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Determinants of Technical Efficiency on Pineapple Farming

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ABSTRACT

This study analyzes the pineapple production efficiency of the Integrated Agricultural Development Project (IADP) in Samarahan, Sarawak, Malaysia and also studies its determinants. In the study area, IADP plays an important role in rural development as a poverty alleviation program through agricultural development. Despite the many privileges received by the farmers, especially from the government, they are still less efficient. This study adopts the Data Envelopment Analysis (DEA) in measuring technical efficiency. Further, this study aims to examine the determinants of efficiency by estimating the level of farmer characteristics as a function of farmer's age, education level, family labor, years of experience in agriculture, society members and farm size. The estimation used the Tobit Model. The results from this study show that the majority of farmers in IADP are still less efficient. In addition, the results show that relying on family labor, the years of experience in agriculture and also participation as the association's member are all important determinants of the level of efficiency for the IADP farmers in the agricultural sector. Increasing agriculture productivity can also guarantee the achievement of a more optimal sustainable living in an effort to increase the farmers' income. Such information is valuable for extension services and policy makers since it can help to guide policies toward increased efficiency among pineapple farmers in Malaysia.

Keywords: Integrated Agricultural Development Project (IADP), Data Envelopment Analysis (DEA), Gross Domestic Product (GDP), Constant Returns to Scale (CRS), Ordinary Least Square (OLS), Variable Returns to Scale (VRS)

1. INTRODUCTION

Agriculture remains an important sector of Malaysia's economy, contributing 3 percent to the Gross Domestic Product (GDP) and providing employment for 12 percent of the population Malaysia, 2010. Sarawak is one of the states that contributes about 1.8 percent of the country's commodity products; apart from the three main crops which are rubber, oil palm and cocoa, Sarawak also produces a number of fruits and vegetables for the domestic market, including bananas, coconuts, durian, pineapples, rice, rambutans and others to sustain the local and overseas needs. Malaysia is among the major crop producers in the world and traditional crops play an important role in the total agricultural production. The principal objectives of the Third National Agricultural Policy of Malaysia (NAP 3) are to enhance food security, increase productivity and the competitiveness of the sector, deepen linkage with other sectors, create new sources of growth and also to conserve and utilize natural resources on a sustainable basis. In order to achieve the vision of a high-income country, farmers are expected to operate under a much more competitive condition and increase their efficiencies to survive.

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Determining the existing level of efficiency will be useful to improve these relationships that can help farmers allocate their resources more wisely and also to assist the government in designing and searching for new policy tools to reach sector-specific goals.

2. MATERIALS AND METHODS

2.1. Study Area and Data Collection

The study area is the Integrated Agricultural Development Project (IADP) in Samarahan, Sarawak involving 14 villages located in the Central Division and Ulu Samarahan. It is one of the poverty alleviation programs through agricultural approach. The aim of this project is to promote integrated approaches in the effort and activities of all departments and agencies under the Ministry of Agriculture and Agro-Based Industry of Malaysia. It is also responsible in preparing the agricultural infrastructure and providing support services in this area. One of the project's objectives is to boost farm productivity and maximize income of the farming community in order to reduce the income gap among the people in the Division. Following the 2005/2006 production period, a questionnaire study was conducted and 124 farms growing pineapples were randomly identified from stratified sampling frame.

2.2. Analytical Procedures for Measuring Technical Efficiency

This study uses a two-step approach. In the first step, the DEA model is used to measure technical efficiencies of farms as an explicit function of discretionary variables. In the second step, farm-specific variables that are assumed to affect the efficiency of the farm are used in a Tobit regression framework to explain variations in measured efficiencies of farmers. Therefore, we begin by first providing a brief description of the DEA, followed by the Tobit's model.

