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Measuring Technical Efficiency of Malaysian Paddy Farming: An Application of Stochastic Production Frontier Approach

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Abstract: Paddy farming is one of the most important activities in Malaysian agriculture sector. However, the actual yields of paddy in some of the states were recorded far less than the potential yield of paddy. This study investigated the level of technical efficiency and the determinants of technical inefficiency for a sample of 230 paddy farmers operating in Peninsular Malaysia by using a trans-log stochastic production frontier. The mean level of technical efficiency for the selected paddy farmers was estimated at 85.8%, while the efficiency of the selected paddy farmers varied from 0.263 to 0.982. Inefficiency model indicated that the attendance at seminar or workshop significantly influenced technical inefficiency. The attendance at seminar or workshop had become an ace factor in increasing technical efficiency and in increasing yield per hectare. Hence, this study suggests that, the farmers should attend seminar or workshop of paddy farming from time to time. Encouraging paddy farmers to attend seminar or workshop can be achieved through offering incentives, subsidies in order to offset the opportunity cost of attendance at seminar or workshop.

Key words: Malaysia, paddy, technical efficiency, stochastic production frontier

INTRODUCTION

Rice is the staple food for Malaysian, therefore, the paddy farming industry being important to nations and the paddy farmers are playing the important role in producing enough rice to the national consumption. Unfortunately, the production of paddy in Malaysia has still not yet met the national demand. Kedah is viewed as the rice bowl of Malaysia and it produces almost one third of total national rice production. Nonetheless, other states in Malaysia (Kelantan, Terengganu, Penang, Perak and Selangor) are producing rice only at lesser concentration (Ministry of Agriculture and Agro-based Industry Malaysia, 2011). There has been comparatively less research on technical efficiency of paddy farming done at these states.

The efficiency of paddy farming has drawn more attention from researchers and scholars recently. Many studies have been conducted to investigate different aspects of efficiency in the paddy farming sector for many different countries, for example: Battese and Coelli (1995) studied the technical efficiency on paddy farmers from Indian village from Aurepalle by using panel data; Dhungana *et al.* (2004) investigated economic inefficiency of Nepalese rice farms. Xiao and Li (2011) measured technical efficiency of paddy production in China; Technical efficiency of southern Thailand's rice farms was estimated by Kiatpathomchai *et al.* (2008) by using input oriented; Huang *et al.* (2002) examined cost efficiency of rice farming in Taiwan; Nassiri and Singh (2009) studied energy use efficiency for paddy production in Punjab by using data envelopment analysis; Nassiri and Singh (2010) studied energy use efficiency for paddy production in Punjab, India by using parametric and non-parametric approach; The economic efficiency on paddy farms in Northwest Selangor was estimated by Radam and Latif (1996). Thiruchelvam (2005) examined the efficiency of rice production in the districts of Anuradhapura and Polonnaruwa in Sri Lanka; Tadesse and Krishnamoorthy (1997) look into technical efficiency analysis on paddy farms in Tamil Nadu state, India.

One of the objectives of this study was to investigate the level of technical efficiency of Malaysian paddy farming as a consequence of the huge gap between actual yield and potential yield of Malaysian paddy farming. The average yield of paddy of the five states (Kelantan, Terengganu, Penang, Perak and Selangor) was recorded around 3.5-4 metric ton ha^{-1} for the past five years

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(Ministry of Agriculture and Agro-based Industry Malaysia, 2011), however, the potential yield of paddy in Malaysia is around 10 tons ha^{-1} (Abdullah *et al*., 2010). Thus, the role of paddy farmers has drawn the questions that asking how efficient of the Malaysian paddy farming practices and how well of the paddy farmers perform in producing rice to meet the national consumption. These became the reasons to answer why the paddy farmers had been chosen for the efficiency analysis. Besides investigating the level of technical efficiency, this study also examined the factors in determining the inefficiency of the paddy farming industry.

MATERIALS AND METHODS

Data for this study was derived from the observations on the two hundred and thirty randomly selected samples from five states (Penang, Perak, Johor, Kelantan and Terengganu) in the Peninsular Malaysia throughout the year 2010. The respondents selected for the interviews were the paddy farmers who mostly own the paddy fields and sometimes they even rent the extra paddy fields from others.

