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# Economic Efficiency of Intensive Shrimp Farming in Transforming Areas of The Coastal Mekong Delta

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Changes of farming activities to intensive shrimp in the coastal Mekong Delta have been happening as an inevitable trend under the pressures of climate change and salinity intrusion. This transformation is associated with high risks in terms of production and management. Thus, the study was conducted to propose solutions for improving economic efficiency of intensive shrimp farmers. The study conducted face–to–face interviews with 125 farmers in both Soc Trang and Kien Giang provinces. By using one–step stochastic frontier analysis, the study showed that the average economic efficiency of shrimp farming in Kien Giang is 89.98%, which is not significant different to that in Soc Trang (86.95%). These efficiency indexes indicate that at the current output level, the shrimp farmers in Soc Trang and Kien Giang can reduce by 10.02% and 13.05%, respectively, of the total observed variable cost. The results also show that three factors have significant effects on the economic efficiency, namely the number of ponds, pond size and density, in which the number of ponds had a negative effect and the other two factors had positive effects on economic efficiency.

**Key words**: Economic efficiency, Shrimp farming, Stochastic frontier analysis, Coastal areas

## INTRODUCTION

Climate change becomes more serious and affects more or less agricultural production activities, especially in the coastal areas under the increasingly pressures of salinity intrusion. Agricultural transformation is considered as an inevitable trend to cope and adapt to new production conditions. The Mekong Delta (MD) is one of the three deltas in the world affected most seriously by climate change, particularly salinity intrusion. In the MD, 9 out of 13 provinces are bordered with the sea, where farming practices mainly relies on precipitation and freshwater from the upstream. Precipitation and freshwater become increasingly scare, especially in 2016 and 2020. As the scarcity of freshwater and low water table, saline water intruded far inland. According to Wassmann *et al*. (2004); Vu *et al*. (2018), more than 60% of total land in the MD was affected by saline water. Consequently, coastal farmers were induced to change their farming activities, mainly shift to intensive mono–shrimp farming. Soc Trang and Kien Giang are the two provinces being famous for sugarcane and rotated rice–shrimp farming. However, recently, the majority of sugarcane farmers in Soc Trang and rice–shrimp farmers in Kien Giang have been transforming to mono–shrimp culture due to the severe impacts from salinity intrusion on productivity and the higher expected profit. Many previous studies show that the financial indicators of mono–shrimp culture are far higher compared to that of sugarcane and rice–shrimp farming. According to the findings of Long (2016), the profit of intensive black tiger shrimp farming reached 551 million VND/ha/season. The study of Long and Hien (2015) also shows that the average profit of the intensive white–leg shrimp in Ca Mau was about 657 million VND/ha/season; Vanh *et al* (2016) found that the profits of various shrimp farming practices in Soc Trang province reached over 600 million VND/ha/season. Meanwhile, according to the studies of Dung (2012) and Minh *et al* (2013), the average profit of the rice–shrimp model ranged from 20–90 million VND/ha/year. For the sugarcane production, the average profit was about 30–55 million VND/ha/year (Nghi *et al*, 2009; Tu *et al*, 2019).

However, the transition to intensive shrimp farming implies that they are probably unable to achieve optimal efficiency due to lack of knowledge and experiences in shrimp farming. Many previous studies show that transition to intensive shrimp farming is considered as a risky decision in terms of high initial investment and negative effects on environment (Cheung *et al*. 2010; Kam *et al*. 2012; World Bank, 2016).

Estimation of economic efficiency has been conducted in many areas of agricultural production in order to provide better understanding of whether the production activities are efficient or not. In order to estimate the economic efficiency, previous studies mainly employed two approaches: (1) using the profit function to estimate profit efficiency or (2) using the cost function to estimate cost efficiency. To our best of knowledge, many studies used the profit frontier function to estimate the economic efficiency for specific crops and livestock (Thong *et al*., 2011; Tien and Thong, 2014; Thong and Phuong, 2015; Hieu, 2014). Some other authors used the cost function approach to measure economic efficiency towards cost minimization such as Ferrier and Lovell (1990); Worthington (2000); Rosko (2001). However, these studies normally employed two–step estimation process, which means that estimation of

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economic efficiency was carried out first, followed by investigation of factors affecting the efficiency gaps. Such estimation procedure may lead to biased results.

Recently, the one–step estimation model is recommended by econometric experts instead of the two–step estimation approach to control estimation biases (Caudill & Ford, 1993; Wang & Schmidt, 2002; Caudill, 2003; Greene, 2005; Belotti *et al.*, 2013; Kumbhakar *et al.*, 2015). Thus, in this study, we employed one–step stochastic frontier analysis to estimate the economic efficiency.

The MD is a key area for agriculture and fishery production, accounting for only 12% of the nation's area but contributing about 70% of fisheries stocks (GSO, 2019). However, according to many previous studies, the livelihoods of rural people engaged in agriculture and aquaculture are vulnerable and poor, especially those in coastal areas and transforming areas. Therefore, it is necessary to measure the economic efficiency of the intensive shrimp farming in coastal areas.

