Technical Efficiency of Pepper Farms in Sarawak, Malaysia: An Application of Data Envelopment Analysis

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Abstract

This study is carried out to analyze the performance of pepper farms in Sarawak by estimating the level of technical efficiency and to identify the determinants of technical efficiency of pepper farms. Data Development Analysis (DEA) method were applied to estimate technical efficiency levels and Tobit analysis were used to investigate the determinants of technical efficiency of pepper farms. A sample of 678 pepper farmers was selected for this study through field survey that was conducted from August to December 2009. The results show that the mean of technical efficiency under constant returns to scale (CRS) and variable returns to scale (VRS) were 0.567 and 0.661, respectively. Meanwhile, efficiency in farm management is positively and significantly influenced by education level, the frequency of contacts with extension agents per year, being member of farmer's association, being full-time pepper farmers, and joining farming courses and study visits.

Keywords: Pepper (*Piper Nigrum L*), Technical efficiency, Data envelopment analysis (DEA), Tobit Analysis

1. Introduction

Today, pepper occupies a central and unique position and it is an important foreign exchange earner for several countries, including Malaysia. Until 2011, Malaysia was the fifth largest pepper producer in the world while Vietnam was the largest pepper producer (100,000metric tonnes) followed by India (48,000 metric tonnes), Indonesia (37,000 metric tonnes), Brazil (35,000 metric tonnes), Malaysia (25,672 metric tonnes), Republic of China (23,300 metric tonnes), and other countries (International Pepper Community (IPC), 2012). Most of Malaysian pepper (90%) is produced in Sarawak and the remainder comes from Johor, Malacca, and Sabah and as a result the commercial name for Malaysian-grown pepper is Sarawak Pepper in the world marketplace. Pepper is popularly used in food, household products, medical products, and cosmetic industry. Malaysian Pepper Board (MPB) is an extension agent under Ministry of Plantation Industries and Commodities (MPIC), Malaysia that is responsible for processing and pepper grading, market information, promotion and extension, quality improvement, trading, market regulation through licensing of pepper dealers and exporters and product development of pepper. The Mission of MPB is to assume a pivotal and leadership role in the development of a sustainable pepper industry through formulation of sound and transparent policies, programs and activities towards enhancing the contribution of industry players and socio-economic well-being of growers in the context of the national development vision.

MPB conducts in depth Research and Development (R&D) exercises to broaden the range of pepper products. It promotes production of new products to meet niche market needs. Pepper crop is cultivated in small farms averaging 0.2 ha in Sarawak. Pepper is one of the important crops to the economy of Sarawak and it is also one of an important source of income for 67,000 rural families in the interior areas of Sarawak. In 2012, the average monthly net income was RM4239 per hectare (MPIC statistic**,** 2013) implying that the pepper crop providing higher income to farmers. Farmers' profit depends on the production level where high yield will provide more income. However, market factors such as pepper prices and price of inputs are affecting pepper farming in Sarawak where pepper prices and price of inputs are not stable due to current economic conditions (demand, supply, world market prices). Pepper is a labour and capital intensive cash crop. Pepper farm requires a proper management of resources and all farming operations to ascertain high yield at minimum cost, and as well as increase farm profit. Production and productivity at farm level is influenced by the efficiency in farm management where it is related with the efficiency of utilization of resources such as agricultural inputs, capital, labour, and land.

Personal preference over inputs contributes to the variation in farm performance where the combinations of inputs use make a different in output maximization among farms. Moreover, pepper farming practices are different among farmers because they come from different location and socioeconomic background. Besides, the involvement of extension agents in pepper farming also can influence the farming practices among farmers. Through extension agents, farmers were learned about technology in pepper farming that can help them to maximize pepper yield even though they had learned about pepper farming practices from their experience. This study is carried out to examine the performance of smallholders pepper in Sarawak by estimating the level of technical efficiency among farms and to identify the determinants of technical efficiency of smallholders pepper. It will identify the sources where improvements can be made to help the pepper farmers to increase production level. The results of this study can provide useful information relevant for policy decision making.

