 May 2023

Performance of Vietnamese shipping firms: a four random components stochastic frontier approach

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Keywords: technical efficiency, stochastic frontier analysis, Vietnamese shipping firms.
Abstract: This study aims to measure the overall technical efficiency score and analyze its determinants in the Vietnamese shipping industry. The data used in the study is the enterprise census data set collected by the General Statistics Office of Vietnam from 2016 to 2020. A major difference in this study compared to other empirical studies about the efficiency in Vietnam is that we applied the stochastic frontier analysis with four random components. The results of measuring efficiency scores show that: The average overall technical efficiency (OTE) score of Vietnamese shipping firms is 0.539. In which the persistent technical efficiency (PTE) score averaged 0.883 and the transitory technical efficiency (TTE) score averaged 0.60. It shows that the potential for operational efficiency of Vietnamese shipping firms is still very large. The results of the analysis of the determinants of OTE showed that. Internal firm characteristics such as firm size, firm age, return on equity of firm have a positive effect on OTE. And state-owned firms are less efficient than non-state firms. Besides, factors such as participation in international shipping, the quality of economic institutions also have a positive relationship with OTE. However, financial constraint, specifically the level of credit outstanding, is the main cause of slowing OTE growth.

1 Introduction

Ocean shipping plays an important role in the logistics service chain, and it is even more meaningful for countries with long coastlines like Vietnam. Well aware of this, the 12th Central Committee of the Communist Party of Vietnam issued Resolution 36-NQ/TW in 2018 on the strategy for sustainable development of the marine economy. This resolution emphasized that "By 2030, the shipping economy will take the second position in the development strategy of Vietnamese marine economic sectors, focusing on the effective exploitation of seaports and shipping services". And to do this, the Government has issued Resolution No. 26/NQ-CP on the master plan and 5-year plan in the strategy of sustainable development of Vietnamese marine economy to 2030, with a vision to 2045.

Over the years, the system of Vietnam's seaports has developed strongly and has received the world's largest tonnage ships to transport goods. Seaports meet the needs of ships entering and leaving the port, the waiting time for ships to dock at the port is short, well serving the clearance of import and export goods and goods transported domestically. Moreover, Vietnam is integrating deeply and widely into the world, as evidenced by new generation free trade agreements such as Comprehensive and Progressive Agreement for Trans-Pacific Partnership (CPTPP), European-Vietnam Free Trade Agreement (EVFTA), Regional Comprehensive Economic Partnership (RCEP) being signed and put into effect. Therefore, the volume of goods through Vietnamese seaports is growing. Specifically, the volume of goods through Vietnamese seaports reached 692 million tons in 2020, up 4% compared to 2019, of which container cargo reached 22.41 million TEUs, up 13% compared to 2019 [1]. This has been creating great advantages for the development of Vietnamese shipping firms.

Although Vietnamese shipping firms have experienced and significant growth over the years, this development is not commensurate with the role and position of Vietnam. The volume of goods imported and exported by sea in Vietnam is largely handled by foreign shipping lines. The international shipping market share of Vietnamese shipping firms tends to decrease, mainly exploiting short routes to China and countries in Southeast Asia. Sea transport routes to developed countries in Europe and America are almost impossible for domestic firms to undertake. Vietnam's international shipping vessels are still very limited in meeting the requirements of safety, maritime security and environmental protection, so many ships are kept in foreign seaports. New-generation free trade agreements expand the transport market for Vietnamese fleets in other developed countries, but the domestic transport market will also have to open to foreign fleets. The services of transporting empty containers and consolidating goods for domestic seagoing vessels will face fierce competition, which may lead to Vietnamese shipping firms losing their domestic market share. In addition, the fleet structure of firms is not reasonable, small tonnage ships and bulk carriers account for a large proportion, large transport ships and container ships account for a very small number. Human resources of the shipping industry are lacking and weak in quality. On the other hand, with the achievements of the fourth technology revolution, the trend of applying technology to the logistics platform is accelerating and has a great impact on the efficiency of a supply chain [2]. However, the logistics platform of Vietnamese shipping industry is still weak and has not caught up with developed countries. The above factors will lead to low operational efficiency of Vietnamese shipping firms. The competitiveness of firms is not high, and it is difficult to win shipping contracts in the market.

