ESTIMATION OF FARM LEVEL TECHNICAL EFFICIENCY AND ITS SOCIO-ECONOMIC DETERMINANTS IN VANILLA PRODUCTION IN KANDY DISTRICT, SRI LANKA

L. G. T. W. Kariyawasam[1], R. A. P. I. S. Dharmadasa[2],
C. Rudrigo[3], and A. M. C. Amarakoon[4]

Abstract

Vanilla is one of the economically important crops in Sri Lanka although it is mainly confined as a home garden crop grown in mid and low country wet zone. Farmer productivity is one of the most important concerns in vanilla cultivation. Thus, the productivity of Vanilla farmers can be raised by improvement in efficiency in the short run. As a result of the near absence of empirical information on farm-level technical efficiency in small scale Vanilla Production in the country generally and Kandy District in particular, a Stochastic Frontier function which incorporated inefficiency factors was estimated using a Maximum Likelihood technique to provide estimates of technical efficiency and its determinants using data obtained from 80 Vanilla farmers in Ganga Ihala Korale Divisional Secretariat division since it has one of the largest numbers of small-holder vanilla producers in the country. The results reveal that Vanilla farmers are not fully technically efficient and the mean technical efficiency estimated is 37.32%. Estimated results of the inefficiency model show that experience and educational level of the vanilla farmers significantly influence the farmers 'efficiency positively whereas age of the farmers contributes to increase the inefficiency. The findings imply that policies that would encourage youth to engage in vanilla farming and improvement in human capital should be made and implemented.

Keywords: Kandy District, Maximum Like hood estimation, Stochastic frontier model, Technical efficiency, Vanilla farmers

1. Introduction

[1] Corresponding Author, L.G.T.W. Kariyawasam, Department of Export Agriculture, Faculty of Animal Science and Export Agriculture, Uva Wellassa University, Sri Lanka. E-mail: thilini.kariyawasam26@gmail.com

[2] R. A. P. I. S. Dharmadasa, Department of Export Agriculture, Faculty of Animal Science and Export Agriculture Uva Wellassa University, Sri Lanka.

[3] C. Rodrigo, Agriculture Economist, TAMP Project, Ministry of National Policies and Economic Affairs, Sri Lanka.

[4] A. M. C. Amarakoon, Department of Export Agriculture, Faculty of Animal Science and Export Agriculture Uva Wellassa University, Sri Lanka.

Sri Lanka as a tropical country sufficient with the ideal climatic conditions throughout the year, fertile soil and also the ample supply of groundwater, agriculture plays a significant role within the economy of the country. While the primary form of agriculture is rice production, export agricultural crops play a significant role in agricultural sector. However, according to the statistical records, minor export crops indicate decline of production due to cyclic seasonal patterns and due to adverse weather conditions (Central Bank of Sri Lanka,2016). Among all Export agricultural crops, vanilla is a highly demanded spice in the world. It is considered as one of the economically important crops in the world and it is the second-most expensive spice after saffron. Vanilla (*Vanilla fragrans*) belongs to Orchidaceae family native to Mexico. Vanillin is the main product extracted from vanilla that is responsible for the characteristic flavor and smell of vanilla. In Sri Lanka, vanilla is popular as a home garden crop grown in mid and low country wet zone and the total extent is less than 100ha (Department of Export Agriculture, Sri Lanka, 2018). Due to the favorable growing conditions for vanilla, it is grown in Kandy, Nuwera Eliya, Mathale, and Kegalle Districts.

Potential for vanilla cultivation is increasing due to its increasing nature of prices and extraordinary demand. As a result, it creates productive employment opportunities and wealth among all the actors in the value chain. Cultivation of most of export agricultural crops like cinnamon, cardamom, coffee, pepper have become challenging and entailing huge expenses with less return. In such context, vanilla is ideal to farmers assuring them of comparatively better prospects in terms of profit for their investment and efforts. Though it is a viable venture for creating employment and reducing rural poverty, the industry has received very limited attention from the responsible authorities. Also, there are many bottlenecks for the vanilla farmers that may badly affect in reducing the production capacity.