2. Efficiency Concepts

Micheal Farrell was a pioneer of efficiency studies in 1957 and his works were based on Debreu (1951) and Koopmans (1951) works. Farrell introduced two concepts to measure efficiency i.e. input-oriented and output-oriented. The input-oriented measures focus on reducing input quantities in production but maintaining the output amount. The output-oriented concept measures how much output should expand without altering input quantities. However, this study used output-oriented measures where focuses to output maximization. Technical efficiency (TE) is achieved when a farmer is able to produce maximum output with a given set of inputs using available technology. The output-oriented measures are illustrated in Figure 1. Assume two input use to produce a single output (Y) and production possibility is represented by two dimensions. Line ZZ' is production possibility curve which indicates the upper bound of production possibilities. Point A is below ZZ' curve means that the farm is operating inefficiently thus point AB/0A is technical inefficiency. It indicates the amount of output that can be increased without increase in input quantities

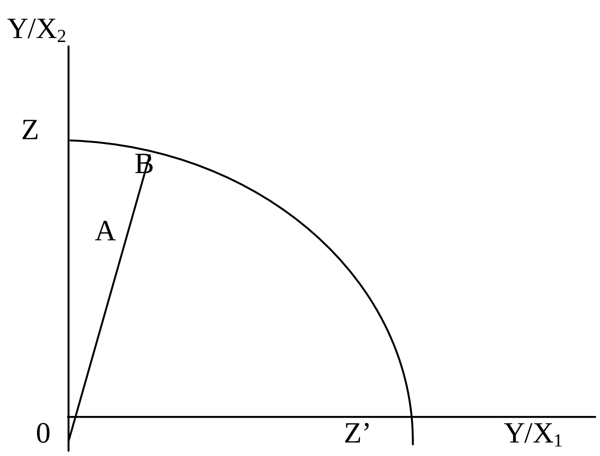

Figure 1: Technical Efficiency from an Output-Oriented Model

(Source: Coelli, Rao, and Battese, 1998)

3. Previous Studies

There are some literatures about efficiency of pepper production in Sarawak. Noorzakiah, Alias, and Sazali (1993) studied the efficiency of resources use in pepper farming. Four hundred eighty seven pepper farms were selected in 1989. They found that farms were not operating at economies of scale because majority pepper farmers have small scale farms where the production cost would increase and provide a lower profit. This means that small farms were not utilized efficiently compared to large farms thus it affected the productivity of farms. Meanwhile, Mohd, Alias, and Ruhana (1993) studied the efficiency of resource use for 112 pepper farms from a survey conducted in 1989. Results from Cobb-Douglas production function showed that fertilizer, chemical inputs, and number of vines were significant at 1% while labour was significant at 10%. The returns to scale was 0.96 which indicates that farms were operating at decreasing returns to scale where output increased by 9.6% if the input use increases by 10%.

Hamid and Mansor (1997) estimated the technical efficiency (TE) in Sarawak using deterministic frontier function and determined the existence of TE differential between *bumiputera* and *non-bumiputera* farmers using Kopp's TE measure. A total respondent was 330 farmers with 226 respondents were *bumiputera* farmers while 104 respondents were *non-bumiputera* farmers. They found that all smallholders were not technically efficient but the results show that *non-bumiputera* farmers were more technically efficient than *bumiputera* farmers. Five factors contributed to the efficiency differential such as harvesting practice, capital intensity (fertilizer application), crop diversity, education, and farming experience. Harvesting practice refers to harvesting season in which *bumiputera* famers started harvesting between the months of January and June and ended between April and August while *non-bumiputera* famers started harvesting between March and May and finished between May and July. *Bumiputera* farmers used less fertilizer and insecticide than *non-bumiputera* farmers and this caused their output to be lower. Meanwhile, farmers also diverted fertilizer and insecticide to other crops and this affected pepper output. Besides, *bumiputera* farmers are also less educated and tended to be less experienced and these factors affected the adoption of correct pepper farming practice. Authors suggested improving *bumiputera* farmer's performance by education and training through extension services.