## METHODOLOGY

### Conceptual framework

Economic efficiency is defined as the ability to produce a given output at the optimal cost or is also considered as the product of technical efficiency and allocative efficiency (Farrell, 1957; Kopp, 1981; Bravo– Ureta & Pinheiro, 1997).

In order to estimate the economic efficiency towards cost minimization, the study employs translog variable cost frontier to estimate the parameters and the level of economic inefficiency because a farm is assumed to achieve a static equilibrium with respect to a subset of inputs given observed levels of other quasi–fixed inputs (Brown & Christensen, 1980; Caves *et al.*, 1981). In addition, we cannot estimate the total cost function because the price of some inputs is not available in the market (Grisley & Gitu, 1985).

According to Grisley & Gitu (1985); Kumbhakar & Lovell (2003), the translog variable cost function can explore the quasi–fixity of some inputs and allow the economies of scale that vary with output levels. The translog variable cost function can be presented in a compact form as follows:

$$c_i \geq c\,(y_i, w_i, z_i\,; \beta, \alpha, \gamma)\,e^{v_i} \quad (1)$$

In which, $c_i$ is the total observed variable cost of farmer $i$; $w_i$ is a vector of variable input prices; $y_i$ is the output produced by $i$–th farmers; $c\,(y_i, w_i, z_i\,; \beta, \alpha, \gamma)$ is a common deterministic variable cost frontier that is non–decreasing, homogeneous and concave in the input prices; ; $\beta, \alpha, \gamma$ are the estimated parameters; and $e^{v_i}$ is the error term that is symmetrically, identically and independently distributed as $v_i \sim iid\ N\,(0,\ \sigma_v^2)$, showing the noise effects outside the control of the farmer.

Equation (1) shows that a producer can reduce their variable cost by the ratio of minimum feasible variable cost to total observed variable cost. This ratio reflects the inefficiency of using inputs with respect to its prices. This inefficiency or shortfall is due to the cost of input–oriented technical inefficiency and the cost of input–oriented allocative inefficiency. Thus, the cost efficiency (abbreviated as $CE_i$ hereafter) can be estimated by using Equation (2) bellows:

$$CE_i = \frac{c\,(y_i, w_i, z_i\,; \beta, \alpha, \gamma)\,e^{v_i}}{c_i} \quad (2)$$

Specifically, the variable cost function can be rewritten in the translog form as follows:

$$\begin{aligned} LnVC_i = {} & \beta_0 + \beta_y\, lny_i + \sum_n \alpha_n\, lnw_{ni} + \sum_m \gamma_{mi}\, z_{mi} \\ & + \frac{1}{2}\,\beta_{yy}\,(lny_i)^2 + \frac{1}{2}\sum_n\sum_k \alpha_{nk}\, lnw_{ni}\, lnw_{ki} \\ & + \frac{1}{2}\sum_m\sum_r \gamma_{mr}\, lnz_{mi}\, lnz_{ri} + \sum_n \alpha_{ny}\, lnw_{ni}\, lny_i \\ & + \sum_m \gamma_{my}\, lnz_{mi}\, lny_i + \sum_m\sum_n \gamma_{mn}\, lnz_{mi}\, lnw_{ni} \\ & + v_i + u_i \end{aligned} \quad (3)$$

In which, $i = 1, \ldots I$ indicates the numbers of producers or farmers that use a vector of variable inputs $x_i = (x_{1i}, \ldots x_{ni}) \in R_+$, with respect to its input prices $w_i = (w_{1i}, \ldots x_{ni}) \in R_+$, and a vector of quasi–fixed inputs $z_i = (z_{1i}, \ldots z_{mi}) \in R_+$ to produce a given output $y_i \in R_+$. Thus, the total variable cost of a specific producer incur is $VC_i = \sum_n x_{ni}\, w_{ni}$. The error term $u_i \geq 0$ follows a independent, identical and symmetric distribution of $u_i \sim iid\ N\,(0,\ \sigma_{u,i}^2)$, indicating the cost of technical and allocative inefficiency.

In order to better control the endogeneity and the effects of unobservable variables on $u_i$, the study employs one–step estimation to specify the relationship between $\mu_i$ (the expectation of $u_i$) and independent variables $h_{u,i}$. The relationship can be written as $\mu_i$ = exp $(h_{u,i}\,;\, b_u)$. In which, $h_{u,i}$ are independent variables that affect the expectation of $u_i$ and $b_u$ are estimated parameters. Note that the independent variables affecting $u_i$ are not the ones used in the variable cost frontier (Kumbhakar *et al.*, 2015).

From Equations 2 and 3, the economic efficiency can be estimated by the following formula:

$$CE_i = exp\,(-u_i) \quad (4)$$

From Equation 3, we can see that the stochastic cost frontier is structurally similar from the stochastic production frontier Schmidt & Lovell, 1979, 1980; Kumbhakar & Lovell, 2003; Coelli *et al.*, 2005). The difference is that the composed error term of the latter frontier is positively skewed, while it is negatively skewed in case of the former frontier. Therefore, the cost efficiency of each producer can be estimated by following the similar manner developed by Jondrow *et al.* (1982).