Technical efficiency is the ability to produce maximum level of output given a similar level of production inputs. According to Battese and coelli (1995), a firm that wants to be technically efficient, needs to produce at the production frontier level. However, it is not always the case due to random factors such as bad weather conditions, animal damages and other firm specific factors which lead to producing below the expected output frontier. In Sri Lanka, there is not expected level of production of vanilla. Therefore, evaluation of technical efficiency is considered to be vital. There are no indications about the technical efficiency levels of farmers as well as the socio-economic characteristics which could be expected to be affecting technical efficiency of Sri Lankan vanilla farmers in literature. Also, there are no scientific evidences about productivity about the vanilla cultivation in Sri Lanka. Therefore, answering the questions of “what are the levels of efficiency (technical) among small-holder vanilla farmers?”, “what are the determinants of inefficiency among small-holder vanilla farmers and their relationship with farmers' socio-economic characteristics?", "how does the technical efficiency change with respect to the different functional form specifications?" and "what are the constraints for vanilla cultivation in farmer level?" would provide better insights into improving the productivity of vanilla farmers. Moreover, computing technical efficiency constitutes a more important source of information for policy makers. The results and findings of the study will also be valuable to government and other development agencies who are interested in improving the livelihoods of rural vanilla farmers. Therefore, this study is an attempt to estimate levels of efficiency (technical) among small-holder vanilla farmers. More specifically, we estimate the determinants of inefficiency among small-holder vanilla farmers and its relationship with farmers' socio-economic characteristics, study the robustness of technical efficiency estimates with respect to different functional form specifications and analyze the constraints for the vanilla cultivation in farmer level and provide policy recommendations based on the efficiency estimates and constraints.

2. Literature Review

A review of literature revealed that very limited research studies were conducted about vanilla in our country, Sri Lanka. But, there was no study regarding the economic analysis of vanilla cultivation. Vanilla is the second most economically important spice in the world after saffron. Palmurugan (2006) defined Vanilla as the Prince of Spice in India. Menz and Fleming (1989) revealed that Vanilla is quite easy for smallholders to grow requiring relatively low capital investment and its value-weight ratio is high. One of important studies conducted by Komarek (2010) related to vanilla cultivation in Uganda revealed that household welfare improves by 16%, without raising food security concerns, when vanilla is grown. It was further found that gross margin is approximately 591USD/acre for vanilla. Accordingly, the gross margin for vanilla is higher than that of other crops like maize, cassava, coffee, and beans in Uganda. Balamurugan (2009) indicated that large farming makes the highest return when compared to medium and small farming as a result of economies of scale. Furthermore, capital productivity analysis indicates smart return on investment in vanilla cultivation under all categories. In addition to that, another study on economic evaluation of vanilla cultivation in Karnataka conducted by Rajesh (2006) found that the benefit cost ratio for the small farms and the large farms was 10.71 and 13.71, respectively.

Rayudu et al (2003), Palmurugan (2006), and Pankaja et al (2009), etc., have conducted studies related to socio economic characteristics of vanilla farmers in India. According to Rayudu et al (2003), socio-economic conditions of Kasargod vanilla farmers in India are to be poor to average. Majority of vanilla growers (68.89 percent) had high school education. It was also revealed that most of the (37.78 percent) vanilla farmers belong to the middle age group. But according to a previous study conducted by Palmurugan (2006) based on Tamil Nadu and Kerala revealed that 62 % vanilla farmers belong to middle age category. Pankaja et al (2009) conducted a study to identify the Correlates of knowledge level of vanilla growers on cultivation practices of vanilla based on Shimoga district of Karnataka and found that age, education, family dependency ratio, social participation, risk orientation, economic orientation, innovation proneness, level of aspiration and management orientation are significantly related to knowledge level of vanilla growers.

Although it is a profitable cultivation, there are many issues related to vanilla. According to Balamurugan (2009) cost of inputs was the major problem for the small-scale vanilla famers. Poor research and development support for the medium farmers and non- availability of skilled labor for large farmers are also issues in vanilla farming. Wide price variation was found to be the most important marketing problem in vanilla cultivation in India. Mexico was the main vanilla producer in the world many years ago. It currently provides just around 5 % of the global production. Pérez et al (2017) showed that most of the challenges and limitations among smallholder farmers were in lack of training to improve production, processing, and marketing. Likewise, various restrictive aspects were identified in the production process that affects crop productivity. Those factors are; cultivation in small parcels, high incidence of diseases, premature abortion of fruits, and low tolerance of plants to stress. Rajesh (2006) revealed that although there are many problems faced by the vanilla farmers due to pest and diseases and non-availability of skilled labors for pollination, vanilla cultivation is a profitable business.

