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Technical efficiency estimates of paddy farming in peninsular Malaysia: A comparative analysis

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ABSTRACT

Estimating technical efficiency of production technology is important for policy purposes, particularly for a sector which has strategic importance in self sufficiency level such as paddy farming. This study compared technical efficiency of paddy farming in east coast and west coast of Peninsular Malaysia by using data envelopment analysis (DEA) and Stochastic Frontier Analysis (SFA). Primary data were collected using a set of structured questionnaire from 230 farmers in east coast and west coast of Peninsular Malaysia. The data are analyzed by using DEA and SFA. The results indicated that the differences in methodologies employed produced different efficiency estimates. The DEA result showed that efficiency score for Peninsular Malaysia is 56%, which is lower from the efficiency score obtained using the SFA at 69%. Due to the large differences in technical efficiency results, recommendation for policy purpose should not depend on only one method as it is inaccurate.

Keywords: Technical efficiency, Data envelopment analysis, Stochastic frontier production, Comparative analysis

INTRODUCTION

Increasing emphasis is being placed on measures of efficiency in various industries to compare their relative performance, given the need to ensure the best use of scarce resources. Few studies have assessed the consistency of efficiency rankings across different methodologies. For example, Radam and Mansor (1999) have assessed four methods of efficiency rankings, which are (a) deterministic parametric frontier (b) linear programming parametric frontier (c) nonparametric frontier; and (d) stochastic parametric frontier on Sarawak pepper farming in Malaysia [1].

There are a few studies that compare the use of Data Envelopment Analysis (DEA) and Stochastic Frontier Analysis (SFA) on productive efficiency. Cullinane *et al*. (2006) has compared the use of these two methods in measuring productive efficiency in container ports. They used data from 30 container ports and found that DEA yielded a lower efficiency score compared to SFA [2]. Jacobs (2001) used the same dataset and compares the efficiency rankings from the cost indices with those obtained using DEA and SFA. He has compared the use of these two methods in measuring productive efficiency in examining hospital efficiency. The paper concludes that the methods each have particular strengths and weaknesses and potentially measure different aspects of efficiency [3]. However, there is a limited number on the comparison of these two methods in measuring productive efficiency in agriculture sector.

This includes a study on the swine industry in Hawaii [4]. It is vital to measure productive efficiency especially in industries which has low self sufficiency level in a particular country.

In Malaysia, paddy and livestock industries have been identified as two important sectors which have strategic importance but low self-sufficiency. Paddy especially is given a greater emphasis as it is a staple food for Malaysian. The government is committed in developing this sector to ensure that rice production can meet the demand. Various subsidies are provided to assist farmers in increasing production, where in the Tenth Malaysia Plan the government set a target of 70% self sufficiency level. Currently, Peninsular Malaysia is producing 58% of paddy in the country. Thus, this paper is focusing on comparing DEA and SFA in measuring productive efficiency of paddy farming in Peninsular Malaysia. Given the result of previous studies, the purpose of this paper is to provide a comparison of the most commonly used methods to compute technical efficiency utilizing two production analysis, namely, Data Envelopment Analysis (DEA) and Stochastic Frontier Analysis (SFA). This paper proceeds as follows. The next section focuses on the methodologies that are used in this study. Section three presents the data and estimation followed by the empirical results. The last section concludes the study with the implications of the findings.

MATERIALS AND METHODS

Data Envelopment Analysis

Data envelopment analysis (DEA) is a nonparametric method in operations research and economics for the estimation of production frontiers. It is used to empirically measure productive efficiency of decision making units. The framework has been adapted from multi-input, multi-output production functions. DEA develops a function whose form is determined by the most efficient producers. This method differs from the ordinary least squares (OLS) statistical technique that bases comparisons relative to an average producer.

DEA has some common characteristics with stochastic frontier analysis (SFA), where both methods identify a "frontier" on which the relative performances of all utilities in the sample are compared by benchmarking firms only against the best producers. It can be characterized as an extreme point method that assumes that if a firm can produce a certain level of output utilizing specific input levels, another firm of equal scale should be capable of doing the same. The most efficient producers can form a "composite producer", allowing the computation of an efficient solution for every level of input or output. Where there is no actual corresponding firm, "virtual producers" are identified to make comparisons [5].

Technical efficiency analysis is applied to output oriented variable return to scale via DEA approach. Coelli *et al.* (1998) stated that output oriented variable return to scale (VRS) technical efficiency can be formulated as follows [5]:

$$\text{Max}_{\theta,\lambda}: \quad \theta$$

$$\text{subject to:} \quad \begin{aligned} &-\theta y_j + Y\lambda \geq 0 \\ &x_j - X\lambda \geq 0 \\ &N1'\,\lambda = 1 \\ &\lambda \geq 0 \end{aligned}$$

where θ denotes the score for technical efficiency of *i*th paddy farmer compared to others in the sample. y_j denotes yield of *i*th paddy farmer, x_j is quantity input used by *i*th paddy farmer, Y is yield data set for all paddy farmers, λ is N×1 vector of constants, X is input data for all paddy farmers and N is total number of paddy farmers. Y_λ and X_λ are the efficient estimations on frontier. N1 denotes N×1 vector of ones. $N1'\,\lambda = 1$ is a constraint that makes comparison only of paddy farmer of similar yield size, by forming a convex hull of intersecting planes, so the data is enveloped more tightly [5].

