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Cost Efficiency of Rice Production in Vietnam: An Application of Stochastic Translog Variable Cost Frontier

Vo Hong Tu[1*] and Nguyen Thuy Trang[1]

[1]Department of Rural Socio-Economics, College of Rural Development, Can Tho University, 3/2 Street, Ninh Kieu District, Can Tho City, Vietnam.

Authors' contributions

This work was carried out in collaboration between both authors. Author VHT designed the study and supervised the work. Authors NTT and VHT conducted the field survey and performed the statistical analysis. Author VHT wrote the first draft of the manuscript. Author NTT managed the literature searches and edited the manuscript. Both authors read and approved the final manuscript.

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ABSTRACT

Overuse of inputs in rice production results in not only lower profit but also environmental pollution. This study aimed to estimate the cost efficiency and to identify the determinants of efficiency gaps. Stochastic Translog variable cost was applied to the data of 199 rice farmers in An Giang, Mekong Delta. The study showed that the mean cost efficiency score was 90% suggesting that on the average these farmers could proportionally reduce their current variable cost by 10% without any reductions in the output level. The mean overused cost was estimated at 3,651 thousand VND (equivalent to 167.74 USD) per ha. This value is equal to the sales of 702.24 kg of output per ha or 10% increase in output level. To improve cost efficiency, rice farmers should cultivate three crops per year and use collective pumping. Regardless of output price, Jasmine and IR50404 rice

**Corresponding author: E-mail: vhtu@ctu.edu.vn;*

varieties and the numbers of paddy plot had negative relationship with cost efficiency. The study further suggests that rice farmers are still using input mix inefficiently.

Keywords: Cost efficiency; rice production; stochastic frontier analysis; Tobit regression; Translog variable cost frontier.

1. INTRODUCTION

The agricultural sector has always played an important role in the economic development of the Vietnamese Mekong Delta (VMD) where more than 75% of residents are living in rural areas and their livelihood activities rely mainly on rice production [1-3]. In the recognition of the role of agricultural sector in economic development and stability, the Vietnamese government had intensively invested and paid considerable efforts to promote the development and growth of agricultural sector, particularly in the improvement of its productivity and encroachment of farmland. After the policy reform or "*Doi Moi*" in 1986, the agricultural sector accounted to an average of more than 26% of total GDP for the period 1987-2013. One of the main objectives of the policy reform was to further liberalize the agricultural sector through de-collectivization of land, independent operation of business, removal of price controls and trade barriers, increase investment in technology and extension services [4]. As a consequence, Vietnam has gradually become one of the leading rice exporters in the world. The majority of rice exports estimate from the VMD, which contribute annually to more than 50% of total rice production and 90% of total export volume in Vietnam [5-7].

Although the VMD has had a long history of rice production and has achieved significant progresses in terms of productivity improvement and the better linkage of actors or stakeholders in value chain [8-12], the rice farmers have been facing challenges such as high input prices, unstable market, low technology and experience-based production. These constraints were considered to be the main factors leading to higher production cost and inefficient use of input mix.

According to Kompas et.al, the total factor productivity (TFP) score and the growth rate in TFP was highest in the VMD as compared to other regions in Vietnam. However, the overall rice production in Vietnam has faced a problem of TFP slowdown. These results suggested that production technology was very high, especially in the VMD. According to Belbase and Grabowski [13], Khai et al. [14], and Shapiro and Müller [15], it was more cost-efficient to improve productivity with existing technologies rather than introducing new ones. It is therefore crucial to consider the ability of farmer to reduce production cost rather than improving productivity because cost reduction is one of the three components resulting in higher profit for rice farmers.

With regards to rice production, some studies used stochastic frontier analysis (SFA) and data envelopment analysis (DEA) to measure the productive efficiency of rice farmers in the VMD. For instance, Kompas estimated the technical efficiency scores of rice farmers in Vietnam and the VMD by applying SFA. The study showed that the average TE was 78% for the Mekong Delta in 1999. Khai and Yabe [16] also estimated such efficiency scores by using the data from the 2006 Vietnam Household Living Standards Survey. The study showed that the mean efficiency was 81.6%. However, neither of the two studies did consider the cost efficiency.