Measuring efficiency at the firm level was suggested by [3], which uses concept of efficiency by [4] and radial efficiency measure by [5]. Efficiency measures can be divided into three different measures: technical efficiency (TE), allocative efficiency (AE) and economic efficiency (EE) [6]. In which, technical efficiency (TE) is the ability to minimize using inputs to produce a given output vector, or the ability to obtain maximum output from a given input vector. It reflects firms trying to avoid waste by optimally combining the inputs of the production process [6]. Besides, the identification of factors affecting technical efficiency is also a very important issue to identify the source of inefficiencies in production [7].

Stemming from the above reasons, this study aims to estimate the overall technical efficiency of Vietnamese shipping firms. At the same time, the study will construct and analyze the model of the factors that determine the technical efficiency of firms. The results of the study are an important scientific basis for planning new development policies for Vietnamese shipping industry.

2 Literature review and theoretical basis

2.1 Estimation of technical efficiency

Since its suggestion by [3], the measurement and analysis of technical efficiency has been of great interest to economists. Along with the development of computational techniques and the application of mathematics in economics, methods of measuring and analyzing technical efficiency have been strongly developed. Those methods are divided into two groups, namely parametric approach and non-parametric approach.

The non-parametric approach focuses on solving problems by maximizing or minimizing a given goal with some constraints. This approach uses linear programming techniques to find a set of weights for each firm that maximizes their relative efficiency score [8]. There are two techniques following the non-parametric approach: Data Envelopment Analysis (DEA) and Free Disposal Hull Approach (FDHA), in which DEA is the popular use. DEA measures technical efficiency by estimating the production frontier based on research data. The most effective combinations will lie on the frontier and TE is measured by the concept of the distance function from the frontier [6,9]. The concept of "data envelope analysis" was first used by [10]. From the idea [3] of the production frontier and the use of linear programming techniques in the analysis of isoquant curves, [10] developed a model to measure the efficiency of decision-making units (DMUs). They used the input-oriented distance function concept and assumed constant return to scale in this model. Several other studies have developed this method by removing the above assumptions [11]. The DEA builds the production frontier based on the data, so it does not need to make assumptions about the functional form or distribution of the efficiency factor. But the frontier of this method is very sensitive to dominant observations because it is made up of the most efficient combinations. Furthermore, the DEA does not take into account the influence of statistical noise. In order to overcome these limitations, [12] introduced the bootstrap technique to analyze the sampling characteristics, thereby obtaining the confidence intervals of the estimate. However, DEA still does not allow us to perform statistical tests and this is one of the biggest limitations of this method.

Meanwhile, the parametric approach uses maximum likelihood estimation techniques to compute the frontier function on a given sample [8]. With this approach, one needs to assume that all industries use the same technology and have the same production frontier. There are three main techniques in parameter frontier estimation, namely stochastic frontier analysis (SFA), thick frontier analysis (TFA) and distribution free analysis (DFA). Of these, the stochastic frontier analysis is most commonly used. SFA uses econometric models to estimate production frontiers and the technical efficiency corresponding to these frontiers. Although SFA requires imposing a specific parameter form for the common technology and assuming a specific distribution for the inefficiency term, it deals with random noise and allows for statistical testing of hypotheses regarding production structure and level of inefficiencies [13]. Thus, it becomes one of the most powerful techniques in technical efficiency measurement today. Since first independently introduced by [14] and [15], SFA has been developed through increasingly more advanced theoretical models. It is widely applied in efficiency and productivity research in various socio-economic fields such as: Agriculture [16], health care [17], tax [18], banking [19].

The basic stochastic frontier model is written by [14] as follows (1):

$$ln y_i = f(x_i|\beta) + \varepsilon_i, (i = 1, ..., n) \quad (1)$$

where: $y_i \in \mathbb{R}_+^p$ is outputs, $x_i \in \mathbb{R}_+^l$ is inputs, and β is a vector of the parameters corresponding to x_i. The error term ε_i includes noise with standard distribution v_i representing measurement errors, and positive disturbance u_i with half-normal distribution that represents inefficiency (v_i and u_i independent), $\varepsilon_i = v_i - u_i$; $v_i \sim N(0, \sigma_v^2)$; $u_i \sim N^+(0, \sigma_u^2)$;. With the distribution assumptions on u_i and v_i, the likelihood function for the model is built and then the model is estimated by the maximum likelihood method.