2.3. Data Envelopment Analysis

DEA is a nonparametric method of estimating technical efficiency of farmers. It is a linear programming method proposed by Farrell (1957) to calculate the non-parametric boundary and the efficiency index for a particular farm is obtained by comparing the input and output obtained. It also does not require the assumption of adjacent technologies or distribution inefficiency. According to Farrell (1957), efficiency is expressed as the actual production of a farm compared with the maximum output that can be achieved, which is a reference to a production frontier. Therefore, the efficiency of farm production is the average distance measurement's output from the frontier level. Coelli (1996) developed such a multi stage methodology and a computer program (DEAP) which implements a robust multi-stage model among other options (Alemdar and Oren, 2006). A ratio of technical efficiency scores obtained from under CRS and VRS assumption measure scale efficiency. According to Coelli (1996), DEA model based on the Constant Returns to Scale (CRS) is stated as follows:

$$\begin{aligned} &\min_{\theta,\lambda} \theta \\ &\text{subject to} - y_i + Y\lambda \geq 0 \\ &\qquad \theta x_i - X\lambda \geq 0 \\ &\qquad \lambda \geq 0 \end{aligned} \quad (1)$$

Where:

- θ = The scale of technical efficiecy for each farm
- λ = As N×1 vector of constants
- y_i and x_i = The total output and farm inputs i,i = 1,2,...,n

The value of $\theta \leq 1$ indicates the level of production reflects the production frontier and technically efficient farms. The Equation 1 has used the assumption that all farms operate at an optimal scale. However, constraints such as finance and imperfect competition that occur at the field cause only part of the farm to operate at that level. Therefore, the above model can be estimated based on the Variable Returns to Scale (VRS), which evaluates the efficiency of farms based on their capabilities. VRS model is formed by inserting the constraints N1'λ in Equation 2, where N1 is N×1 vector (Coelli, 1996):

$$\begin{aligned} &\min_{\theta,\lambda} \theta \\ &\text{subject to} - y_i + Y\lambda \geq 0 \\ &\qquad \theta x_i - X\lambda \geq 0 \\ &\qquad N1'\lambda = 1 \\ &\qquad \lambda \geq 0 \end{aligned} \quad (2)$$

Constraints of $N1'\lambda = 1$ indicate the inefficiency of a farm evaluated against other farms of similar size. In this way, the efficiency of the farm can be evaluated based on technical and scale efficiency. Technical efficiency describes the ability of farms to achieve maximum production with the use of inputs given while the scale efficiency is the ratio between CRS and VRS.

The differences for both show the levels of scale inefficiency of production of farmers. The output-oriented DEA model based on the VRS is stated as follows (Coelli *et al*., 2002):

$$\begin{aligned} &\max_{\varphi,\lambda} \varphi \\ &\text{subject to} - \varphi y_i + Y\lambda \geq 0 \\ &\qquad x_i - X\lambda \geq 0 \\ &\qquad N1'\lambda = 1 \\ &\qquad \lambda \geq 0 \end{aligned} \quad (3)$$

where, $1 \leq \varphi < \infty$ and φ-1 is an increase in the ratio of output that can be achieved by farmers i-th, with a given quantity of inputs which is constant. $1/\varphi$ is the technical efficiency which has a value between 0 and 1 in Equation 3. The findings also explain scale efficiency. This study uses the program DEAP 2.1 (Coelli *et al*., 2002) to measure the technical efficiency of the output-based DEA model.

2.4. Tobit's Analysis

The present study uses a censored regression to analyze the role of farm-specific attributes in explaining efficiency in production of crops. We use a two-stage approach where the Tobit model is used to run a regression of the inputs and farm-specific characteristics as independent variables against the efficiency scores.

