Asian Journal of Agriculture and Rural Development
Volume 10, Issue 3 (2020): 729-739

http://www.aessweb.com/journals/5005

TECHNICAL EFFICIENCY AMONG PEPPER FARMERS IN SARAWAK, MALAYSIA: A STOCHASTIC FRONTIER ANALYSIS

Anita Rosli [a]
Alias Radam [b]
Khalid Abdul Rahim [b]
Amin Mahir Abdullah [c]

[a] *Department of Social Science and Management, Faculty of Humanities, Management and Science, Universiti Putra Malaysia, Bintulu Campusa and Institut Ekosains Borneo, Universiti Putra Malaysia Bintulu Campus, Malaysia.*
[b] *School of Economics and Business, Universiti Putra Malaysia, Serdang Campus, Malaysia.*
[c] *Faculty of Agriculture, Universiti Putra Malaysia, Serdang Campus, Malaysia*

✉ anitarosli@upm.edu.my *(Corresponding author)*

Article History
Received: 2 July 2020
Revised: 26 August 2020
Accepted: 28 September 2020
Published: 19 October 2020

Keywords
Piper nigrum L
Translog
Maximum likelihood estimation
Inefficiency model
Farm performance.

ABSTRACT

This study aimed to estimate the technical efficiency among pepper (*Piper nigrum.* L) farmers in Sarawak, Malaysia, using Stochastic Frontier Analysis (SFA). SFA involves a one-step process that can estimate technical inefficacy factors simultaneously with the production frontier. 678 pepper farmers were involved in this study, and the data were collected from 2012 to 2013. The mean score for technical efficiency was 0.518, indicating that pepper farmers were not efficient. However, the inefficiency model showed that education level, membership in farmers' association, full-time as a pepper farmer, attending courses and visiting sample farms were factors that significantly improved inefficiency. The major problem of pepper farming in Sarawak is poor agricultural practices where farmers do not fully utilize the available agricultural inputs to produce maximum output. Based on the findings, farmers must improve their knowledge and skills in pepper farming through agronomic education.

Contribution/Originality: This study contributed to improving farm performance among pepper farmers in Sarawak, Malaysia, by estimating technical efficiency and determining efficiency or inefficiency factors in pepper farming. The findings highlighted technical efficiency levels and the reasons pepper farmers had not achieved full technical efficiency, and improved farm performance among pepper farmers.

DOI: 10.18488/journal.ajard.2020.103.729.739
ISSN(P): 2304-1455/ ISSN(E): 2224-4433

How to cite: Anita Rosli, Alias Radam, Khalid Abdul Rahim, and Amin Mahir Abdullah (2020). Technical Efficiency among Pepper Farmers in Sarawak, Malaysia: A Stochastic Frontier Analysis. *Asian Journal of Agriculture and Rural Development*, 10(3), 729-739. 10.18488/journal.ajard.2020.103.729.739

1. INTRODUCTION

1.1. Background of the study

Pepper (*Piper nigrum* L) is one of the families in Piperaceae and is widely used in the food, cosmetics, household, and medical industries. Thus, pepper has a special position in the world marketplace as a foreign exchange source for producer countries, including Malaysia. In 2018, Vietnam was the largest pepper producer in the world with a total of 205,000 tonnes, representing 40% of total world pepper production. It was followed by Brazil (72,000 tons), Indonesia (70,000 tons), India (64,000 tons), Malaysia (31,073 tons), Sri Lanka (18,600 tons), and other countries (70,000 tons) (Malaysian Pepper Board (MPB), 2018). Malaysia is the fifth largest pepper producer, representing 5.9% of total worldwide pepper production.

In Malaysia, pepper is the fifth most important commodity after palm oil, rubber, timber, and cocoa (Ministry of Plantation Industries and Commodities (MPIC), 2019). In the world market, pepper from Malaysia is known as Sarawak pepper because most pepper production (approximately 97%) comes from Sarawak state. Pepper grown in Malaysia is for both domestic use and export to other countries. In 2016, approximately 40% of the total pepper production was exported and the remainder was for domestic consumption (Malaysian Pepper Board, 2017). Traded pepper can promote a sustainable pepper industry and the income of pepper farmers, especially in Sarawak. The Malaysian Pepper Board (MPB) is an agency under the Ministry of Plantation Industries and Commodities (MPIC), and is the agency responsible for managing the pepper industry in Malaysia.

1.2. Problem statement

Pepper is a traditional crop and source of income for approximately 67,000 people in rural Sarawak. The current estimate of the area underpepper cultivation is approximately 13,000 hectares (Department of Agricultural Sarawak, 2020). High production at the farm level is important to ensure that pepper continues to be one of the income sources for rural farmers, and in a competitive manner. Therefore, development of the pepper industry is of great importance, especially production at the farm level. In crop production, high yield is important as this will benefit farmers by their gaining increased sales revenue. However, high yields should be in line with minimizing the quantity and cost of agricultural inputs, which will enable farmers to achieve high productivity and profits in crop production. Thus, farmers need to know how to manage agricultural inputs to the optimal level and to avoid wastage in using agricultural inputs. Farmers can achieve high technical efficiency levels in farming if they are able to utilize available inputs and current technology at an optimal level to produce maximum output (frontier level). However, technical efficiency in production depends on how farmers utilize agricultural inputs. This is also influenced by background factors such as demographic, economic, and social factors. Besides, through extension agents, farmers can learn to use modern farming methods to manage their farms even though they may have inherited farming knowledge from their parents and learned through experience. These factors could influence farmers' decisions in pepper farming practices and efficiency in input utilization, representing the difference between efficiency and inefficiency in farm management.

Currently there is a shortage of information on pepper farming in Sarawak using the parametric method (see Appendix 1). However, few efficiency studies on pepper farming in Sarawak have been reported. (Noorzakiah, Alias, & Shazali, 1993) reported that large farms utilized resources efficiently compared with small farms. The study suggested that small farms should be aggregated to form larger farms to enable cooperative farms to buy agricultural inputs in large quantities, in order to reduce expenditure and improve productivity. (Mohd, Alias, & Ruhana, 1993) found that the difference between value marginal product and price of input indicated that these inputs were not used efficiently and farms were not operating at maximal profit; the study suggested that farmers should improve the efficiency of inputs use to attain an optimal level. Abdul and Mansur (1997) found that *bumiputeras*[1] farmers were less technically efficient compared with *non-bumiputeras*[2] farmers. Fertilizer application, crop diversification, education level, harvesting practices, and farming experience all contributed to farmers' technical efficiency (Abdul & Mansur, 1997).

