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Analyzing technical efficiency in Vietnamese seafood processing firms: A semi-parametric stochastic frontier approach

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ABSTRACT

This research aims to estimate and analyze the technical efficiency of Vietnamese seafood processing firms by applying the semi-parametric stochastic frontier model and Tobit regression. The data used in this study is a panel sample of 170 Vietnamese seafood processing firms in the period from 2013 to 2018. It is collected from enterprise census data of the General Statistics Office of Vietnam and provincial competitiveness index data of the Vietnam Chamber of Commerce and Industry. The estimated results show that: The scores of technical efficiency of firms averaged 0.712 and there was a decline during the study period. There is still plenty of room for technical efficiency in firms; The gap in technical efficiency in firms is still large and there is a strong difference in efficiency between firm's ownerships and firm sizes; Firms with export activities, large scale, foreign direct investment capital, and low equity restrictions will have a positive impact on technical efficiency; However, there is no evidence to show the impact of the firm's age and firm located in industrial zones factors on the efficiency of firms. In addition, the institutional quality and business environment also have an impact on the performance of firms.

1. Introduction

Vietnam has a coastline of 3260 km, internal waters, and a territorial sea of 226,000 km^2, which are great advantages for fishing and aquaculture in Vietnam (Wang et al., 2021). Vietnam's seafood industry has been currently creating regular jobs for millions of workers and contributes significantly to the country's economic growth. The annual export of aquatic products has brought a large source of foreign currency to the state budget, which is very important in the construction and development of the country. Exported products contribute to enhancing the position of Vietnam in general and Vietnam's seafood industry in particular in the international market. It has actively contributed to the transformation of the agricultural and rural economic structure, effectively contributing to hunger eradication, poverty reduction, and improvement of the living standards of rural and coastal people. The seafood processing industry has developed into a spearhead economic sector, a large commodity production industry, and a leader in international economic integration with a fast and efficient growth rate. According to data from the Vietnam Association of Seafood Exporters and Producers (VASEP), seafood export turnover will reach about 8.9 billion USD in 2021 and Vietnam will become the third largest producer of processing and exporting aquatic products in the world. Developing seafood processing for domestic consumption and export is one of the top priorities of the Vietnamese economy.

The concept of technical efficiency (TE) was first introduced by Farrell (1957) in the process of assessing the source of differences in total factor productivity. 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 the firm trying to avoid waste by optimally combining the inputs of the production process. Although this concept was born during the period of neoclassical economics, the measurement of TE was not interested because the production theory of this

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period assumed the firm was always at maximum technical efficiency. However, Leibenstein (1966) pointed out many inadequacies between reality and that theoretical assumption, so it is necessary to determine the TE level of the firm as well as the economic sector.

In addition, the seafood processing sector has received many incentives from the Government of Vietnam in recent years. This has attracted a large amount of foreign direct investment (FDI) into this industry. Along with that, the improvements in the business environment and the quality of economic institutions in Vietnam have created positive conditions for seafood processing firms to develop and stabilize production to achieve the best efficiency. Despite great achievements, Vietnamese seafood processing firms have been facing many challenges in terms of production technology, product quality improvement, and market expansion (Nguyen, 2022). The growth of firms mainly depends on the factors of natural resources, low-skilled cheap labor, and not much reliance on science and technology. Most of the seafood processing firms are small and medium-sized, lacking capital, and slow to innovate in technology. These can lead to low scores of technical efficiency of firms. Thereby increasing product costs and reducing competitiveness when firms integrate internationally. In particular, in the context of new generation trade agreements (CPTTP, EVFTA, RCEP...) coming into force, it will cause many difficulties for Vietnamese seafood processing firms.

Referring to sustainable development for Vietnamese seafood processing firms, this study applies a semi-parametric stochastic frontier analysis model to estimate and analyze the technical efficiency of Vietnamese seafood processing firms. The objective of the study is to evaluate the technical efficiency of Vietnam's seafood processing industry and analyze the impact of factors on the technical efficiency of firms. The study will show opportunities and challenges for firms in improving production efficiency. The research results will suggest strategic solutions to improve the competitiveness of seafood processing firms in the domestic and international markets.