Efficiency of firm means its attainment in producing as large as possible an output from a given set of inputs at the lower cost (Farrell, 1957). Also, Ogunniyi (2008) defined the three components of efficiency as technical, allocative and economic efficiency. Technical efficiency is defined as the ability to produce a given level of output with a minimum quantity of inputs under certain technology. According to Battese and Coelli (1995), for a firm that wants to be technically efficient it needs to produce at the production frontier level. But that is not always the situation due to random factors such as bad weather conditions, animal damages and other firm specific factors which lead to producing below the expected output frontier. Therefore, efficiency measurements attempt to identify those factors that are firm specific that delay the production along the frontier. Generally, there are two families of methods based on efficient frontier such as non-parametric methods and parametric methods to measure the technical efficiency. Under the non-parametric methods DEA (Data Envelopment Analysis) and SFA (Stochastic Frontier Approach) are the main methods commonly used to estimate efficiency of Decision Making Units (Bezat, 2009). DEA does not allow to estimate or measure the error. However, DEA is good at estimating "relative" efficiency, thus the measurements are only valid in a sample. The stochastic approach considers additionally a random variable. Also, this approach treats deviations from production function as comprising both random error and inefficiency error. In addition to that, according to Kolawole (2006), SFA method distinguishes a functional form for the cost, profit, or production relationship among inputs, outputs and non-factors.

3. Methodology

The study was conducted to identify the technical efficiency of vanilla farmers in Ganga Ihala Korale Divisional Secretarial Division (DSD), which is the highest vanilla producing DSD in Kandy District of Sri Lanka. Before, the data collection started, a discussion was held with Kandy Vanilla Growers Association. According to the association, the majority of experienced farmers are in Ihala Korale DSD. As Ganga Ihala Korale DSD consists of many Grama Niladhari Divisions (GNDs), four GNDs (Malwaththagama, Karagala, Watakedeniya, and Girauwala) were selected according to the presence of vanilla farmers. There are about 250 vanilla farmer families in those GNDs. A sample 80 farmers were selected using quota sampling method. Fifty percent of farmers are in Karagala GND while Girauwala, Malwaththagama and Watakedeniya represent 30%, 10% and 10% farmers, respectively. Depending on the percentages, 40 from Karagala, 24 from Girauwala, 8 from Malwaththagama and 8 from Watakedeniya were randomly selected using a list of farmers to collect data using a self-administered questionnaire.

3.1 Analytical Model

The problem of measuring the production efficiency of an industry is important to both the economic theorists and the economic policy makers (Farrel, 1957). If economic plan is to concern itself with particular industries, it is important to know how far a given industry can be expected to increase its output by simply increasing its efficiency without absorbing further resources (Farrel, 1957). Two main methods are generally used to analyze the efficiency of production. They are parametric method, where the stochastic production frontier, which was independently proposed by Aigner, Covell, and Schemidt (1977) and Meeusen and Van den Broek (1977) is used, and non-parametric method where Data Envelopment Analysis (DEA) is used to compute technical efficiency scores. This study employs stochastic production frontier as it makes allowance for stochastic errors due to statistical noise or measurement errors while it accounts for firm specific inefficiency (Forsund et al, 1980; Battese, 1992; Coelli et al, 1998).

Although there are its well-known limitations, the stochastic production frontier is specified using the Cobb-Douglas functional form in this study as it provides an adequate representation of the production technology as long as interest rests on efficiency measurement and not on the analysis of the general structure of the production technology.

The specification of the production function form is given by:

$$lnY = \beta_0 + \sum_{j=1}^{4} \beta_j \, lnX_{ij} + V_i - U_i \qquad (1)$$

Where:

ln denotes Natural logarithms; Y is the output of vanilla produced, pods (kgs), v is a pure noise component with mean 0 and constant variance σ_v^2 and that $u_i \geq 0$ follows a half normal distribution with variance σ_u^2. βs are unknown parameters to be estimated. The subscripts, j, i and refer to the j-th input (j = 1,2,…,4), i-th vanilla farmer (i=1,2,…, 80) respectively.

We specify its Cobb-Douglas stochastic production frontier in the following way:

$$lnY = \beta_0 + \beta_1 ln\mathrm{X}_1 + \beta_2 ln\mathrm{X}_2 + \beta_3 ln\mathrm{X}_3 + \beta_4 ln\mathrm{X}_4 + \mathrm{v_i} - \mathrm{u_i} \qquad (2)$$

X_1= Fertilizer (kgs)

X_2= Vanilla cultivated land area (acres)

X_3= Labour (man hours)

X_4= Number of matured vanilla veins (vanilla plants)

The inefficiency model specified for Battese and Coelli (1995) specification is,

$$u_{ij} = \delta_0 + \sum_{j=1}^{9} \delta_j Z_{ij} + W_i \qquad (3)$$

Where;

δ_j (j=0,1,….,6) are unknown parameters; W_i is unobservable random variables.

