Efficiency and Environmental Awareness of Paddy Farmers: Stochastic Frontier Analysis vs Data Envelopment Analysis

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***Abstract*— This study compares the paddy production efficiency and farmers environmental awareness using both stochastic frontier analysis (SFA) and data envelopment analysis (DEA), the primary data collected from paddy farmer organizations known as Pertubuhan Peladang Kawasan (PPK) under Muda Agricultural Development Authority, Kedah, Malaysia. From the results, the coefficients of area and wage are observed significant and positive impact on paddy production while the effect of overall cost, cost on seed and fertilizer are found negative but the cost on fertilizer is recorded significant. The knowledge on environment and contract with agricultural officers are two exogenous factors that has positive significant impact while the education of the farmer factor has a negative significant impact. All the PPKs performance considered is observed on an average but they have the opportunity to increase more than 50% of their production by using same amount of inputs. The performance of Kerpan PPK is found higher than that of other PPKs when the effects of exogenous factors are considered in SFA. The performance of Kubang Pasu PPK is found minimum comparing to the other PPKs using DEA which is observed similar with SFA with exogenous factors. Again, the Kepala Batas PPK is recorded higher relative performance.**

***Keywords*—** *Data envelopment analysis, Efficiency, Rice production, Stochastic frontier analysis.*

1. Introduction

When Paddy has been one of the strategic sectors for food security in Malaysia and under the Ninth Malaysia Plan (NMP) (2006 –2010), the Government of Malaysia adopted a policy goal to increase self-sufficiency to 90% in rice production. However this plan is dropped under Tenth Malaysian Plan (TMP) (2011-2015) due to lack of land available for production. Although Malaysia's rice production and productivity increase each year, its yield per capita declines each year. From a high of 174.6 kg of rice per capita in 1974, rice yield per capita has since fallen steadily, falling to 86.0 kg of rice per capita in 2008 [1]. This has not in any way, guaranteed self-sufficiency as over 700,000 tons or 30% of its rice needs were being imported their neighbouring countries annually. Again, there is growing concerns that the global warming affects the productivity of rice crop [2]. Rice production in Malaysia is constrained by bio-physical and economic factors especially high costs of production and high application rates of chemical fertilizers. The actual outputs from rice production process are not only paddy rice but also the potential negative environmental effects. The flooded condition generates methane gas emission, while the excessive use of N-fertilizers causes the emission of nitrogen gases and the leaching of nitrate. In regards to this scenario, a strategy must be planning in details to increase domestic rice production and cut rice imports, for the forthcoming years. It is believed that the nation has planned many strategies and programs to overcome the existing problems in the rice production in Malaysia. However, the existing rice production systems, the efficiency of paddy farmers along with environmental awareness are under question.

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Efficiency measures are important because of its vital role on productivity growth. Efficiency measurement has been the concern of researchers with an aim to investigate the efficiency levels of farmers engaged in agricultural activities. Identifying determinants of efficiency levels is a major task in efficiency analysis. One of the most important avenues for reducing production cost is to increase yield per unit area by increasing efficiency. If one knows the existing efficiency level of paddy farmers in using the inputs for rice production then government can take viable plans to increase the rice production up to the maximum level. If paddy farmers are technically efficient, then the government has to increase investment and has to adopt new technology in order to increase production to meet its consumption needs. The internal productivity of the country can be increased by improving the technical efficiency of the paddy farmers.

A number of studies examined the technical efficiency of paddy farmers in developing countries [3] and a few studies focused on the productivity analysis in agricultural sector in Malaysia [4]. The most influential factors of technical efficiency of irrigated rice farmers are identified by the studies of [5], [6], [7] and [8], mentioned that the actual farm yields of rice in Malaysia vary from 3 to 5 tons per hectare, where potential yield is 7.2 tons. Studies by [9] mentioned that rice production in Malaysia is going to end due to the continued decline in cultivated area, negligible gains in productivity, continued increases in the cost of production and decreasing profitability. Studies are available by [10] to see the impacts of changes in government intervention policy, namely the fertilizer subsidy on the Malaysian paddy and rice industry using simulation approach. A study by [11] reveals that positive attitudes toward ecosystem services are most likely held by farmers with high income, showing that financial means are key determinants of farmers' environmental attitudes. However, little work has been done to estimate the technical efficiency along with environmental role in agricultural production system as studies by [12], [13] and [14], which are expected to play an important role in the reduction of environmental pollution. Unfortunately, they did not employ any sophisticated technique whether stochastic frontier analysis or data envelopment analysis to measure paddy farmer's efficiency along with environmental awareness in northern region of Malaysia in efficiency analysis.