The efficiency problems of pepper production in Sarawak are similar to those of pepper production in Indonesia. An efficiency study on pepper farmers in Southeast Sulawesi, Indonesia, by Dewi and Sahardi (2009) found that traditional farmers were inefficient in regard to farm labor and the application of nitrogen, organic fertilizers, and fungicides. Grahasita (2012) studied 40 pepper farmers in the district of East Belitung, Indonesia and found that 32.5% had achieved technical efficiency whereas 67% had not reached an adequate level. Farmers attained allocative efficiency in the use of urea, fertilizers, and labor but were inefficient in regard to organic and chemical fertilizers and herbicide utilization.

As pepper is one of the key commodities in Malaysia and an important crop for rural farmers in Sarawak, it is important to determine farm performance among pepper farmers. Thus, the objective of this study was to determine technical efficiency among pepper farmers in Sarawak using Stochastic Frontier Analysis (SFA). SFA involves a one-step process that estimates technical inefficacy factors simultaneously with the production frontier. This research will highlight the key factors influencing technical efficiency and where improvements could be made to improve pepper farmers' efficiency. The findings from this study will be useful as a guideline for related agencies and policymakers to improve the pepper industry, especially production performance at the farm level. Additionally, this study also determines an appropriate functional form to present data and stochastic frontier models in the two functional forms commonly used for SFA, i.e., Cobb–Douglas and Translog.

2. MATERIALS AND METHODS

2.1. Data collection

Data were collected from 2012 to 2013. The survey covered the nine main districts in Sarawak, including Kuching, Serian, Sri Aman, Betong, Sarikei, Bintangor, Sibu (including Kapit, Song areas), Miri, and Bintulu (including Kampung Sungai Asap). Pepper farmers were selected by each MPB branch (see Appendix 2) using a

[1]*Bumiputeras* refers to indigenous native peoples in Sarawak state, including Malays, Melanau, and Dayak (Ibans, Orang Ulu, Kenyah, Kayan, Kelabit, Punan, etc.).

[2] *Non-Bumiputeras* refers to non-native ethnic groups in Sarawak state, such as Indians and Chinese.

stratified random sampling method. The number of respondents was set according to the total number of pepper farmers registered by each MPB branch (refer Appendix 2). Even though the data had been collected several years previously, these still reflect the current pepper farming situation in Sarawak because the farmers' background and methods had changed little. For example, pepper farming is dominated by the Ibans community compared to other races. The majority of pepper farms are located in rural areas and are predominantly managed by older farmers.

A total of 800 questionnaires was distributed during the survey; however, some information was provided only partially, in particular production factor components. Only 678 questionnaires were valid for analysis after the data cleaning process. The number of samples represented 2.5% of the population. Based on Sekaran and Bougie (2016) a population number in the range 20,000–30,000 could represent 377–379 sample respondents. Thus, the number of samples adequately represented the population of pepper farmers in Sarawak.

2.2. Stochastic frontier model

Aigner, Lovell, and Schmidt (1977) and Meeusen and van Den Broeck (1977) introduced stochastic frontier production function (SFPF) with two types of error term: random effects (V) and inefficiency effects (U), and cross-sectional data specification:

$$Y_i = f(\Sigma X_i; \beta) + (V_i - U_i) \qquad i = 1, 2, \ldots N \qquad \ldots\ldots\ldots\ldots (1)$$

Y_i is the total amount of output produced by i farms, X_i is the inputs used by i farms, β is a coefficient to be estimated, and N indicates the total number of sample farmers included in the study.

V_i is a random variable representing factors that cannot be controlled, such as pest and disease attack and weather, and it is independently and identically distributed: $V_i \sim Niid\,(0,\sigma_v^2)$. Meanwhile, U_i is a non-negative random variable representing inefficiency factors in production operation and it is half-normal distribution: $Ui \sim Niid\,(0, \sigma_U^2)$. U_i values more than zero ($U_i > 0$) indicate the efficiency level relative to the frontier level, i.e., the production level lies below the frontier line. Thus, U_i equals zero ($U_i = 0$) indicates that the production level lies on the frontier line. The inefficiency effects model introduced by Battese and Coelli (1995) is represented as:

$$Ui = \Sigma\, Zi\delta + Wi \qquad \ldots\ldots\ldots\ldots (2)$$

Zi is a (1xm) vector of farm specificity by i farms, and values are fixed constant; δ is an (mx1) unknown vector scalar parameter of farmer-specific inefficiency factors where a positive sign indicates that the explanatory variables increase technical inefficiency and vice versa. Wi is a random variable with truncation of normal distribution with zero mean and variance, σ^2. The point of truncation is negative ($-Zi\delta$), where $Wi \geq -Zi\delta$, which assumes that Ui has non-negative truncation of $N(Zi\delta, \sigma^2)$ distribution. Ui is assumed to be independently distributed, with truncations at zero means of $N\,(mit, \sigma u^2)$ distribution where $mit = Zit\delta$, and Zit is a vector of variables that may influence farm efficiency.