Tobit's model was introduced by Tobin (1958) involving a censored regression model of the economy (Hayashi, 2000) and first analyzed in the econometric literature (Maddala and Lahiri, 2009). As the efficiency index derived from data envelopment analysis is bound between 0 and 1 values, thus it is suitable for use as a simulation analysis to identify the determinant of technical efficiency among farmers. Efficiency index derived from the Equation 4 can be used as a measure of the performance of farmers. Based on previous studies, the influence of efficiency of farmers by Ordinary Least Square (OLS) has been used by Deller and Nelson (1991) to identify this factor through a regression model. Since the measurement of efficiency is censored with the value between 0 and 1, hence some arguments state that the estimation of OLS is inconsistent and inefficient (Mugera and Featherstone, 2008). For that reason, this study used the Tobit Model to replace OLS (Ray, 2004). The Tobit Model was also used by Bravo-Ureta *et al*. (2007); Chavas and Aliber (1993); Featherstone *et al*. (1997); Fried *et al*. (1999) and Rowland *et al*. (1998).

Briefly, Tobit's model can be written as follows:

$$y^*_t = x'_t \beta_0 + \epsilon_t, t = 1,2,3,...,n \quad (4)$$

$$y_t = y^*_t \text{ if } y^*_t > c; \text{dan } y_t = c, \text{otherwise} \quad (5)$$

where, y_t is a DEA efficiency index used as a dependent variable, $\epsilon_t|x_t$ is $N(0,\sigma_0^2)$ and $\{y_t,x_t\}(t = 1,2,...,n)$ is a vector of independent variables related to farm-specific attributes, value of c is known. y_t* is a latent variable. β is an unknown parameter vector associated with the farm-specific attributes and ε is an independently distributed error term that is assumed to be normally distributed with zero mean and constant variance, σ^2. A Tobit regression model applying the maximum likelihood approach is used to estimate the model in Equation 4 such that Equation 6:

$$L = \prod_{yt=0}(1 - Ft)\prod_{yt>0}\frac{1}{(2\prod\sigma^2)^{1/2}}e[1/2\sigma^2](yt - \beta x)^2 \quad (6)$$

where, $F_t = \int_{-\infty}^{\beta^t xt/\sigma} \frac{1}{(2\prod^{1/2})} e - ^{-i^2/2} \partial i$.

The Equation 5 refers to the efficiency score of farmers 100% (y = c) and the second term represents inefficient farmers (y > c). F_t is normally scattered in the $\beta^t x_t / \sigma$.

Farm level technical efficiency scores are used in the regression model to show the relationship between the measurement of the efficiency and characteristics of farmers. Based on the literature, several variables have been identified to explain the technical efficiency levels among farmers in the study area. The variables are age, education level, family labor, year of agricultural experience, association participation and farm size. Justifications for inclusion of these variables are based on surveys and interviews conducted during the research survey in which these variables affect their productivity. Therefore, the hypothesis of the study estimates that these variables also influence the level of technical efficiency of farmers in the study area.

3. RESULTS AND DISCUSSION

3.1. Descriptive Statistics

A study on the performance of farmers is conducted to determine its ability to provide maximum output with the given inputs. Therefore, the DEA efficiency score can be summarized to show how much supposedly the farmers maximum output production is without addition of input if it can be considered as the best technical efficiency. DEAP 2.1 program developed by Coelli (1996) was used to calculate the technical efficiency of farmers' pineapple cultivation in IADP Samarahan, Sarawak. The technical efficiency is estimated by using the approach of maximizing the output subject to constant input and evaluated on the CRS and VRS. Scores for technical efficiency, scale efficiency and the level of the position of each farmer were estimated (**Table 1**).

3.2. Efficiency Score

Table 1 shows the descriptive statistics for the results of technical efficiency of pineapple farmers as classified. Scores ranging from 0-100% show that the estimation of the CRS for farmers is less than 0.2. On the average, all of them are far from the maximum output capacity that is in the interval of 82.3-86.3%, without increasing the input which is about 0.1766. This reflects the average level for farmers to be able to maximize output with a target increase in total is more than 80%.

When the VRS technology is assumed, the average technical efficiency is higher than 0.2. This shows that farmers can produce their output around 70-74% by using the same inputs. The VRS technical efficiency is used to measure the relative decline in output that is not a result of the constant return to scale. The scores of technical efficiency in CRS and VRS are to determine whether the trend is of farmers operating at increasing return to scale or return to decline. If the score of technical efficiency at VRS is larger than CRS, this means that the farmers are increasing their scale of returns.