However, the basic stochastic frontier model is built for cross sectional data, so there are certain limitations. This has been pointed out by [20] such as: Not exist consistent estimate of specific efficiency; Assume ineffective independence with the regression coefficients of the model; Requesting parametric distribution assumptions for ineffective and disturbance components to estimate the model. After that, many studies were conducted to solve these limitations. In particular, the special concern revolves around the advantage of panel data structure. In [20], authors are one of the first to develop theoretical framework to expand the stochastic frontier model for cross sectional data to a stochastic frontier model for panel data. But the technical efficiency is estimated by [20] which is time-invariant. This is a big limitation when applying the model to practice, especially for long panel data. [21] has overcome the model of [20] by constructing ineffective is the quadratic function of time variable. Meanwhile, the models of [16,22] allow the mean of inefficiency to change over time, but they are simpler because the time variable only depends on one or two parameters.

The above-mentioned panel data models have a big drawback that cannot be distinguished from technical efficiency with the unobserved individual heterogeneity. Therefore, the technical inefficiency confuses all time-invariant unobserved individual properties. There are many different approaches that have been proposed to overcome this problem. In [23], Greene has proposed a stochastic panel data model in which unobserved individual heterogeneity is distinct from technical efficiency. The model is built in the form as (2)

$$y_{it} = c_i + x_{it}'\beta + \varepsilon_{it} \text{ with } \varepsilon_{it} = v_{it} - u_{it} \qquad (2)$$

where, v_{it} is disturbance, $u_{it} \geq 0$ is inefficiency.

Although model (2) distinguishes between unobserved individual heterogeneity and technical inefficiency, it only considers transitory inefficiency. In [24,25], the authors replaced model (2) with a model with four random components. In this model, inefficiency is decomposed into transitory inefficiency and persistent inefficiency. The model of [24] and [25] is written as follows:

$$y_{it} = \beta_0 + x_{it}'\beta + c_i - \eta_i + v_{it} - u_{it} \qquad (3)$$

where: $c_i \sim N(0, \sigma_c^2)$ denotes the unobserved individual heterogeneity, $\eta_i \sim N(0, \sigma_c^2)$ denotes the persistent inefficiency, $u_{it} \sim N(0, \sigma_u^2)$ denotes transitory inefficiency, and $v_{it} \sim N(0, \sigma_v^2)$ is the regular disturbance. Model (3) can be estimated using the single-stage maximum likelihood method of [24] or the multi-step estimation procedure of [25]. Although the multi-step estimation procedure is not as efficient as the single-stage maximum likelihood method, it is simpler and easier to implement. For the multi-step estimation procedure, model (3) can be rewritten as

$$y_{it} = \beta_0^* + x_{it}'\beta + \alpha_i + \varepsilon_{it} \qquad (4)$$

where:

$$\begin{aligned} \beta_0^* &= \beta_0 - E[\eta_i] - E[u_{it}]; \\ \alpha_i &= c_i - \eta_i + E(\eta_i); \\ \varepsilon_{it} &= v_{it} - u_{it} + E[u_{it}]. \end{aligned} \qquad (5)$$

Model (4) is a standard panel data model and can be estimated by using typical panel data estimation method. After estimating (4), we get the predicted values $\widehat{\alpha_i}$, $\widehat{\varepsilon_{it}}$ of α_i and ε_{it}, these values are substituted for α_i and ε_{it} in (5). We then apply the standard stochastic frontier techniques for (5) to obtain the estimated values $\widehat{\eta_i}$, $\widehat{u_{it}}$ of η_i, u_{it}. Finally, persistent technical efficiency (PTE) is defined by $exp(-\widehat{\eta_i})$, transitory technical efficiency (TTE) derived from $exp\,(-u_{it})$, and overall technical efficiency (OTE) of the firm is defined by [25] as follows (6):

$$OTE = PTE * TTE \qquad (6)$$

2.2 *Technical efficiency determinants*

In [7], Timmer applying a two-stage regression model to study the influence of factors on production efficiency argued that determining the level of technical efficiency is an important issue, but determining the origin of inefficiency is even more important. If the production factors of the firm grow steadily, the production process is optimized, the productivity and operational efficiency of the firm will be higher, and the cost of each output unit will decrease. This leads to improved competitiveness of the firm [26]. There are many factors that determine the technical efficiency of firms that have been shown by many studies. In this study, we group the factors according to some aspects such as the internal characteristics of the firm; international trade activities; financial constraints; and the quality of economic institutions.