[17] Nhut estimated and compared the cost efficiency of mono rice culture to crop rotation farming in two different zones – flood-protected area and non-flooded area in the VMD. The study showed that the mean cost efficiency scores in the flooded area were 71% and 74% for mono rice and crop-rotation patterns, respectively. Cost efficiency values were bit lower in the non-flooded area, 65% for mono rice and 67% for crop-rotation farming. However, the data of this study was collected in 2004/2005 years. It is crucial to provide updated values for policy makers and researchers. Moreover, the study applied DEA approach to estimate the cost efficiency, which has well-known drawbacks such as non-parametric, mathematical programming-based and impossible to separate noise effects apart from a common deterministic frontier.

Economic efficiency was first proposed by Farrell under the term *overall efficiency*. The concept is defined as the ability to produce predetermined quantity of output at optimal cost of inputs or the product of technical efficiency and allocative efficiency [18-22]. According to Coelli et al. and Kumbhakar and Lovell, economic efficiency can be cost efficiency, revenue efficiency and profit efficiency. In this study, we think that the cost efficiency is more appropriate because many literature showed that the rice farmers did not use efficiently their inputs and input mix [11,16,25,26]. Further, the cost reduction seems to be more important to increase farmers' production profits in this context. Cost efficiency is explicitly input-oriented, which indicates the ability to obtain predetermined output at minimum cost with respective input prices [16,18,19,23,27-30]. Cost efficiency can be decomposed into cost allocative efficiency and input-oriented technical efficiency.

Hence, the objectives of this study were to estimate the cost efficiency of rice farmers using SFA approach and to investigate the factors affecting their cost efficiency using Tobit regression. The remainder of this paper is presented as follows. Section 2 describes the analytical framework to estimate cost efficiency by using SFA approach and Tobit regression to investigate the factors affecting cost efficiency. In this section, we also provide a brief description of data collection and characteristics of data used for the measurement of cost efficiency. Following this, section 3 illustrates empirical results and detailed discussions about cost efficiency as well as the determinants of efficiency gaps. Finally, section 4 provides conclusions of this study.

2. METHODOLOGY AND DATA

2.1 Analytical Framework

The process to obtain cost efficiency by using stochastic frontier analysis is described as follows: We adopted the translog variable cost frontier to obtain estimates of the parameters and the magnitude of cost efficiency because a producer can be assumed to be in static equilibrium with respect to a subset of inputs given observed levels of other quasi-fixed inputs [31,32]. Moreover, we could not estimate the total cost function because the prices of all inputs are unavailable [33]. According to Kumbhakar and Lovell, and Grisley and Gitu, the Translog variable cost frontier can exploit the quasi-fixity of some inputs and allow scale economies to vary with respect to output level. The Translog variable cost frontier can be written in the compact form as follows:

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

Where c_i is the total observed variable cost of producer i; w_i is a vector of variable inputs' prices; y_i is a scalar output produced by the *i*-th producer; $c(y_i, w_i, z_i; \beta, \alpha, \gamma)$ is the common deterministic cost frontier of all producers that is non-decreasing, linearly homogenous and concave in input prices; β, α, γ are parameters to be estimated; and e^{v_i} is symmetric, identical and independently distributed as $v_i \sim iid\, N(0, \sigma_v^2)$, indicating noise effects not under the control of producers. The inequality (1) indicates that producers can reduce their expenditure by the ratio of minimum feasible cost to total observed cost. This shortfall is due to the cost of input-oriented technical inefficiency and the cost of input allocative inefficiency. The cost efficiency abbreviated as CE_i hereafter can be obtained from equation (2).