We specify the inefficiency model in the following way:

$$U_i = \delta_0 + \delta_1 \mathrm{Z}_1 + \delta_2 \mathrm{Z}_2 + \delta_3 \mathrm{Z}_3 + \delta_4 \mathrm{Z}_4 + \delta_5 \mathrm{Z}_5 + \delta_6 \mathrm{Z}_6 + W_i \qquad (4)$$

Where;

Z_1= Age of the farmer (Years)

Z_2= Gender (a dummy variable; 1= female and 0= male)

Z_3= Experience (Years)

Z_4=Years of schooling (Years)

Z_5= Access to the Extension services (Considered as dummy variable; 1= Yes, 0= No)
Z_6 = Household size (number of family members)
The expression of Technical Efficiency relies on the value of the unobservable U_i, which must be predicted. These predictions are obtained by deriving the expectation of the appropriate function of $\boldsymbol{U_i}$ conditional on the observed value of $v_i - u_i$

The maximum likelihood method is used to estimate the parameters of both the stochastic frontier model and inefficiency effects model. According to Battese and Corra (1977), the variance parameter of the likelihood function is estimated in terms of $\sigma^2 = \sigma^2_u + \sigma^2_v$ and $\gamma = \sigma^2_u / \sigma^2$. So that $0 \leq \gamma \leq 1$

Much of stochastic frontier analysis is directed towards the prediction of inefficiency effects. The most common output-oriented measure of technical efficiency is the ratio of observed output (q_i) to the corresponding stochastic frontier output.

$$TE = \frac{Y_i}{\exp(x_i\beta + v_i)} = \frac{\exp(x_i\beta + v_i - u_i)}{\exp(x_i\beta + v_i)} = \exp(-u_i) \quad (5)$$

Finally, the technical efficiency of production for the ith vanilla farmers could be defined by $TE = exp(-U_i)$
The technical efficiency index (TEi) is equal to 1 if the farm is perfectly efficient and equal to zero if perfectly inefficient. On one hand, If the value of γ equals zero the difference between farmers yield and the efficient yield is entirely due to statistical noise. On the other hand, a value of one would indicate the difference attributed to the farmers' less than efficient use of technology i.e. technical inefficiency (Coelli, 1995).
Finally, a stochastic translog production function was estimated to test the robustness of the functional form. The following is the translog specification of the function:

$$lnY = \beta_0 + \beta_1 ln\mathrm{X}_1 + \beta_2 ln\mathrm{X}_2 + \beta_3 ln\mathrm{X}_3 + \beta_4 ln\mathrm{X}_4 + +\beta_5 (ln\mathrm{X}_1)^2 + \beta_6 (ln\mathrm{X}_2)^2 + \beta_7 (ln\mathrm{X}_3)^2 + \beta_8 (ln\mathrm{X}_4)^2 + \beta_9 (ln\mathrm{X}_1 * ln\mathrm{X}_2) + \beta_{10} (ln\mathrm{X}_1 * ln\mathrm{X}_3) + \beta_{11} (ln\mathrm{X}_1 * ln\mathrm{X}_4) + \beta_{12} (ln\mathrm{X}_2 * ln\mathrm{X}_3) + \beta_{13} (ln\mathrm{X}_2 * ln\mathrm{X}_4) + \beta_{14} (ln\mathrm{X}_3 * ln\mathrm{X}_4) + v_i - u_i \quad (6)$$

3.2 Constraints Analysis for Vanilla Cultivation

The information on constraints faced by farmers in vanilla production was collected with the help of questionnaire and the responses were ranked according to the following scale.

Most Important = 4
Important = 3
Less Important = 2
Least Important = 1
The average value for each constraint was then calculated to find the level of importance of the constraints.

4. Results and Discussion

4.1 Socio-economic Characteristics of Farmer

For this study, a farmer is defined as a person who makes the decisions about vanilla cultivation. According to the data, 52.5% females and 47.5% males are involved vanilla cultivation as the main decision makers. It can therefore be indicated that vanilla cultivation is female-dominating. Age is considered as one of the important factors for taking decisions about adoption new strategies to increase the production and finally the income as the maturity plays a vital role in decision-making.

Majority of farmers (71.25%) lie in the age between 45-74 years. about 50% of the vanilla farmers have achieved up to 9-13 years of education. although vanilla farming is considered to be a lucrative job, the income levels of the farmers are not satisfactory. Most of them earn an income of no more than 30000 LKR per month. Also, majority (53.75 %) of vanilla farmers do not diversify their income into other sources. Therefore, only source of income is vanilla cultivation for them. The rest of the farmers diversify their income into several sources such as government employment, other business ventures etc. Majority of the farmers in vanilla cultivation is females with no other job. Their sole income is earned through vanilla cultivation. Normally extension services are very important for the farmers as they help increase the awareness about new strategies to enhance the production and motivate farmers to expand the production capacity. It is surprising that most of the vanilla farmers do not have access to extension facilities. Only 17.5% of farmers have received extension facilities from the government whereas some information related to cultivation and its improvement has been received from private sector also.