The parameters of the stochastic frontier are estimated by maximum-likelihood estimation (MLE) using the Frontier program. The likelihood function of variance random error σv^2, the inefficiency effects σU^2, and overall variance in the model σ^2 are related by $\sigma^2 = \sigma V^2 + \sigma U^2$, and ratios of $\gamma = \sigma U^2 / \sigma^2$ measure the total deviation of output from the frontier that can be attributed to inefficiency, and have a value between zero and one (Battese & Corra, 1977). The parameterization of γ has advantages in obtaining MLE because the parameter space for γ can be searched for a suitable starting value for the iterative maximization algorithm (Coelli, Rao, & Battese, 1998). If value γ is equal to zero, the variation of output among farms is due to statistical noise, while if γ is equal to one, this indicates that variation is attributed to inefficiency (Coelli, 1995). Batiese (1992) defined technical efficiency as a level of production less than its frontier output. As a mathematical function, technical efficiency (TE) could be defined as:

$$TE = Y / Y_i^* \qquad \ldots\ldots\ldots\ldots (3)$$

Y_i, is the farm output, Y_i^*, frontier output supposedly produced
Y_i / Y_i^*, and can also be interpreted as:

$$TE = f(\Sigma X_i; \beta)\, exp\,(V_i - U_i) \,/\, f(\Sigma X_i^*; \beta) - exp\,(V_i)$$
$$TE = -U_i$$

2.3. Empirical model estimation

The stochastic frontier model is presented and analysed using Cobb–Douglas and Translog functional methods to identify which functional forms adequately represent the data and the model. Based on previous efficiency studies (see Appendix 1), about 64% of studies presented SFA in the Cobb–Douglas production function. The specification of the stochastic frontier model in Translog is as follows:

$$In\ Y_i = \beta_0 + \beta_1 In\ X_{1i} + \beta_2 In\ X_{2i} + \beta_3 In\ X_{3i} + \beta_4 In\ X_{4i} + \beta_5 In\ X_{5i} + \beta_6 In\ X_{6i} + \beta_7 (In\ X_{1i})^2 + \beta_8 (In\ X_{2i})^2 + \beta_9 (In\ X_{3i})^2 + \beta_{10} (In\ X_{4i})^2 + \beta_{11} (In\ X_{5i})^2 + \beta_{12} (In\ X_{6i})^2 + \beta_{13} (In\ X_{1i}\ In\ X_{2i}) + \beta_{14} (In\ X_{1i}\ X_{3i}) + \beta_{15} (In\ X_{1i}\ In\ X_{4i}) + \beta_{16} (In\ X_{1i}\ In\ X_{5i}) + \beta_{17} (In\ X_{1i}\ In\ X_{6i}) + \beta_{18} (In\ X_{2i}\ In\ X_{3i}) + \beta_{19} (In\ X_{2i}\ In\ X_{4i}) + \beta_{20} (In\ X_{2i}\ X_{5i}) + \beta_{21} (In\ X_{2i} In\ X_{6i}) + \beta_{22} (In\ X_{3i}\ In\ X_{4i}) + \beta_{23} (In\ X_{3i}\ In\ X_{5i}) + \beta_{24} (In\ X_{3i}\ In\ X_{6i}) + \beta_{25} (In\ X_{4i} In\ X_{5i}) + \beta_{26} (In\ X_{4i}\ In\ X_{6i}) + \beta_{27} (In\ X_{5i}\ In\ X_{6i}) + \beta_{28} (D_1 i) + V_i - U_i,$$

$$i = 1 \ldots 678 \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

where Yi is the total amount of output by i farms per year and there are six main production factors used, whereas X_1 is the number of fruiting pepper vines. The number of fruiting vines used in this study as pepper yield depends on the number of mature vines on a farm. On a farm, because not all pepper vines are ready to harvest, the number of fruiting vines is appropriate as an independent variable compared to farm size. X_2 is labor measured by man-days, X_3 is fertilizer (kg) per year, X_4 is herbicide (litres) per year, X_5 is fungicide cost (RM) per year, X_6 is pesticide cost (RM) per year, and dummy ($\beta_{28}\ D_1 i$) represents the use of the *Semongok* variety. *Semongok* varieties consist of three types: *Semongok* Aman, *Semongok* Perak, and *Semongok* Emas. These varieties are new pepper varieties recently adopted by pepper farmers, and are quite stable from the third year onwards compared with the Kuching variety previously used widely (Paulus, 2008). The remaining component variables of parameters $\beta 7$ to $\beta 27$ in the model are shown in Table 1. For the Translog production function, each independent variable needs to be set as a square (for example, X_{1i}^2 for vines) and interaction between variables ($\beta 13$ ($In\ X_1 i\ In\ X_2 i$), vines and labor).

The calculation of elasticity for each input is needed when Translog production function is applied. The returns to scale (RTS) in production can be calculated as the total elasticity of inputs. Referring to the empirical stochastic frontier Translog production function in equation (4) and assuming the elasticity of the pepper vine variable X_1, the calculation of elasticity (E) of input X_1 is:

$$Ex_i = \partial In Y / \partial Inx_i = \beta_1 + 2\beta_7 (\bar{X}_{1i}) + \beta_{13} (\bar{X}_{2i}) + \beta_{14} (\bar{X}_{3i}) + \beta_{15} (\bar{X}_{4i}) + \beta_{16} (\bar{X}_{5i}) + \beta_{17} (\bar{X}_{6i}) \quad \ldots (5)$$

Meanwhile, the empirical specification for the technical inefficiency model is:

$$Ui = \delta 0 + \delta 1g + \delta 2el + \delta 3ce + \delta 4m + \delta 5ftp + \delta 6crv + \delta 7ex + Wi \qquad \ldots\ldots\ldots\ldots (6)$$

Ui is the inefficiency for *i* farms, *g* refers to the farmer's age, *el* is education level, *ec* the number of contacts with extension agents per year, *m* is membership in the farmers association, *ftp* is as s full-time pepper farmer, *crv* is attending courses and visiting sample farms, and *ex* is pepper farming experience.

2.4. Research hypotheses

The hypotheses tests were conducted by generalization of the likelihood-ratio (LR) test statistic with null ($H_0 = 0$) and alternate ($H_1 > 0$) hypotheses. The calculation of hypotheses tests followed was thus:

$$LR = -2\{In[L(H_0)/L(H_1)]\} = -2\{In[L(H_0)/L(H_1)]\} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (7)$$

$L(H_0)$ and $L(H_1)$ represent the value of the likelihood function of the null and alternative hypothesis, respectively. The null hypothesis (H_0) is rejected when value LR exceeds the critical value. In SFA, three main hypotheses were tested to evaluate the validation of method application:

(1) Functional form to represent data and stochastic frontier model
$H_0 = 0$. Cobb–Douglas production function adequately represents the data and stochastic frontier model.
$H_1 > 0$. Cobb–Douglas form does not adequately represent the data and stochastic frontier model.
(2) Presence of technical efficiency effects in the stochastic frontier model
H_0: $\delta = 0$. There are no technical inefficiency effects in the stochastic frontier model.
H_1: $\delta > 0$. There are technical inefficiency effects in the stochastic frontier model.
(3) The frontier model is stochastic
H_0: $\gamma = 0$. The frontier model is non-stochastic.
H_1: $\gamma > 0$. The frontier model is stochastic.