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

The detailed expression of Translog variable cost can be written as

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

where the subscript $i = 1, \dots, I$ is the number of producers who use a vector of variable inputs $x_i = (x_{1i}, \dots, x_{ni}) \in R_+$, at its respective prices $w_i = (w_{1i}, \dots, w_{ni}) \in R_+$, and a vector of quasi-fixed inputs $z_i = (z_{1i}, \dots, z_{mi}) \in R_+$ to produce a single output $y_i \in R_+$. Total variable cost that each producer incur is $VC_i = \sum_n x_{ni} w_{ni}$. The term $u_i \geq 0$ is symmetric, identical and independently distributed as $u_i \sim iid\, N(0, \sigma_u^2)$, reflecting the cost of inefficiency.

Using equation (2) and (3), cost efficiency can be obtained by using maximum likelihood estimation and its measure is given by

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

It is clearly in equation 3 that the stochastic cost frontier is structurally indistinguishable from the stochastic production frontier [21-24]. The main difference is that the composed error term of the stochastic cost frontier is positively skewed, while it is negatively skewed in case of the stochastic production frontier. The cost efficiency of each producer therefore can be obtained by adopting the similar manner developed by Jondrow, et al. [34]. that u_i is predicted by the conditional expectation of u_i, given the value of random composed error $v_i + u_i$ The expression of u_i is given by

$$E(u_i|v_i + u_i) = \sigma^* \left[\frac{\phi(\varepsilon_i\lambda/\sigma)}{\left(1-\Phi(\varepsilon_i\lambda/\sigma)\right)} + \left(\frac{\varepsilon_i\lambda}{\sigma}\right)\right] \quad (5)$$

where $\sigma^* = (\sigma_u^2\sigma_v^2/\sigma^2)^{1/2}$; and $\phi(.)$ and $\Phi(.)$ represent the standard normal density and cumulative distribution functions.

Based on Young's theorem on the equation of second cross partial derivatives, the restrictive assumption of symmetry ($\alpha_{nk} = \alpha_{kn}$ and $\gamma_{mr} = \gamma_{rm}$) must be imposed on the model prior to estimation. Moreover, because the cost function must be homogeneous of degree 1 in input prices, the restrictions $\sum_n \alpha_n = 1$ and $\sum_k \alpha_{nk} = 0$ are also imposed.

For better understanding about how to estimate the cost efficiency, we assume that a producer use two inputs (x_1 and x_2) to produce a single output p, represented in Fig. 1. The isoquant curve SS' describes the technically efficient producers or production frontier which permits the measurement of technical efficiency. If an observed producer uses a mix of inputs, defined by the point A to produce a certain level of output, the technical inefficiency of the producer could be defined as the distance BA. This distance shows the ability to reduce proportionally their inputs mix without compromising their current output level. Commonly, the technical efficiency is defined in percentage term as a radial contraction of inputs by the ratio OB/OA. From Fig. 1, it is also possible to estimate the cost efficiency of the given producer if the input prices are available. The isocost line PP' represents the minimum cost frontier at the factor price vector. Let *w* and *x* represent the vector of input prices and the observed vector of inputs, respectively, associated with the point A. Let x^* represent the cost-minimizing input vector associated with point C. Then the cost efficiency of the producer, which is defined as the ratio of observed input cost and minimum possible cost is given by equation (6).

$$CE = \frac{wx^*}{wx} = \frac{OC}{OA} \quad (6)$$

Because the cost efficiency contains input-oriented technical efficiency and input allocative efficiency, it is also possible to decompose the cost efficiency into allocative efficiency by the ratio OC/OB. However, in this study we focus only on the cost efficiency.