This study explores the existing rice production systems and the current management practices (proper distribution and application of seed and fertilizer on the basis of rice cultivated area), measure technical efficiency of paddy farmers in northern region of Malaysia; identify its determinants causing efficiency differential among paddy farmers, and its relation to paddy farmer's environmental orientation. It makes some recommendation based on the findings that may assist policy makers to design and formulate agricultural policy to increase rice production in Kedah, Malaysia.

2. Material and Methods

The study has been conducted by using the materials and methods as follows:

2.1 Survey Area

This study is conducted in MADA for area in Kedah, Malaysia to provide a picture of rice production systems and paddy farmers' efficiency along with their environmental awareness.

2.2 Data Collection Procedures

The questionnaire includes sections on the background characteristics of the paddy farmer's e.g. household size, gender, ethnic group, religion, education level, and so on; knowledge on rice production or output, yield of rice, rice production cost, human labor used, land area, amount of seed, and amount of manure and so on; farm-specific information about paddy farmers.

2.3 Sample Size and Sampling Design

There are 4 districts available in MADA and among these 4 districts, 1 PPK is selected randomly from each Wilayah in Kedah state. From each PPK, 50 paddy farmers are selected randomly and the sample total size for this study is 200. The sample size is calculated:

$$n = z^2 \left[\frac{P(1-P}{d^2} \right] * Deff \qquad (1)$$

where n is sample size, z is two-sided normal variate at 95% confidence level (1.96), P is indicator percentage, d is precision and $Deff$ is

design effect.
To obtain data on indicators at 10% precision and 95% confidence interval, assuming a design effect of 2.08 and the most conservative estimate of indicator percentage (50%).

2.4 Stochastic Frontier Analysis Model

In this framework, the stochastic frontier production model is suggested by [15] defined as:

$$Y_i = f(X_i, \beta) + \varepsilon_i = f(X_i, \beta) + V_i - U_i, i = 1,2,..N \quad (2)$$

where, Y_i represents the rice production of the *i-th* paddy farmers of the farm families, X_i is a vector of input quantities of the *i-th* paddy farmers, and β is a vector of unknown parameters for the stochastic frontier. V_i is distributed as $NID(0, \sigma_v^2)$, and independent of U_i. The U_i is non-negative random variable that represents technical inefficiencies in production and is assumed to be distributed as $NID(\mu, \sigma_u^2)$ with truncation at zero. The relationship between U_i and the output-oriented technical efficiency (TE) is:

$$TE = \exp(-U_i) \quad (3)$$

2.5 Stochastic Frontier Inefficiency Effects Model

In this framework suggested by [16] add the following assumption that U_i is non-negative random variable which is assumed to account for technical inefficiency in production and to be independently distributed as truncations at zero of the $N(\mu, \sigma_u^2)$ distribution; where $U_i = Z_i\delta$; where Z_i is a $(1xp)$ vector of explanatory variable which may influence the inefficiency of Paddy farmers and δ is a $(1xp)$ vector of parameters to be estimated. The Technical inefficiency effect, U_i in the stochastic frontier model is specified as:

$$U_i = Z_i\delta + W_i \quad (4)$$

where, the random variable, W_i follows truncated normal distribution with mean zero and variance σ^2, such that the point of truncation is $-Z_i\delta$ .Parameters of the stochastic frontier given by equation (2) and inefficiency model given by equation (3) are simultaneously estimated by using maximum likelihood estimation. After obtaining the estimates of U_i the technical efficiency of the *i-th* paddy farmers is given by:

$$TE = \exp(-U_i) = \exp(-Z_i\delta - W_i) \quad (5)$$

2.6 Data Envelopment Analysis Model

Consider *n* DMUs (decision making unit) or paddy farmers of the farm families with *m* inputs and *k* outputs each one producing different output (*y*) and using different inputs (*x*). The efficiency of the paddy farmers (Constant Return to Scale) is measured:

$$Max_{\theta,\lambda}\theta$$

Subject to

$$\theta y_r - \sum_{j-1}^{n} \lambda_j y_{rj} \ge 0$$

$$-x_i + \sum_{j-1}^{n} \lambda_j y_{rj} \ge 0 \quad (6)$$

$$\lambda_j \ge 0, j = 1,..n, i = 1,..m, r = 1,..k$$

The efficiency of paddy farmers (Variable Return to Scale) is measured:

$$Max_{\theta,\lambda}\theta$$

Subject to

$$\theta y_r - \sum_{j-1}^{n} \lambda_j y_{rj} \ge 0$$

$$-x_i + \sum_{j-1}^{n} \lambda_j x_{ij} \ge 0 \quad (7)$$

$$\sum_{j-1}^{n} \lambda_j = 1$$

$$\lambda_j \ge 0, j = 1,..n, i = 1,..m, r = 1,..k$$

where, θ indicates the efficiency score of DMUs, and it will satisfy $\theta \le 1$, with a value of 1 indicating a point on the frontier, x_{ij} indicates the *i-th* input of the *j-th* DMU or paddy farmers, y_{rj} indicates the *r-th* output of the *j-th* DMU or paddy farmers, λ_j indicates the weight of the *j-th* DMU or paddy farmers.

3. Results and Discussion

Table 1 presents the frequency distribution of factors which are associated with paddy farming. More than 90% of the farmers are over aged that is their age is more than 40 years. Most of the farmers (about 80%) have education up to SPM, however, about 15% farmers are illiterate and only 5.5% farmers have education more than SPM. More than 97% farmers are Malay and only 2.5% farmers are from other race. More than 75% farmers did not participated in any course or training on technology in the last five years. About 70% farmers did not take loan for cultivating paddy. Every three out of five farmers keep in touch with agriculture extension officer. According to majority of the farmers the soil condition for cultivation of paddy is very good while only 2.5% farmers rated it very bad or damaged. More than 87% farmers are found to be living primarily on farming. Almost half of the farmers do farming on their farms. Consider *n* DMUs (decision making unit) or paddy farmers of the farm families with *m* inputs and *k* outputs each one producing

3.1 Results of Likelihood-Ratio Test

To find out appropriate production function for paddy farming in Kedah, Malaysia, the following hypothesis is set up.

HA: There is a significant difference in Cobb Douglas production model and Translog production model.

It is evidence from Table 2 that the hypothesis HA may not be rejected at 1% level of significance. That is, there is a significant difference to express paddy farming system in Kedah using Cobb Douglas production model and Translog production model. Since the log likelihood value of Cobb Douglas production model is greater than that of Translog production model, the Cobb Douglas production model is found more appropriate.

Table 1
Frequency Distribution of Factors which are Associated with Paddy Farming

	Frequency	Percentage
Age distribution of the respondents		
<30	5	2.5
30-39	12	6.0
40-49	40	20.0
50-59	54	27.0
>59	89	44.5
Educational background of the farmers		
No education	31	15.5
Upto SPM	158	79.0
More than SPM	11	5.5
Race of the respondent		
Malay	195	97.5
Others	5	2.5
Got training on technology or attain in courses in 5 years		
Yes	47	23.5
No	153	76.5
Take loan for cultivation		
Yes	56	28.0
No	139	69.5
Contact with Agricultural Officer		
No	85	42.5
Yes	115	57.5
Soil condition of paddy field		
Very good	104	52.0
Moderate	88	44.0
Damaged	5	2.5
Cultivation of paddy as primary work		
Yes	175	87.5
No	25	12.5
Farming system		
Individual	94	47.0
Mini state	13	6.5
Estate	93	46.5