Among the factors of firm characteristics, the factor recognized by many studies around the world is firm size. It is the means of production and business operation of firms. Firms which too large or too small can face management difficulties and create technical inefficiencies [27]. The expansion of firm scale is an industrial development trend and an inevitable result of competition between firms. With a certain level of science and technology, firms can reduce long-term average costs by expanding production to achieve economies of scale [26]. Most studies show that firm size has a positive effect on firm performance [27-29]. However, there are also studies that show an inverse relationship between these two factors. In [30], Nikaido has shown a negative relationship between firm size and technical efficiency in small and medium firms. He explains the result that in some cases, small and medium firms often receive significant policy support from the government, so they have not been able to expand their scale. Next is the number of years of operation of the firms (firm age). The studies of [7,29] and [31] all show a close relationship between the age of a firm and its level of technical efficiency. In [27], authors argue that firm age positively affects production efficiency through learning by doing. Most studies argue that firms increasingly draw on experience to produce more efficiently. Therefore, older firms will have a higher level of efficiency. This is also supported by the study of [31] on Vietnamese manufacturing firms. However, authors in [27] also show that the marginal effect of this factor tends to decrease over time as firms mature in their field. This can also make the efficiency of the firm subject to the opposite effect of time. Moreover, recent empirical evidence shows that young firms produce more efficiently than older ones. This can be explained by the fact that young firms embody the latest technology and the technological wear and tear of older firms [32]. In addition, there are a number of other factors such as the type of firm ownership, the rate of return on equity, etc., which have also been mentioned by the studies [28].

Besides, there have been a lot of empirical studies related to international trade activities, especially import and export activities with the performance of firms [33]. There are two hypotheses to explain the relationship between international trade and firm performance, namely the self-selection hypothesis and the learning by doing hypothesis. The self-selection hypothesis holds that only the most productive firms decide to enter international markets [33,34]. The learning by doing hypothesis argues that firms in international markets can take advantage of economies of scale and gain knowledge from greater exposure to best practices, from which promotes the productivity and performance of the firm [35].

Access to credit will facilitate long-term investment, reduce volatility and improve firm productivity [36]. At the same time, one of the biggest barriers to firm survival and expansion is access to credit, especially for small and medium-sized firms. Evaluation of the impact of debt balance on the efficiency of firms has been conducted by many studies. However, the results follow different trends, most studies show a positive impact of debt balance on firm efficiency [37]. The explanation for this positive relationship is that debt allows firms to export and import inputs and means of production. It drives firms to scale, make technological improvements, and invest in R&D and other tools needed to increase productivity. Meanwhile, [38] finds a negative relationship between debt balance and firm performance. It can be seen from the [39] that debt balance has a positive effect on firm performance at a certain debt level (threshold debt level) and this effect becomes negative when this threshold debt level is reached.

The important role of economic institutions for development has been shown in previous studies. The results show that economic institutions have a direct impact on economic efficiency in the same period and resource distribution in the following period [40]. The economic institution contributes to the performance of firms by creating favorable conditions for firms to produce or to direct their activities. If the quality of institutions is good, there will be no informal costs, reliable legal institutions, strong enforcement of property rights and will have a positive impact on the productivity and growth of firms. In contrast, poor institutional quality makes it difficult to enforce contracts, so paying bribes is necessary. And it will increase the operating costs of firms, giving firms an incentive to absorb ineffective technologies for the production process rather than absorb modern technology [41]. Most recent research results show a positive impact of the quality of economic institutions on the efficiency and productivity of firms [42,43].

3 Methodology and data

The study uses the SFA model of [25] to estimate the overall technical efficiency for Vietnamese shipping firms. The frontier production function of firms can be estimated in both Cobb-Douglas and Translog forms. Applying equations (3) and (4), we can rewrite the frontier production function for Vietnamese shipping firms as follows (7), (8), (9), (10):

Cobb-Douglas form

$$Ln(VA_{it}) = \beta_0 + \beta_1.LnK_{it} + \beta_2.LnL_{it} + \beta_3.t + c_i - \eta_i + v_{it} - u_{it} \quad (7)$$

or

$$Ln(VA_{it}) = \beta_0 + \beta_1.LnK_{it} + \beta_2.LnL_{it} + \beta_3.t + \alpha_i + \varepsilon_{it} \quad (8)$$