According to Kumbhakar *et al.* (2015), the expectation of technical efficiency in a one–step estimation procedure is calculated by the following formula:

$$E(u_i) = \sigma\left(\frac{\phi(0)}{\Phi(0)}\right) = \sqrt{2/\pi}\ exp\ (h_{u,i}\ ;\ b_u) \quad (5)$$

Kumbhakar *et al.* (2015) indicates that the estimated coefficients of factors affecting the inefficiency scores from the one–step model cannot be used directly to explain the effects of independent variables on $u_i$ because the relationship between them is not linear. Thus, the estimated coefficient does not reflect the marginal effects. The marginal effect of the $k$–th independent variables on $E(u_i)$ is obtained by the following formula:

$$\frac{\partial E(u_i)}{\partial h[k]} = b[k]\ \frac{\sigma_{u,i}}{2}\left(\frac{\phi(0)}{\Phi(0)}\right) = b[k]\ \sigma_{u,i}\phi(0) \quad (6)$$

In which, $\phi(0)$=0,3989

To provide a better understanding of economic efficiency, lets suppose a farm uses two inputs ($x_1$ & $x_2$) to produce an output p, as shown in Figure 1. The isoquant UU' shows a technically efficient production frontier, from which one can measure technical efficiency. Assume the farmer A uses a specific set of inputs, the technical inefficiency can be defined by the distance BA. This distance reflects the ability to reduce inputs without compromising the output level. Typically, the technical efficiency is measured as a percentage of radial contraction of inputs by the OB/OA ratio.

As shown in Figure 1, we also can measure the economic efficiency for a specific farmer if the data on input prices are available. The iso–cost PP' represents the minimum cost frontier at the factor price vector. Suppose, $w$ and $x$ represent, respectively, the vector of input prices and its respective observed inputs at point A. Suppose $x^*$ represents the vector of cost–minimized inputs, corresponding to point D.

Thus, the economic efficiency of a farm is defined as the ratio of the minimum variable cost and the observed variable cost. In other words, the economic efficiency is the product of input–oriented technical efficiency and allocative efficiency. The formula of economic efficiency is below:

$$CE = \frac{wx^*}{wx} = \frac{OB}{OA} \times \frac{OD}{OB} = \frac{OD}{OA} \quad (7)$$

In which: OB/OA shows technical efficiency and OD/OB indicates allocative efficiency.

According to the literature review, the variables commonly used in estimating the economic efficiency of the agricultural production model in general and especially of the shrimp farming model are presented in detail in Table 1 below:

**Data collection**

The study selected two coastal provinces (Soc Trang and Kien Giang) in the MD where the conversion ratio to mono–shrimp culture is highest, of which Kien Giang is the province influenced by the West Sea and Soc Trang is affected by the East Sea.

In the period from 2011–2018, the shrimp production area of Soc Trang province increased by an average of 13.3% annually, the highest compared to other coastal provinces such as Tra Vinh 7.5%/year, Bac Lieu 7.2%/year, Ben Tre 4.3%/year and finally Ca Mau 4.1%/year (GSO, 2019). Kien Giang was selected as the study site because this is the only coastal province in the MD affected by the West sea.

For the two provinces of Soc Trang and Kien Giang, the study selected the districts having the highest conversion ratios, namely Cu Lao Dung in Soc Trang and U Minh Thuong and An Bien in Kien Giang. An Bien and U Minh Thuong are the two districts having a large area of rice–shrimp farming and the highest conversion ratio to intensive mono–shrimp farming of the province. The total shrimp farming area of the two districts in 2017 was about 22,384 ha (Department of Agriculture and Rural

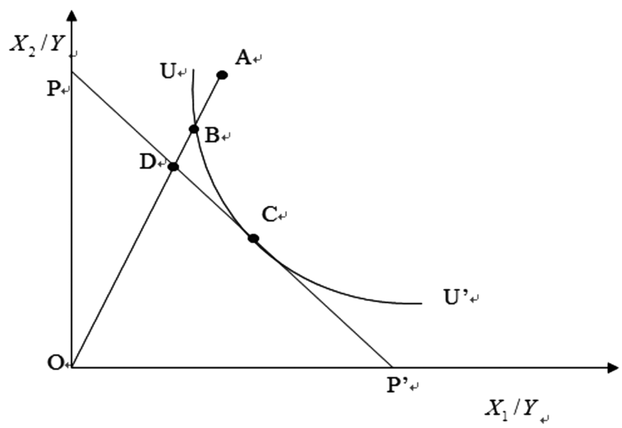


**Fig. 1.** Economic, technical and allocative efficiency.
Source: Modified by the authors from Farell (1957)

**Table 1.** The variables commonly used in estimating economic efficiency

| Variable | Description | Source |
|---|---|---|
| Agricultural production in general | 1. Fertilizer<br>2. Pesticide<br>3. Labor<br>4. Capital<br>5. Feed<br>6. Fuel | Coelli *et al.*, 2005<br>Kumbhakar & Lovell, 2003<br>Reinhard *et al.*, 2000,<br>Reinhard *et al.*, 1999 |
| Shrimp farming | 1. Feed<br>2. Number of larva<br>3. Labor<br>4. Medicine<br>5. Fixed cost | Au, 2009,<br>Begum *et al.*, 2016, Den *et al.*, 2007,<br>Chi & Yabe, 2014,<br>Thong & Phuong, 2015 |

