The Journal of Animal & Plant Sciences, 29(1): 2019, Page: 299-305
ISSN: 1018-7081

TECHNICAL AND COST EFFICIENCY ESTIMATES OF RICE PRODUCTION IN VIETNAM: A TWO-STAGE DATA ENVELOPMENT ANALYSIS

Le Truc Linh[1,3], Pai Po Lee[1], Ke Chung Peng[2] and Rebecca H. Chung[1*]

[1]Department of Tropical Agriculture and International Cooperation, National Pingtung University of Science and Technology, Pingtung 91201, Taiwan; [2]Department of Agribusiness Management, National Pingtung University of Science and Technology, Pingtung 91201, Taiwan; [3]School of Agriculture and Aquaculture, Tra Vinh University, Tra Vinh, Vietnam

[*]Corresponding author. Email: rebecca@mail.npust.edu.tw; yenlinhtv@gmail.com

ABSTRACT

The study was aimed at estimating efficiency of rice farms in the Mekong Delta of Vietnam using data envelopment analysis (DEA) approach. In this regard, data for the crop year 2014 were collected from 400 rice farms. The findings showed that the average efficiency scores were 80.9 percent for technique, 90.7 percent for allocation, 73.4 percent for cost, and 83.2 percent for scale, respectively, of rice producers. There were very few farms (1.25 percent) which were fully allocative and cost efficient, suggesting that majority of the farms have potential to improve their efficiency in terms of technique, allocation, cost and scale. The primary cause of inefficiency in the rice farms was attributed to technique, implying that higher cost efficiency might be achieved by improving technical efficiency. Further, the regression results indicated that rice farm size, credit access, and training were found to have significantly negative effects on technical and cost efficiency of farms. Therefore, this study arrived at suggestion that the quality of credit access and training programs need to be upgraded for improving technical and cost efficiency of the farmers.

Keywords: Data envelopment analysis, Mekong Delta, Rice farmers, Efficiency

INTRODUCTION

Vietnam has become one of the major rice exporting countries in the world, in spite of the fact that it used to import rice before 1989. In 2015, Vietnam exported 6.59 million tons of rice with the value over 2.8 billion USD. Compared with the previous year, there was an increase of approximately 4.0 percent in volume; however the return value was declined by 4.5 percent (Vietnam Customs Statistics, 2016). According to Institute of Agricultural Science for Southern Viet Nam (2016), among rice exporting countries, Vietnam was ranked third in volume export followed by India (10.2 million tons) and Thailand (9.6 million tons).

Although standing among the top rice exporters in the world, rice production in Vietnam are facing several challenges such as small scale farming and low quality which make the Vietnam's rice relatively less competitive. As this can be recognized by the fact that the 5 percent broken rice of Vietnamese priced around 320-390 USD/ton while Thai rice was relatively higher at 340-420 USD/ton (Institute of Agricultural Science for Southern Viet Nam, 2016). Therefore, in addition to estimate technical efficiency of Vietnam's rice farming which aids to improve rice production, measurements of cost efficiency should not be overlooked as well.

A great number of studies were carried out to estimate technical and profit efficiency of rice farming in many countries around the world including Vietnam (Hien *et al.*, 2003; Huy, 2009; Dang, 2012; Khai and Yabe, 2011; Linh, 2012; Tung, 2013; Tu and Yabe, 2015). These studies mainly focused on the estimate technical efficiency and identify determinants towards farms' efficiency. However, there were few studies addressed on cost efficiency which also holds an important role in improving farms' efficiency. Better understanding of cost efficiency could help the farmers adjust their production cost which in turn will improve profit. As stated by Jiang and Sharp (2014), the small number of empirical studies on cost efficiency are due to the lack of data of input prices and the large variation in input prices over time and even among different places.

Studies on cost efficiency were conducted in many countries and on varieties of crops such as rice (Coelli *et al.*, 2002; Dhungana *et al.*, 2004; Thanh Nguyen *et al.*, 2012; Thath, 2014; Egbodion and Ahmadu, 2015; Tu and Trang, 2016), maize (Ogundari *et al.*, 2006; Dia *et al.*, 2010; Paudel and Matsuoka, 2009), coffee (Rios and Shively, 2005), raisin (Bayramoglu and Gundogmus, 2008), and dairy farms (Jiang and Sharp, 2014). In the case of rice production, Tu and Trang (2016) found that cost efficiency of rice farmers in Vietnam was relatively high of 90 percent compared to about 56.2 percent in Bangladesh (Coelli *et al.*, 2002), 66 percent in Nepal (Dhungana *et al.*, 2004), and 56 percent in South Korea (Thanh Nguyen *et al.*, 2012).

