



Factors Affecting the Economic Efficiency of Small-Scale Rubber Plantations: With Special Reference to Kalutara District in Sri Lanka

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Abstract

The Rubber Industry has been a major partner in the Sri Lankan economy. According to the literature, farmers in developing countries have failed to achieve full potential of Technical Efficiency (TE) and Allocative Efficiency (AE). This paper investigates the Economic Efficiency (EE) of Small Rubber Plantation Owners (SRPOs) in Sri Lanka by employing stochastic production frontier using a sample of 120 SRPOs. The results showed that the average TE of selected SRPOs is 82.86%. This indicates that output can be further increased by 17.14% without increasing the level of input. Gender and the number of family members were identified as the variables that have the greatest impact on the TE. The AE analysis identified some inefficient situations such as overused land and labour. Also, it was revealed that SRPOs have not reached the maximum efficiency level while 32 of them have reached an efficiency level above 90%.

Keywords: Cobb-Douglas Production Function, Economic Efficiency, Rubber Cultivation, Stochastic Production Frontier

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Introduction

The total revenue of the global rubber production is more than 400 billion US\$ per year by using over 27 million tons of natural rubber (NR) and Synthetic Rubber (SR) to value added products (Asian Development Bank, 2017). The global rubber products market consists of over 50,000 different products that serve different consumer needs in diverse sectors including automotive, industrial, agricultural, mining and health. By 2012, the Sri Lankan rubber product makers earned over 1,100 million USD through exports and local sales. It then decreased to around 816 million USD in 2020 due to market dynamics.

The extent of rubber cultivation in Sri Lanka is divided into two main sections, namely under cultivation (immature lands) and under tapping (mature lands). According to 2019 Annual Report of the Central Bank of Sri Lanka, under cultivation covers 26,000 hectares while 112,000 hectares are under tapping. Accordingly, the total area under rubber cultivation has increased to 138,000 hectares. Also, 860.99 hectares are under replanting and 350.21 hectares are under new cultivation (Central Bank of Sri Lanka, 2020; Rubber Development Department, 2020).

The rubber industry in Sri Lanka consists of two interdependent sectors: the rubber plantation industry and the rubber-producing industry. The rubber plantation industry consists of two sub-sectors, namely plantations and small-scale rubber growers (Waduge et al., 2015). In 2018, 70% (89,243 ha) of rubber cultivation was owned by small scale rubber cultivators and 30% (37,442 ha) by the state estate sector (owned by 20 local plantation companies and government agencies). Accordingly, a large part of rubber cultivation is done by the small-scale growers (Ministry of Plantation Industries & Export Agriculture, 2020).

By 1982 the total extent of land area under rubber cultivation was around 180,000 ha and the total annual production was 125 million kilograms. However, the total extent under rubber cultivation declined subsequently and at present it is around 120,000 ha. Rubber contributes about 0.6% of the total GDP. According to figures published in 2020 by the Rubber Research Institute of Sri Lanka, rubber production amounted to 78.2 million kilograms in 2020. Although during the period from 2011-2020, the total area of rubber land has increased from 128,119 hectares to 137,106 hectares, the rubber yield per hectares and rubber productivity has decreased significantly. The average yield of rubber has decreased from 1459 kg per hectare in 2011 to 772 kg per hectare by 2020. Also, when the total rubber production is considered, it was 152,030 metric tons in 2012 and it has come down to 82,600 metric

tons in 2018 (Rubber Development Department, 2020). The cost of production per kg of rubber has significantly increased from Rs.136/kg to Rs 205/kg during year 2012 to year 2020. Export price of rubber (f.o.b) has also decreased from Rs. 421/kg to Rs. 370/kg during the same period (Ministry of Plantation Industries, n.d.).

Rubber production process involves complex technologies and quality management techniques and management skills. Even small-scale production plants need high scale investment and machinery. SMEs lack the capability of mobilizing such resources and they engage in production of low value-added products for the replacement market. Their profit margin is very low and reserves are not accumulated to support re-investment (Ministry of Plantation Industries, n.d.).