2. Literature reviews

One of the most powerful techniques for analyzing firm performance developed from the 1970s to the present is stochastic frontier analysis. The stochastic frontier analysis uses econometric models to estimate production frontiers and the technical efficiency corresponding to these frontiers. The basic stochastic frontier analysis model was first introduced independently by Aigner et al. (1977) and Meeusen and Van den Broeck (1977). But this model is built for cross-sectional data and has some limitations pointed out by Schmidt and Sickles (1984). Later, Schmidt and Sickles (1984) were the first to develop a theoretical framework to extend the stochastic frontier model to panel data. However, the estimated technical inefficiency estimated by them is time-invariant. This is a major limitation when applying the model in practice, especially for long data. This has been remedied by Cornwell et al. (1990) and Battese and Coelli (1992). However, these stochastic frontier models have the major drawback of being unable to distinguish technical inefficiency from unobserved individual heterogeneity. Thus, technical inefficiency cancels out all of the individual effects that are not observed over time. In recent years, various studies have been done to fix this as well as several other problems, such as the stochastic frontier models of Greene (2005), Chen et al. (2014), Colombi et al. (2014), Kumbhakar et al. (2014), and Belotti and Ilardi (2018).

When estimating the above stochastic frontier models we need to make assumptions about the parameter being imposed on the form of the frontier production function and, for some specific cases, the assumption about the distribution of technical inefficiency. The commonly used distributions are half normal and the exponential distribution. In order to relax these assumptions, the semi-parametric stochastic frontier approach was born. Banker and Maindiratta (1992) were the first to attempt to estimate a semi-parametric stochastic frontier model. They proposed a theoretical framework that combines stochastic frontier and deterministic frontier and developed maximal likelihood estimation techniques of non-parametric characterization of concave monotonous production frontiers. Followed by the studies of Fan et al. (1996) and Kneip and Simar (1996), who proposed to use of non-parametric kernel regression in the theoretical framework of maximal likelihood parameter estimation. Specifically, a semi-parametric multi-stage likelihood estimation method was proposed by Fan et al. (1996), in which the Nadaraya-Watson non-parametric estimator is used in the first stage to estimate the average production relationship, then the full maximal likelihood parameter estimate is used in the next stage to obtain the conditional expectation of technical inefficiency, and this value is used in the final stage to define the frontier. Then, Kneip and Simar (1996) developed the estimation procedure of Fan et al. (1996) for panel data.

Semi-parametric stochastic frontiers are also mentioned in a series of studies by Park et al. (1998; 2003; 2007) in which the effects on firm inefficiency are endogenous. They used the kernel smoothers in these models as Adams and Sickles (2007). Another method to estimate the semi-parametric stochastic frontier model is proposed by Kumbhakar et al. (2007). This method uses local likelihood estimation to estimate the production frontier. The main difference between this method and the likelihood estimation method is that the estimation is localized in the sense of the individual's contribution to the likelihood function. It is determined by the weights based on the kernel base instead of the equivalent weights. Kneip et al. (2015) extended the study of Kumbhakar et al. (2007) by relaxing the parametric assumption about the distribution of inefficiency, while Park et al. (2015) proposed a parameter substitute for local likelihood estimators and provide a theoretical framework that allows validating variables in local likelihood estimators.

Semi-parametric methods have also been included in the stochastic frontier model to deal with the specifications of technical inefficiency. Cornwell et al. (1990) used a time-quadratic Taylor chain to establish a time-varying inefficiency model. While Lee and Schmidt (1993) determined time-varying inefficiency for cross-sectional data using one-factor multiple models. The extension of the mixed model and the general factor model was carried out by the studies of Ahn et al. (2007; 2013) and Kneip and Sickles (2011). The estimation procedure for these models was developed by Sickles and Zelenyuk (2019). Recently, Simar et al. (2017) have proposed to use of the local least squares method as an alternative to the local likelihood method for estimating stochastic frontier models. The local least squares method is much simpler to compute and much easier to implement than the local likelihood method.