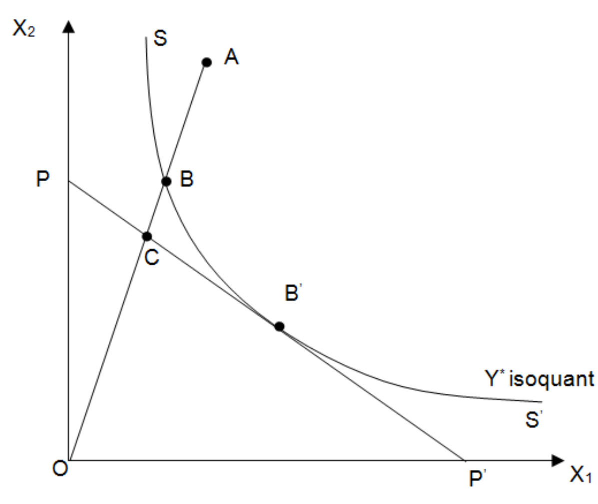

Fig. 1. The measurement of cost efficiency

2.2 Data

The primary data for this study were collected in 2014 in four districts of An Giang province, located in the upstream part of the VMD and borders with Cambodia. According to SOCC, and GSO, An Giang province was the largest rice producer in the VMD within the period 2002-2010 and has transferred this position to Kien Giang province to maintain the second place since 2011. Annually, An Giang province contributes approximately 16% (about 4 million tons in 2013) to the total rice production in the VMD. Although An Giang province suffers seasonal flood annually from July to November, many rice farmers could produce three rice crops per year in the areas with flood-protected dike systems. The reasons of intensive rice farming in An Giang province in particular and the VMD in general are due to increasing demands on rice consumption, and the mission to ensure food security that have been assigned to the region by the Prime Minister (for more details, please see the resolution 63/NQ-CP about national food security issued in 2009 in Vietnamese).

We conducted the survey through face-to-face interviews with 199 farmers in four districts of An Giang province. Two districts An Phu and Chau Doc were located in upstream part, Chau Phu district in the middle part, and Thoai Son district in the downstream region of the province. Although the study sites were selected with respect to its locations in terms of different periods of flooding to ensure the representative of the selected observations, the natural conditions were assumed to be identical. This assumption is important for the study to pool all samples because they share the common deterministic frontier. Table 1 provides a summary of the data set used for the measurement of cost efficiency.

As shown in Table 1, the study considered four variable inputs: phosphorus and potash fertilizer, pesticide, labor and seed quantity and one quasi-fixed input – miscellaneous cost (including energy, nitrogen fertilizer cost, capital and others) to estimate cost efficiency. The price of a mix input was derived by the ratio of total cost to its total quantity. For instance, the price of fertilizer (active nutrient of phosphorus and potash) was the ratio of total cost of these kinds of fertilizers to total active nutrient quantity. The same procedure was applied to calculate the prices of labor and seed. The price of pesticide was the ratio of total pesticide cost to one hectare. Because we included family labor cost based on its opportunity cost, the cost share of labor was highest, accounting for more than 77% in total cost. The cost shares of fertilizer, pesticide and seed were 6.64%, 11.24% and 4.45%, respectively.

Stata software version 12 was used to estimate cost efficiency using stochastic cost frontier and to estimate the determinants of cost efficiency scores using Tobit function.

Table 1. Brief description of the data set

Variables	Unit	Notation	Mean	Min	Max	St.dev.
Price of fertilizer$^{\Psi}$	Th. VND/Kg	W_1	20.71	13.53	31.99	3.77
Price of pesticide	Th. VND/Kg	W_2	417.91	169.75	1,003.09	149.25
Price of seed	Th. VND/Kg	W_3	11.98	3.94	39.35	6.03
Price of labor*	Th. VND/day	W_4	115.83	80	150	17.94
Miscellaneous cost†	Th. VND/ha	Z_1	11,215.95	4,722.01	27,999.46	3,013.73
Output level	Kg/ha	Y	7,128.91	5,015.43	8,865.43	676.48
Total variable cost	Th. VND/Kg	VC	37,406.27	23,037.84	60,918.93	7,068.55
Fertilizer cost share	%		6.64	2.95	11.96	1.81
Pesticide cost share	%		11.24	4.97	22.05	3.44
Seed cost share	%		4.45	0.19	23.89	3.71
Labor cost share	%		77.67	57.12	87.93	5.42