All examined evidence show that Sri Lankan rubber industry has recorded a downward trend in all economic parameters during last decade (2011-2020). Policy makers, related professionals and researchers have extensively emphasized the importance of technical efficiency of rubber industry in Sri Lanka.

The role of technical efficiency in small scale rubber industry has been widely recognized at global level (Adebayo, 2006; Ahmad et al., 2002; Giroh & Adebayo, 2007, 2009; Izadi et al., 2002; Jondrow et al., 1982; Kumbhakar, 1991). A study by Rathnayake and Amaratunga (2016) stated that farmers in developing countries have failed to harness the full potential of technology and to achieve allocative efficiency of paddy farming. However, many of these studies have not considered the predicted technical efficiencies regressed against socioeconomic variables and allocative efficiency simultaneously. In Sri Lankan context, there are substantial literature on technical efficiency of paddy, tea and other related crops (Mustaph & Hashim, 2011; Pongchompu & Chantanop, 2015; Shantha et al., 2012; Shantha 2018, 2013.), while studies on technical efficiency and allocative efficiency measurement of small-scale rubber industry are not available. This represents a significant gap in the literature. With this background, it will be of timely importance to measure the economic efficiency of the smallholder rubber plantations in order to identify the potential to increase production without incurring additional costs for inputs.

Addressing this knowledge gap, this study attempts to evaluate the technical and allocative efficiency of the Sri Lankan rubber industry with special reference to Kaluthara district. The study also examines the factors that would affect the allocative efficiency of small-scale rubber estate owners. A study of this nature will provide rubber plantation owners/farmers and policymakers with insights for improving production.

The next section of the paper reviews the literature on measuring technical efficiency and the relevant empirical evidence. After that, the methodology adopted in the paper is described. It is followed by a section in which findings of the study are reported, and the final section includes conclusions, recommendations, and implications.

Literature Review

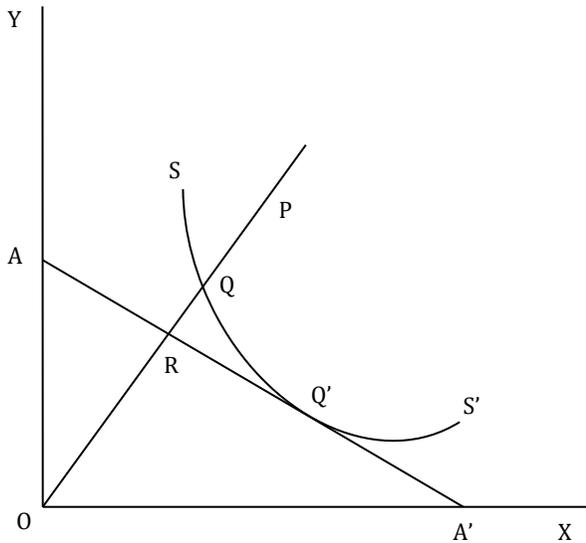
Technical and Allocative Efficiency

The study by Koopmans (1951) is credited with introducing a formal definition of economic efficiency. Economic efficiency is defined as the ability to produce a predetermined quantity of finished products at a minimum cost at a certain technical level (Koopmans, 1951). According to that definition, overall economic efficiency (EE) is divided into two parts: technical efficiency (TE) and allocative efficiency (AE) (Farrell, 1957).

TE is the efficient use of available resources to maximize profits with fixed factors, factor prices, and a given technology (Sadoulet & Janvry, 1995). Also, if the value of the marginal product of each variable input maximizes profit by equating it to its price, it is called farm allocative or price efficiency (Radam & Latiff, 1996). EE is achieved when TE and pricing/AE are combined (Nugent & Yotopoulos, 1979).