The studies on technical efficiency at the firm level in Vietnam in recent years often apply the data envelope model, the basic stochastic frontier model, and the meta frontier model (Minh et al., 2007; Ho, 2012; Le et al., 2018; Nguyen et al., 2019). Minh et al. (2007) estimated the technical efficiency of Vietnamese SMEs using both models based on survey data of 1492 firms from 2000 to 2003. Ho (2012) applied the mixed meta-frontier models of O'Donnell et al. (2008) and the global Malquist index model to estimate technical efficiency in the agricultural sector in Vietnam. Meanwhile, Le et al. (2018) and Nguyen et al. (2019) used the stochastic meta-frontier model of Huang et al. (2014) to estimate. Notes from the literature review show that, due to limitations of estimation procedures, the semi-parametric stochastic frontier model has not been applied by studies on firm efficiency in Vietnam.

3. Methodology

The method applied in this study is the semi-parametric stochastic frontier model of Simar et al. (2017), the model is built as follows:

$$y_i = f(x_i, z_i) + v_i - u_i, i = 1, \dots, n \quad (1)$$

where, $f(x_i, z_i)$ is production frontier, $y_i \in \mathbb{R}_+^1$ is output, $x_i \in \mathbb{R}_+^p$ is the input vector, and $z_i \in \mathbb{R}^k$is a vector of k variables affecting the production, v_i is the statistical noise, which is assumed to have zero expectation and positive finite variance, that is $E(v_i|x_i, z_i) = 0,\ VAR(v_i|x_i, z_i) \in (0, \infty)$. While u_i is inefficient. It is a one-way distribution with positive expectation and also positive finite variance, i.e. $E(u_i|x_i, z_i) = \ \mu(x_i, z_i) \in (0, \infty)$ and $VAR(u_i|x_i, z_i) \in (0, \infty)$. As with other stochastic frontier models, u_i and v_i are assumed to be independent.

We put:

$$\varepsilon_i^* = v_i - u_i + \mu(x_i, z_i) \quad (2)$$

and

$$r_1(x_i, z_i) = m(x_i, z_i) - \mu(x_i, z_i) \quad (3)$$

Then Eq. 1 can be rewritten as follows:

$$y_i = r_1(x_i, z_i) + \varepsilon_i^* \quad (4)$$

Because of $E(\varepsilon_i^*|x_i, z_i) = 0$ we can use standard non-parametric methods (local polynomial least squares) to get an estimator $\hat{r}_1(x_i, z_i)$ of $r_1(x_i, z_i)$. To estimate the level of inefficiency for each firm, we also need to make an assumption about the distribution of inefficiency.

$$u_i\ |x_i, z_i \sim N^+\left(0, \sigma_u^2(x_i, z_i)\right) \quad (5)$$

With this distribution assumption, the conditional expectation of inefficiency can be estimated using the following relationships:

$$\sigma_u^3(x_i, z_i) = \sqrt{\frac{\pi}{2}}\left(\frac{\pi}{\pi-4}\right) r_3(x_i, z_i) \quad (6)$$

and

$$\mu_u(x_i, z_i) = \sqrt{\frac{2}{\pi}}\sigma_u(x_i, z_i) \quad (7)$$

where, $r_3(x_i, z_i) = E((\varepsilon_i^*)^3\ |x_i, z_i)$ is the third moment of the composed error. In particular, the residuals $\hat{\varepsilon}_i^*$from the non-parametric estimate of the model (4) are used to obtain a non-parametric estimator $r_3(x_i, z_i)$ of the third moment of the composed error. Then an estimate of technical inefficiency is obtained by substituting $r_3(x_i, z_i)$ for Eq. 6 and Eq. 7 (Simar et al., 2017). Finally, the technical efficiency of the firm is determined by:

$$TE_i = \exp\left(-\mu_u(x_i, z_i)\right) \quad (8)$$

4. Empirical estimated results

4.1. Data and variables

The study uses enterprise census data from the General Statistics Office of Vietnam in the period from 2013 to 2018. The study has been processed to obtain data on the inputs and outputs of seafood processing firms. Each firm has an aggregate output variable which is the value added (AV), and two input variables include the average number of employees in the year (L) and Total capital in the year (K). AV and K are calculated according to the instructions of the General Statistics Office of Vietnam according to 2010 comparative prices. The research calculates to get the data in each firm each year. Then merge the data between the years to obtain a sample panel data of 170 (1020 observations) seafood processing firms in the period from 2013 to 2018. Descriptive statistics of the variables are described in Table 1.

In addition, the study uses provincial competitiveness index (PCI) data during the period of 6 years from 2013 to 2018 from the Vietnam Chamber of Commerce and Industry to assess the impact of institutional quality and business environment on the production efficiency of Vietnamese seafood processing firms.

Table 1: Descriptive statistics of output and inputs of firms in the period from 2013 to 2018

Year	Variable	Observations	Mean	Std. dev	Min	Max
	AV (million VND)	170	20835.6	42744.8	44.0	306881.0
2013	K (million VND)	170	83840.3	149933.9	362.0	994575.0
	L (person)	170	177.0	286.9	2.0	1676.0
	AV (million VND)	170	22550.3	45728.4	69.6	290994.0
2014	K (million VND)	170	85784.2	157397.8	358.0	1189619.0
	L (person)	170	174.9	286.9	4.0	2100.0
	AV (million VND)	170	20171.7	34992.3	91.0	219577.0
2015	K (million VND)	170	89297.0	148755.4	363.0	928036.0
	L (person)	170	170.8	285.6	3.0	2100.0
	AV (million VND)	170	22605.7	38814.2	60.9	259308.0
2016	K (million VND)	170	97463.9	170157.2	364.0	990894.0
	L (person)	170	174.1	277.2	2.0	1857.0
	AV (million VND)	170	22542.0	40896.7	95.0	232002.0
2017	K (million VND)	170	103964.3	184840.1	368.0	1039392.0
	L (person)	170	174.2	281.3	1.0	1814.0
	AV (million VND)	170	23876.7	46617.1	84.7	300174.5
2018	K (million VND)	170	110443.6	186625.4	313.0	1054553.0
	L (person)	170	160.0	259.7	2.0	1688.0

4.2. Estimation results of technical efficiency

To estimate the efficiency of Vietnamese seafood processing firms, the study uses the semi-parametric stochastic frontier model of Simar et al. (2017). The specific model for each firm is as follows:

$$LnAV_{it} = m(LnK_{it}, LnL_{it}, Z_{it}) + v_{it} - u_{it}, i = 1, \dots, n; t = 1, \dots, m \quad (9)$$

The $\hat{r}_1(x_i, z_i)$, $\hat{r}_3(x_i, z_i)$, estimators to calculate $\mu_u(x_i, z_i)$ and thereby determine the TE of the firms are performed by the npregress kernel command (Cattaneo and Jansson, 2018) on Stata16. The distribution of firms' technical efficiency is shown in Table 2. It can be seen that the TE score of Vietnamese seafood processing firms averaged 0.712 between 2013 and 2018, leaving plenty of room for technical efficiency in firms. The mean standard deviation of TE over the whole period is still large (0.136), showing that there has not been a significant narrowing of the TE gap between firms. The TE results show that Vietnamese seafood processing firms do not have the optimal combination of inputs on existing production technology to produce the best efficiency. In particular, the TE of firms tends to decline during this period, showing that this combination is becoming less and less effective. Furthermore, when looking at the TE histogram and Kernel density of the firms (Fig. 1), we see that the majority of firms have lower-than-average TE levels. This proves the inefficiency in the production of Vietnamese seafood processing enterprises today.