Four inputs were used in this study: size of paddy farm, expenses on seeds, expenses on fertilizer and finally number of workers. Output yield was measured in metric tons per hectare for annual yield of paddy farms.

Stochastic Frontier Analysis

Stochastic frontier models date back to Aigner *et al.*, (1977) and Meusen and van den Broek (1977), who independently proposed a stochastic frontier production function with a two-part ‘composed’ error terms [6, 7]. One is an ordinary statistical noise captures statistical noise, measurement error, and other random events (economic situations, quakes, weather, strikes, and luck) that are beyond the human control. The other captures inefficiency.

Stochastic frontier models in which the inefficiency effects (u_i) are expressed as an explicit function of a vector of firm-specific variables and a random error were proposed by Kumbhakar *et al.*, (1991) and Reifschneider and Stevenson (1991) [8, 9]. The model presented in equation 1 is a modified Battese and Coelli (1995) model that we use in our analyses, which also allows for the use of panel data. The error term consists of the two terms (v_i) and (u_i), whereby the former accounts for the noise in the regression and is assumed to be normally distributed. The technical inefficiency term (u_i) is usually modelled as a half-normally distributed term [10]. Equation 1 is a translog stochastic function and is self-explanatory.

$$lnY_i = \beta_0 + \beta_1 lnL_i + \beta_2 lnK_i + \beta_3 lnE_i + \beta_4 lnF_i + \beta_5(lnL_i)^2 + \beta_6(lnK_i)^2 + \beta_7(lnE_i)^2 + \beta_8(lnF_i)^2 + v_i - u_i, \qquad i = 1,2,\ldots,N. \tag{1}$$

where, Y_i denotes production of observable output, L_i denotes fertilizer, K_i denotes seed, E_i denotes pesticide and F_i denotes labor. *ln* refers to the natural logarithms; β_i are unknown parameters to be estimated. v_i are iid, and $N(0,\sigma_v^2)$ random errors, and are assumed to be independently distributed of the u_i which are non-negative random variables associated with technical inefficiency. The distribution of u_i is obtained by truncation at zero of the normal distribution with mean m_i and variance σ_v^2, where;

$$m_i = \delta_0 + \delta_1 A + \delta_2 M + \delta_3 H + \delta_4 E + \delta_5 W + \delta_6 T \tag{2}$$

where, A, M, and H denote age, marital status, and household, respectively. E denotes education dummy variable (no formal education=1, primary school=2, secondary school=3, university or collage=4). W and T denote working experience and training, respectively. δi are unknown (technical inefficiency) parameters to be estimated.

In computer program of FRONTIER 4.1 (Coelli, 1996) parameterisation is used whereby δ_v^2 and δ_u^2 are replaced with $\sigma^2 = \sigma_v^2 + \sigma_u^2$ *and* $\gamma = \sigma_u^2/(\sigma_v^2 + \sigma_u^2)$. The gamma coefficient, therefore, will allow us to infer as to what proportion of the total error term is actually accounted for by technical inefficiency [11].

Data and estimations

The study utilized the data pertaining to the paddy production in 2010, which was gathered through direct interview survey from sample of 230 paddy farmers. This study covered east coast and west coast of Peninsular Malaysia. These set of data will be analyzed using data envelopment analysis (DEA). Meanwhile, the data can be conducted using stochastic frontier analysis (SFA) in the east and west coast of Malaysia.

RESULTS AND DISCUSSION

The result from DEA showed Peninsular Malaysia exhibited 56% of technical efficient. Table 1 showed frequency of technical efficiency estimates of paddy farming in west coast, east coast and Peninsular Malaysia. The study showed technical efficiency measures ranging from 5% to 97% for west coast and 1% to 98% for east coast. East coast of Peninsular Malaysia proposed 51% of technical efficient; on the order hand, west coast of Peninsular Malaysia reported 58% of technical efficient. Although average of efficiency score of Peninsular Malaysia was reported only 56%, even so, there were 7.1% which accounted to 17 paddy farmers had achieved 100% of technical efficient. Suggesting that among the 230 paddy farmers, these 17 paddy farmers had well performed and they were being the best practice guidance for the rest of paddy farmers. From these 17 paddy farmers, 6 paddy farmers were from east coast of Peninsular Malaysia while 11 paddy farmers were from the west coast. On the other hand, the data is employed to estimate technical efficiency by means of SFA. The average of efficiency score of Peninsular Malaysia was reported only 69%, even so, there were 16.9% which accounted to 39 paddy farmers had achieved 100% of technical efficient. In addition, the study shows technical efficiency measures ranging from 13% to 99% for west coast and 37% to 98% for east coast. The average technical efficiency for west coast is estimated at 66% and east coast showed 72%. It indicates that farmers in east coast are more efficient in managing their paddy production compared to farmers in west coast.