As shown in Figure 1, SS' is the Isoquant that shows the alternative input combinations of X and Y required to produce a unit of output, and AA' is the iso-cost curve that shows the maximum input combinations that can be purchased from the manufacturer's existing budget. Farrell's (1957) explanation of efficiency is based on the returns to scale. Every input package in this iso-cost curve is considered to be optimally efficient and any point outside that line is assumed to be technically inefficient. Separation efficiency can be achieved if the output unit is generated using any input combination located on the iso-cost curve. If a unit of output is generated using the input combination at point P , the technical inefficiency (TIE) of the point P 's input combination is indicated by the distance QP . Then the technical inefficiency ratio is QP/OP and the efficiency ratio is $1 - QP/OP$. As the input combination switches from P to Q , the technical inefficiency decreases and the efficiency level is reached. The lowest cost input combination in manufacturing an output unit is Q' , and the allocative inefficiency (AIE) at that level is indicated by the distance RQ . Accordingly, the AE ratio is RQ/OQ and the separation efficiency is $1 - RQ/OQ$. The AE depends on changing the input combination from Q to R .

Figure 1: Technical Efficiency and Allocative Efficiency



Source: Farrell (1957, p. 254)

According to Farrell (1957), overall or EE is the result of technical and segregation efficiency. This measurement comes from the multiplication interaction of the technical and allocative components.

$$\text{Technical Efficiency (TE)} = 1 - QP/OP = OQ/OP$$

$$\text{Allocative Efficiency (AE)} = 1 - RQ/OQ = OR/OP$$

$$\text{Economic Efficiency (EE)} = TE \times AE = OQ/OP \times OR/OQ = OR/OP$$

There are two methods in the literature that are commonly used to measure the TE. That is, the Stochastic Frontier Approach (SFA), which is the parametric method (econometric method), and the Data Envelopment Analysis (DEA) method, which is a non-parametric method (Aigner et al., 1977; Battese & Coelli, 1992; Meeusen & Van den Broeck, 1977).

The parametric approach assumes a linear relationship between the output and the input and uses statistical techniques to estimate the parameters of the function. The non-parametric approach is completely different. It assumes no primary linear relationship between inputs and outputs and thus creates a linear function based on empirical observations of inputs and outputs. In the non-parametric approach, the data

envelopment analysis methodology is used to assess the TE of each individual decision-making unit (Shantha, 2018). Battese and Coelli (1995) pointed out that SFA is more suitable than DEA to estimate TE in agricultural products.

Aigner et al. (1977) and Meeusen and Van den Broeck (1977) have improved the stochastic frontier approach to assess the manufacturer's TE using parametric econometric methods. The peculiarity here is that the error term in estimating a production function consists of two parts: the random error and inefficiency component. According to Battese and Coelli (1992) and Battese and Corra (1977), the Stochastic Frontier Production Function can be shown as follows.

$$Y_i = f(X_i \beta) + e_i \quad i = 1, \dots, N \quad (1)$$

where Y_i is the production (or the logarithm of the production) of the i^{th} firm; f is a fitted functional form of the frontier, X_i is a vector of inputs used by the i^{th} firm; β is the vector of unknown parameters.

$$e_i = V_i - U_i \quad i = 1, \dots, N \quad (2)$$

where e_i is the error term; V_i is a random variable which is assumed to be independently and identically distributed and independent of U_i , which is the inefficiency component that achieves TE; U_i is also a non-negative random variable ($U_i \leq 0$) calculated for the TE of a product.

There are various factors that contribute to TE and AE of rubber industry, mainly socio-economic, demographic, ecological, cultural, political and regional factors. Various studies have been focused on different factors, in line with their objectives. Sharma et al. (2003) estimated TE and total factor productivity of rubber industry in fifty US states from 1977 to 2000 and found that, on average, TE is around 75%. Hashim and Mustapha (2011) have taken inflation, mean years of schooling, regional location, and sectoral differences as main factors for TE of rubber plantation in Malaysia. According to Adar (2011), there are several factors that can influence the level of TE of annual crop farming, namely farmers' formal education, farming experiences, contact with extension officers, age of farmers, other income sources, and sales system results. Pongchompu and Chantanop (2005) has used farmer's practices, skills, motivation and experiences of officers, supervisory management competencies, soil fertility, rubber tree types and weather condition as explanatory variables for measuring TE of rubber production. Kittilertpaisan et al. (2016), measured TE of rubber growers and considered age, educational level, family size, farming experiences, sex and plant age as factors effecting TE.