Development Kien Giang, 2017). Cu Lao Dung of Soc Trang was selected as the representative site for this study because it is an islet district located between Bassac River and adjacent to the East Sea. So, it can be considered as the most vulnerable area under salinity intrusion. According to the statistical data of Soc Trang (2019), the total sugarcane area of the district decreased from more than 8,400 in 2013 to 5,109 ha in 2019 due to the impacts of saline intrusion. Most of this affected area has been converted to intensive shrimp farming.

The study used structured questionnaires to interview all farmers who had transformed to intensive shrimp farming in two provinces. The total number of observation that represent for the population of transformed farmers in the study sites is 160 households, of which Soc Trang 90 households and Kien Giang 70 households.

**Data analysis**

The study employed stochastic frontier analysis (SFA) proposed by Aigner. Lovell & Schmindt (1977) and Meeusen & Van Den Broeck (1977). The translog function will be used to specify the cost function (Coelli *et al.*, 2005). Input variables used to measure the economic efficiency of shrimp farming include feed, number of shrimp larva, labor, chemicals/medicines and pond rehabilitation costs (Den *et al.*, 2007; Au, 2009; Chi & Yabe, 2014; Thong & Phuong, 2015; Begum *et al.*, 2016). The output of the shrimp farming may be one or more depending on different shrimp farming practices. For the intensive white–leg shrimp farming in Soc Trang province, there is only a single output. However, for the intensive shrimp farming in Kien Giang, some farmers stocked two or three types of shrimp in a pond. To ensure the consistency in analysis as well as comparison, the study, therefore, only considers the farmers who culture intensively only white–leg shrimp or produce a single output. Thus, the valid sample size in Kien Giang was reduced to 35.

As mentioned in the theoretical framework, the variables used in the one–step model to estimate the economic efficiency consist of two groups of variables: the first group of variables are the input prices ($W_i$), other quasi–fixed costs ($Z_1$) and output ($Y$); The second group of variables includes factors affecting economic inefficiency ($u_i$), which is denoted $h_i$. The variables used in estimating economic efficiency in one–step model are shown in Table 2:

The empirical model of one–step SFA for estimating economic efficiency towards cost minimization is presented as follows:

$$\begin{aligned}
LnVC_i &= \beta_0+\beta_y \ln y+\alpha_1 \ln w_1+\alpha_2 \ln w_2+\alpha_3 \ln w_3+\alpha_4 \ln w_4 \\
&+\alpha_5 \ln w_5+\gamma_1 z_1+\frac{1}{2}\beta_{yy}(\ln y)^2+\frac{1}{2}\alpha_{11}(\ln w_1)^2 \\
&+\frac{1}{2}\alpha_{22}(\ln w_2)^2+\frac{1}{2}\alpha_{33}(\ln w_3)^2+\frac{1}{2}\alpha_{44}(\ln w_4)^2 \\
&+\frac{1}{2}\alpha_{55}(\ln w_5)^2+\frac{1}{2}\gamma_{11}(\ln z_1)^2+\alpha_{y1}\ln y \ln w_1 \\
&+\alpha_{y2}\ln y \ln w_2+\alpha_{y3}\ln y \ln w_3+\alpha y_4 \ln y \ln w_4 \\
&+\alpha_{y5}\ln y \ln w_5+\alpha_{yz}\ln y \ln z_1+\alpha_{12}\ln w_1 \ln w_2 \\
&+\alpha_{13}\ln w_1 \ln w_3+\alpha_{14}\ln w_1 \ln w_4+\alpha_{15}\ln w_1 \ln w_5 \\
&+\alpha_{1z}\ln w_1 \ln z_1+\alpha_{23}\ln w_2 \ln w_3+\alpha_{24}\ln w_2 \ln w_4 \\
&+\alpha_{25}\ln w_2 \ln w_5+\alpha_{2z}\ln w_2 \ln z_1+\alpha_{34}\ln w_3 \ln w_4 \\
&+\alpha_{35}\ln w_3 \ln w_5+\alpha_{3z}\ln w_3 \ln z_1+\alpha_{45}\ln w_4 \ln w_5 \\
&+\alpha_{4z}\ln w_4 \ln z_1+\alpha_{5z}\ln w_5 \ln z_1+v_i+u_i \qquad (8)
\end{aligned}$$