Translog form

$$lnVA_{it} = \beta_0 + \beta_1 lnK_{it} + \beta_2 lnL_{it} + \beta_3.t + \frac{1}{2}\beta_4(lnK_{it})^2 + \frac{1}{2}\beta_5(lnL_{it})^2 + \frac{1}{2}\beta_6 t^2 + \frac{1}{2}\beta_7 lnK_{it}.lnL_{it} + \frac{1}{2}\beta_8 t.lnK_{it} + \frac{1}{2}\beta_9 t.lnL_{it} + c_i - \eta_i + v_{it} - u_{it} \quad (9)$$

or

$$lnVA_{it} = \beta_0 + \beta_1 lnK_{it} + \beta_2 lnL_{it} + \beta_3 t + \frac{1}{2}\beta_4(lnK_{it})^2 + \frac{1}{2}\beta_5(lnL_{it})^2 + \frac{1}{2}\beta_6 t^2 + \frac{1}{2}\beta_7 lnK_{it}.lnL_{it} + \frac{1}{2}\beta_8 t.lnK_{it} + \frac{1}{2}\beta_9 t.lnL_{it} + \alpha_i + \varepsilon_{it} \quad (10)$$

where:

VA_{it} is the output, K_{it} and L_{it} are the two inputs of the i^{th} firm at time *t*.

The study uses the generalized likelihood ratio (LR) test to select the form of the frontier production function suitable to the data, the value of the LR test is calculated as follows (11):

$$LR = -2\{log[L(H_0)] - log[L(H_1)]\} \quad (11)$$

where:

$L(H_0), L(H_1)$ are the values of the rational function estimated in Cobb-Douglas and Translog form, respectively. If LR is less than the value of $\chi^2_{-Critical}$ obtained from the table Kodde & Palm [44], then choose the Cobb-Douglas function. Otherwise, we choose the Translog production function.

The PTE, TTE values are predicted after estimating the frontier production function using the multi-step estimation procedure of [25]. And from there we get OTE of Vietnamese shipping firms.

However, measuring efficiency is only an early stage, and it is important for this study to determine the influence of exogenous factors on performance differences between firms. Because the value of the dependent variable OTE is in the [0,1] (censored sample), if we use the OLS method to analyze the model, it will lead to the estimated results of the parameters may be biased and not consistent. Instead, we use Tobit regression to estimate the impact of the independent variables on the overall technical efficiency score [45]. On the basis of the theory on the impact of factors on the efficiency of firms presented above, the study constructs a model of some factors that determine the technical efficiency of Vietnamese shipping firms, as follows (12):

$$OTE_{it} = \alpha_0 + \alpha_1.lnK_{it} + \alpha_2.lnAge_{it} + \alpha_3.lnRoe_{it} + \alpha_4.Ownership_{it} + \alpha_5.Intertrate_{it} + \alpha_6.lnDte_{it} + + \alpha_7.lnPci_{it} + \varepsilon_{it} \quad (12)$$

where, overall technical efficiency (*OTE*) is the dependent variable. The independent variables include: Variables belonging to the characteristics of the firm such as firm size (*lnK*, natural logarithm of total assets), the natural logarithm of firm age (*lnAge*), return on equity (Roe), type of firm ownership (*Ownership*); Variable on international trade activities (Intertrade); The variable on debt balance (*lnDte*), is taken as the natural logarithm; And the variable on the quality of economic institutions (*lnPci*), is also taken as the natural logarithm. The meanings and measurements of these variables are presented in Table 1.

The literature review also shows that many empirical studies have focused on analyzing the relationship between research and development (R&D), innovation and firm performance [46]. However, due to data limitations, our study has not mentioned these factors.

The data for this study are secondary data about Vietnamese ocean shipping firms, collected by the General Statistics Office of Vietnam. And provincial competitiveness index data, collected by the Vietnam Chamber of Commerce and Industry. The data are collected in the years from 2016 to 2020. We calculate to get data for the variables in the technical efficiency estimation model and the model of factors affecting it in each year. Finally, we merge the data of the years to get a sample for Vietnamese shipping firms. The sample obtained is the balanced panel data of 78 firms for 5 years (390 observations), measurement and descriptive statistics of the variables are presented in Table 1.