4. Methodology

4.1. Data

The field survey was conducted in the month of August to December 2009. The survey covered the nine main areas in Sarawak such as Kuching, Serian, Sri Aman, Betong, Sarikei, Bintangor, Sibu, Miri, and Bintulu. Random sampling was used to select respondents to represent each district. The ratio or number of pepper farmers surveyed in these areas was based on prior information provided by the MPB on the density and concentration of the pepper producers and pepper produced by these farmers. Data were collected through face-to-face interviews based on questionnaires. Face-to-face interview is the best method in data collection because enumerators can clarify the question, clear doubts, and motivate respondents if they do not understand about the questions and questionnaire structure (Uma, 2003). Beside, face-to-face interview is very effective if potential respondents are illiterate. Through the survey 800 questionnaires were distributed however, only 678 questionnaires were valid for analysis after data cleaning process.

4.2. Data Envelopment Analysis (DEA)

Data Envelopment Analysis (DEA) is non-parametric approach that estimated by using mathematical programming. Farmer is Decision Making Unit (DMU) to control the input and output. DEA approach measures the ratio of weighted output to weighted input to measure efficiency. The ratio ranges from 0 to 1. In DEA it is assumed the deviation factors come from inefficiency but if any noise exists, it influences the placement of the DEA frontier (Coelli, *et.al.*, 1998). The efficiency scores are calculated rather than estimated. This is the reason why DEA model is considered a non-statistical technique. There are two basic model of DEA i.e. constant returns to scale (DEA-CRS) and variable returns to scale (DEA-VRS). DEA-CRS model proposed by Charnes, Cooper, and Rhodes (1978) and this model also known as the CCR model. The CRS model is introduced by Charnes, *et. al.*, (1978) is as follows:

$$\min_{\theta,\lambda} : \theta$$

Subject to

$$-\theta y_i + Y\lambda \geq 0,$$
$$\theta x_i - X\lambda \geq 0,$$
$$\lambda \geq 0, \quad (1)$$

where θ is *i*th farm's score of TE, y_i is pepper yield of *i*th farm, and x_i is quantity input use by *i*th farm. Assume N is number of farm where Y represents output for N farms, X represents input for N farm, λ is a vector of constants Nx1, and θ is a scalar. Yλ and Xλ are efficiency estimation on the frontier. The value θ represents efficiency score of farm which is bounded by value of 0 and 1. If the value of θ is equal to 1(θ = 1), farm is full technical efficiency while if value of θ less than 1 ($\theta \leq 1$), farm is in technical inefficiency condition. The proportional increase in output that could be achieved by *i*th farm decision making unit (DMU), with input quantities held constant, is indicated by (θ – 1).

In DEA-CRS restriction, it is assumed all DMUs are performing at optimal scale thus technical efficiency measurement is confounded by scale efficiency (SE). The extension of CRS-DEA model is DEA-VRS model as proposed by Banker, Charnes, and Cooper (1984) and this model also known as BCC model. VRS-DEA is modified from CRS-DEA model by adding the convexity constraint N1′λ to CRS-DEA model as follows:

$$\min_{\theta,\lambda} \theta,$$

Subject to

$$: -y_i + Y\lambda \geq 0,$$
$$\theta x_i - X\lambda \geq 0,$$
$$N1'\lambda = 1$$
$$\lambda \geq 0, \quad (2)$$

N1' is a vector of (N x 1) and a convexity restriction while λ is (N x 1) a vector of intensity variables. $1 \leq \theta < \infty$ and θ – 1 is the quantities increase in output with input quantities held constant. The introduction of DEA-VRS model allows the measurement of technical efficiency separated from SE effects. SE represents the ratio of the average output of a farm operating at the point compared to the average output at the point of operating with technically efficiency. Figure 2 shows the scale efficiency obtained from technical efficiency of VRS and CRS.