Coelli (1996) had developed the software FRONTIER 4.1, which can be used to generate both the stochastic production frontier and the inefficiency model simultaneously. The FRONTIER 4.1 was widely applied in different fields of research in the past 15 years, especially in agricultural studies (Binuomote *et al*., 2008; Bakhsh *et al*., 2006; Bamiro *et al*., 2006; Battese and Coelli, 1995). This study applied FRONTIER 4.1 with the trans-log production function for the analysis of technical efficiency:

$$\ln Y_j = \beta_0+\beta_H \ln H_j+\beta_S \ln S_j+\beta_F \ln F_j+\beta_L \ln L_j+\beta_{HH}(\ln H_j)^2+\beta_{SS}(\ln S_j)^2+\beta_{FF}(\ln F_j)^2+\beta_{LL}(\ln L_j)^2+\beta_{HS}(\ln H_j \ln S_j)+\beta_{HF}(\ln H_j \ln F_j)++\beta_{HL}(\ln H_j \ln L_j)+\beta_{SF}(\ln S_j \ln F_j)+\beta_{SLT}(\ln S_j \ln L_j)+\beta_{FL}(\ln F_j \ln L_j)+v_j-u_j \quad (1)$$

where, j represents the jth farmer, Y_j is the yield per hectare of the jth farmer, H_j is the total size of the jth farmer's paddy fields, S_j is expenditure on seeds, F_j is expenditure on fertilizer and finally L_j is the number of workers engaged in paddy farming. The selected variables were similar with previous studies (Piya *et al*., 2012; Koc *et al*., 2011; Agahi *et al*., 2008; Ekunwe *et al*., 2008; Alemdar and Oren, 2006; Sahin *et al*., 2007; Radam and Latif, 1996). Table 1 provides descriptive statistics of the variables. The expenditure on seeds, expenditure on fertilizer and number of workers are directly related to production effort, whereas, total size of paddy fields are the important fixed inputs for the farm operation.

Technical inefficiency model consists of five determinants and this model attempts to investigate the factors causing the differences in technical efficiency levels among the selected farmers. The technical inefficiency model can be formulated as follows:

$$U_j = \delta_0+\delta_1 TRAC+\delta_2 EXPEND+\delta_3 EXPERI+\delta_4 EDU+\delta_5 SEM+w_j \quad (2)$$

where, U_j is the inefficiency of the ith farmer. Here, TRAC represents the tractor ownership (A = 1 if the farmer owns at least a tractor, otherwise 0), EXPEND represents expenditure of farmer on pesticide or herbicide, EXPERI represents years of experience as a farmer, EDU represents the education level of farmer (D = 1 if the farmer had more than 6 years education, otherwise 0),

Table 1: Descriptive statistics of the variables

Variables	Description	Mean statistics*	SD (%)*
Stochastic production function			
Output	Continuous (tons ha^{-1})	4.713	1.588
Inputs			
Total size of paddy fields	Continuous (ha^{-1})	4.694	4.792
Expenditure on seeds	Continuous (RM)	1376.500	1558.800
Expenditure on fertilizer	Continuous (RM)	373.280	1024.740
Number of workers	Continuous (person)	2.461	1.612
Inefficiency model			
Tractor	Dichotomous, value 1 if farmer owns at least a tractor, otherwise 0	72.000*	31.300%*
Expenditure on pesticide/herbicide	Continuous (RM)	807.430	1512.360
Farmer specific characteristics			
Experience	Continuous (years)	21.783	14.178
Education	Dichotomous, value 1 if farmer accepted more than 6 years education, otherwise 0	129.000*	56.100%*
Attending seminar and workshop	Dichotomous, value 1 if farmer had ever attended any seminar or workshop regarding paddy farming, otherwise 0	145.000*	63.000%*

*No. of farmers from the selected sample

SEM represents the attendance of farmer on any seminar or workshop regarding paddy farming (E = 1 if the farmer had ever attended any seminar or workshop regarding paddy farming, otherwise 0) and finally w_i is the error term.

However, there are some conditions to be applied in this study, i.e., the Eq. 1 is only valid if it is proved that the Cobb-Douglas production function is not suitable for the analysis. Besides, the Eq. 2 can only be further investigated if there is any existing technical inefficiency effect and the technical inefficiency effect must be stochastic. These conditions had lead to three hypotheses to be tested by generalized likelihood ratio tests before proceed to stochastic frontier analysis and technical inefficiency analysis.