**Table 2.** Description of variables used in estimating economic efficiency

| Variables | Denotion | Unit | Description |
|---|---|---|---|
| Variables used in variable cost frontier | | | |
| *Feed_price* | $W^1$ | VND/kg | Price of one kg of feed |
| *Med_price* | $W^2$ | VND/1000 m$^2$ | Cost of medicine/1000 m$^2$ |
| *Fuel_price* | $W_3$ | VND/1000 m$^2$ | Price of fuel/1000 m$^2$ |
| *Larva_price* | $W_4$ | VND/larva | Price of one shrimp larva |
| *Labor_price* | $W_5$ | VND/ day | Price of a working day |
| *Other cost* | $Z_1$ | VND/ha | Quasi–fixed costs |
| *Output* | $Y$ | Kg/ha | Kg/ha/season |
| *Variable cost* | $VC$ | VND/ha | Total cost/ha/season |
| Variables affecting economic efficiency | | | |
| *Education* | $h_1$ | Schooling year | Schooling year of the head |
| *Organization* | $h_2$ | Dummy | 1=membership of organization ; 0=No |
| *Density* | $h_3$ | Larva/m$^2$ | Density of shrimp larva |
| *Labor* | $h_4$ | Workers | Number of laborers in a household |
| *Shrimp pond* | $h_5$ | Pond | Number of shrimp pond |
| *Distance* | $h_6$ | m | Distance from pond to river |
| *Pond size* | $h_8$ | 1000 m$^2$ | Shrimp pond size |
| *Experience* | $h_9$ | Years | Experiences of shrimp farming |

In which, $u_i$ is a function of the variables $h_i$. The relationship between the expectation of economic inefficiency ($\mu_i$) and $h_i$ is presented as below:

$$\mu_i = exp\left( \beta_0 + \sum_{n=1}^{8} \beta_n h_{ni} \right) \quad (9)$$

## RESULTS AND DISCUSSIONS

### Estimation of economic efficiency

Economic efficiency is defined as the product of technical efficiency and allocative efficiency. In other words, the economic efficiency implies the possible minimum variable cost that farmers can achieve by minimizing input and combining input prices reasonably. As discussed, the study uses a one–step SFA to estimate economic efficiency. Thus, the dataset used to estimate the parameters consist of two parts: the first is the independent variables (input prices and output) to specify the cost frontier and the second is the independent variables affecting economic inefficiency. Tables 3 and 4 provide a descriptive statistic of all variables used in the model.

The results in Table 4 show that there is a big difference in investment costs between the two study sites. The total variable cost in Soc Trang is about 8 million lower than that in Kien Giang province. The cost difference is due to the differences in intensive levels. Shrimp output in Soc Trang is much higher than in Kien Giang, namely about 9.7 tons/ha in Soc Trang compared to 7.1 tons/ha in Kien Giang.

To investigate the factors affecting economic efficiency, namely the expectation of $u_i$, the independent variables used in the model are summarized in Table 4.

Now, we turn to estimate the parameters. Prior to specify the cost frontier, it is necessary to determine the best fit model (Cobb–Douglas or the translog form) by using log– likelihood ratio test (Coelli *et al.*, 2005; Greene, 2012; Kumbhakar *et al.*, 2015). The LR test result shows that the value of $\chi^2$ = 51.41, which is much greater than the critical value of $\chi^2$ at the significant level of 1% (Table 5). This result means that the observed data is better fit with translog form. Table 6 also show that the translog cost frontier by one–step SFA is accepted compared to the two–step SFA through the value of $\chi^2$ = 34.49, which is far greater than the critical $\chi^2$ value at the significant level of 1%.

Because the data were collected from two different locations that have different intensive levels, it is necessary to test whether we can pool data to estimate the common cost frontier or not. The test was conducted by adding a dummy variable (Kien Giang and Soc Trang)

**Table 3.** Descriptive statistics of variables used in cost frontier specification

| Variables | Unit | Soc Trang | | Kien Giang | |
|---|---|---|---|---|---|
| | | Mean | SD | Mean | SD |
| *Feed_price* | VND/kg | 31,136.67 | 2,566.65 | 30,900.00 | 4,771.91 |
| *Med_price* | VND/1000 m$^2$ | 63,900.47 | 68,366.76 | 9,749.82 | 18,555.61 |
| *Fuel_price* | VND/1000 m$^2$ | 35,918.11 | 25,854.65 | 2,455.20 | 4,465.56 |
| *Larva_price* | VND/larva | 99.40 | 12.95 | 100.45 | 16.37 |
| *Labor_price* | VND/ day | 146,088.89 | 16,604.21 | 187,280.70 | 23,322.55 |
| *Other cost* | VND/ha | 48,018,136 | 38,441,898 | 64,000,000 | 115,000,000 |
| *Output* | Kg/ha | 9,781.90 | 6,346.73 | 7,129.48 | 11,158.94 |
| *Variable cost* | VND/ha | 482,800,000 | 230,200,000 | 490,100,000 | 766,400,000 |