4.2 Summary Statistics of Input and Output Variables

Table 1 indicates the summary statistics of the variables used in the stochastic production frontier. On average, vanilla farmers possess less than an acre for vanilla cultivation and they obtain about 3.6 kilograms of vanilla per acre from previous cropping cycle. Normally, farmers cultivate vanilla as a mix crop with other commercial crops like tea, coffee, and pepper, etc. Therefore, the land area is not consumed individually by vanilla i.e. land consumed by vanilla is very low. However, according to the recommendations of department of export agriculture, spacing should be 3m x 1.5 m among veins. Thus, major reason for relatively lower production output (about 3.6 kg per acre) is that they do not follow the recommendations.

It is a fact that proper application of nutrients via fertilizer is a must for a better growth of the plant. It is evident that vanilla cultivation depends on organic fertilizers and farmers apply about 10 kilograms per acre. Labor input plays an important role in pollination in vanilla cultivation and it demands more skilled labor. On average, 23.5 man hours are needed per acre in doing the need labor work. There are a large number of veins in the fields with different ages. Normally veins after 3 years of planting are considered as matured veins because veins start to bear the flowers after three years of planting. In that case, only number of matured veins is considered for the study. Accordingly, average number of matured veins per acre is 14 ranging for a maximum and minimum of 40 and 5 respectively. Average education level of the vanilla farmers is about 9 years and most of them are older farmers (53.9 years). Although the farmers are old, they are new to vanilla cultivation and their experience is about six years in vanilla farming.

Table 1: **Summary statistics for Variables in the Stochastic Frontier Production Functions for the Vanilla Farmers**

Variable	**Mean**	**Standard Deviation**	**Minimum**	**Maximum**
Output (kg/ acre)	3.591875	2.63569	1	10
Land (acres)	0.43125	0.1777808	0.25	0.75
Fertilizer (kg/ acre)	10.0625	4.464611	5	20
Labour (man hours/ acre)	23.4625	11.4954	8	50
Matured veins/ acre	14.25	6.839017	5	40
Age	52.9125	12.58107	25	76

Table 1 Continued

Years of schooling	8.757381	2.353674	2.5	12.5
Household size	3.5	1.079146	2	7
Experience	5.9625	2.222974	3	10

Source: Field Survey, 2018

4.3 Results of Cobb Douglas Production Function

Bravo-Ureta and Rieger (1991) stated that the MLE (Maximum Likelihood Estimation) approach is far more an appropriate and efficient method in estimating frontier functions than the conventional OLS (Ordinary Least Square). Therefore, in estimating the parameters of Cobb Douglas production function, first OLS method was employed and next MLE method was employed. The results of the estimations are depicted in Table 2. R^2 value of OLS estimation is 57.37 while the adjusted R^2 is 55.10. The sign of the coefficients for all the variables in production function are positive showing that all the inputs in production function positively affect the output. Before we estimate the production function using the MLE method, we should statistically show that the residuals of the production function is negative skewed. Otherwise, stochastic frontier production function often suffers from many errors (Hafner et al, 2018). When checked, the estimated skewness of the residuals of production function is negative with the value of - 0.2326059. Having checked the negative skewness, we estimated the model using MLE approach.

The results show that estimates of γ, the variance ratio parameter which relates variability of u_i to the total variability, is 0.6873. It indicates that majority of error variance for the vanilla farmers is due to the inefficiency error u_i and not due to the random error v_i. This result indicates that the random component of the inefficiency effects does make a significant contribution in the analysis. The estimated ML coefficients for Fertilizer, land area, labor and number of matured veins showed positive values of 0.289, 0.311, 0.602 and 0 .497 respectively. All these values are significant at 1% significance level. This indicates that increment of the input levels (fertilizer level, land area, labor hours and number of matured veins by one per cent) by one percent, will lead to increase the output by 0.289 percent, 0.311 percent, 0.602 percent and 0 .497 percent respectively. The most significant factor of the vanilla production is labor because results show the elasticity of labor is the highest (0.602). This is due to the fact that vanilla is a labor intensive crop especially due to hand pollination.