Table 2: TE distribution of firms in the period from 2013 to 2018

TE	Observations	Mean	Std. dev.	Min	Max
2013	170	0.735	0.151	0.516	1.000
2014	170	0.731	0.144	0.538	1.000
2015	170	0.706	0.127	0.539	1.000
2016	170	0.709	0.133	0.494	1.000
2017	170	0.704	0.132	0.492	1.000
2018	170	0.688	0.124	0.488	1.000
Mean	170	0.712	0.136	0.488	1.000

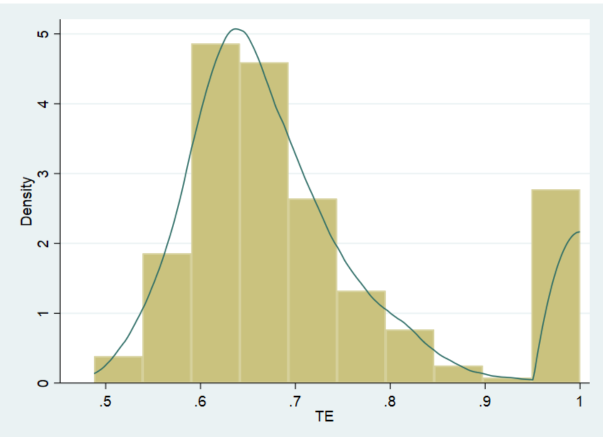

Fig. 1: Histogram and Kernel density on TE of firms

When considering technical efficiency by ownership and size of firms, the research results show that (Table 3). The TE score of domestic seafood processing firms (TE_{DOMs}) is lower than that of foreign direct invested firms (TE_{FDIs}). In fact, FDI seafood processing firms often apply modern production technologies and have more optimal corporate governance methods than domestic firms. In addition, there are preferential tax policies of the Government when FDI firms invest in the fields of agriculture, forestry, and seafood processing. Therefore, FDI firms produce more efficiently than domestic firms. Considering the size of the firms, the study also shows that small and medium-sized firms have much lower TE scores than large ones. This reflects the difficulty in the production of these firms. Those are the difficulties in accessing land, accessing capital to develop technology for production.

Table 3: Distribution of TE by firm's ownership and firm size

Variable	Observations	Mean	Std. Dev.	Min	Max
TE_{DOMs}	924	0.705	0.131	0.488	1.000
TE_{FDIs}	96	0.784	0.155	0.538	1.000
TE_{SMEs}	852	0.692	0.120	0.488	1.000
TE_{LARs}	168	0.818	0.145	0.610	1.000

5. The determinants of technical efficiency of the seafood processing industry in Vietnam

Research aimed at determining the level of technical efficiency is an important issue. But more important than that is identifying the source of the inefficiency. In the next section, the study uses the Tobit regression model to explore the factors affecting the technical efficiency of Vietnamese seafood processing firms.

5.1. Theoretical model and research hypothesis

Productivity can be generally defined as the value of output produced by a unit of labor or capital (Carayannis and Grigoroudis, 2014). Furthermore, higher productivity means improved competitiveness (Wysokińska, 2003). Because firms are able to compete when the productivity of their labor and other factors of production grows steadily, they can reduce their unit costs of output (Biener et al., 2016). Changing firm productivity is mainly contributed to technological progress. Trade theory holds that import and export activities lead to an increase in technological knowledge over time which in turn increases productivity (Melitz, 2003; Helpman et al., 2004). The reserve of technological knowledge is spread through different channels. The first is that through the import of goods, advanced goods increase the stock of knowledge. The second channel is through the technological diffusion of foreign direct investment. And the third channel is through exports. There are two main theories that explain productivity growth through exports: The theory of self-selection (Melitz, 2003; Yeaple, 2005) and the theory of learning by exporting (Bernard and Jensen, 1999; Wagner, 2007). Therefore, the export activity of firm is the key factor affecting the performance of firm.

H1: Firm's export activities have a positive effect on the efficiency of firms.