Source: Own estimates, data available on request from the authors

**Table 4.** Descriptive statistics of variales affecting economic efficiency

| Variables | Soc Trang | | Kien Giang | | Difference |
|---|---|---|---|---|---|
| | Mean | SD | Mean | SD | |
| *Education* | 7.71 | 3.64 | 9.85 | 3.69 | 1.88*** |
| *Organization* | 0.07 | 0.25 | 0.14 | 0.35 | 0.05* |
| *Density* | 91.96 | 36.45 | 60.74 | 73.26 | –45.43*** |
| *Labor* | 1.88 | 1.11 | 1.86 | 0.81 | –0.04 |
| *Shrimp pond* | 1.92 | 1.15 | 1.71 | 0.82 | –0.16 |
| *Distance* | 54.42 | 134.91 | 114.61 | 198.09 | –42.38** |
| *Pond size* | 3.18 | 2.16 | 7.13 | 5.58 | 8.22*** |
| *Experience* | 5.28 | 5.20 | 8.94 | 4.97 | 3.66*** |

Source: Own estimates, data available on request from the authors
Note: ***and ** indicate the significant levels of 1% và 5%, respectively.

along with the interaction variables between location/study sites and the input prices in the cost function. The t–test shows that there is no significant difference between the two datasets, except for the fuel variable. Thus, we can pool the data and specify a common variable cost frontier for the two groups of farmers in Kien Giang and Soc Trang.

Now, we turn to specify the translog variable cost function, which is presented in Table 6 below:

**Table 5.** LR tests for determining the specification of cost frontier

| Indicators | Cobb–Douglas | Translog | |
|---|---|---|---|
| | | Two–step SFA | One–step SFA |
| Log–likelihood | –44,5052 | –18,7991 | –9,2709 |
| $\chi^2$ | | 51,4100 | 19,0564 |
| Prob> $\chi^2$ | | 0,0045 | 0,0646 |

Source: Own estimates, data available on request from the authors

From the estimates of Table 6, we can obtain the economic efficiency for shrimp farmers. The results of economic efficiency are summarized in Table 7:

Table 7 shows that the average economic efficiency of the shrimp farming in Kien Giang province was 89.98%, which is insignificant different with that in Soc Trang province (86.95%). This result partly reflects inefficiencies in utilization of inputs and resource allocation. The economic efficiency also has a large variation among farmers. For instance, the highest economically efficient farmer in Kien Giang reached 97.96% while the lowest was 55.35%. Similarly, the economic efficiency of shrimp farmers in Soc Trang varied greatly with the highest value of 97.58% while the lowest score of only 22.73%. Probably, the reasons for these large variations (economic efficiency scores) are due to the great differences in technical knowhow and management knowledge as well as environmental conditions of shrimp production.

The majority of shrimp farmers in Soc Trang had the

**Table 6.** Estimates of variable cost frontier by using one–step SFA

| Estimates of variable cost frontier | | | | | |
|---|---|---|---|---|---|
| Variable | Coef. | se | Variable | Coef. | se |
| $\ln W_1$ | 8,578 | 54,603 | $\ln W_2 \ln Z_1$ | –0,053** | 0,023 |
| $\ln W_2$ | 2,838 | 3,716 | $\ln W_2 \ln Y$ | 0,024 | 0,034 |
| $\ln W_3$ | –0,986 | 4,252 | $(\ln W_3 \ln W_3)/2$ | –0,002 | 0,028 |
| $\ln W_4$ | –7,975 | 42,042 | $\ln W_3 \ln W_4$ | 0,047 | 0,310 |
| $\ln W_5$ | –18,267 | 45,160 | $\ln W_3 \ln W_5$ | –0,152 | 0,254 |
| $\ln Z_1$ | –0,636 | 6,673 | $\ln W_3 \ln Z_1$ | 0,017 | 0,022 |
| $\ln Y$ | –4,923 | 8,646 | $\ln W_3 \ln Y$ | –0,050 | 0,048 |
| $(\ln W_1 \ln W_1)/2$ | 0,414 | 1,451 | $(\ln W_4 \ln W_4)/2$ | 1,227 | 1,627 |
| $\ln W_1 \ln W_2$ | –0,172 | 0,262 | $\ln W_4 \ln W_5$ | –0,141 | 2,358 |
| $\ln W_1 \ln W_3$ | 0,266 | 0,328 | $\ln W_4 \ln Z_1$ | 0,337 | 0,510 |
| $\ln W_1 \ln W_4$ | 0,317 | 2,522 | $\ln W_4 \ln Y$ | –0,373 | 0,309 |
| $\ln W_1 \ln W_5$ | –0,555 | 4,184 | $(\ln W_5 \ln W_5)/2$ | 1,338 | 2,053 |
| $\ln W_1 \ln Z_1$ | –0,399 | 0,518 | $\ln W_5 \ln Z_1$ | 0,239 | 0,300 |
| $\ln W_1 \ln Y$ | –0,182 | 0,608 | $\ln W_5 \ln Y$ | 0,629 | 0,481 |
| $(\ln W_2 \ln W_2)/2$ | 0,015 | 0,018 | $(\ln Z_1 \ln Z_1)/2$ | 0,048 | 0,042 |
| $\ln W_2 \ln W_3$ | 0,008 | 0,015 | $\ln Z_1 \ln Y$ | –0,004 | 0,058 |
| $\ln W_2 \ln W_4$ | –0,225 | 0,227 | $(\ln Y \ln Y)/2$ | 0,207** | 0,103 |
| $\ln W_2 \ln W_5$ | 0,039 | 0,173 | Constant | 117,308 | 551,570 |
| **Estimates of factors affecting economic inefficiency (Mu)** | | | | | |
| Variable | Coef. | se | Variable | Coef. | se |
| *Education* | 0,029 | 0,129 | *Shrimp pond* | 1,039** | 0,436 |
| *Experience* | 0,041 | 0,118 | *Distance* | –0,004 | 0,005 |
| *Organization* | 0,356 | 1,894 | *Labor* | –0,003 | 0,632 |
| *Pond size* | –1,137** | 0,457 | Constant | –0,124 | 2,188 |
| *Density* | –0,027* | 0,015 | | | |
| $U_{sigma}$ | –0,607 | 0,437 | | | |
| $V_{sigma}$ | –2,919*** | 0,179 | L–Likelihood | –9,27 | |
| Lamda | 3,176*** | 0,165 | Wald $\chi^2$ value | 228,33 | |