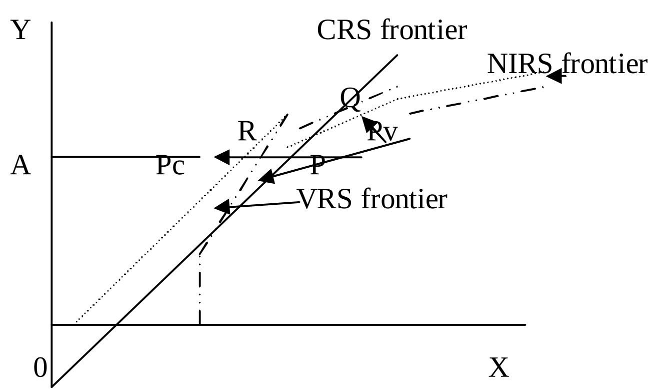

Figure 2: Scale Economies in DEA

(Source: Coelli, et.al., 1998)

Assume the farm uses one input to produce one output. Technical inefficiency of the point P is the distance PPc for CRS assumption while technical inefficiency for VRS assumption is PPv. Thus, difference of Pc and Pv is scale inefficiency. The relationship between technical efficiency of VRS and CRS is as below:

$$TEcrs = APc / AP \quad (3)$$

$$TEvrs = APv / AP \quad (4)$$

$$SE = APc / APv \quad (5)$$

SE show whether the farm is operating at increasing or decreasing returns to scale and Non-increasing returns to scale (NIRS) is included. It can determine when NIRS technical efficiency score equals to VRS technical efficiency score. Point P shows NIRS is not equal to technical efficiency of VRS, which indicates increasing returns to scale. Meanwhile, point Q shows NIRS is equal to technical efficiency of VRS, this means the farm is operating at decreasing returns to scale.

4.3. Tobit Analysis

Tobit analysis was used to find out socioeconomic and farm-specific factors that influenced the technical efficiency in farm management. The Tobit model is developed by James Tobin (1958). The Tobit model response variable Y lie between value 0 and 1. The Tobit model only observed the value of Y that greater than zero thus this model also known as censored normal regression model. However, if the value of Y is zero or less than zero, Y is not observed or censored.

$$y^*i = x_i \beta + u_i \quad (6)$$

$$y_i = y^*i \quad \text{if} \quad y^*i > 0$$

$$y_i = 0 \quad \text{if} \quad y^*i \leq 0$$

where y* is the latent dependent variable, x_i is the explanatory variable, y is the observed dependent variable, β is coefficient to be estimated, and u_i's are independently normally distributed N (0, σ^2). The inefficiency factors (socioeconomic and farm-specific factors) were separately regressed with DEA scores to find out the sources of efficiency and inefficiency.

5. Results and Discussion

5.1. Description of the Variables

Table 1 represents the summary statistics of the variable used in the efficiency analysis. The average pepper yield is 617.58 kg for 534 pepper vines, which means that one pepper vine can produce 1.16kg black pepper. The mean for fertilizer used is 531.82kg, meaning that 1kg of fertilizer for one pepper vine. The total herbicide used is 6.79L for 534 pepper vines. On average, pesticide cost and fungicide cost are RM98.88 and RM305.34 respectively for 534 pepper vines. Fungicide is the most costly input due to its expensive price compared to other inputs. Minimum labour used among farms is two persons and maximum is seven persons. On average, farms use 2 to 3 labourer in the farm. Labour is measured by man-days per year. The number of working hours per day and the number of working days per month for agriculture in Sarawak pepper is not fixed because pepper farmers also focus on other crops. Thus the number of working hours per day and working days per month are standardized. Assuming pepper farmer or family labour works four hours per day for pepper farm and they work in farm 20days per month, it means one labour work 80 hours per month. The standard of working hour per day is eight hours, and 80 hours are divided by 8 thus one labour is equal to 10 man-days. This study considers labour who works during a year as a permanent labour thus one labour is equal to 120 man-days per year.