Table 1 Definition and descriptive statistics of variables

Variables	***Definition***	***Obs***	***Mean***	***SD***
VA	Value added of the firm in the year (calculated at constant prices in 2010)	390	29047.360	83575.650
K	Total assets at the end of the year of the firm (calculated at constant prices in 2010)	390	126798.300	287064.500
L	Total number of full-time employees in the year of the firm	390	47.174	64.789
t	Year of study (from 1 to 5)	390	3.000	1.416
lnVA	Is the natural logarithm of VA	390	8.418	1.565
lnK	Is the natural logarithm of K	390	10.065	1.533
lnL	Is the natural logarithm of L	390	3.284	1.035
lnAge	Calculated by the natural logarithm of the firm age	390	1.926	0.567
Roe	Calculated by profit after indirect tax / Equity	390	0.415	0.493
Ownership	Is a dummy variable that takes the value of 1 if it is a state-owned firm and otherwise takes the value of 0.	390	0.070	1.800
Intertrade	Is a dummy variable that takes the value of 1 if the firm has international shipping in the year, otherwise it is equal to 0	390	0.315	0.465
lnDte	Calculated as the natural logarithm of total debt / equity	390	1.097	0.976
lnPci	Calculated by the natural logarithm of the provincial competitiveness index in Vietnam	390	4.161	0.053

4 Empirical results

We conduct the generalized likelihood ratio test for the sample with the null hypothesis "The frontier production function follows the Cobb-Douglas form". The test results show that the value of LR is 18.020 is smaller than the value of $\chi^2_{-Critical}$ is 21.666 at a significant level of 1%. Therefore, there is not enough evidence to reject the null hypothesis, so the Cobb-Douglas production function form is chosen. And the results of the frontier production function model for Vietnamese shipping firms are presented in Table 2. We see that the estimated coefficients are statistically significant and in accordance with economic theory. In which, the elasticity of capital relative to output is quite large (0.548) and is close to the elasticity of labor relative to output. This indicates a significant contribution of capital to output and no labor intensiveness in firms. The sum of these two elasticity coefficients is greater than 1, indicating that firms are increasing return to scale. Besides, the estimated coefficient of the time variable is 0.178, which implies that the contribution of technological progress to the productivity growth of firms reaching an average of 17.8 % of the year [16].

Table 2 Estimation results of frontier production function of Vietnamese shipping firms in the period from 2016 to 2020

Variable	Coef.	Std. Err.	z	P>|z|
LnK	0.548***	0.039	14.100	0.000
LnL	0.578***	0.057	10.080	0.000
t	0.178***	0.024	7.540	0.000
_cons	1.157***	0.265	4.370	0.000

Note: ***, ** and * indicates significant at 1%, 5% and 10% level of significance

After estimating the frontier production function of firms, we predict the persistent technical efficiency (PTE), transitory technical efficiency (TTE) and overall technical efficiency (OTE) of firms. The results of PTE, TTE and OTE are presented in Table 3. We see that the average overall technical efficiency (OTE) of firms reached 0.539, of which persistent technical efficiency (PTE) reaching an average of 0.883 and transitory technical efficiency (TTE) reaches an average of 0.607 in the period from 2016 to 2020. This shows that the room for efficiency in production of Vietnamese shipping firms is still very large, especially TTE. On the other hand, the standard deviation of OTE is still large and there is no decline during the research period, showing a large gap in the performance of firms. However, there is a good sign when considering the histogram and the kernel density of the OTE of firms described in Figure 1. Most firms have an OTE score close to the average of the whole industry and the proportion of firms with OTE larger than the average greater than the proportion of firms with OTE smaller than the average.

Table 3 Performance of Vietnamese shipping firms in the period from 2016 to 2020

Year	Variable	Obs	Mean	Std. Dev.	Min	Max
2016	*PTE*	78	0.883	0.048	0.695	0.955
	TTE	78	0.664	0.117	0.355	0.866
	OTE	78	0.588	0.112	0.316	0.817
2017	*PTE*	78	0.883	0.048	0.695	0.955
	TTE	78	0.566	0.147	0.253	0.839
	OTE	78	0.502	0.140	0.206	0.783
2018	*PTE*	78	0.883	0.048	0.695	0.955
	TTE	78	0.535	0.131	0.241	0.856
	OTE	78	0.474	0.126	0.210	0.790
2019	*PTE*	78	0.883	0.048	0.695	0.955
	TTE	78	0.631	0.149	0.206	0.833
	OTE	78	0.561	0.145	0.179	0.772
2020	*PTE*	78	0.883	0.048	0.695	0.955
	TTE	78	0.640	0.168	0.060	0.860
	OTE	78	0.569	0.163	0.049	0.776