Giroh et al. (2012) investigated the factors militating against TE of women rubber tappers in Nigeria. The study covered 60 women rubber tappers and was carried out in rubber research institute of Nigeria, at Iyamo Benin City, Nigeria. The findings of the study revealed both the descriptive and inferential statistical results. Radam et al. (2012) has conducted an empirical survey in Malaysia, using stochastic frontier analysis. The study analysed TE of manufactured rubber product industries across the country. Three hundred and thirteen firms that manufacture rubber products were identified from annual surveys of industries by Malaysian Statistics Department in 2004. The mean TE was found to be 0.7033 (70.3%). It was also observed that only 10% of the firms (about 34 farms) have TE scores more than 80%.

Poungchompu and Chantanop (2005) evaluated the productive performance in terms of TE of para rubber farms in Thailand. The study targeted at finding out the major influential factors affecting production output as well as TE of para rubber farms in North-Eastern region of Thailand. The results of the study indicated that, both the variance parameters of gamma and sigma squared, were statistically significant at 1% level. In examining the literature on the variables used for the TE function, Battese and Coelli (1995) used variables such as the age of the farmer, experience, education, and type of clone. In addition to those variables, Aliyu et al. (2017) used the distance from the home to the farm, the number of members in the household, gender, marital status, and access to extension services, while Wijesuriya et al. (2011) employed the variables such as the age of the rubber tree and the labour used for other activities.

A substantial volume of literature has used yield or productivity of small-scale rubber growers as the dependent variable together with Cobb-Douglas production function for measuring TE (bin Sepien & Etherington, 1980; Hadi & Budhi, 1997; Waduge et al., 2015; Aliyu et al., 2017; Wijesuriya et al., 2007; Syarifa et al., 2019). The Cobb-Douglas production function was selected to be the most suitable functional form based on log-likelihood ratio test (LR test). Further, based on reviewed empirical literature, the study selected the most suitable variables, which were theoretically and empirically most suitable for measuring TE and AE of rubber industry in Sri Lanka.

Methodology

The Research Context

The traditional rubber growing districts of the country are Colombo, Gampaha, Kalutara, Kandy, Matale, Galle, Matara, Kurunegala, Ratnapura and Kegalle. Among

the rubber growing districts, Kegalle (Total hectares in 2018 are 37,165 - Small estates amount to 21,316 hectares), Kalutara (Total hectares in 2018 are 28,765 - Small estates amount to 17,804 hectares) and Ratnapura (Total hectares in 2018 are 26,605 - Small estates amount to 14,048 hectares) are the main districts. These three districts represent 74% of the total cultivation (Rubber Research Institute of Sri Lanka, 2020). Out of these three districts, small rubber estate owners in the Kalutara district of Sri Lanka were selected for this study. Kalutara District is the second largest rubber growing district in Sri Lanka in terms of the area cultivated and it is also a traditional rubber growing region. It is considered a well-developed district for inputs and outputs as well as markets (Waduge et al., 2015). There is also a significant climate change in the district which is conducive to rubber production (Waduge et al., 2015). Around 23,469 rubber cultivators were reported in 14 Divisional Secretariats in the Kalutara District based on the Economic Census of 2013/2014 (Department of Census and Statistics, 2018). Therefore, Kalutara district is considered as the population of this study.