3. RESULTS AND DISCUSSION

3.1. Summary statistics

The summary statistics for variables used in the efficiency analysis are shown in Table 1. The mean pepper yield for 534 fruiting vines was 617.58 kg and the average for fertilizer, herbicide, fungicide cost, and pesticide cost was 531.82 kg, 6.78 l, RM 311.73 (USD 77.93), and RM 98.88 (USD 24.72), respectively; only 244 sample farmers planted the *Semongok* variety. The average age of farmers was 49 years, with farming experience of approximately 18 years. On average, farmers made contact with extension agents four times per year. The majority of the farmers (504) had joined a farmers' association, and full-time pepper farmers (562) and 269 others had attended courses for pepper farm management and visited sample farms. The level of education is categorized into no formal education (1), adult school

(2), primary school (3), lower secondary school (4), and upper secondary school (5). On average, pepper farmers attended adult education and, although the majority were literate, they had attained only a low educational level.

Table-1. Summary statistics for selected variables.

Variable	Total	Minimum	Maximum	Mean	Standard deviation
Pepper yield	678	150	6,925	617.58	623.41
Number of fruiting vines	678	100	3,500	534.03	430.63
Fertilizer (kg)	678	50	4,000	531.82	489.54
Herbicide (l)	678	3	32	6.79	4.32
Pesticide cost (RM)	678	10	691.07	98.88	80.48
Fungicide cost (RM)	678	14	2,760	305.34	339.51
Labor input (man-days)	678	2	7	2.62	0.94
Level of education	678	1	5	2.81	1.02
Frequency of contact with extension (per year)	678	2	9	4.12	1.32
Membership in farmers' association	504	0	1	0.74	0.44
Full-time pepper farming	562	0	1	0.83	0.38
Courses and visits	269	0	1	0.4	0.49
Farming experience (years)	678	5	50	17.74	7.77
Farmer's age	678	22	76	47.88	10.95
Semongok variety	244	0	1	0.36	0.48

3.2. Stochastic frontier estimation

The MLE of the stochastic frontier model is given in Table 2.

Table-2. MLE of stochastic frontier production model.

Variable	Parameter	Coefficient		Standard Error		*t*-Ratio	
		Cobb–Douglas	Translog	Cobb–Douglas	Translog	Cobb–Douglas	Translog
Constant	β_0	1.218	5.964	0.117	2.282	10.396*	2.613*
Pepper vines	β_1	0.292	0.077	0.035	0.690	8.292*	0.112
Labor	β_2	0.071	−1.054	0.035	0.791	2.011**	−1.332
Fertilizer (kg)	β_3	0.534	−0.351	0.022	0.412	24.521*	−0.851
Herbicide (l)	β_4	0.063	0.739	0.036	0.780	1.734***	0.948
Fungicide cost (RM)	β_5	0.023	0.006	0.011	0.256	2.034**	0.023
Pesticide cost (RM)	β_6	0.039	0.515	0.019	0.405	2.033**	1.272
Vines^2	β_7		0.115		0.073		1.584
Labor^2	β_8		0.104		0.083		1.252
Fertilizer^2	β_9		0.158		0.040		3.987*
Herbicide^2	β_{10}		0.060		0.105		0.578
Fungicide^2	β_{11}		0.002		0.014		0.178
Pesticide^2	β_{12}		−0.033		0.024		−1.381
Vines*labour	β_{13}		−0.078		0.133		−0.582
Vines*fertilizer	β_{14}		−0.201		0.078		−2.568
Vines*herbicide	β_{15}		−0.072		0.143		−0.508
Vines*fungicide	β_{16}		0.024		0.041		0.589
Vines*pesticide	β_{17}		0.119		0.068		1.737***
Labor*fertilizer	β_{18}		0.118		0.081		1.461
Labor*herbicide	β_{19}		−0.041		0.138		−0.295
Labor*fungicide	β_{20}		0.030		0.048		0.625
Labor*pesticide	β_{21}		−0.099		0.081		−1.228
Fertilizer*herbicide	β_{22}		0.026		0.072		0.356
Fertilizer*fungicide	β_{23}		−0.056		0.027		−2.070**
Fertilizer*pesticide	β_{24}		−0.053		0.041		−1.292
Herbicide*fungicide	β_{25}		−0.030		0.045		−0.668
Herbicide*pesticide	β_{26}		−0.053		0.074		−0.718
Fungicide*pesticide	β_{27}		0.013		0.024		0.548
Semongok variety	β_{28}	0.044	0.034	0.044	0.019	2.333**	1.767***
Sigma^2	σ^2	0.045	0.042	0.002	0.003	18.664*	15.102*
Gamma	Γ	0.99	0.99	0.472	0.008	2.120**	128.206*
LN (likelihood)		89.483	116.076				
LR test		241.165	252.647				
Mean ($\bar{x}$)		0.429	0.518				

Note: *, **, and *** indicate that the variable is significant at 1, 5, or 10%, respectively.

According to Cobb–Douglas stochastic production function the mean technical efficiency of 678 sample pepper farms was 43%, suggesting that pepper yield could be increased by 57% if farmers achieved technical efficiency at the optimal farmer (frontier) level. The estimation of variance parameters sigma² (σ^2) and gamma (γ) were 0.045 and 0.99, respectively, and both *t*-ratio values were significant at the 1% level. This suggests that 100% of the variation in the sample of pepper farmers' yield was due to differences in their technical inefficiency in input utilization. The MLE for the number of fruiting vines, family labor, fertilizer, herbicide, fungicide cost, pesticide cost, and *Semongok* variety showed positive values of 0.292, 0.071, 0.534, 0.063, 0.023, 0.039, and 0.044, respectively, and these variables were significant. This means that an increment of 1% in inputs such as the number of fruiting vines, family labor, fertilizer, herbicide, fungicide cost, pesticide cost, and *Semongok* variety would increase output by 0.29, 0.07, 0.53, 0.06, 0.02, 0.03, and 0.04%, respectively.