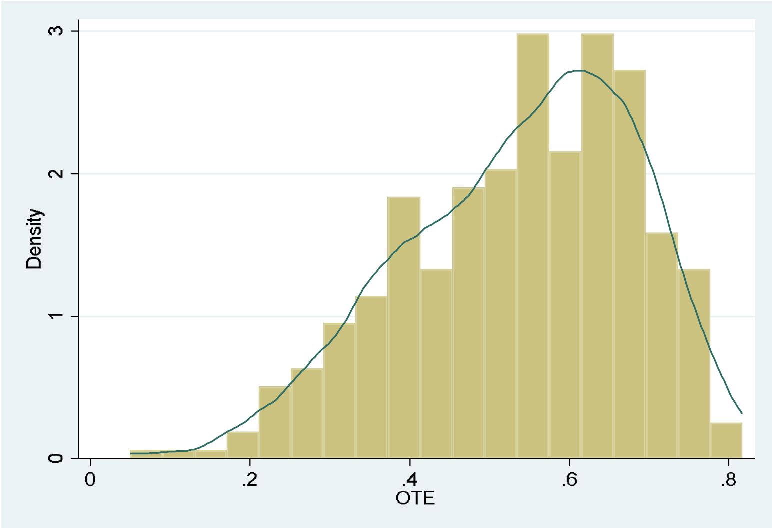

Figure 1 Histogram and Kernel density of the OTE (own editing)

The distribution of OTE of firms over the years showed a picture that did not flourish the performance of Vietnamese shipping firms in recent years. OTE of firms not only without growth during the research period but also seriously decreased in 2017 and 2018. This shows that firms do not have the optimal combination of inputs to improve their output. It reflects the current production situation of Vietnamese shipping firms today. Firms mainly exploit bulk ships and general cargo ships in order to save investment and easy to operate, so the production efficiency is not high. Ships that bring high added value such as container ships, liquefied gas tankers account for a very small proportion in the fleet structure of firms. The fleet quality in firms is weak in terms of technical equipment and operating level. Most of the ships are old, so maintenance costs are high to meet the requirements of international maritime conventions, and operating skills of crews are still limited. In addition, firms are still limited in updating information about the situation of shipping, goods demand, and related policies. These factors are the fundamental cause of constraining the technical efficiency of Vietnamese shipping firms today.

Next, we conduct an analysis of the factors that determine the technical efficiency of Vietnamese shipping firms. Before estimating the model (12), we tested the multicollinearity between the independent variables by analyzing the variance inflation factors (VIF). The estimation results presented in Table 4 show that all VIFs are less than 2, so there is no evidence of multicollinearity. Therefore, the selected variables in the model (12) are suitable.

Table 4 The variance inflation factors of the independent variables

Variables	**VIF**	**1/VIF**
lnK	1.800	0.555
Intertrade	1.780	0.562
lnAge	1.240	0.807
lnpci	1.140	0.874
lnDte	1.140	0.876
Ownership	1.040	0.959
Roe	1.030	0.970
Mean VIF	**1.310**	

Table 5 Estimation results of factors affecting the technical efficiency of Vietnamese shipping firms

OTE	***Coef.***	***Std. Err.***	***t***	***P>|t|***
lnK	0.009***	0.002	3.78	0.000
lnAge	0.016***	0.004	3.69	0.000
Ownership	-0.013**	0.006	-2.39	0.017
Roe	0.005***	0.001	4.11	0.000
Intertrade	0.047**	0.021	2.25	0.025
lnDte	-0.001**	0.000	-2.13	0.034
lnPci	0.014***	0.005	2.82	0.005
_cons	-1.159**	0.516	-2.24	0.026

Note: ***, ** and * indicates significant at 1%, 5% and 10% level of significance