Meanwhile, scale efficiency measures the relative loss of output due to the constant's returns to scale represented by the value of one or close to one. The results of this study show that on average, there were no farmers operating at that stage (**Table 2**). Based on these principles, the analysis of the results of this study shows that all farmers who are inefficient are in the position of operating at increasing returns to scale. This result is consistent with previous studies by Byrnes *et al*. (1987) and Wu *et al*. (2003). According to the theory, increasing returns to scale suggests that the increase of output is higher than inputs. In contrast, the diminishing return to scale indicates that the increase of output is less than the increase in inputs.

Table 1. Frequency distributions of technical efficiency scores obtained with the DEA model

	DEA		
Efficiency scores	CRS	VRS	SE
1.00	2 (1.6)	5 (4.0)	42 (33.9)
0.90-0.99	1 (0.8)	1 (0.8)	43 (34.7)
0.80-0.89	1 (0.8)	2 (1.6)	16 (12.9)
0.70-0.79	1 (0.8)	-	5 (4.0)
0.60-0.69	2 (1.6)	3 (2.4)	13 (10.5)
0.50-0.59	3 (2.4)	3 (2.4)	1 (0.8)
<0.50	114 (91.9)	110 (88.7)	5 (4.0)
Mean	0.1766	0.2927	0.8893
Minimum	0.010	0.013	0.167
Maximum	1.000	1.000	1.000
Standard deviation	0.2486	0.2158	0.1586

Sources: Field survey (2005)

Table 2. Efficiency of pineapple production based on the scale of production among farmers in IADP samarahan, sarawak

Production scale	Frequency	Percentage
Increase Return to Scale (IRS)	64	15.6
Constant return to scale (Optimal)	42	33.8
Decrease Return to Scale (DRS)	18	12.9
Total	124	100.0

Sources: Field survey (2005)

Table 3. Variables used in the tobit model

Variables	Definition
TE	Technical efficiency score
Age	Year of age
Level of education	1= Secondary school and above, 0 = others
Family labor	1= Yes, 0 = No
Agriculture experience	Year of agriculture experience
Association	1= Member of association, 0 = others
Land	Size of farm

Table 4. Summary statistics for variables in the Tobit regression model

Variables	Mean	Standard deviation	Minimum	Maximum
Age	51.00	11.14	29.0	84
Level of education	0.68	0.47	0.0	1
Family labor	0.23	0.43	0.0	1
Agricultural experience	32.77	12.28	4.0	64
Association	0.93	0.26	0.0	1
Land	3.60	5.08	0.5	51

Sources: Field survey (2005)

Table 5. Results of the Tobit regression analysis

Variable	Tobit	SE	t-ratio	Significance
Constant	0.0733	0.054250	1.352	0.1760
Age	-0.0007	0.001479	-0.457	0.6480
Level of education	0.0317	0.055770	0.568	0.5700
Labor	0.0837	0.033790	2.476	0.0130
Experience	0.0002	0.001471	0.165	0.8690
Association	0.1541	0.073970	2.083	0.0380
Acre	0.0240	0.012690	1.883	0.0600
R-square				0.6414
Adjusted r-square				0.6230

Sources: Field survey (2005)

3.3. Determinant Factors

Further analysis was conducted using Tobit to identify the determinants of technical efficiency among pineapple farmers. In this analysis, the score of technical efficiency of CRS and VRS of the farmers are used as the dependent variable, while the independent variables consist of the variable of age, education level, use of family labor, agricultural experience, participation in association and land acreage. Definition of the variables are shown in **Table 3**. The SHAZAM programs were used to analyze and the model estimated is as follows:

$$TE = \beta_0 + \beta_1 Age + \beta_2 Education + \beta_3 Labour$$
$$+ \beta_4 Experience + \beta_5 Association + \beta_6 Farmsize + \varepsilon$$

Table 4 shows the summary statistics for the variables used in the Tobit regression model. The average age of the pineapple farmers is 51 years old and 64% of the farmers has secondary education and above. Due to the diversity of crops, labor intensive assistance among pineapple farmers (23%) are necessary. The farmers have a mean of 32 years of agricultural experience, while on average each farmer runs almost 4 acres of land for pineapple plantation. In addition, most of the farmers are actively involved in the agricultural association (93%) as a way of getting information and assistance from the IADP as input in ensuring the smooth running of the project.