This study was designed to estimate cost efficiency of rice farmers located in the Mekong Delta of Vietnam and further to identify the determinants to cost efficiency. The results can be served as references of the rice farmers to improve their technical and cost efficiency individually and of policymakers to adjust or design rice related policies for enhancing Vietnam's competitiveness in the world rice market.

MATERIALS AND METHODS

Analytical Framework: Data envelopment analysis (DEA) is a non-parametric approach which has been applied in a great number of studies in various fields. One of the advantage using DEA is that it does not require to make specific assumptions of the production function that are often required in linear and nonlinear regression models.

Technical and Scale efficiency: Technical efficiency refers to the efficiency in transforming inputs to outputs. Farms' technical efficiency is fully depended on the type of returns to scale. The Charnes, Cooper and Rhodes (CCR) model is based on the assumption of constant returns to scale (CRS) to estimate the gross efficiency; while the BCC (Banker, Chames and Cooper) model is based on variable returns to scale (VRS) to calculate pure technical efficiency (Ramanathan, 2003).

In this study, the assumption of VRS was employed for analysis due to the consideration that the data points are enveloped by this approach more tightly, as a result scores of technical efficiency estimated would be higher than those gained under CRS. Given this feature, the VRS specification has been adopted in many studies (Coelli *et al*., 1998).

The model of DEA for estimating technical efficiency as follows

$$TE_{VRS} = \min_{\theta,\lambda} \theta$$

Subject to

$$\begin{aligned} &Y\lambda - Y_i \geq 0, \\ &\theta X_i - X\lambda \geq 0, \\ &N1'\lambda = 1 \\ &\lambda \geq 0 \end{aligned} \qquad (1)$$

where Y is output vector, X represents the input vector, θ represents a scalar and λ is an n x 1 vector of constants. The estimated θ value is the TE for the i^{th} firm. The TE of a firm is restricted to values between 0 and 1. Technically efficient farms are those with an efficiency score equal to one. In contrast, technically inefficient farms have an efficiency score lower than one.

Scale efficiency (SE) can be calculated by dividing TE score under CRS by TE score under VRS. In which, technical efficiency under CRS can be obtained by deleting the convexity constraint ($N1'\lambda = 1$) in equation (1). Then scale efficiency can be expressed as follows

$$SE = TE_{CRS}/TE_{VRS}$$

Cost and Allocative efficiency: The cost and allocative efficiencies are estimated by solving the DEA problem of cost minimization

$$\min_{\lambda,x_i^*} w_i' x_i^*$$

Subject to

$$\begin{aligned} &Y\lambda - Y_i \geq 0, \\ &x_i^* - X\lambda \geq 0, \\ &N1'\lambda = 1 \\ &\lambda \geq 0 \end{aligned} \qquad (2)$$

where w_i and x_i^* represent the input price and input quantity vectors for the i^{th} farm, respectively; and Y_i is the output levels. The i^{th} farm's cost efficiency (CE) is the ratio between minimum cost and observed cost for the i^{th} farm as follow

$$CE = w_i' x_i^* / w_i' x_i$$

The allocative efficiency (AE) is the ratio of cost efficiency to technical efficiency and expressed as

$$AE = CE/TE$$

This study employed a two-stage method which combines a DEA analysis and a regression analysis. In the first stage, DEA was applied to estimate technical and cost efficiency. These efficiency scores were then regressed to explain efficiency differences among farms related to farm-specific characteristics in the second stage. Liu *et al.* (2013) pointed out that using the two-stage method is quite popular in agriculture research, and Tobit analysis is usually used in the second-stage to identify the environmental factors which may influence on the efficiencies. However, when comparing Tobit model and ordinary least squares (OLS) regression models, Hoff (2007) concluded that in many cases OLS could be more sufficient. Moreover, McDonald (2009) also found that OLS is a stable estimator, and its computation is easy. Therefore, this study adopted OLS in the second stage to detect the factors that influence farm efficiency.

Study Area and Data Management: This study used primary data which were purposively collected from six districts in Tra Vinh and Dong Thap provinces, situated in the Mekong delta of Vietnam. The delta is well-known in the world due to its fertilization and these two study areas are characterized by a prevalence of rice cultivating. Questionnaire was designed to collect data from 400 rice producers.