Source: Own estimates, data available on request from the authors efficiency scores distributed over 70%, accounting for approximately 95.56%. With the average economic efficiency of 89.98%, shrimp farmers in Soc Trang Province can reduce about 13.05% of total variable costs at the current output level. The total costs that farmers can save or in other words the difference between the observed costs and the possible minimum costs are shown in Figure 2:

Figure 2 shows that the total variable cost that shrimp farmers used inefficiently or the cost that shrimp farmers in Soc Trang can reduce on the average 78.03 million VND/ha/season (the difference between the observed variable cost and the possible minimum cost).

Similarly, in the case of Kien Giang province, the average economic efficiency mainly distributed over 90%, accounting for more than 65.71%. The economic efficiency scores above 70% accounted for about 97.14%. The study also found that on the average, the shrimp farmers can reduce by 10.02% of total current variable costs while keeping the output constant. The total variable cost that the shrimp farmers can save is shown in Figure 3:

Figure 3 shows that the total variable cost that shrimp farmers in Kien Giang can save on the average is 58,01 million VND/ha/season.

Under the current inefficient combination of inputs, it is necessary to investigate the factors affecting economic efficiency gaps. The results are presented in the next section.

**Table 7.** Economic efficiency of shrimp farmers by study sites

| | Soc Trang | | Kien Giang | |
|---|---|---|---|---|
| Economic efficiency | No. | % | No. | % |
| ≥90 | 42 | 46,67 | 23 | 65,71 |
| 80–90 | 38 | 42,22 | 9 | 25,71 |
| 70–80 | 6 | 6,67 | 2 | 5,72 |
| 60–70 | 2 | 2,22 | 0 | 0 |
| 50–60 | 0 | 0 | 1 | 2,86 |
| 40–50 | 1 | 1,11 | 0 | 0 |
| 30–40 | 0 | 0 | 0 | 0 |
| <30 | 1 | 1,11 | 0 | 0 |
| Mean | 86,95 | | 89,98 | |
| Min | 22,73 | | 55,35 | |
| Max | 97,58 | | 97,96 | |
| t–test | 1,55 | | | |
| Comprehensive EE | 87,80 | | | |
| Standard deviation | 9,85 | | | |

Source: Own estimates, data available on request from the authors

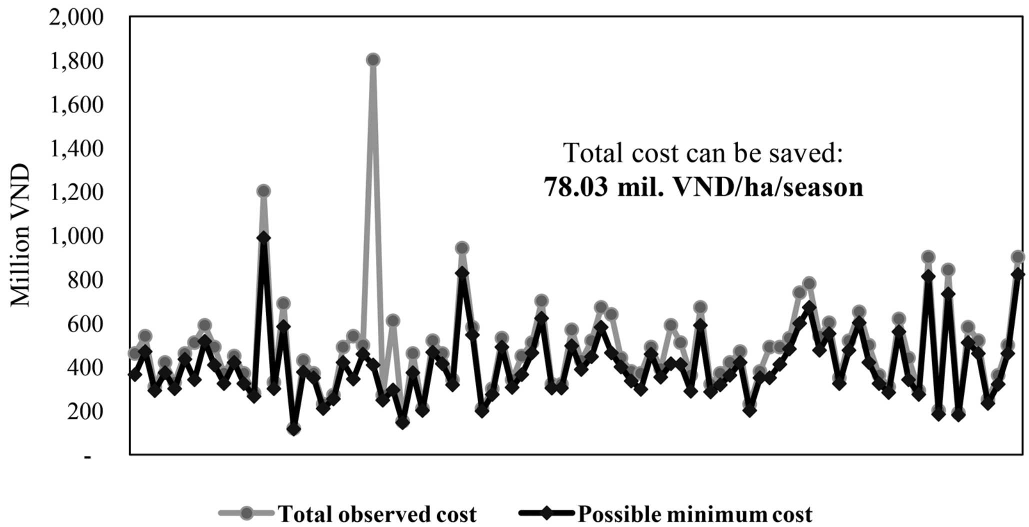


**Fig. 2.** Observed and possible minimum variable costs in Soc Trang.
Source: Own estimates, data available on request from the authors