Fertilizer is the main factor increasing the yield of pepper, with a coefficient of 0.534, followed by the number of fruiting vines (coefficient 0.292), suggesting the need for improvement in production and productivity. In the present study, pepper farmers are increasing RTS in production as the total elasticity of production is 1.06.

For the stochastic frontier Translog production function, the estimated coefficients of fertilizer^2, the interaction of number fruiting vines and pesticide, and *Semongok* variety were 0.158, 0.119, and 0.034, respectively, and these variables show positive and significant effects on pepper yield. Fertilizer^2 was significant at 1%, the interaction of the number of fruiting vines and pesticide was significant at 10%, and the *Semongok* variety was significant at 5%. Meanwhile, the interaction of fertilizer and fungicide cost was significant at 5%, but this interaction negatively affects pepper yield with a coefficient of –0.056. These findings indicate that there may be an incorrect relation between fertilizer and fungicide application on pepper farms.

The results further suggest the flexibility of the Translog production function in representing the input–output relationship compared with the Cobb–Douglas production function, because the latter function is restricted to a constant RTS rule. The mean of technical efficiency in stochastic frontier Translog production was 0.518, which is higher than that from the Cobb–Douglas production function. Therefore, technical efficiency estimation is influenced by its functional form.

The input–output relationship can be measured using elasticity analysis, because the first order of coefficient in stochastic frontier Translog production function does not directly explain the elasticity of inputs and output as in the Cobb–Douglas production function (Sharma & Leung, 1999). The elasticity of each input and total output elasticity is given in Table 3. The elasticities of fruiting pepper vines, labor, fertilizer, herbicide, fungicide cost, and pesticide cost were 0.336, 0.880, 0.520, 0.050, 0.012, and 0.038, respecively. The results indicate that a 1% increase in fruiting pepper vines, labor, fertilizer, herbicide, fungicide cost, and pesticide cost would increase the yield of pepper by 0.33, 0.88, 0.52, 0.05, 0.01, and 0.03%, respectively. All inputs positively influenced pepper yield. The total output elasticity was 1.873, suggesting that sample pepper farmers increased RTS in production. This means that a 1% increment in all inputs would increase pepper yield by 1.87%. However, the RTS of 122 farmers in 1989 surveyed by Mohd et al. (1993) were found to be 0.96, indicating that farms were decreasing RTS in their operation. These results demonstrate that pepper farming in Sarawak improves with agricultural input utilization. However, the differentiation of RTS is due to sampling size and the economic conditions over the survey period.

Table-3. Partial elasticity and RTS of farms (Translog production function).

Variable	Elasticity
Pepper vines	0.336
Labor	0.882
Fertilizer	0.520
Herbicide	0.050
Fungicide cost	0.012
Pesticide cost	0.038
Semongok variety	0.034
Total output	1.873

3.3. Hypothesis test

The hypothesis test is presented in Table 4. The first hypothesis was to determine an appropriate functional form to represent data and stochastic frontier models. The Translog production function adequately represents the data and stochastic frontier model in this present study. The hypothesis was rejected at a 5% critical value of 32.67, with a degree of freedom of 21. Besides, the rejection of Cobb–Douglas is justified because nonlinear variables and some interaction among variables are relatively important in the present study (see Table 4). This finding is consistent with Azumah, Donkoh, and Awuni (2019) and Kostlivý and Fuksová (2018) who also rejected the Cobb–Douglas function and accepted the Translog function.

Table-4. Hypothesis testing.

Null hypothesis	In[L(H_0)]	In[L(H_1)]	*LR*	D.F.	Critical value	Decision
(1) Cobb–Douglas function	89.483	116.076	53.186	21	32.67	Rejected
(2) $\gamma = \delta_0 \ldots = \delta_7 = 0$	10.247	116.076	252.647	9	19.68	Rejected
(3) $\gamma = 0$	119.208	116.076	6.262	2	5.138	Rejected

The second hypothesis, that the technical inefficiency effect does not exist, was rejected with the LR test of 252.647 at a 5% critical value of 19.68. Thus, the technical inefficiency effect exists among sample pepper farmers. The third hypothesis, that the frontier production function is non-stochastic. was rejected at a 5% critical value of 5.138. This finding indicates that the stochastic frontier model adequately represents pepper farmers. In summary, the results of hypothesis testing suggest that the stochastic frontiers Translog production function is the best model to represent the data in this study.

3.4. Technical efficiency score

A summary of efficiency scores among farms is presented in Table 5. Technical efficiency scores for pepper farmers ranged from 0.193 to 0.998, and no farm was found to be fully efficient. The mean technical efficiency was 0.518 indicating that, on average, pepper farmers are able to produce only 52% of pepper production using available inputs and current technology. Thus, they could improve pepper production by 48% through better use of agricultural inputs.

Table-5. Technical efficiency scores for sample pepper farmers.

Efficiency index	Number of farmers
<0.100	0
0.100–0.199	1
0.200–0.299	23
0.300–0.399	111
0.400–0.499	175
0.500–0.599	205
0.600–0.699	100
0.700–0.799	43
0.800–0.899	10
0.900–0.999	10
1.000	0
Min.	0.193
Max.	0.998
Mean	0.518
SD	0.136

3.5. Technical inefficiency model

The next stage of the present study was to determine the efficiency (or inefficiency) factors, and this analysis is important for policy articulation. The inefficiency model was estimated simultaneously with the stochastic Translog production function, as the Cobb–Douglas production function was rejected in this study (see Table 6). The estimated coefficients for determinants of efficiency explain variation in the level of technical efficiency among farmers. However, for the inefficiency model, a positive sign of parameters indicates that the explanatory variables positively affect inefficiency and vice versa.