Table 1: Frequency of Efficiency Estimates of Paddy Farming in West Coast, East Coast and Peninsular Malaysia

Efficiency Levels	Data Envelopment Analysis **(DEA)**			Stochastic Frontier Analysis **(SFA)**		
	West Coast	**East Coast**	**Peninsular Malaysia**	**West Coast**	**East Coast**	**Peninsular Malaysia**
<0.50	45	45	90	25	8	31
0.51-0.60	33	17	50	35	14	46
0.61-0.70	27	13	40	15	20	38
0.71-0.80	20	6	26	30	16	45
0.81-0.90	4	3	7	13	16	31
0.91-1.00	11	6	17	22	16	39
Average	0.58	0.51	0.56	0.66	0.72	0.69
Minimum	0.05	0.01	0.05	0.13	0.37	0.45
Maximum	0.97	0.95	0.96	0.99	0.98	0.95

Source: *The research findings*

The estimation of a firm's technical efficiency allows further investigation of the sources of efficiency, and hence inefficiency, which could be of great importance to the implementation of policies [12]. Thus, an analysis tests for the significance of the factors, which presumably influence the efficiency of the paddy production in west coast and east coast. Table 2 reports the results for the efficiency effects model.

Table 2: Estimates of the Efficiency in Production Function

Variables	**Data Envelopment Analysis (DEA)**			**Stochastic Frontier Analysis (SPF)**		
	East Coast	**West Coast**	**Peninsular Malaysia**	**East Coast**	**West Coast**	**Peninsular Malaysia**
Pesticides	0.00003	-0.000007	0.000001	0.01	0.01	n.a
Education	-0.002	-0.018	-0.001	0.24	0.05	n.a
Working Experience	0.00007	-0.00009	0.0005	-0.12	-0.85	n.a
Training/Seminar	-0.059	0.075	0.014	0.94	0.41	n.a

Source: *The research findings*

The DEA model showed that in Peninsular Malaysia, variables of pesticide, experience and Training/Seminar have positive impact to efficiency, suggesting that an increase in these variables will lead to an increase in efficiency, similar with the finding of Ghee-thean *et al.,* (2012), Koc *et al.,* (2011) and Ekunwe *et al.,* (2008) [13, 14, 15]. Yet, the variables of training and education have negative impact on efficiency effect, suggesting that an increase in these variables will lead to a decrease in efficiency. Inefficiency model of west coast of Peninsular Malaysia noted that variables of training/seminar were found negatively affected inefficiency, consistent with the finding of Ghee-Thean *et al*., (2012). On the other hand, the model of east coast of Peninsular Malaysia stated that variables of pesticide and experience were found negatively affected inefficiency, in line with results of previous studies Koc *et al.*, (2011) and Ekunwe *et al.,* (2008), while, variables of education and seminar were found positively affected inefficiency. This incident might be caused by different farming behaviors of paddy farmers in east coast and west coast of Peninsular Malaysia and other uncontrollable factors. However, none of the determinants (pesticide, education, experience and training/seminar) had shown significant influence in technical efficiency for Peninsular Malaysia in Stochastic Frontier Analysis (SFA) model. Different with result of east coast of Peninsular Malaysia, variable of seminar showed the single significant negative effect to inefficiency. This result indicated that suppose paddy farmers who absent from seminar of paddy farming, perform less efficient compared to those who attend the seminar. In Malaysia, seminar of paddy farming is usually held by the authorities and private companies. Seminar is held for the purpose to improve knowledge of paddy farmers, to expose latest technology, machinery or skill to the paddy farmers and also to introduce new fertilizers or seeds. It is convinced that having a seminar is also a chance to have the paddy farmers gather for experience or knowledge sharing, hence, indirectly causing productivity of paddy yield to be improved.

CONCLUSION

The DEA model results revealed that efficiency score for Peninsular Malaysia is 56%, which is lower from the efficiency score obtained using the SFA at 69%. The DEA analysis showed that paddy yield of Peninsular Malaysia has the potential to increase its efficiency of 44% in the existing technological condition. However, paddy yield of east coast and west coast of Peninsular Malaysia were having 49% and 42% of potential to be improved, respectively. The average of efficiency score of Peninsular Malaysia under SFA model was reported 69%. In the model, paddy yield of east coast and west coast were having 28% and 34% of potential to be improved, respectively. It indicates that farmers in east coast are more efficient in managing their paddy production compared to farmers in west coast. Due to the large differences in technical efficiency results, recommendation for policy purpose should not depend on only one method as it is inaccurate. Moreover, these results could be inferred that there was great relative potential to increase technical efficiency of paddy farms in Peninsular Malaysia. Raising current paddy yield up to target yield requires improvement in farming efficiency. Authorities should give more attention on improving farming efficiency of these two areas, thus improve productivity in achieving targeted paddy yield.

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