Sample

Among the SRPOs in the 14 D. S. Divisions of the Kalutara District who belong to the population of this study, the highest percentage of population was reported from the Bulathsinhala, Palindanuwara and Walallawita Divisional Secretariats where there are 4,959, 3,626 and 2,782 cultivators, respectively as per the Economic Census of 2013/2014 (Department of Census and Statistics, 2018). Accordingly, the sample was selected using the multi-stage sampling method based on these three Divisional Secretariats (Aliyu et al., 2017). The sample obtained was proportionally selected representing 52, 38, and 30, respectively from Bulathsinhala, Palindanuwara and Walallawita Divisional Secretariats totalling to 120 growers. Sample selection was performed using a simple random sampling method (Shantha et al., 2012; Wijesuriya et al., 2011). A summary of these details is given in Table 1.

Table 1: Population and Sample Size of Each D. S. Division

D. S. Division	Number of SRPOs	Sample Size
Bulathsinhala	4959	52
Palindanuwara	3626	38
Walallawita	2782	30
Total	11367	120

During the data collection in September 2020, information related to the questionnaire was obtained through the interview method and the sample data was

collected with the assistance of the Rubber Extension Officers of the Rubber Research Institute.

Method of Analysis

The technical efficiency obtained through the stochastic frontier production function is in the range of 0 - 1. If TE = 1 the farmer is fully efficient and, if TE = 0 farmer is fully inefficient. The variances of the components of the random error term $V_i(\sigma_v^2)$, $U_i(\sigma_u^2)$ and the overall model variance σ^2 were used to measure the total variance of output from the frontier under these relationships;

$$\sigma^2 = \sigma_u^2 + \sigma_v^2 \tag{3}$$

$$\gamma = \sigma_u^2 / \sigma^2 \tag{4}$$

Taking these factors into account, the Cobb-Douglas stochastic frontier production function for this analysis can be identified as follows.

$$\ln Y_i = \beta_0 + \sum \beta_j \ln X_{ji} + v_i + u_i \quad i= 1, \dots, N \tag{5}$$

This production function includes six product inputs. The Maximum Likelihood Estimation (MLE) method was used to estimate the parameters using the Stata software. A Tobit model was used to identify the effect of inefficiency.

Identifying Variables

Primary data from 120 rubber cultivators covering three D.S. Divisions in the Kalutara District were used in this study. Relevant measurements were estimated through the Cobb-Douglas production function based on cross-sectional data. The specified model is represented by Equation (6) and Table 2.

$$\begin{aligned} \ln Y_i = \beta_0 + \beta_1 \ln X_{1i} + \beta_2 \ln X_{2i} + \beta_3 \ln X_{3i} + \beta_4 \ln X_{4i} \\ + \beta_5 \ln X_{5i} + \beta_6 \ln X_{6i} + v_i - u_i \end{aligned} \tag{6}$$

where,

$\beta_0, \beta_1 \dots \beta_6$ are parameters to be estimated

$v_i \ i = 1, \dots, N$ – Random error

$u_i \ i = 1, \dots, N$ – A random variable that is assumed to account for technical inefficiency in production.

Table 2: Variable Definition and Units of Measurements Used for the Models

Variable	Definition	Units
Y	Rubber Output	Kg/ac
X_1	Extent of land	Acres
X_2	No. of Tapping Trees	Per ac
X_3	Labour hours	Hrs./ac
X_4	Quantity of fertilizer	Kg/ac
X_5	Raw material cost	Rs/ac
X_6	Weeds controlling	Person days/ac

Determinants of Technical Efficiency

The inefficiency model based on Battese and Coelli (1992) is given by Equation (7).

$$TE_i = \alpha_0 + \alpha_1 Z_{1i} + \alpha_2 Z_{2i} + \alpha_3 Z_{3i} + \alpha_4 Z_{4i} + \alpha_5 Z_{5i} + \alpha_6 Z_{6i} + \alpha_7 Z_{7i} + \alpha_8 Z_{8i} + w_i \quad (7)$$

where,

$i = 1, \dots, N$

Z_1 – Number of members in the family

Z_2 – Rubber farming experience (years)