Education level, membership in farmers' association, full-time pepper farming, attending courses and visiting pepper farms significantly contributed to variations in technical efficiency. Farmers who had lower education levels or no formal education were technically more inefficient than those with more years of formal education. Farmers with more years of formal education were better able to grasp and understand pepper farming knowledge and skills compared with farmers at a lower educational level.

Table-6. Inefficiency model.

Variable	Parameter	Coefficient	Standard error	*t*-Ratio
Constant	δ_0	1.245	0.18	6.923*
Farmer's age	δ_1	0.002	0.001	1.173
Level of education	δ_2	−0.028	0.01	−2.875*
Farming experience	δ_3	−0.002	0.002	−1.215
Frequency of contacts with extension	δ_4	−0.012	0.007	−1.591
Membership in farmers' association	δ_5	−0.273	0.027	−10.053*
Full-time pepper farming	δ_6	−0.135	0.032	−4.241*
Courses and visits	δ_7	−0.05	0.025	−1.984**

Note: * and ** indicate that the variable is significant at 1 and 5%, respectively.

Approximately 74% of the respondents in the present study are members of farmers' organizations. Organizational membership appears to benefit members because they can share their knowledge and experience of pepper farming. Moreover, full-time pepper farmers were more efficient compared with part-time. When farmers focus on pepper farming, they are more efficient because they put more effort into the main crop than into other crops. In addition, attending courses and study visits contributed to technical efficiency among pepper farmers in Sarawak. However, because pepper farmers' involvement in farming courses and visits was low, relevant agencies such as MPB and higher education institutions (with an agricultural background) should provide more farming courses and encourage farmers to join their training programs.

As expected, farmers' age negatively influenced technical efficiency. This finding implies that younger farmers tend to have a higher technical efficiency level compared with older farmers. Although pepper farming experience and frequency of contacts with extension officers per year did not significantly contribute to technical efficiency (in the present study), both explanatory variables positively affected technical efficiency. Farmers with many years of experience in pepper farming manage their farms more efficiently compared with those with less pepper farming experience. Frequency of contacts with extension agents could improve pepper farming practices; farmers visit extension offices not only for subsidies but also for solutions to their farming problems. In the case of pepper farming in Sarawak, most farmers are in the interior areas and it is difficult for them to visit the extension offices located in towns. Therefore, frequent visits by extension agents to farmers will enable them to obtain advice about new knowledge and skills in pepper farming.

The results of this study have similarities with other efficiency studies in agricultural production. Research conducted by Alem, Lien, and Hardaker (2018) and Bushara and Abuagla (2016) found that agricultural practices affected farm performance. As expected, fertilizer usage increased production and had a significant relationship with pepper yield. The use of fertilizer should be increased to boost production (Ai, Liu, Sirisrisakulchai, & Sriboonchitta, 2018; Dang, 2017; Dube & Mugwagwa, 2017). However, some agricultural inputs could harm production, such as fungicide, whereas the interaction between fungicide and fertilizer was found to be significantly negative regarding pepper yield in this study. Dang (2017) also found that nitrogen fertilizer and pesticide negatively affected white maize yield. Farmers need to use the correct types and amounts of agricultural input on the farm to ensure a boost to farm production. This study also found that the new variety *Semongok* significantly influenced pepper yield and technical efficiency. Thus, a new variety significantly improved farm production and influenced technical efficiency (Chiona, Kalinda, & Tembo, 2014; Dessale, 2019; Ngango & Kim, 2019; Yahaya, Shamsudin, Radam, & Abd Latif, 2016). Besides, socioeconomic factors including experience, farmer's age, education, contact with extension agencies, education level, membership in farmers' association and attending agricultural training have significantly improved technical inefficiency among farmers (Dessale, 2019; Dube & Mugwagwa, 2017; Lema, Tessema, & Abebe, 2017; Moses & Okpachu, 2019; Owusu, 2018; Pradhan & Mukherjee, 2018).

4. CONCLUSION, LIMITATIONS, AND RECOMMENDATIONS

The pepper farmers in the present study are technically inefficient. The major problem associated with pepper farming in Sarawak, Malaysia, is poor agricultural practices where farmers do not fully utilize the available agricultural inputs to produce maximum output. Farmers must improve their knowledge and skills in pepper farming through agronomic education. Government and relevant agencies such as the MPB, Department of Agriculture and higher education institutions (with an agricultural background) should provide more training to pepper farmers to educate them about good agricultural practices, especially hands-on training to those with less knowledge and experience in pepper farming. Hands-on training also seems appropriate for more elderly groups with a low educational level, because they can learn about farming methods better through live demonstrations compared to theoretical training. However, this study focuses on pepper farming only in Sarawak and thus does not appropriately reflect pepper farming practices in other pepper-producing countries, because different countries have different cultural, sociodemographic, environmental, and agricultural practices. Thus, efficiency studies on pepper farming in other countries are highly recommended.

Funding: Research Graduate Fellowship (GRF) from School of Graduate Studies, UPM.
Competing Interests: There are no competing interests in this research.
Acknowledgments: All authors participated equally in the design and estimation of the current research.

REFERENCES

Abdul, H. J., & Mansur, J. (1997). Technical efficiency of pepper farms in Sarawak. *Journal of Malaysia Economics, 31*, 71-85.

Ai, X., Liu, J., Sirisrisakulchai, J., & Sriboonchitta, S. (2018). Technical efficiency analysis of major agriculture production provinces in China: A stochastic frontier model with entropy. *Journal of Physics Conference Series, 1053*(1), 1-8.

Aigner, D. J., Lovell, C. A. K., & Schmidt, P. (1977). Formulation and estimation of stochastic frontier production function models. *Journal of Econometrics, 6*, 21-37.

Alem, H., Lien, G., & Hardaker, J. B. (2018). Economic performance and efficiency determinants of crop-producing farms in Norway. *International Journal of Productivity and Performance Management, 67*(9), 1418-1434.

Azumah, B. S., Donkoh, S. A., & Awuni, J. A. (2019). Correcting for sample selection in stochastic frontier analysis: Insights from rice farmers in Northern Ghana. *Agricultural and Food Economics, 7*(9), 1-15.