Table 2: **OLS Estimates and Maximum Likelihood Estimates for Parameters of the Stochastic Frontier (Cobb-Douglas Model)**

Variable	**Parameter**	**Coefficient**		**Standard Error**		**t Ratios**	
		OLS	MLE	OLS	MLE	OLS	MLE
Constant	β_0	-2.323***	-1.993***	0.506	0 .481	-4.58	-4.14
Ln Fertilizer	β_1	0.282**	0.289***	0.114	0.109	2.46	2.64
Ln Land area	β_2	0.307**	0.311***	0.124	0 .118	2.47	2.64
Ln Labor	β_3	0.587***	0.602***	0.108	0 .103	5.40	5.83
Ln matured veins	β_4	0.502***	0 .497***	0.104	0 .098	4.83	5.05
R^2		0.5737					
σ^2			0.3173834				
γ			0.6873				

*, **, *** significant at 10%, 5%, 1% significance levels, respectively.
Source: Field Survey, 2018

In this study, variables such as farmer's age, experience and years of schooling are significant in the inefficiency model indicating the implications of inefficiency among vanilla farmers. Table 3 represents the estimated results of inefficiency model. Farmer's age is statistically significant at 5% significance level. Negative coefficient indicates that, when farmer is aging it affects to increase the inefficiency in production. In other words, it implies that younger farmers tend to be more technically efficient than the older farmers. Ahwireng (2014), Kuwornu et al (2013), Basnayake and Gunaratne (2011), Karunarathna (2014) also found similar results in their previous studies on the effect of age on farmers' efficiency.

As a significant factor at 10% significance level, experience shows negative relationship with inefficiency indicating that inefficiency is high among farmers who do not have much experience in vanilla cultivation. Similar results were found by Karunarathna (2014), Otitoju and Arene (2010) between experience and the inefficiency. The variable, years of schooling, is a significant factor at 10% significance level. Negative sign of the coefficient implies that there is high inefficiency among households those who possess low education level. It implies that increasing households' education level can significantly reduce their levels of inefficiency. Basnayake and Gunaratne

(2011), Karunarathna (2014), Otitoju and Arene (2010) also revealed the same results in previous studies regarding farmer's educational level and inefficiency.

Table 3: **Determinants of Inefficiency-Cobb-Douglas Model**

Variable	**Parameters**	**Coefficient**	**Standard Error**	**z-statistic**
Age of the farmer	α_1	0.0469532**	.0284855	2.38
Gender	α_2	-0.8315514	.8043088	-1.85
Experience	α_3	-.2696274*	.1571423	-1.72
Years of schooling	α_4	-.4072552**	.1571883	-2.59
Access to the Extension services	α_5	-.7566292	.7897189	-0.96
Household size	α_6	.1254958	.207415	0.61

*, **, *** significant at 10%, 5% and 1% significance levels
Source: Field Survey, 2018

The mean technical efficiency of the vanilla farmers was found to be 37.32%, which indicates that the output could be increased by 62.68 % if all farmers achieve the technical efficiency level of the best farmer (100%). The maximum technical efficiency 89.91% is which could be achieved by vanilla farmers. It is further evident from the Table 4 that most of the farmers' (34) efficiency lies between 21% and 40% whereas efficiency of 20 farmers lies in the range of 41% to 60%.

Table 4: **Distribution of Technical Efficiencies**

Efficiency Level	**Number of Farmers**
0.01 – 0.20	17
0.21 – 0.40	34
0.41 – 0.60	20
0.61 – 0.80	4
0.81 – 1.00	5

Source: Field Survey, 2018

4.4 Translog Production Function Results

A stochastic translog production frontier was estimated as a test of robustness in the choice of functional form. The estimates of γ, the variance ratio parameter, which relates variability of u_i to the total variability is 0.5250 according to the results obtained by the translog model. It indicates that majority of error variance for the vanilla farmers is due to the inefficiency error u_i. Therefore, majority of error variance is not due to the random error v_i. Thus, it can be concluded as 52.50 % of the total variation in the vanilla yield is due to the technical inefficiencies in the area according to the results obtained by the translog model.

The results of translog production function further revealed that interaction term of labor and fertilizer is significant at 10% significant level. So is the case with the interaction term of the fertilizer and matured veins. Mean efficiency obtained by the translog production function is 0.277885. However, Cobb Douglas production function obtained by the Maximum Likelihood Estimation indicated the mean efficiency as 0.3732663. Table 5 represents the results of maximum likelihood estimates for parameters of the stochastic frontier (translog model). According to the estimated results of inefficiency (translog) model, farmer's age, gender, experience and years of schooling significantly affect inefficiency of vanilla farmers. Table 6 represents the estimated results of inefficiency (translog model).