Note: $^{\Psi}$ indicates the price of phosphorus and potash fertilizer; * refers to the "mean" price of family and hired labor, in which family labor price was determined by the opportunity cost; † includes energy cost, nitrogen fertilizer cost, capital and others; Th. stands for thousand; and 1 USD = 21,770 VND on June 8th 2015
Source: Own estimates from the survey in 2014 by the author

3. RESULTS AND DISCUSSION

3.1 Cost Efficiency

Prior to estimating the stochastic production frontier, it is necessary to identify the variables that significantly correlate with output level using ordinary least square [16,19]. The same was applied for the estimation of stochastic cost frontier. Based on the properties of cost function, the function has to satisfy the properties of non-decreasing in input price and output level. However, the price of nitrogen fertilizer violated the former property and had insignificant relationship with variable cost, hence this variable was excluded in the model.

Further, the cost function must be homogeneous degree of 1 in input prices.

After testing and imposing the restrictive assumptions, the results of the Translog function estimated by maximum likelihood are presented in Table 2. It is clearly shown that the presence of cost inefficiency was found in the study based on z-test ($z_{value} = \tilde{\lambda}/se(\tilde{\lambda}) = 52.33$). This value exceeded the critical one $z_{0.95} = 1.645$ so we rejected the null hypothesis that there are no inefficiency effects at the 5% level of significance. This result was in line with the results of Nhut. The estimated value of γ = 0.7922 suggested that 79% of variation in variable cost was due to cost inefficiency.

We now turn to estimate the cost efficiency for each rice farmers, which are summarized in Table 3.

As shown in Table 3, the mean cost efficiency of rice farmers in the study sites was 90%, suggesting that on the average these farmers could reduce proportionally their current variable cost by 10% without any reductions in the output level. This value (90%) was higher compared to the findings of Nhut. In fact, the study of Nhut showed that the mean cost efficiency scores in flooded area were 71% and 74% for mono rice and crop rotation patterns, respectively. The cost efficiency scores were only 65% for mono rice and 67% for crop rotation farming in non-flooded area. This improvement of cost efficiency indicated that rice farmers had paid many efforts on variable cost reduction.

One of the primary interests from this study was to estimate the total variable cost that rice farmers overused or the total losses due to inefficient use of inputs with respect to prices. These losses also suggest the potential profit of rice farmers could gain if they make use of variable inputs efficiently.

Table 2. Coefficients of Translog variable cost function with MLE

Predictor	MLE		MLE (cont.)		
	Coefficient	**Std. error**	**Predictor**	**Coefficient**	**Std. error**
Constant	99.9147	58.3215	$\ln W_1 \ln W_2$	-0.0491	0.1543
$\ln Y$	-23.0822	13.0414	$\ln W_1 \ln W_3$	0.1134	0.1031
$\ln W_1$	-0.5361	3.8342	$\ln W_1 \ln W_4$	0.5474	0.3615
$\ln W_2$	3.1823	2.4829	$\ln W_1 \ln Z_1$	-0.5369	0.1962
$\ln W_3$	-1.1040	1.9797	$(\ln W_2 \ln W_2)/2$	0.2832	0.1225
$\ln W_4$	-0.5422	4.3873	$\ln W_2 \ln W_3$	-0.0974	0.0633
$\ln Z_1$	0.6519	3.3365	$\ln W_2 \ln W_4$	-0.1367	0.1560
$(\ln Y \ln Y)/2$	3.0132	1.6855	$\ln W_2 \ln Z_1$	0.1557	0.1379
$\ln Y \ln W_1$	0.5529	0.4650	$(\ln W_3 \ln W_3)/2$	0.2554	0.0766
$\ln Y \ln W_2$	-0.5782	0.3341	$\ln W_3 \ln W_4$	-0.2714	0.1225
$\ln Y \ln W_3$	0.2742	0.2306	$\ln W_3 \ln Z_1$	-0.0407	0.0894
$\ln Y \ln W_4$	0.2445	0.5648	$(\ln W_4 \ln W_4)/2$	-0.1394	0.3839
$\ln Y \ln Z_1$	-0.3477	0.4781	$\ln W_4 \ln Z_1$	-0.0562	0.2862
$(\ln W_1 \ln W_1)/2$	-0.6116	0.3995	$(\ln Z_1 \ln Z_1)/2$	0.3646	0.1680
Log likelihood	162.6002		λ	1.9365	0.0370
Wald χ^2 value	1595.23		γ	0.7922	