In order to get the information on determinants of inefficiency, efficiency scores were regressed upon some demographic information of the farmers and the environmental variables. Technical efficiency score was used as the dependent variable. Since the scores are bounded in between zero to one, the use of the ordinary least-square regression model is unsuitable. Hence, a Tobit analysis model was employed. **Table 5** shows the Tobit regression results that examined the relationships between technical efficiency scores and age, level of education, labor uses, agricultural experience, participation in association and land size. As seen from the table, relying on labor (1% level), participating in association (5% level) and land size (10% level) have significant effects on efficiency scores. Signs of the parameters are positive and as expected. This indicates that farms with the addition of family labor are more efficient. Farms with less family labor usage are inefficient. During the survey, it was found that the farmers are helped by their children and villagers especially when harvesting the crops. This is to avoid damage due to the delay in harvesting the agricultural product.

Association participation also has a positive relationship with the level of technical efficiency among pineapple farmers. This shows that the more active the farmers are in their involvement in the farmer association and in the society, the more information of farm activities carried out and agricultural input distribution they have compared to those who do not join the association. It can also provide the farmers the opportunity to share information and modern practices with other farmers. Signs of the area parameter are positive and as expected. This indicates that the bigger farms are more efficient and this result is consistent with the result by Gul (2006). Meanwhile, the farmer's age is negative and is not significantly related to technical efficiency and this result is supported by Onyenweaku *et al*. (2004). Farming experience is positive and not significantly related to technical efficiency. The findings are consistent with the results by Rahman and Umar (2009) and Idiong (2007). This means that being an experienced farmer is not good enough to achieve higher level of efficiency. However, this result contradicts that of Onyenweaku and Nwaru (2005). Education shows no significant relationship with technical efficiency. This result is consistent with that of Onu *et al*. (2000) but does not tally with that of Onyenweaku and Effiong (2005). A logistic analysis is also performed and it shows that farmer-related variables such as family labor, agricultural experience and land areas are more important than the variables of age and farmers' education in determining the efficiency level in IADP Samarahan, Sarawak. The results of this study are consistent with the findings of the study conducted by Coelli *et al*. (2002); Dhungana *et al*. (2004); Binam *et al*. (2004); Spellman *et al*. (2008) and Wadud and White (2000).

4. CONCLUSION

The objective of this study was to apply a two-step methodology to investigate the technical efficiency and assess the factors that influence the efficiency of crop production in IADP Samarahan, Sarawak. The lack of empirical studies in Malaysia, which focus on the factors affecting the efficiency of the crop production, motivated this study. Most of the pineapple cultivators in IADP Samarahan scored less than 0.5, which means they were operating at an inefficient level and should be more productive to maintain the number of inputs and to produce at the production frontier level of the border or best practices. The policy implication from this study suggests that the introduction of contract labor to assist farmers in farm work, the strengthening of association and active participation and the increase in the area of crops are important factors in contributing to the improvement of technical efficiency among pineapple farmers in achieving the target of pineapple production of 16,000 tons/acre in IADP Samarahan itself (MAAI, 2008). It is important to contribute to the increase in food security and competitiveness in the agricultural sector to achieve the production target of 25 tonnes/acre in order to generate net income of RM2830 (MPIB, 2010). Increasing agricultural productivity and sustainability in the use of natural resources can also guarantee the achievement of a more optimal sustainable living in an effort to increase the farmers' income in line with the recommendations of the third objective of the National Agricultural Policy.

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