Eight explanatory variables were used as determinants of efficiency i.e. farmers' age, education level, farming experience, contacts with extension agents per year, membership of farmer's organization, attending courses and study visits, and full-time pepper farming. The education level is segregated into five categories albeit, did not obtain any formal education (1), attended adult school (2), attended only Primary School (3), finished Lower Secondary School (4), and manage to attend Upper Secondary School (5) where 91 respondents did not obtain any formal education, 122 respondents attended adult school, 317 respondents attended only Primary School, 118 respondents finished Lower Secondary School, and 30 of the respondents manage to attend Upper Secondary School. A mean education level is 2.81 implying that a majority of farmers attend adult education and primary school. The minimum frequency of contacts with extension agents per year is two times per year while the maximum frequency of nine times per year with a value of four times per year. Majority of farmers represented by 504 farmers join the farmer's organization. Besides, 562 of 678 farmers focus on pepper cultivation compared to other crops. Only 269 farmers join farming courses and study visits. A minimum farming experience is 5 years and a maximum is 50 years with a mean value of 18 years farming experience. A minimum age of farmers in the sample is 22 years old while maximum age of farmers is 76 years old, with mean value of 48 years old.

Table 1: Summary statistics of variable used in the efficiency analysis

Variable	Total	Minimum	Maximum	Mean	Standard Deviation
Pepper yield	678	150.00	6925.00	617.58	623.41
Number fruiting vines	678	100.00	3500.00	534.03	430.63
Fertilizer (kg)	678	50.00	4000.00	531.82	489.54
Herbicide (Litre)	678	3.00	32.00	6.79	4.32
Pesticide cost (RM)	678	10.00	691.07	98.88	80.48
Fungicide cost (RM)	678	14.00	2760.00	305.34	339.51
Labour (man-days)	678	240	840	2.62	0.94
Education level	678	0.00	5.00	2.81	1.02
Contacts with extension	678	2	9	4.12	1.32
Farmer’s organization	504	0	1	0.74	0.44
Full-time pepper farming	562	0	1	0.83	0.38
Course and visit	269	0	1	0.40	0.49
Farming experience	678	5.00	50.00	17.74	7.77
Farmers’ age	678	22.00	76.00	47.88	10.95

5.2. DEA results

The data estimated by using Data Envelopment Analysis (Computer) Program (Coelli, 1996). The technical efficiency scores among farms are presented in Table 2. Mean of technical efficiency under technical efficiency under returns to scale (TEcrs) assumption and under technical efficiency under variable returns to scale (TEvrs) assumption is 0.57 and 0.66 respectively. On average, the farmers are only producing 57% (CRS) and 66% (VRS) of the output of best-practices farmers at the same level inputs. This means, farms should improve about 34% (VRS) to 43% (CRS) of the efficiency in input utilization at the same production level.

Table 2: Efficiency Scores of farms from DEA

Efficiency Index	TEcrs	TEvrs	SE
0.100 - 0.199	0	0	0
0.200 - 0.299	13	4	0
0.300 - 0.399	88	47	0
0.400 - 0.499	167	92	1
0.500 - 0.599	171	145	4
0.600 - 0.699	105	117	44
0.700 - 0.799	56	107	161
0.800 - 0.899	40	74	168
0.900 - 0.999	16	34	252
1.000	22	58	48
Min	0.214	0.214	0.497
Max	1.000	1.000	1.000
Mean	0.567	0.661	0.864
Standard Deviation	0.170	0.187	0.108

Technical efficiency scores under CRS (TEcrs) and under VRS (TEvrs) range from 0.214 to 1.000 respectively. Under TEcrs 22 farms are technically efficient while under TEvrs 58 farms are technically efficient. This means that the number of farms achieving full technical efficiency under TEvrs assumption is more than the number of farms achieving full technical efficiency under TEcrs assumption. Technical efficiency under VRS-DEA model was higher than CRS-DEA model implying that the VRS-DEA model more flexible and envelops the data in a tighter way than the CRS-DEA model. Meanwhile, scale efficiency (SE) scores of farms range from 0.497 to 1.00 where 48 farms are scale efficient and a mean value of scale efficiency is 0.864. The mean of scale efficiency of farms is relatively high (0.86), indicating that farm inefficiencies are due to inefficiency in inputs use.