The first hypothesis is, there is no technical inefficiency effect, $\gamma = \delta_0+\delta_1+...+\delta_8 = 0$; the second hypothesis is, there is technical efficiency effect yet it is non-stochastic so $\gamma = 0$; finally, the third hypothesis is the Cobb-Douglas production model is preferable (Ghee-Thean *et al*., 2012; Sharma and Leong, 1999). According to Coelli *et al*. (1998), these three null hypotheses can be performed using generalized likelihood ratio test, given:

$$\lambda = -2[\ln\{L(H_o)\}-\ln\{L(H_1)\}]$$

where, $L(H_0)$ and $L(H_1)$ denote the values of the likelihood function for the null and alternative hypotheses, respectively. The value of λ is needed to be compared with the critical value of chi-square from the table of ordinary chi-square or from the table in Kodde and Palm (1986). Suppose λ of the hypothesis is greater than the critical value of chi-square, then this null hypothesis is rejected and otherwise. It should be reminded that the table in Kodde and Palm (1986) can only be referred if the case of $\gamma = 0$ occurs (the first and the second hypotheses); while the third hypothesis should refer to the table of ordinary chi-square distribution.

Besides, according to Sharma and Leung (1999) the input-output elasticity of each input cannot be obtained directly from the trans-log production function like obtain from Cobb-Douglas production function. Thus, input-output elasticity of each input has to be measured separately and it can be formulated as follows:

$$\text{Elasticity of variable H, } \partial \ln Y_j/\partial \ln H_j$$
$$= \beta_C+2\ \beta_{HH}\ (\text{mean of } \ln H_j)+\beta_{HS}\ (\text{mean of } \ln S_j)$$
$$+\beta_{HF}\ (\text{mean of } \ln F_j)+\beta_{HL}\ (\text{mean of } \ln L_j)$$

where, $\ln H_j$ is the input variable (for example: total size of paddy fields) in the stochastic production frontier. Sharma and Leung (1999) stated that the elasticity examines the sensitivity of the yield per hectare of the jth farmer ($\ln Y_j$) from a one percent change of total size of paddy fields ($\ln H_j$). Return to scale denotes the variation change in yield per hectare due to the variation change in the application of all the inputs (total size of paddy field, expenditure on seeds and fertilizer, number of workers). The return to scale can be calculated by summing up all the input-output elasticity Sharma and Leung (1999).

RESULTS AND DISCUSSION

This study had found that the average paddy production in the sample was 4.713 tons h^{-1}. Besides, all the null hypotheses testing that performed by generalized likelihood ratio tests were rejected, then this study had proceed to stochastic frontier analysis and technical inefficiency analysis (Table 2).

The mean technical efficiency for the sampled paddy farmers was estimated at 85.8%. The estimates coefficients for the frontier and inefficiency models are presented in Table 3. The coefficient of expenditure on seeds was positive and significant. Nevertheless, total size of paddy

Table 2: Generalized likelihood ratio tests

Null hypothesis	ln [L(H0)]	ln [L(H1)]	LR	Critical value	df	Decision
$\gamma = \delta_0 = \delta_1 = \ldots = \delta_6 = 0$	70.6	118.7	96.2	11.40*	7	Rejected
$\delta = 0$	116.3	118.7	4.8	3.81*	2	Rejected
Cobb-Douglas production function	109.9	118.7	17.6	0.16	10	Rejected

*Critical value obtained from Table 1 in Kodde and Palm (1986)

Table 3: Parameter estimates of the stochastic frontier analysis and technical inefficiency model

Variables	Coefficient	SE	t-test
Stochastic frontier analysis			
Constant	-1.776	1.176	-1.510
Total size of paddy fields	-2.641	0.744	-3.548***
Expenditure on seeds	1.963	0.880	2.230**
Expenditure on fertilizer	0.011	0.110	0.096
No. of workers	0.538	0.693	0.776
$(Size)^2$	-0.702	0.180	-3.892***
$(Seed)^2$	-0.367	0.164	-2.235**
$(Fertilizer)^2$	0.013	0.012	1.083
$(Workers)^2$	0.069	0.099	0.697
(Size) (Seed)	1.028	0.286	3.595***
(Size) (Fertilizer)	0.033	0.046	0.713
(Size) (Workers)	-0.044	0.268	-0.164
(Seed) (Fertilizer)	-0.020	0.042	-0.481
(Seed) (Workers)	-0.209	0.277	-0.755
(Fertilizer) (Workers)	0.026	0.032	0.833
Sigma-squared	0.674	0.445	1.513
Gamma	0.995	0.004	272.600***
Inefficiency model			
Constant	-1.898	1.653	-1.148
Tractor	-0.313	0.201	-1.557
Expenditure on pesticide…etc.	-0.00001	0.00006	-1.242
Experience	-0.061	0.042	-1.459
Education	-0.095	0.160	-0.594
Seminar/workshop	-0.788	0.463	-1.700*