Note: The notations Y, W_1, W_2, W_3, W_4, Z_1 refer to output, price of fertilizer, price of pesticide, price of seed, price of labor and miscellaneous cost, respectively. Source: Own estimates, data available from the authors

Table 3. Cost efficiency of rice production

Cost efficiency (%)	Frequency	Percentage	Cumulative
≥ 90	119	59.80	59.80
80-90	68	34.17	93.97
≤ 80	12	6.03	100.00
Mean CE		90.00	
Minimum CE		72.21	
Maximum CE		97.20	
Standard deviation		5.45	

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

Fig. 2 illustrates total economic losses in terms of cost inefficiency. The differences between observed variable cost and cost frontier were the overused cost that the rice farmers incurred. The mean overused cost was about 3,651 thousand VND (equivalent to 167.74 USD) per ha. This value is equal to the sales of 702.24 kg of output per ha. As summarized in Table 1, the average output was 7,128.91 kg/ha suggesting that if rice farmers made efforts to reduce production cost, the total possible reduced cost would be equal to the efforts to increase approximately 10% (i.e. 702.24/7128.91) of output level. According to Belbase and Grabowski, Khai, Yabe, Yokogawa and Sato, Shapiro and Müller, and Khai and Yabe, it is more cost-efficient to improve productivity by using existing technologies rather than introducing new ones.

Hence, farmers in the study site should reduce their costs to increase their production profit.

This result suggests that the rice farmers seriously overused their variable inputs and that cost reduction is one of the significant ways to increase their profit in rice production.

3.2 Factors Affecting the Efficiency

The second stage of efficiency analysis is the analysis of the factors affecting the efficiency scores or the sources of inefficiency [16,17,19,35-38]. The results from this analysis are important for policy implications. In this study, we therefore used the estimated efficiency scores as dependent variable. The independent variables were the endogenous and exogenous characteristics of rice farmers (see Table 4 for the detailed description). However, in this study, we only considered the exogenous factors or technical interventions which were associated with the cost efficiency because the endogenous factors (age, gender, education and technical training) were already covered in previous studies of Khai and Yabe, and Nhut.

Table 4 presents the results of the Tobit regression estimating the factors affecting efficiency of rice farmers. The results showed that *Crop* had positively and highly significant impact on the cost efficiency at the 5% level. This implies that for farmers who cultivated three rice crops per year had more potential to reduce variable cost as compared to those who produced two crops annually. The possible reasons are due to appropriate management, investment and proper location selection programs for intensive rice farming.

The variables *Eco* and *Sesource* had positive but insignificant effects on cost efficiency at the 10% level of significance. The former refers to ecologically engineered rice cultivation, which was introduced in the VMD since 2009. The latter represents the sources of rice varieties that the rice farmers bought or used. In the study sites, there were two main sources of rice varieties: self-produced seed and seed centers / companies / research institutes. Moreover, family size and OM6976 rice variety had insignificant impacts on the cost efficiency.

The remaining variables related to farm size, rice varieties such as IR50404, Jasmine, pumping methods and the numbers of paddy plot had negative but significant relationship with the cost efficiency. Among them, Jasmine and IR50404 rice varieties had the highest negative coefficients, suggesting that regardless of selling price, the farmers incurred higher cost to produce these rice varieties, keeping output constant. With regards to pumping methods, its negative coefficient suggests that self-pumping method was not a wise choice for rice farmers. Indeed, collective pumping is more cost-efficient as compared to individual or self-pumping. Further, the farmers with more paddy plots had lower cost efficiency scores than those with few plots. The possible explanation for this is due to higher transportation cost that the farmers with more plots incurred.