Table 5: **Maximum Likelihood Estimates for Parameters of the Stochastic Frontier (Translog)**

Variable	**Parameter**	**Coefficients**	**Standard Error**	**Z Statistics**
Constant	β_0	2.281275	3.731884	0.61
Ln fertilizer	β_1	0.4213862	1.18654	0.36
Ln Land area	β_2	0.7740481	1.63712	0.47
Ln Labour	β_3	-1.995355	1.587321	-1.26
Ln matured veins	β_4	0.0582833	1.01462	0.06
Ln fertilizer sqr.	β_5	-0.1039478	.2312429	-0.45
Ln Land area sqr.	β_6	0.2796704	.4382434	0.64
Ln Labour sqr.	β_7	0.2961068	.2200469	1.35
Ln matured veins sqr.	β_8	0.1795624	.2278591	0.79
Ln Labour* Ln fertilizer	β_9	0.3193287*	.171048	1.87
Ln Labour* Ln matured veins	β_{10}	0.0256208	.0676106	0.38

Table 5 Continued

Ln Labour* Ln Land area	β_{11}	-0.150182	.2938902	-0.51
Ln fertilizer* Ln Land area	β_{12}	0.1329557	.2825609	0.47
Ln fertilizer* Ln matured veins	β_{13}	-0.2289207*	.1171988	-1.95
Ln Land area* Ln matured veins	β_{14}	0.0669881	.1253108	0.53
σ^2		0.2308967	.127804	
γ		0.5250		

Source: Field Survey, 2018

Table 6: **Results of the Inefficiency Model for Translog Function**

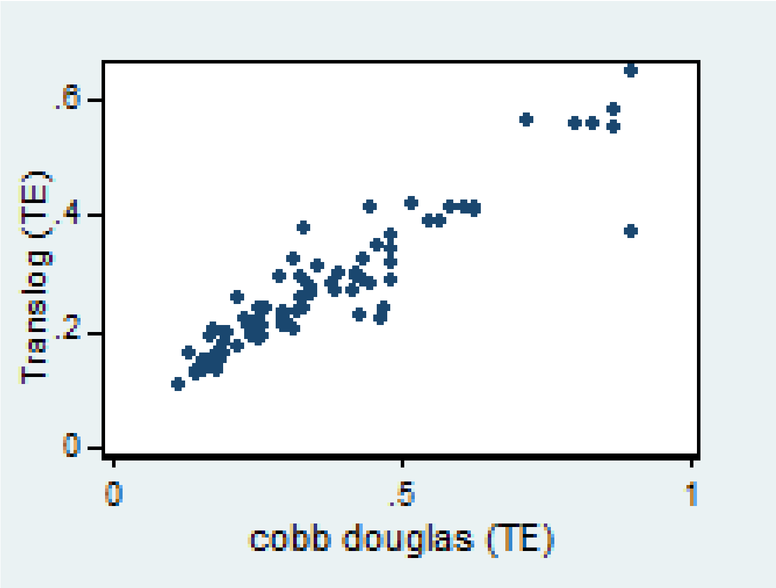
Variable	**Parameter**	**Coefficients**	**Standard Error**	**Z Statistics**
Age of the farmer	α_1	.06767**	.0284855	2.38
Gender	α_2	-1.48548*	.8043088	-1.85
Experience	α_3	-.2696274*	.1571423	-1.72
Years of schooling	α_4	-.4072552**	.1571883	-2.59
Access to the Extension services	α_5	-.7566292	.7897189	-0.96
Household size	α_6	.1254958	.207415	0.61

Source: Field Survey, 2018

4.5 Robustness of Technical Efficiency Estimates

Technical efficiency estimates obtained by Cobb-Douglas and translog models do not differ very much. If the estimates are very close, it could be shown in the below scatterplot as a 45-degree line. Actually, the mean technical efficiency obtained from the Cobb-Douglas model is 0.3732663 while the translog model showed the mean technical efficiency as 0.277885. The results shown in the Figure 1 implies that there cannot be significant interaction effect in the chosen stochastic frontier model.

Figure 1: **Robustness of Technical Efficiency Estimates**



Source: Field Survey, 2018

4.6 Constraints Analysis for the Vanilla Cultivation

Being an emerging industry, farmers in the vanilla industry faces several constraints in the case of development. The constraints and their mean value of responses are given in the Table 7.

Table 7: **Constraints for Vanilla Cultivation**

Constraint Category	**Constraint**	**Mean Value**
Environmental	Low soil fertility	1.01
	Severe rain	1.16
	Severe mist	2.16
	Heavy incidence of diseases	1.13
	Animal attacks	3.26
Socio-economic	Lack of availability of credit	2.24
	Poor contact with extension person	2.08

Table 7 Continued

	Problem of theft	2.36
	Lack of knowledge about curing beans	3.06
Marketing	Traders buy immature pods for low price	2.28
	Inadequate number of buyers for proper prices	2.89
	Lack of price information	2.59