Another factor that has an impact on the efficiency of the firm that has been mentioned by many studies is the size of the firm (Admassie and Matambalya, 2002; Pitt and Lee 1981; Rios and Shively, 2005). The size of the firm is a means of transporting products and activities of firms. The expansion of firm scale is a trend in the process of industrial development and is an inevitable result of competition between firms. If other factors remain unchanged, seafood processing firms with large assets will attract more orders, leading to more stable production and more efficient operations. In addition, with a certain level of science and technology, firms can reduce long-term average costs by expanding their capacity to achieve economies of scale (Biener et al., 2016).

H2: Firm's size has an impact on the efficiency of firms.

Another factor affecting the technical efficiency of firms, which has been recognized by many studies around the world, is the number of years of operation of the firm (Timmer, 1971; Pitt and Lee, 1981; Chu and Kalirajan, 2011). Most studies argue that firms' age positively impacts productivity through work experience. Therefore, older firms will have higher levels of efficiency and productivity. However, Admassie and Matambalya (2002) also showed that the marginal effect of this factor tends to decrease over time as firms grow in their manufacturing sector. This can also make the efficiency and productivity of the firm subject to the opposite effect of time.

H3: The number of years of operation of the firm is closely related to the efficiency of firms.

The type of ownership and concentration of ownership influence corporate governance and thus the performance of the firm. The existence of a technological gap between domestic firms and FDI firms has become a reality. FDI firms operating in multinationals often have better financial results than purely domestic firms (Mathur et al., 2004). Trade theory has also argued that foreign owners have better access to technology, so FDI firms are often more efficient than domestic firms (Temouri et al., 2008). Besides, when the percentage of share ownership increases, it will cause major shareholders to increase monitoring of the manager's actions and encourage good behavior, thereby improving the performance of the firm (Hanousek et al., 2012; Schmalz, 2018). If most of the shareholders hold a similar proportion of the firm equity, there will be competition for control, resulting in the normal operations of the firm being impeded. In addition, the decentralized decision-making caused by the dissemination of different opinions will reduce the efficiency of decision-making and increase management costs, thereby constraining the growth of the firm. In this study, equity restriction describes the equity structure of the firm. It is expected to have a negative impact on technical efficiency.

H4: Equity restriction has a negative effect on the efficiency of firms.
H5: The firm's ownership has an impact on the efficiency of firms.

Another factor affecting the performance of manufacturing firms that have been mentioned by many studies is the production location of the firm. Most studies show that firms' products in industrial zones and industrial clusters have better production efficiency than outside firms. When a firm is set up in an industrial zone, it will be positively affected by factors such as Synchronous infrastructure, the welfare factors of the science park, benefits factors from the government, and space geography (Phillips and Yeung, 2003). Moreover, when firms operate in industrial zones, they will create benefits from industrial linkages. This leads to superior firm performance because of savings on transportation costs, shared infrastructure, increased availability of labor, forward knowledge, and technology spillovers (Debaere et al., 2010).

H6: Industrial zone has a positive impact on the efficiency of firms.

The above factors belong to the group of characteristics of the firm. This group of factors evaluates the subjective effects on the efficiency of the firm. In addition, the group of objective factors belonging to the institutional quality and business environment also have a significant impact on the efficiency and productivity of firms. The business environment includes the institutional environment, the macro-policy environment, and the legal environment in which firms operate (Dollar and Kraay, 2003). A good business environment will help to better allocate input resources, help firms use resources more efficiently, and give them the incentive to expand production scale to increase operational efficiency. A good business environment helps firms reduce transaction costs and variable costs (Aron, 2000). Conversely, poor institutional quality makes it difficult to enforce contracts and pay bribes, which will increase the operating costs of firms. It gives firms an incentive to absorb ineffective technologies for the production process rather than absorb modern technology (Fredriksson and Svensson, 2003). In addition, Bowen and De Clercq (2008) have shown that the relationships between the factors of the institutional environment related to corruption, financial capital, and human capital of firms are closely related to activities that create high-productivity of firms. Economic institutions directly affect economic performance in the same period and resource allocation in the following period (Acemoglu and Johnson, 2005). Economic institutions contribute to economic growth by creating favorable conditions for firms to do business or to direct their activities. When two economies have relatively similar infrastructure, market size, and financial systems, the better institutional economy will have no informal costs, reliable legal institutions, and ownership is firmly enforced. This will help firms operate more efficiently and have better economic opportunities (Ramadani et al., 2019).