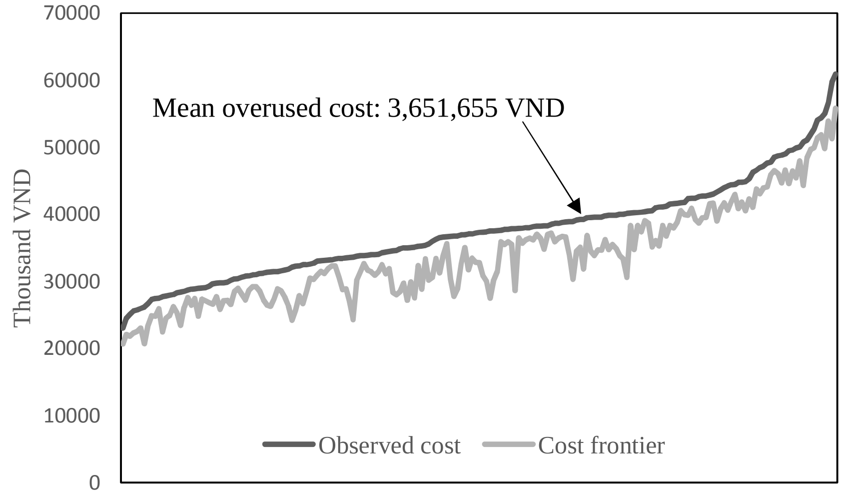

Fig. 2. Overused cost for rice cultivation

Note: 1 USD = 21,770 VND June 8th 2015

Table 4. Descriptive statistics of the variables and Tobit regression coefficients

Variable	Description	Mean	St. dev.	Coefficient	St. error
Farsize	Rice area in hectares	2.3433	4.0134	-0.2177**	0.0940
Famsize	Number of members	4.6582	1.3794	-0.1854	0.2670
Crop	1 = three crops/year 0 = two crops/year	0.8542	0.3537	2.7188**	1.3076
Sesource	1 = verified source, 0 = otherwise	0.3517	0.4787	1.2298	0.7806
IR50404	1 = IR50404, 0 = otherwise	0.3266	0.4701	-3.1572***	1.0913
OM6976	1 = OM6976, 0 = otherwise	0.3115	0.4642	-1.5593	1.0008
Jasmine	1 = Jasmine, 0 = otherwise	0.1206	0.3264	-5.1669***	1.2719
Pump	1 = self-pumping, 0 = co-operative	0.5276	0.5004	-2.9275***	0.8066
Eco	1 = eco rice 0 = otherwise	0.3718	0.4845	1.2839	0.8289
Pieces	Pieces of land	1.3266	0.8521	-1.0983**	0.4384
Constant				93.2952***	2.0487
Sigma				4.7621	0.2395
Log-likelihood				-591.1588	

*Note: ***, ** and * represents the significant levels of 0.01, 0.05 and 0.1, respectively*

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

4. CONCLUSION

This study concludes that the mean cost efficiency score was 90%, suggesting that on the average these farmers could proportionally reduce their current variable cost by 10% without any reductions in the output level. Further, the 79% of variation in variable cost is due to cost inefficiency. The mean overused cost was estimated about 3,651 thousand VND (equivalent to 167.74 USD) per ha. This value is equal to the sales of 702.24 kg of output per ha or the efforts to increase approximately 10% of output level. The study suggests that cost reduction for rice farmers in the study sites is crucial to increase production profit. Furthermore, farmers who cultivated three rice crops per year had higher cost efficiency than those who cultivated two crops per year. Farmers who cultivated Jasmine and IR50404 rice varieties incurred higher cost of production, regardless of their selling price at constant output. Using collective pumping services rather than individual pumping can also improve cost efficiency. Finally, the farmers with more plots of paddy land had lower cost efficiency scores than those with few plots, which could possibly be explained by the higher transportation cost that the farmers with more plots incurred.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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