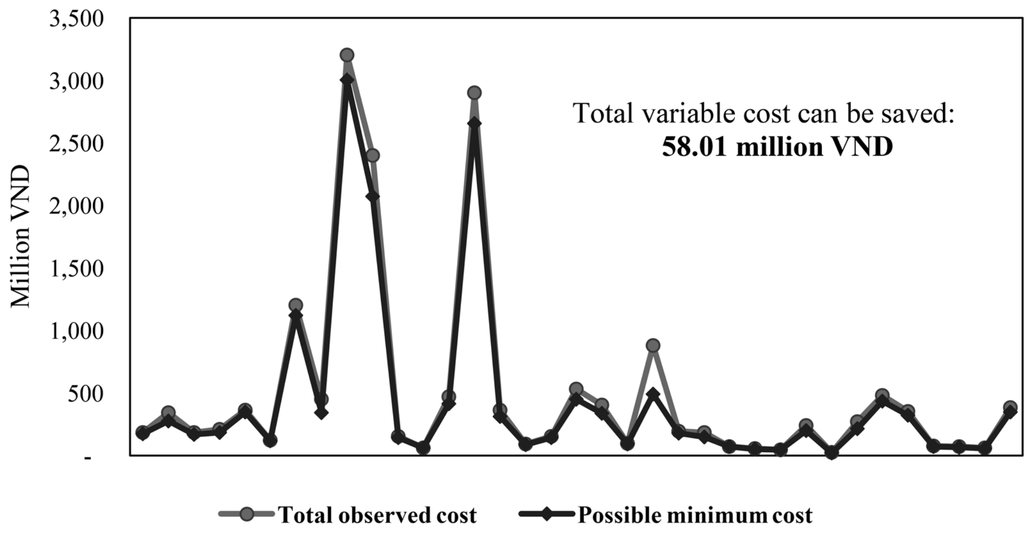


**Fig. 3.** Observed and possible minimum variable costs in Kien Giang.
Source: Own estimates, data available on request from the authors

**The factors affecting economic efficiency gaps**

The regression results in one–step SFA in Table 7 show that there are three factors that significantly affect the economic efficiency gaps of shrimp farmers, namely the number of ponds, pond size and density, in which the number of ponds is positively correlated with $E(u_i)$ while the remaining two factors have negative effects. Note that the negative effect of a certain variable on $E(u_i)$ mean the positive relationship of this factor with the economic efficiency.

The research results show that the more shrimp ponds the farmers have, the greater the inefficiency effects $E(u_i)$ they get. In the other words, the farmers with less shrimp ponds have greater economic efficiency scores. This can be explained that the farmers with many ponds will encounter many difficulties or challenges in production and management because their human resources are limited.

The study also found that the farmers with larger pond size will have greater economic efficiency scores. This can be explained that the farmers can take advantage of available natural feed resources in the shrimp pond, which helps to reduce production costs.

The same is true for the density variable. The study found that the farmers stocked more shrimp larva will achieve greater economic efficiency. This can be explained that the farmers in the study sites still have low stocking densities, so it is possible to increase the stocking densities to increase the economic efficiency but they have to follow the recommendations of the extension center (about 100 shrimp larva/$m^2$), particularly in Kien Giang.

## CONCLUSIONS

The research results show that the average economic efficiency of the shrimp farming in Kien Giang is 89.98%, which is not significant different compared to that in Soc Trang (86.95%). The majority of shrimp farmers in Soc Trang has the efficiency scores distributed over 70%, accounting for about 95.56%. With this average economic efficiency, at the current output level, the shrimp farmers in Soc Trang can reduce by 13.05% of the total observed variable cost. In the case of Kien Giang, the average economic efficiency concentrated mainly in the range of 90% or more, accounting for more than 65.71%. For the shrimp farmers in Kien Giang, the research results show that on the average, the farmers can reduce by 10.02% of total current variable costs while keeping the output unchanged.

The regression results show that three factors have significant effects on the economic efficiency, namely the number of ponds, pond size and density, in which the number of ponds had a negative effect and the other two factors had positive effects on economic efficiency gaps.

## AUTHOR CONTRIBUTIONS

Nguyen Thuy Trang designed the study questionnaire, collected and analyzed the data, and drafted the manuscript; Vo Hong Tu analyzed the data, and drafted the manuscript; and Mitsuyasu Yabe supervised the research and made critical revisions to the manuscript under the Technical Cooperation Project "Building capacity for Can Tho University to be an excellent institution of education, scientific research and technology transfer" of JICA. All authors read and approved the final manuscript.

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