H7: Institutional quality is closely related to the efficiency of firms.

5.2. Research design

The value of technical efficiency is in [0, 1] so it can only be observed in a limited way. Therefore, if the normal linear regression model is applied to evaluate the impact on the performance of the firm, the obtained estimators will be biased and unstable. To solve such problems, it is appropriate to apply the Tobit regression model (Cameron and Trivedi, 2009; Ling et al., 2018; Phan and Hien, 2021). In this study, Stata 16 is used to conduct Tobit regression for the data of 170 Vietnamese seafood processing firms from 2013 to 2018, the model is set up as follows:

$$TE_{it} = \beta_0 + \beta_1 Ex_{it} + \beta_2 Size_{it} + \beta_3 Age_{it} + \beta_4 Er_{it} + \beta_5 Ownership_{it} + \beta_6 In\_zone_{it} + \beta_7 Pci_{it} + \varepsilon_{it} \quad (10)$$

where, β_0 is the intercept coefficient; *it* is the index for firm *i* at time *t*; technical efficiency (TE) is the dependent variable; export activity of the firm (Ex), age of the firm (Age), equity restrictions (Er), type of ownership (Ownership), firm located in the industrial zone (In_zone), and business environment (Pci) are the independent variables. The variables in the models are presented in Table 4, and descriptive statistics of the variables are presented in Table 5.

Regression results on the impact of factors on the performance of firms are presented in Table 6. We see that the regression coefficient of the variable *Ex* is positive and statistically significant, showing that hypothesis H1 is supported. That is, seafood processing firms that participate in export activities will have better efficiency than firms that only produce for domestic consumption.

Table 4: Description of the variables in the model

Variable		Meaning
Dependent variable	TE	Technical efficiency was estimated using Simar et al.'s (2017) method.
	Ex	This is a dummy variable, where Ex = 1 is an export firm, Ex = 0 is the opposite.
	Size	This is a dummy variable, where Size = 1 is a large firm, Size = 0 is a small or medium firm.
	Age	Firm's age (measured by the fiscal year subtract year of establishment)
The independent variables	Er	Equity restriction reflects the shareholding structure of firm
	Ownership	This is a dummy variable, where Ownership=1 is a FDI firm, Ownership = 0 is a domestic firm.
	In_zone	This is a dummy variable, where In_zone = 1 is a firm located in industrial zone, In_zone = 0 is the opposite.
	Pci	This is an institutional of provincial business environment in Vietnam

Table 5: Descriptive statistics of the variables in the determinants of technical efficiency model

Variable	Observations	Mean	Std. dev.	Min	Max
TE	1020	0.712	0.136	0.488	1.000
Ex	1020	0.541	0.499	0.000	1.000
Size	1020	0.165	0.371	0.000	1.000
Age	1020	11.428	6.462	1.000	42.000
Er	1020	0.093	0.259	0.000	5.000
Ownership	1020	0.097	0.296	0.000	1.000
In_zone	1020	0.276	0.447	0.000	1.000
Pci	1020	61.239	3.352	53.910	70.690

It is the export of processed seafood that requires firms to improve their production levels, applies modern production and management techniques to ensure product quality, and improve productivity to compete in the world market. At the same time, the regression coefficient of the *Size* variable shows that large seafood processing firms produce better results than small and medium-sized ones. This means that Vietnamese seafood processing firms reap significant benefits from scale. It also reflects the difficulties in accessing capital, land, and technology of small and medium-sized seafood processing firms. There is no evidence to show the impact of the factors "age of firm" and "firm located in industrial zones" on the technical efficiency of firms. Therefore, hypotheses H3 and H6 have not been supported. The regression coefficient of the equity constraint *Er* is negative and significant at the 1% level, implying that when this variable increases by 1%, the technical efficiency of the firm decreases by 0.104 %. This shows that when designing a shareholding structure, firms need to properly centralize power, otherwise decision-making and management will be ineffective due to excessive decentralization. Besides, FDI firms operate more efficiently than domestic ones. Therefore, hypotheses H4 and H5 are supported.