Both inputs and output data of the rice farmers for the winter-spring season of 2014 (November 2013–March 2014) were collected from July to September 2014. The output was yield of rice harvested and expressed in kilograms. The inputs were data related to both quantities and the respective prices for seed, fertilizer, and labor (hired labor and family labor). The input prices were expressed in Vietnamese currency (VND). These three variables were commonly used in previous study reported by Coelli *et al.* (2002). Chemicals were not included because rice farmers could not remember how many kilograms of chemicals used. Farm-specific variables such as size of farm (ha), household size (people), age, education level, and experience of the farmers (years), technical training, credit access and membership of cooperative (dummy variables) were also collected for identifying their influences on farms' technical and cost efficiencies. These variables are commonly adopted in many previous studies such as Coelli *et al.* (2002), Tipi *et al.* (2009), and Shrestha *et al.* (2016).

RESULTS

Descriptive Statistics: The descriptive statistics for the variables used in this study are provided in Table 1. The average yield of these farms is 7.26 tons/ha, which is slightly higher than the average of the Mekong Delta, 6.79 tons/ha, in 2014 (General Statistics Office, 2015). Table 1 also illustrates information portraying the characteristics of these rice farms. These farms have a wide range of size from 0.1 to 10 hectares, with an average of 1.59 hectare per farm indicating that rice farmers in the sample is operating at a medium scale of land. On average, household size is five people per family; the age of the farmer is 49; education level is less than seven years; these farmers have almost 25 years of rice cultivating experience; only 40 percent of rice farmers have had training during the past year; approximately 60 percent of farms have availed credit access; and 50 percent of sampled producers are members of agricultural cooperatives.

Table 1. Summary statistics of inputs, output variables and the characteristics of rice farms in the sample, 2014.

Variables	Unit	Mean	Standard Deviation	Minimum	Maximum
Output and Inputs					
Rice output	kg/ha	7259.55	986.61	5000.00	10200.00
Seed	kg/ha	156.98	44.54	30.00	280.00
Fertilizer	kg/ha	449.11	99.31	250.00	900.00
Labor	man-days/ha	30.11	3.66	21.00	43.00
Seed^{+}	1000 VND/kg	10.23	3.21	3.75	19.00
Fertilizer^{+}	1000 VND/kg	10.53	1.65	5.51	20.88
Labor^{+}	1000 VND/day	111.42	8.03	67.63	135.76
Farm-specific variables					
Farm size	ha	1.59	1.44	0.10	10.00
Household size	persons	4.75	1.40	1.00	11.00
Age of the farmer	years	47.91	10.29	22.00	79.00
Education level	years	6.92	3.01	0.00	12.00
Experience	years	24.81	9.24	2.00	50.00
Training	dummy	0.39	0.49	0.00	1.00
Credit access	dummy	0.61	0.49	0.00	1.00
Member of agricultural cooperatives	dummy	0.50	0.50	0.00	1.00

$^{+}$1 US$ = 21,270 VND (as of June 31, 2014)

Technical, Allocative, Cost and Scale Efficiency: The technical, allocative and cost efficiency of rice farms are measured by applying the DEAP 2.1 program (Coelli, 1996). The assumption of VRS estimation was adopted for analysis and the efficiency scores as presented in Table 2. It can be seen that rice producers had obtained fairly high technical efficiency score of 0.809. In addition, almost 50 percent of the sampled farms obtained technical efficiency scores of more than the average score. However, only 20 farms (5 percent) were fully efficient (TE=1), indicating technical inefficiency of rice farmers.

Regarding scale efficiency, which was located in the last column of Table 2, the mean score was found to be 0.832, implying that on average rice producers in the sample achieved about 83 percent of the optimal scale efficiency. Only one third of farms had scale efficiency scores of more than 0.900 and 2 percent of farms were fully scale efficient (SE=1). The findings indicate that these farms on average could improve their efficiency about 17 percent by altering the scale of farms. Specifically, at the bottom of Table 2 illustrate the percentage distribution of return to scale for the sampled rice farms. It can be seen that only 2 percent of farms in this study were operating at an optimal scale. Meanwhile, most of farms (93.5 percent) exhibited increasing return to scale which means that these farms tend to operate at sub-optimal scale.

Table 2. Technical, allocative, cost and scale efficiency measures of rice farms in the sample, 2014.