Table 2
Selection of the Appropriate Stochastic Frontier Production Model

Production Function	Degree of Freedom	Log Likelihood value	Chi Square: Difference between the Degree of Freedom	Chi Square: Value
Cobb Douglas	11	-261.76	12	315.84***
Translog	23	-419.68		

3.2 Results of Stochastic Frontier Analysis

To Maximum likelihood estimation of the Cobb Douglas production model is shown in the Table 3. Total production area and overall cost of cultivation have positive significant impact on the production of paddy at 1% and 5% level respectively whereas wage of labor, cost on seed and fertilizer have negative impact on production. However, influence of cost on seed is significant at 1% level.

The gamma parameter (γ) indicates whether all deviations from the stochastic frontier model are due to random error or technical inefficiency. If gamma (γ) is close to zero this indicates that all deviations from the model are caused by random error. However, if gamma (γ) is equal to unity, then all deviations are caused by technical inefficiency [17], [18] and [19]. The estimated gamma parameter (γ) is 0.73, indicating that all deviations from the model are attributable to technical inefficiency.

Table 3
Maximum Likelihood Estimation of Cobb Douglas Stochastic Frontier Production Model

Parameters	Estimate	Std. Error	Z-value
Intercept	6.13***	1.315	4.657
Area	1.79***	0.191	9.331
Overall Cost	0.16**	0.061	2.540
Wage	-0.10	0.140	-0.692
Seed	-0.67***	0.117	-5.667
Fertilizer	-0.19	0.227	-0.837
Sigma Square (σ^2)	1.56***	0.235	6.626
Gamma(γ)	0.73***	0.074	9.858

*** highly significant, ** 5% level of significant

Figure 1 presents the PPK-wise performance in paddy production of Kedah, Malaysia. It is observed from Figure 1 that most of the PPK is performing on an average. That is, most of the PPKs or farms have opportunity to increase more than 50% of their production using same amount of inputs. However, rice producing farmers 1, 2, 3, 4 and 10 from Kubang Pasu PPK and rice producing farmers 16, 19 and 22 from Kerpan PPK have very low performance which is below 0.30. That is, these farmers can increase their production about 70% using the current amount of inputs. Though farmers 5, 6, 8, 9 and 11 from Kubang Pasu PPK and farmers 5 from Kerpan PPK have high performance which is above 0.80, they still can improve their production with the same technology to be efficient.

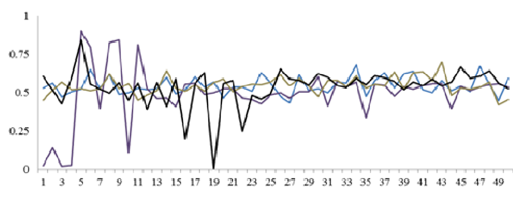

Figure 1: Performance of Selected PPKs in Kedah, Malaysia using SFA

Effect of exogenous factors is considered in production function and maximum likelihood estimation of the variables is shown in Table 4. Similar to [15] and [16] models, Table 3 and Table 4 respectively are showing same directional effect for area and fertilizer whereas for overall cost and wage have opposite directional effect. In [16] model, area and wage have significant positive effect on production. Effect of overall cost, cost on seed and fertilizer are negative however, only cost on fertilizer is significant for producing paddy in Kedah, Malaysia. As exogenous factors, knowledge on environment and keep in touch with agricultural officers has positive significant impact. Effect of education of the farmers is significant but negative impact on production of rice. The estimated gamma parameter (γ) is 0.00008, indicating that all deviations from the model are due to random error.