Table 5 presents the results of estimation of the factors determining the technical efficiency of Vietnamese shipping industry. According to the internal characteristics of the firm, the coefficients of the variables *lnK*, *lnAge* are all positive and have statistical significance at 1% level. And when these variables increase by 1%, the technical efficiency of Vietnamese shipping firms increases by 0.009% and 0.016%, respectively. This shows that firms benefit significantly from economies of scale. And older firms produce more efficiently than younger firms. It implies that working experience plays an important role and has a positive impact on the performance of Vietnamese shipping firms. These results are also similar to the work of [31] for Vietnamese manufacturing firms. Along with that is the positive impact of the return on equity on the technical efficiency of firms. It shows that the ability to manage and use capital of firm owners is one of the decisive factors to the performance of the firm. In addition, the estimation results of the *Ownership* variable show that state-owned shipping firms operate less efficiently than non-state firms. In fact, some state-owned shipping firms in Vietnam are assigned a large amount of assets for production, but the management and supervision systems are still weak and do not keep up with practical requirements. Moreover, these firms have not encouraged employees, and have not paid attention to the responsibility of the head for the performance of the firms. These make them inefficient in production, at risk of business losses, and loss of state capital.

Regarding international trade activities, the results show that this factor has a positive relationship with technical efficiency. That is, firms participating in international shipping will achieve higher efficiency than firms only in domestic shipping. This shows that Vietnamese shipping firms have taken advantage of economies of scale and learned best practices when participating in international shipping activities. It is consistent with the argument that international trade is a complementary factor to increase the productivity and efficiency of the firm [47].

The estimated results also show the negative impact of financial constraints on the performance of firms. If the credit balance of firms increases by 1%, the technical efficiency score will decrease by -0.001% at 5% significance level. This result shows that Vietnamese shipping firms may have surpassed the debt threshold and it is the cause of inhibiting their performances.

Regarding the quality of economic institutions, the research results show the positive impact of this factor on the performance of firms in Vietnamese shipping industry. Over the years, the state has issued many legal documents guiding the Vietnam Maritime Code, contributing to strengthening the legal corridor and facilitating the development of shipping. These include policies related to ships, crew members, and infrastructure for shipping. Along with that, the quality of economic management, business convenience, and administrative reform efforts of local governments in Vietnam have always been improved. These have had a great impact on the performance of enterprises in general and the shipping industry in particular.

5 Conclusions

This study applies the four random component SFA model and the Tobit regression model in order to not only evaluate the performance of Vietnamese shipping firms but also analyze the combination of factors affecting can improve this efficiency. The research results have shown that: The overall technical efficiency (OTE) of Vietnamese shipping industry from 2016 to 2020 averaged 47.4% to 58.8%. In which, persistent technical efficiency (PTE) averaged 88.3%, while transitory technical efficiency (TTE) averaged from 53.5% to 66.4%. This result implies that on average a Vietnamese shipping firm suffers an overall level of technical inefficiencies between 41.2% and 52.6%. For the factors that determine the technical efficiency of firms, the estimated results show that. Firm size, firm age, return on equity, and international shipping are positively related to the OTE of firms. Meanwhile, factors such as credit balance and state-owned have a negative relationship with OTE. From the research results, we make some recommendations to promote the performance of Vietnamese shipping industry as follows:

Management and production technology in firms need to be continuously optimized to enhance the contribution of TTE to OTE. Firms with low efficiency scores need to expand their scale, especially when it comes to participating in international shipping activities. At the same time, the quality of governance in these firms also needs to be improved to catch up with those with high technical efficiency scores. In addition, Vietnamese shipping firms can apply different development routes depending on the conditions of each firm to improve their performance.

The government needs to continue to have better financial policies in supporting firms to develop large tonnage fleets to replace the current small and old fleets. At the same time, firms should be supported to develop specialized fleets such as container ships, oil tankers, liquefied gas tankers, etc., so that firms can achieve better operational efficiency. Those policies should be concretized, such as: Exemption of import tax for firms that replace old ships with new ships or ships with larger tonnage or ships with specialized ships; Reduce tonnage fees for a certain period of time when firms put into operation container ships, liquefied gas tankers, and clean energy ships; Reduce corporate income tax and other fees when Vietnamese shipping firms have a large monthly import and export container volume or have long-term transportation contracts with foreign partners.

The government should step up administrative reform in the field of shipping, simplify administrative procedures, especially those in ship registration and procedures at seaports. Continue to review, amend and supplement

Vietnamese legal document system on shipping, creating a stable and favorable legal corridor to support firms to operate effectively. Promote digital transformation in seaports, customs, etc. so that firms can reduce time costs. Actively participate in international conventions on maritime, promote international cooperation in shipping, support in legal procedures for firms opening shipping services abroad. Along with that, local authorities need to be transparent in the implementation of policies, creating favorable conditions for production and business of firms.

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