Table 3 shows the returns to scale of sample farm. Farms were categorized into three groups, sub-optimal (IRS), optimal (CRS), and super-optimal (DRS). About 77.28% (524 farms), 7.73% (50 farms), and 15.33% (104 farms) of farms were sub-optimal, optimal, and super-optimal respectively. Thus, majority of farms shows increasing returns to scale. The mean of yield for optimal farms and super-optimal farms is higher than sub-optimal farms. Besides, there are great differences in the mean of the number of vines and gross return among sub-optimal, optimal, and super-optimal farms. Farms in sub-optimal should increase the efficiency of input use to increase the yield while farms in super-optimal should reduce input use to obtain more profit.

Table 3: Characteristics of farms with respect to returns to scale

Characteristics	Number of farm	Yield (kg)	Number of Vines	Mean gross return
Sub-Optimal (IRS)	524	459.77	397	2457.18
Optimal (CRS)	50	1217.80	775	8283.50
Super-Optimal (DRS)	104	1124.15	1107	6716.95

5.3. Determinants of Technical Efficiency

Determinants of the technical efficiency are presented in Table 4. Farmers' age has a negative relationship with efficiency. Older farmers are inefficient compared to young farmers. However, farmers' age does not significantly influence inefficiency. Farming experience has positive relationship with farmers' age because older farmers have more farming experience. However, in the case of Sarawak, pepper farming experience does not significantly influence efficiency among farms but this factor has positive relationship with efficiency. Farmers who attend educational farming programmes are more efficient than farmers who have no schooling. Education level has significant influence with technical efficiency at 1%. Farmers who have education are more efficient than farmers who do not because it is easier for farmers who have education to grasp the farming information, knowledge and skills through reading materials provided to them by the extension agents. The frequency of contacts with extension agents per year does not significantly influence technical efficiency but show positive relationship with technical efficiency. Attending farming courses and study visits has significant relationship with technical efficiency at 5%. Joining farmer's association significantly influences efficiency at 1%. The benefits of joining farmer's association include consultation services; obtain subsidies, and marketing facility. Full-time pepper farming is significant factor in influencing efficiency where this factor was significant at 5%. Farmers who cultivate pepper as a main cash crop in the farm are more efficient because they put more effort to the main crop compared with other crops**.** Diversity of crops in farm affects efficiency since land is allocated to many crops, economies of scale cannot be exploited, and inputs are diverted to other crops (Hamid and Mansor, 1999).

Table 4: Determinants of technical efficiency

Explanatory Variable	DEA		
	Coefficient	Standard Error	Probability value
Constant	0.390	0.049	0.000*
Education level	0.025	0.007	0.001*
Contacts with extension	0.007	0.005	0.146
Farmer's organization	0.161	0.017	0.000*
Fulltime pepper farming	0.039	0.018	0.030**
Course and visit	0.027	0.013	0.043**
Farming experience	0.001	0.001	0.141
Farmers' age	-0.000	0.001	-0.625

*,**,*** represents significant at 1%, 5%, and 10%.

5. Conclusion

The findings in this study show that pepper farms are technically inefficient where the mean of technical efficiency of pepper farms are low. Farms are not efficient in input utilization and are not producing pepper yield at maximum level hence they are not minimizing cost and maximizing profit.

The inefficiencies are due to improper farm management and misallocation of inputs used. It is imperative that farmers should improve their farm management skills through agronomic education given by extension agents.

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