*,**,***Statistically significant at 0.1, 0.05 and 0.01 level, respectively

Table 4: Input elasticity

Input variable	Elasticity
Total size of paddy fields	-0.319
Expenditure on seeds	0.242
Expenditure on fertilizer	0.003
No. of workers	-0.031
Return to scale	-0.105

fields showed the significant negative sign. The finding was in contrast to a priory expectation. This experience of contrast to a priory expectation had also been reported by Piya *et al.* (2012), Agahi *et al.* (2008), Bakhsh *et al.* (2006) Bamiro *et al.* (2006), Thiruchelvam (2005), Sharma and Leung (1999) and Battese and Coelli (1995). However, the sensitivity of output due to the changes of input had to be further verified and analyzed in elasticity analysis due to the lack of direct interpretation of parameters in trans-log production function (Sharma and Leung, 1999). In the square term, the coefficients of expenditure on seeds and total size of paddy fields showed the significant negative signs. In the interaction term, it was no surprise that the interaction between total size of paddy fields and expenditure on seeds showed the significant sign. Therefore, it was easy to note that these two inputs showed the leading effects in the stochastic frontier analysis.

In the inefficiency model, the estimated coefficients showed that all the variables had negative signs meaning that there were negative relationships between each variables and technical inefficiency. These findings were consistent with the previous findings (Battese and Coelli, 1995; Kiatpathomchai *et al.*, 2008). This study showed that only the variable for seminar or workshop was found to be effective in improving the technical efficiency of paddy production activities (Table 3).

The elasticity analysis that applied for the purpose to verify the sensitivity of output due to the changes of a input while other inputs remain constant, had showed that two inputs had positive effects and two inputs had negative effects on paddy production (Table 4). Expenditure on seeds and fertilizer with the elasticity 0.242 and 0.003, respectively indicating that although the use of these two inputs are almost reaching the optimal level, yet increase in expenditure on seeds and fertilizer can still increase the yield of paddy production. This findings was consistent with Piya *et al.* (2012), Agahi *et al.* (2008) and Bakhsh *et al.* (2006). However, size of paddy field and labor had the negative elasticity indexes which were 0.319 and 0.031 meaning that a one percent increase in the particular input, will lead to 0.319 and 0.031 percent decline in paddy production. This incident happened in this study due to these two inputs used had exceeded the optimal level. The negative elasticity index had frequently been found in previous studies (Piya *et al.*, 2012; Agahi *et al.*, 2008; Bakhsh *et al.*, 2006; Bamiro *et al.*, 2006; Thiruchelvam, 2005; Battese and Coelli, 1995). The negative elasticity of size of paddy field can be interpreted that the objective to improve production of paddy farming has no relative to increase the size of paddy field. It also can be believed that there is no persuasive reason to encourage the merging of small paddy fields into larger paddy field (Squires and Tabor, 1991). Besides, number of workers with the negative elasticity index was found to be consistent with the findings of Piya *et al.* (2012) and Bamiro *et al.* (2006). The negative elasticity of worker can probably be explained the involvement of family members in paddy farming had raised up the number of workers. It can be inferred that children from paddy farming families involved in the farming activity by helping their parents to manage the paddy farms, their involvement not only tends to reduce the cost of employing extra farm workers, but also as a significant contribution to the family. Finally, the return to scale is estimated at -0.105 meaning that it is at the third stage of production level. The negative effect of return to scale is seriously contributed by variable of size of paddy farms.

CONCLUSION

There are still rooms for improvement in technical efficiency that can be achieved by paddy farmers to fully utilize existing inputs. In addition, only the variable of seminar and workshop had a statistically significant influence in technical inefficiency model, suggesting that attending seminar and workshop of paddy farming can increase the technical efficiency of farmers. This activity can be encouraged and organized by government authority for the purposes of sharing knowledge and experience of paddy farmers, sharing latest information and farming practice in the paddy farming sector, announcing latest government policy or implementation on paddy farming sector. More farmers should be encouraged to attend more frequently to the seminar and workshop regarding paddy farming. Encouraging paddy farmers to attend seminar and workshop should be done by the government authority. This can be achieved through offering incentives, subsidies in order to lessen the opportunity cost of attending seminar and workshop. The government authority is encouraged to come out a policy to compel paddy farmers to attend seminar or workshop by setting it as a requirement to renew their licenses in order to improve their technical efficiency and paddy production. Besides, this study suggests an investigation on the effect of attending seminar or workshop in other domestic agriculture farming or other countries farming industries, this will be an interesting research area to further examine the role and importance of attending seminar or workshop in improving farming efficiency.

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