Batiese, G. E. (1992). Frontier production functions and technical efficiency: A survey of empirical applications in agricultural economics. *Agricultural Economics, 7*(3-4), 185-208.Available at: https://doi.org/10.1016/0169-5150(92)90049-5.

Battese, G. E., & Coelli, T. J. (1995). A model for technical inefficiency effects in a stochastic frontier production function for panel data. *Empirical Economics*, *20*(2), 325-332.Available at: https://doi.org/10.1007/bf01205442.

Battese, G. E., & Corra, G. S. (1977). Estimation of a production frontier model: With application to the pastoral zone of Eastern Australia. *Australian Journal of Agricultural Economics*, *21*(3), 169-179.Available at: https://doi.org/10.1111/j.1467-8489.1977.tb00204.x.

Bushara, M., & Abuagla, M. (2016). Measuring production efficiency of sorghum small farmers in Rahad Agricultural Scheme season (2011-2012). *Journal of Socialomics*, *5*(192), 1-10.

Chiona, S., Kalinda, T., & Tembo, G. (2014). Stochastic frontier analysis of the technical efficiency of smallholder maize farmers in Central Province, Zambia. *Journal of Agricultural Science*, *6*(10), 108-118.Available at: https://doi.org/10.5539/jas.v6n10p108.

Coelli, T. J., Rao, P. D. S., & Battese, G. E. (1998). *An introduction to efficiency and productivity analysis*. London: Kluwer Academic Publishers.

Coelli, T. J. (1995). Recent developments in frontier modelling and efficiency measurement. *Australian Journal of Agricultural Economics*, *39*(3), 219-245.Available at: https://doi.org/10.1111/j.1467-8489.1995.tb00552.x.

Dang, N. H. (2017). Estimation of technical efficiency and its determinants of white maize production in Vinh Long Province: A stochastic production frontier approach. *Review of Integrative Business and Economics Research*, *6*(4), 341-352.

Department of Agricultural Sarawak. (2020). Pepper and pepper research in Sarawak. Retrieved from https://doa.sarawak.gov.my/modules/web/pages.php?lang=bm&mod=webpage&sub=page&id=138. [Accessed 13 July 2020].

Dessale, M. (2019). Analysis of technical efficiency of small holder wheat-growing farmers of Jamma district, Ethiopia. *Agriculture & Food Security*, *8*(1), 1-8.Available at: https://doi.org/10.1186/s40066-018-0250-9.

Dewi, S., & Sahardi. (2009). Efficiency of production factors on pepper in integrated farming and traditional system in South East Sulawesi. *Abstract retrieved from Indonesian Center for Assessment and Development of Agricultural Technology (ICADAT)*.

Dube, L., & Mugwagwa, K. E. (2017). Technical efficiency of smallholder tobacco farmers under contract farming in Makoni district of Manicaland province, Zimbabwe: A stochastic frontier analysis. *Scholars Journal of Agriculture and Veterinary Sciences*, *4*(2), 68-78.

Grahasita, R. (2012). *Efficiency of pepper farming in East Belitung district*. Unpublished Doctoral Dissertation, Universitas Gadjah Mada, Indonesia.

Kostlivý, V., & Fuksová, Z. (2018). Technical efficiency and its determinants for Czech livestock farms. *Agricultural Economics*, *65*(4), 175-184.

Lema, T. Z., Tessema, S. A., & Abebe, F. A. (2017). Analysis of the technical efficiency of rice production in Fogera district of Ethiopia: a stochastic frontier approach. *Ethiopian Journal of Economics*, *26*(2), 88-108.

Malaysian Pepper Board (MPB). (2018). Laporan Tahunan MPB 2018. Retrieved from: https://www.mpb.gov.my/mpb/images/penerbitan/laporantahunan/Laporan_Tahunan_2018.pdf. [Accessed 13 August 2020].

Malaysian Pepper Board. (2017). *Pepper statistic: Production and consumption*. Kuching, Sarawak: MPB Headquarters.

Meeusen, W., & van Den Broeck, J. (1977). Efficiency estimation from Cobb-Douglas production functions with composed error. *International Economic Review*, *18*(2), 435-444.Available at: https://doi.org/10.2307/2525757.

Ministry of Plantation Industries and Commodities (MPIC). (2019). Agricommodity pocket Putrajaya, Malaysia. Retrieved from: https://www.mpic.gov.my/mpi/images/01Bahagian/PSA/2020/2019_Agricommodity_Pocket_Stats_Resize.pdf.

Mohd, M. I., Alias, R., & Ruhana, B. (1993). Resource use efficiency in pepper farming In Sarawak. In Ibrahim, M. Y, Bong, C.F. J., and Ipor, I. B. (Ed), The Pepper Industry, Problems and Prospects (pp. 313-321). Bintulu, Sarawak: Universiti Putra Malaysia.

Moses, J. D., & Okpachu, S. A. (2019). Analysis of technical efficiency of guava farmers in Yobe State: A stochastic frontier approach. *Agricultural Research & Technology*, *5*(6), 1-11.Available at: doi.org/10.29023/alanyaakademik.472420.

Ngango, J., & Kim, S. G. (2019). Assessment of technical efficiency and its potential determinants among small-scale coffee farmers in Rwanda. *MDPI*, *9*(7), 1-12.Available at: https://doi.org/10.3390/agriculture9070161.

Noorzakiah, M. S., Alias, R., & Shazali, A. M. (1993). Utilization of resources in pepper farming: The case of Sarawak. In Ibrahim, M. Y, Bong, C.F. J., and Ipor, I. B. (Ed), The Pepper Industry, Problems and Prospects (pp. 299-312). Bintulu, Sarawak: Universiti Putra Malaysia.

Owusu, R. C. (2018). Benchmarking technical efficiency of rice farms in Ghana: An empirical application of alternative production frontier approaches. *The Central European Review of Economics and Management*, *2*(3), 125-154.Available at: https://doi.org/10.29015/cerem.577.

Paulus, A. D. (2008). *Pepper varieties planted by farmers in Sarawak*. Sarawak: Department of Agricultural (DOA) Sarawak, Kuching, Sarawak.