	Technical efficiency	Allocative efficiency	Cost efficiency	Scale efficiency
Summary efficiency				
Mean	0.809	0.907	0.734	0.832
Std. dev.	0.087	0.060	0.097	0.102
Minimum	0.607	0.656	0.521	0.563
Maximum	1.000	1.000	1.000	1.000
Frequency distribution				
<60%	0.00	0.00	5.75	0.75
60-69%	9.75	0.50	31.50	6.50
70-79%	40.25	6.25	40.25	37.25
80-89%	34.75	30.00	15.25	25.75
90-100%	15.25	63.25	7.25	29.75
Fully efficient farms	20.00	5.00	5.00	8.00
Returns to scale				
Increasing returns to scale (%)				93.50
Decreasing returns to scale (%)				4.50
Constant returns to scale (%)				2.00

Rice producers were found to have fairly low cost efficiency; nevertheless, they on average obtained high allocative efficiency. The estimated cost efficiency of farms varied from 0.521 to 1, with the mean score of 0.734; while the mean allocative efficiency was 0.907 and over 63 percent of farms had higher score than the average. For both scores, only 5 farms (1.25 percent) were fully efficient, in other words, there were approximately 98.75 percent of farms in this study were found to be under the status of cost and allocative inefficiency.

In order to show whether the farmers have overused inputs or not, the ratios of technical efficient input levels to cost efficiency input levels were calculated. The former values are obtained in technical efficiency DEA model and the later values are obtained in the cost minimizing DEA model. If the ratio is greater than one, indicating that the input in question is over used. The findings shown in Table 3 indicate over-used seed (1.760) and fertilizer (1.178) and under-used labor (0.84).

Table 3. The ratios of input use by rice farmers in the Mekong Delta, 2014.

	Seed	Fertilizer	Labor
Mean	1.760	1.178	0.874
Standard Deviation	0.794	0.220	0.110
Minimum	0.680	0.721	0.700
Maximum	4.347	1.673	1.462
Overusing farms (%)	84.25	72.25	9.75

Factors Influencing Efficiencies: In order to identify the sources of efficiency variations across rice farms, a number of farm-specific variables were regressed on technical, allocative and cost efficiency using OLS model. The findings are presented in Table 4. It can be seen that farm size, credit access, training and membership of cooperatives have impacts on all three efficiencies of farms while household size, age and experience of the farmer appear to be irrelevant. Education was found to be significantly positive to technical efficiency only.

Table 4. Factors influencing technical, allocative and cost efficiency in the sample, 2014.

Variables	Technical efficiency		Allocative efficiency		Cost efficiency	
	Coefficients	*t*-value	Coefficients	*t*-value	Coefficients	*t*-value
Constant	0.788**	27.133	0.904**	46.219	0.714**	22.441
Farm size	-0.008**	-2.733	-0.007**	-3.320	-0.013**	-3.936
Household size	0.002	0.762	0.000	0.074	0.002	0.692
Age of the farmer	0.000	0.707	0.000	0.054	0.000	0.599
Education level	0.003*	2.117	-0.001	-0.670	0.002	1.382
Experience	0.000	0.196	0.000	0.926	0.000	0.572
Credit access	-0.034**	-3.799	0.005	0.758	-0.028**	-2.844
Training	-0.021*	-2.316	-0.023**	-3.792	-0.038**	-3.801
Cooperative member	0.003	0.334	0.036**	6.046	0.033**	3.351
R-square	0.084		0.131		0.121	
Sig.	0.000		0.000		0.000	

Note: * and ** indicate significance level of 5% and 1%, respectively.

DISCUSSION

On average, technical, allocative and cost efficiency measures were 0.809, 0.907 and 0.734, respectively. Bayramoglu and Gundogmus (2008) stated that the allocative and technical efficiency estimates are considered as evidence to the sources of deviations from cost minimizing efficiency. The results of this study clearly showed that allocative efficiency was relatively higher than technical efficiency, therefore, the primary sources of rice farms' inefficiency was identified as technical rather than allocative efficiency. In other words, rice farms are possible to achieve higher cost efficiency by improving technical efficiency. The average cost efficiency of rice farmers in this study was much lower compared to the finding of Tu and Trang (2016), in which rice farmers in An Giang province of the Mekong Delta scored 0.90 for cost efficiency.

The majority of rice farmers in this study operate under increasing returns to scale, suggesting improvement in farm size. As noted by Coelli *et al.* (2002) that the reflection of scale efficiency is only associated with farms' size.