Table 4
Maximum Likelihood Estimation of Cobb Douglas Stochastic Frontier Production Model with Exogenous Factors

	Estimate	Std. Error	*Z* value
Input Variable			
Intercept	10.877***	1.832	5.937
Area	2.605***	0.269	9.701
Overall Cost	-0.042	0.129	-0.323
Wage	0.693***	0.252	2.749
Seed	-0.068	0.258	-0.265
Fertilizer	-2.667***	0.249	-10.718
Exogenous Factor			
Intercept	3.301***	1.417	2.329
Environmental Knowledge	0.253***	0.046	-5.472
Contact with AO (dummy)	2.222***	0.327	6.798
Education	-0.783***	0.086	-9.145
Primary work (dummy)	-0.444	0.393	-1.129
Age	0.253	0.181	1.401
Sigma Square (σ^2)	5.653***	0.139	40.809
Gamma (γ)	0.00008	0.0000022	0.598

From Figure 2, it is evidence that paddy production performance of Kerpan PPK is higher than that of all other PPKs when effects of exogenous factors are considered. Performance of Kubang Pasu PPK is very low except the rice producing farmer of number 9. There are nine farmers in Kerpan PPK, three farmers in Kepala Batas PPK and Kubang Sepat PPK which are performing with score of one or near to one. That is, performances of these farmers are found very high.

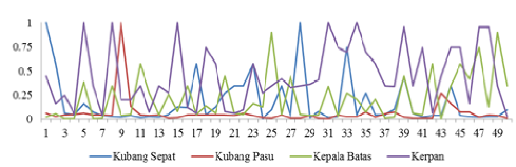

Figure 2: Performance of Selected PPKs using SFA when Exogenous Factors are considered in Kedah, Malaysia

3.3 Results of Data Envelopment Analysis

Table 5 presents the descriptive statistics of relative performance of the selected PPKs. DEA provides relative efficiency or relative performances of all paddy producing farmers for the selected PPKs are estimated. In case of both Kubang Sepat PPK and Kepala Batas PPK, relative performance with score of one is not observed for any farmers but the exception is Kubang Pasu and Kerpan PPKs. Minimum relative performance of a farmer for Kubang Sepat PPK, Kubang Pasu PPK and Kerpan PPK are found at 0.001 however, minimum performance of a farmer of Kepala Batas PPK is found at 0.70. Overall average performance of farmers is 0.787. Average relative performance of the farmers of Kubang Pasu PPK is only 0.632 whereas for Kepala Batas PPK is 0.937.

Table 5
Descriptive Statistics of Performance of Selected PPKs using DEA

	Minimum	Maximum	Mean
Kubang Sepat	0.001	0.996	0.794
Kubang Pasu	0.001	1	0.632
Kepala Batas	0.7	0.998	0.937
Kerpan	0.001	1	0.783
Overall	0.001	1	0.787

Figure 3 is showing performance of the selected PPKs by Data Envelopment Analysis (DEA). Performance of Kubang Pasu PPK is found minimum using DEA which is similar with SFA findings with exogenous factors. In terms of performance, Kepala Batas PPK has higher relative performance. Few farmers of PPKs for Kubang Sepat, Kubang Pasu and Kerpan are showing very low relative performances which are near to zero, on the other hand, not a single farmer in Kepala Batas PPK who has such a low performance.

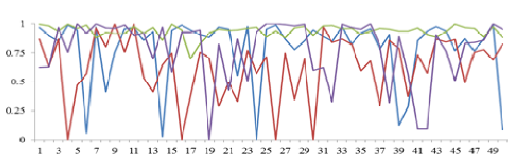

Figure 3: Performance of Selected PPKs using DEA

4. Conclusions and Suggestions

This study explored the farming system of paddy and the farm specific performance using SFA and DEA in Kedah, Malaysia. Cobb Douglas production function is found more appropriate than Translog production using Likelihood-Ratio test. Performance of the paddy farmers is measured using both [15] and [16] models. Area and cost on seed have significant positive and negative effect on paddy production in both models respectively. Overall cost has positive significant effect when the exogenous factors are not considered in model. However, wage has positive significant effect when the exogenous factors are considered in model. In relative performance, paddy farmers from Kepala Batas PPK are more efficient than other PPKs. Performance of Kubang Pasu PPK is found lowest. There is a similarity in SFA and DEA results when the exogenous factors are considered in the model.

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References

[1] World Bank, Rice Irrigation in Malaysia: "*Economic Change and Choice of Irrigation Technology*", World Bank Report, 2010.