Pradhan, K. C., & Mukherjee, S. (2018). Examining technical efficiency in Indian Agricultural production using production frontier model. *South Asia Economic Journal*, *19*(1), 22-42.Available at: https://doi.org/10.1177/1391561418761073.

Sekaran, U., & Bougie, R. (2016). *Research methods for business: A skill-building approach* (7th ed.). United Kingdom: John Wiley & Sons Ltd.

Sharma, K. R., & Leung, P. (1999). Technical efficiency of the long-line fishery in Hawaii: An application of stochastic frontier. *Marine Resource Economics*, *13*, 259-274.

Yahaya, K., Shamsudin, M. N., Radam, A., & Abd Latif, I. (2016). Profit efficiency among paddy farmers: A Cobb-Douglas stochastic frontier production function analysis. *Journal of Asian Scientific Research*, *6*(4), 66-75.Available at: https://doi.org/10.18488/journal.2/2016.6.4/2.4.66.75.

APPENDIX

Appendix-1. Efficiency studies using SFA in the agricultural sector.

Author (year); country	Subject of research	Data	Type of functional form
Moses and Okpachu (2019); Nigeria	Guava farmers	Cross-sectional	Cobb–Douglas
Payang, Poyearleng, Ngaisset, and Xia (2019) Africa	Maize farmers	Cross-sectional	Cobb–Douglas & Translog
Azumah et al. (2019); Ghana	Rice farmers	Cross-sectional	Cobb–Douglas & Translog
Ngango and Kim (2019); Rwanda	Coffee farmers	Cross-sectional	Cobb–Douglas
Dessale (2019); Ethiopia	Wheat farmers	Cross-sectional	Cobb–Douglas
Alem *et al.* (2018); Norway	Crop farms	Panel data	Translog cost function
Kostlivý and Fuksová (2018); Czech Rep.	Livestock (organic farms)	Panel data	Cobb–Douglas & Translog
Owusu (2018); Ghana	Rice farms	Cross-sectional	Translog
Ai et al. (2018); China	Agricultural production	Annual data	Cobb–Douglas
Alem. (2018); Norway	Crop farms	Panel data	Translog
Lefroy and Key (2018); Australia	Broadacre farming	Panel data	Translog
Pradhan and Mukherjee (2018); India	Agricultural production	Cross-sectional & panel data	Cobb–Douglas
Becerra-Perezab, Lopez-Reyesa, and Tyne (2017); Mexico	Corn	Cross-sectional	Cobb–Douglas
Ali and Jan (2017); Pakistan	Sugarcane	Cross-sectional	Cobb–Douglas
Lema et al. (2017); Ethiopia	Rice production	Cross-sectional	Cobb–Douglas
Zhang, Xie, and Affuso (2017); USA	Crop farms	Annual data	Cobb–Douglas
Dube and Mugwagwa (2017); Zimbabwe	Smallholder tobacco farmers	Cross-sectional	Cobb–Douglas
Dang (2017); Vietnam	White maize farmers	Cross-sectional	Cobb–Douglas
Cillero, Thorne, Wallace, Breen, and Hennessy (2017); Ireland	Beef	Panel data	Cobb–Douglas
Latruffe, Bravo-Ureta, Carpentier, Desjeux, and Moreira (2017); Europe	Dairy farms	Annual data	Cobb–Douglas
Yahaya et al. (2016); Malaysia	Paddy farmers	Cross-sectional	Cobb–Douglas
Bushara and Abuagla (2016); Sudan	Small farmers	Cross-sectional	Cobb–Douglas
Kittilertpaisan, Kittilertpaisan, and Khatiwat (2016); Thailand	Rubber farmers	Cross-sectional	Cobb–Douglas
Islam, Tai, and Kusairi (2016); Malaysia	Fish cage culture	Cross-sectional	Cobb–Douglas
Poungchompu and Chantanop (2015); Thailand	Rubber	Cross-sectional	Cobb–Douglas
Bathon and Maurice (2015); Negeria	Groundnut-based cropping farmers	Cross-sectional	Cobb–Douglas
Masunda and Chiweshe (2015); Zimbabwe	Dairy farms	Cross-sectional	Cobb–Douglas
Dudu, Cakmak, and Öcal (2015); Turkey	Crop farms	Panel data	Cobb–Douglas
Osmani and Kambo (2015); Albania	Apple	Cross-sectional	Translog
Zhou et al. (2015); China	Pig	Annual data	Translog
Chiona et al. (2014); Zambia	Maize farmers	Cross-sectional	Cobb–Douglas & Translog
Mburu, Ackello-Ogutu, and Mulwa (2014); Kenya	Wheat farmers	Cross-sectional	Cobb–Douglas
Guesmi, Serra, and Featherstone (2014) USA	Arable crop farms	Annual data	Cobb–Douglas
von Cramon-Taubadel and Saldias (2014); Chile	Farmers	Cross-sectional	Translog
Trujillo and Iglesias (2014); Colombia	Pineapple farmers	Cross-sectional	Cobb–Douglas

Appendix-2. Farmer numbers surveyed by area according to MPB branches .

MPB office	District	Number of farmers	Questionnaire	Sample
MPB Kuching	Siburan	689	123	102
	Bau	593		
	Lundu	656		
	Asajaya	410		
	Simunjan	1,904		
MPB Serian	Serian	4,562	132	110
MPB Sri Aman	Pantu	1,341	131	111
	Sri aman	1,464		
	Engkilili	1,714		
MPB Betong	Betong	3,213	93	81
MPB Sarikei	Saratok	1,404	137	110
	Sarikei	1,824		
	Pakan	1,495		
MPB Bintangor	Julau	1,886	80	77
	Meradong	888		
MPB Sibu	Sibu	298	71	62
	Kanowit	851		
	Selangau	398		
	Kapit	347		
	Song	166		
	Belaga	166		
	Mukah	225		
MPB Bintulu	Bintulu	222	13	10
	Tatau	221		
MPB Miri	Miri	369	20	15
	Marudi	176		
	Limbang	138		
Total		27,620	800	678

Source: Malaysian Pepper Board (2011).