Source: Field Survey, 2018

The environmental factors play an important role in crop production as these factors can often enhance or otherwise restrict the production and production efficiency. Among all environmental constraints, animal attacks were perceived as the major constraint for vanilla cultivation. Within the selected area, farmers always suffer from animal attacks on their cultivations. Wild boar, crested porcupine and beavers like animals highly damage the veins just after planting and also the matured veins. With regard to the socio economic constraints, most important constraint was the lack of knowledge on curing process of vanilla. Normally curing process is an extremely time consuming activity and there is a high risk involved with it because if one step fails, it will destroy the whole process. In Sri Lanka, farmers sell their harvest as uncured pods. If farmers can sell their harvest as cured pods, they can reap maximum advantage from the vanilla cultivation as the price of cured pods is considerably higher than that of the uncured pods as marketing constraints like the environmental and the socio economic constraints severely affect the vanilla farmers. Inadequate number of buyers to purchase the harvest for proper prices is the most important marketing constraint they face.

5. Conclusion and Recommendations

Vanilla production in Sri Lanka is absolutely an important component in export agricultural field towards the country's growth and development as it can produce a number of new employment, entrepreneurs and also can generate high income from exportation. However, efficiency of the production is critical in earning a substantial income. Therefore, this study was conducted to estimate the efficiencies of small-holder vanilla farmers in Ganga Ihala Korale DSD in Kandy District. The study area was chosen based on the fact that it has one of the largest concentrations of vanilla farmers in the country.

The general objective of study was to estimate levels of efficiency among small-holder vanilla producers in Kandy District. It was supported by three specific objectives; to investigate the effect and socio-economic characteristics of farmers' efficiencies, to investigate the constraints faced by vanilla farmers and to provide policy recommendations for efficiency improvements and overcoming constraints. To achieve these objectives, the stochastic frontier approach was employed. Both Cobb Douglas and translog models were used for the estimations.

Since the Cobb-Douglas production function was found as the most appropriate functional form, the analysis and discussions of the estimated coefficients for efficiency were based on that functional form. The estimated coefficients of the Cobb-Douglas frontier function showed that, land, and labor fertilizer and number of matured veins are the most significant factors which affect farmers' output levels. Furthermore, the determinants of inefficiencies among vanilla farmers were also analyzed. The determinants of inefficiencies were made up of farmers' socio-economic characteristics. Among those factors, age, experience and years of schooling were found to change the farmers' efficiency levels.

Constraints were analyzed focusing on three important areas: environment, socio economic aspects and marketing. The major constraints faced by farmers are animal attacks, lack of knowledge on curing the harvest and inadequate number of traders to buy their products at proper prices.

Based on the results of the study, the following recommendations are made for policy implementation. Strategies to increase the labor productivity should be adopted as vanilla farming demands more skilled labor for hand pollination. There is a need for farmers to increase the land area for vanilla cultivation while reducing the number of mixed crops with vanilla. Since fertilizer was found as the factor that affect the output, awareness should be given to the farmers on how to prepare appropriate fertilizer mixtures and the awareness about proper application of fertilizer to extract optimum yield should be done. Organically cultivated vanilla is likely to have much more demand and high prices in the international market in coming days. Promotion of organically grown natural vanilla will provide motivation to its cultivation. As the farmers grow vanilla applying only organic fertilizers, conversion of traditional vanilla cultivations into organic cultivations will not be a difficult activity. Proper direction and awareness about the organic production procedure is the only requirement. Further, necessary support to promote organic production and certification of vanilla must be provided.

There is a need for the government to create an enabling environment that will encourage the youth to involve in vanilla production as a tool for generating employment as the results revealed that young farmers are more efficient. Efforts should be made to improve farmers' education, since education was found to affect farmers' productivity positively. This can be achieved through increased extension contact, non-formal education and through farmer-based organizations. With the involvement of government, it is better to introduce hydroponic technology for vanilla that is practiced in other countries especially for the area where most of the farmers suffer from animal damages on their crops. Live fences using gliricidia can be introduced as a precautionary action to the animal damages since gliricidia are the best variety of vanilla veins as they support the shade loving nature of vanilla. Extension services should assist the farmers with knowledge of curing process. A number of authorities should be developed under the government regulations to collect the harvest from the farmers at proper prices. Also, they should provide awareness to the farmers about how to enhance the quality of the harvest to earn high prices.

The major limitation was lack of statistical records about vanilla farmers; especially no accurate information about the count of vanilla farmers is available. Therefore, it is hard to take an accurate number of farmers who are involved in vanilla cultivation. In addition, in some areas farmers are not exposed as vanilla growers and also they don't like to expose their cultivations to the visitors due to the problem of thieves. In some area thieves are the major bottleneck for vanilla cultivation.

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