The regression coefficient of the variable *Pci* shows that there is a positive impact of institutional quality and business environment on the efficiency of Vietnamese seafood processing firms. The *Pci* assesses the quality of economic governance, the convenience and friendliness of the business environment, and the administrative effort of provincial governments in Vietnam. The quality of Vietnam's institutions and business environment has always improved in recent years, which has had an impact on the performance of firms in general and the seafood processing industry in particular. Time for administrative procedures related to production and business of firms is shortened; informal costs for firms are lower and lower; a more fair competitive environment; the support in labor training and services related to firm’s operations is better performed by the government; legal institutions as well as convenient administrative procedures. These things have helped Vietnamese seafood processing firms to allocate resources reasonably, optimize inputs, and to produce more efficiently.

Table 6: Regression results for the determinants of technical efficiency scores

Explanatory Variables	Coef.	Std. Err.	t	P>|t|
Ex	0.008***	0.002	4.59	0.000
Size	0.122***	0.012	10.34	0.000
Age	0.000	0.001	-0.50	0.618
Er	-0.104***	0.015	-6.91	0.000
Ownership	0.046***	0.014	3.28	0.001
In_zone	-0.012	0.010	-1.22	0.222
Pci	0.002***	0.001	3.57	0.001
_cons	0.845***	0.073	11.58	0.000
var(e.TE)	0.015	0.001		

Note: ***, ** and * indicates significant at 1%, 5% and 10% level of significance based on t-statistics

6. Conclusion and recommendation

Empirical studies to estimate a firm’s TE in Vietnam often apply traditional data envelopment and stochastic frontier production function methods. Therefore, there are often some disadvantages such as depending on assumptions about the distribution of inefficiency or being influenced by dominant observations. This study has overcome those limitations by applying a semi-parametric stochastic frontier model to estimate and analyze the TE scores of Vietnamese seafood processing firms. Thereby, it can be seen that there is still a lot of room for TE in firms. In addition, there is a strong differentiation in TE between types ownership of firms and sizes of firms, and the gap in technical efficiency between firms has not been narrowed. Factors belonging to the characteristics of firms such as exports and size have a positive impact on operational efficiency. Meanwhile, the factor limiting equity makes firms more inefficient in production. In addition, the objective factors of institutional quality and business environment also have a positive impact on the efficiency of seafood processing firms. From the estimation results and model analysis, the study can make some recommendations as follows.

The government needs to have specific policies for small and medium-sized seafood processing firms. Support these firms in accessing land, accessing credits for production technology, developing human resources, etc. In addition, there should be an equal mechanism among domestic seafood processing firms and FDI firms, especially in promoting the development of private seafood processing firms. From there, help firms spread and absorb advanced technology, and improve production efficiency.

Empirical research results show that export has a positive impact on the technical efficiency of seafood processing firms. Therefore, the government needs to have solutions to help domestic seafood processing firms to participate in international trade activities more actively. It is necessary to focus on supporting small and medium seafood processing firms to participate in the internationalization process by linking firms together, linking domestic firms and FDI firms. Supporting firms to find markets and international trade contracts, providing legal advice when firms participate in international markets.

Institutional quality and the business environment need to be further improved. It is necessary to create favorable conditions for seafood processing firms to develop. Reducing the cost and time of dealing with administrative procedures for firms, removing barriers and making government information transparent, having the necessary services to support firms, and being flexible in the framework legislation in solving problems arising with firms could help Vietnamese seafood processing firms to optimally combine input factors of the production process, thereby improving production and business efficiency.

Compliance with ethical standards

Conflict of interest

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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