It not surprised to find out that most rice farmers over-used seed in this study. This result is consistent with the finding from previous studies conducted in the Mekong Delta. Hien *et al.* (2003) found that seed was over-used by rice farmers in winter-spring season. In addition, data presented in Tu and Yabe (2015) showed that amount of seed used by rice farmers was significantly higher (about 50 percent) compared to those under ecologically engineered rice production given the yields per hectare were almost the same. Therefore, this outcome suggests that technical trainers for rice farmers need to address the overuse issue of seed. On the other hand, labor was under-used as expected; many young people in rural areas migrate to cities for better jobs and opportunities leads to shortage of labor, and in turn forces farmers to apply agricultural machineries instead. This could be considered to be a good trend for improving both technical and cost efficiencies.

As was noted above, in order to increase technical efficiency, rice farms should engage in expanding their operation scale. However, farm size was found to be significantly negative to technical, allocative and cost efficiencies from the OLS regression, indicating that small farms were more efficient than larger ones. This may be attributed to the complexity and difficulties by management when farm size becomes big. Along the line, Ali *et al.* (1994), Tien and Thong (2014), and Etim and Udoh (2014) have also found a negative relationship between efficiency and farm size.

Credit access was found to be negatively affected the technical and cost efficiency, which indicates that access to credit was of no avail in enhancing efficiency of rice producers. This may be because farmers' skills and knowledge at managing capital are limited. That is, most rice farmers in this study are lack of human capital in managerial skill; furthermore, most training provided are usually focused on rice cultivation techniques rather than on entrepreneurship. Therefore, rice farmers normally do not know how to manage their capital effectively nor deal with the fluctuation of input and output markets. The inverse relationship between credit access and farms' efficiency can also be found by Tien and Thong (2014) and Shamsudin (2014). For example, Shamsudin (2014) found that access to credit was not effective in improving the rice farm efficiency.

The inverse relationship of technical training with all three types of efficiency revealed that training delivered for the farmers in the sample seem to be ineffective. The negative effects of training are unexpected, which are contradictory most literature. For instance, Shrestha *et al.* (2016) reported that training of farm manager is one of the most effective factors for increasing economic efficiency of vagetable farmers in Nepal. This unexpected finding may direct researchers and policy makers to address the issue of quality for these services such that efficiency could be improved. In addition, offering better credit opportunities for farmers and training related to enhance entrepreneurship need to take into consideration.

The dummy variable of cooperative membership was included in the OLS regression to identify the relative role of agricultural cooperative on efficiency in the study. Rice member farmers in cooperatives scored significantly higher for both allocative and cost efficiencies compared to non-member farmers. This implies that agricultural cooperatives could contribute to increase efficiency for their members. This result was in line with the findings of Binam *et al.* (2004), Tipi *et al.* (2009) and Dhehibi *et al.* (2014). More specifically, Binam *et al.* (2004) found that members of clubs or farmer associations obtain higher technical efficiency than individual farmers. Dhehibi *et al.* (2014) also pointed out that technical efficiency scores of farmers in cooperatives in the West Bank of Palestin were found to be higher than those were not members of cooperatives.

Conclusions: In the first stage of DEA measures, the results showed that on average rice farmers attained technical efficiency of 80.9 percent, allocative efficiency of 90.7 percent, cost efficiency of 73.4 percent, and scale efficiency of 83.2 percent. Few farms (1.25 percent) were found allocative and cost efficient, suggesting improvement in most of the farms so as to become competitive in the world rice market. Another finding that higher score of allocative efficiency than that of technical efficiency point out that the primary source of inefficiency for the rice farms participated in this study was identified to be technical efficiency; that is, the rice farms are possible to achieve higher cost efficiency by improving technical efficiency.

From the OLS regression analysis in the second stage, farm size, credit access, and training were found to have negative impacts on efficiencies while membership of cooperatives have positive effects. Other variables, household size, age and experience of the farmer, were found not to be statistically insignificant on efficiency. Education was found to be significantly positive to technical efficiency only.

Furthermore, based upon the OLS regression results, the provision of access to credit and training were ineffective, or in fact lower the efficiency. Moreover, efficiency of farms tends to decrease when farm size is increased. These unexpected outcomes may be attributed to the limited human capital in entrepreneurship which constrained rice farmers to effectively use capital to manage their farms. Therefore, the results of this study suggest that the quality of credit access and training programs need to be upgraded to improve efficiency of rice production for the farmers in the region. In addition, the training provided by extension offices usually is confined on the aspect of cultivation technique rather than managerial skills. Therefore, other than to offer better credit opportunities for farmers, training related to managerial skills need to be considered as well.

Acknowledgments: The authors are grateful to the rice farmers, whom provided desired information. In addition, the authors would like to express their gratitude to the heads of the Rural Development Division, and Department of Agriculture and Rural Development in Tra Vinh and Dong Thap Provinces for their genuine support to this study.

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