[2] F. Y. Tao, Z. Z. Hayashi, T. Sakamoto, and M. Yokozawa, "*Global Warming, Rice production and Water Use in China: Developing a Probabilistic Assessment*", Agric. Forest. Meteorol, 148: 94-110, 2008

[3] G. E. Battese, and G. S. Broca, "*Functional form of stochastic frontier production functions and models for technical efficiency effects: a comparative study for wheat farmers in Pakistan*", Journal of Productivity Analysis, 8: 395-414, 1997.

[4] C. O. Akinbile, K.M. Abd El-Latif, A. Rozi and M. S. Yusoff, "*Rice production and water use efficiency for self-sufficiency in Malaysia: A review*", Trends Appl. Sci. Res., 6(10): 1127-1140, 2011.

[5] K. M. Gedara, C. Wilson, S. Pascoe, and T. Robinson, "*Factors Affecting Technical Efficiency of Rice Farmers in Village Reservoir Irrigation Systems of Sri Lanka*",

Journal of Agricultural Economics, 63: 627–638, 2012.

[6] M. Diagne, M. Demont, P. A. Seck, and A. Diaw, "*Self-sufficiency policy and irrigated rice productivity in the Senegal River Valley*", Food Security, 5(1): 55-68, 2013.

[7] Y. Tun, and H. J. Kang, "*An Analysis on the Factors Affecting Rice Production Efficiency in Myanmar*", Journal of East Asian Economic Integration, 19(2), 167, 2015.

[8] S. Singh, R. Amartalingam, W. S. Wan Harun and M. T. Islam, "*Simulated impact of climate change on rice production in Peninsular Malaysia*", Proceeding of National Conference on Climate Change 1996, pp. 41–49.

[9] G. P. Lopez, Economic reforms for paddy sub-sector, The Star Online, 25June, available at http://biz.thestar.com.my/news/story.asp?file=/2007/6/25/business/18087959&sec=business, 2007.

[10] N. N Ramli, M. N.,Shamsudin, Z. Mohamed, and A. Radam, "*The Impact of Fertilizer Subsidy on Malaysia Paddy/Rice Industry Using a System Dynamics Approach*". International Journal of Social Science and Humanity, 2(3): 213-219, 2012.

[11] P. Poppenborg, and T. Koellner, "*Do attitudes toward ecosystem services determine agricultural land use practices? An analysis of farmers' decision-making in a South Korean water shed*". Land Use Policy, 31: 422-429, 2013.

[12] S. Reinhard, C.A.K. Lovell, and G. Thijssen, "*Econometric Estimation of Technical and Enviroutch Dairy Farms",* American Journal of Agricultural Economics. 81:1, 44-60, 1999.

[13] T. Zhang, and B. D. Xue, "*Environmental Efficiency Analysis of China's Vegetable Production",* Biomedical and Environmental Sciences 18, 21-30, 2005.

[14] Y. Wu, "*Analysis of Environmental Efficiency in China's Regional Economics",* Paper Prepared for Presentation at the 6th International Conference (IS China's Development Sustainable?) on the China Economy, 2007.

[15] G. E. Battese, and T. J. Coelli, "*Frontier Production Functions, Technical Efficiency and Panel Data: With Application to Paddy Farmers in India*", Journal of Productivity Analysis, 3(1/2), 153-169, 1992.

[16] G. E. Battese, and T. J. Coelli, "*A model for technical inefficiency effects in a stochastic frontier production function for panel data*", Empirical Economics 20: 325-332, 1995.

[17] P. Phan, "*Trade Liberalization and Manufacturing Performance in Thailand 1990-2000*", PhD Thesis, School of Economics, Faculty of Commerce, University of Wollongong, 2004.

[18] T. J. Coelli, D. S. P Rao, C. J. O'Donnell, and G. E. Battese, "*An Introduction to Efficiency and Productivity Analysis",* 2nd edn, Springer, New York, 2005.

[19] T. B. Tran, R. Q. Grafton and T. Kompas, "*Firm Efficiency in a Transitional Economy: Evidence from Vietnam*", Asian Economic Journal, vol. 22, no. 1, pp. 47-66, 2008.