Z_3 – Number of years of education

Z_4 – A dummy variable to indicate gender where $Z_4 = 1$ if the respondent is a male and 0 otherwise

Z_5 – Age of cultivation (years)

Z_6 – A dummy variable to indicate the use of rain cover where $Z_6 = 1$ if rain cover is used and 0 otherwise

Z_7 – Distance from home to cultivation (meters)

Z_8 – Frequency of attendance of extension officers

w_i – Error term

The parameters of the Cobb-Douglas production function are used to obtain the estimates for the allocative efficiency analysis. Here, the marginal output value and unit factor cost of each input are statistically compared in the analysis of AEs.

It is clear from the literature that there are three alternative approaches to the separation of efficiency analysis. The calculation of AE can be done through the Marginal Value of Product (MVP) and Marginal Factor Cost/price (MFC) of

resources. The output efficiency of each application is determined by comparing the MVP and the Unit Factor Price (UFP). Theoretically, to separate efficiency, the MVP should be equal to its unit factor cost. Marginal Physical Product (MPP) and MVP can be estimated as follows.

$$\text{MPP} = \text{APP} \times \text{Input Elasticity}$$

$$\text{MVP} = \text{MPP} \times \text{Output price}$$

The average physical product (APP) is the quantity of total output produced per variable input unit when all the other factors remain fixed. This can be found by dividing the total physical product (TPP) by the quantity of the variable input. Also, the MVP values of each input divided by the relevant unit factor cost, is called the Allocative Efficiency Index. If the index is greater than one, a specific application is underutilized and if the index is less than one, the input is over utilized (Rathnayake & Amaratunga, 2016).

To calculate the Cost Function or the AE by the “implicit cost function”, Schmidt and Knox Lovell (1979) first measured AE via Cobb-Douglas Cost Frontier. Here, it is explained how the cost efficiency can be measured by the implicit cost function. The implicit cost function is derived from the Cobb-Douglas cost frontier. AE is calculated by estimating the “Input Distance Function” (Rathnayake & Amaratunga, 2016).

Results

Descriptive Statistics

The summary of the statistics of the variables based on the survey conducted in 2020 are given in Table 3. This research was conducted in Kaluthara district which is the second largest rubber cultivated district in the country. The selection of rubber farmers who were the respondents was based on the existence of rubber farming as the main source of family income. The average production of a farmer per acre in a year is 685.34 kg and the gross income per acre is Rs. 204,058. Compared to Malaysia, Indonesia and Vietnam, the productivity of Sri Lankan rubber is far behind. In Malaysia, the yield per acre is 1565 kg. In Indonesia it is 886 kg per acre and in Vietnam it is 1120 kg per acre. Total cost of production per acre is Rs. 108,996 per year and net profit per acre is Rs. 95,063 per year. Both yield and profit margin of sample rubber growers were significantly high compared to the national average since this study considered only growers who managed young rubber trees. The mean value of the extent of cultivated area of sample growers is 1.25 acres and number of tapping

trees is 161 per acre. Total labour usage is 738 hours per acre per year and it is around 92 working days. The labour cost constitutes around 83% of total cost and it is the main cost component of the cost structure.

Table 3: Summary Statistics of the Sample

Variable	Mean	Standard Deviation	Maximum Value	Minimum Value
Rubber harvest (Kg/ac in a year)	685.34	363.16	1,686.67	80
Extent of land (ac)	1.25	0.74	5	0.25
Number of Tapping trees (per ac)	161.28	46	300	67
Labour (Labour hours/ac in a year)	738.20	425.69	2,100	135
Fertilizer (Kg/year)	57.83	93.88	4,200	0
Raw material costs (Rs/ac in a year)	7,196.97	4,037.63	24,210	1,402.5
Weeds control (person days/year)	6.73	5.28	30	2
Market Rubber Selling Price (Rs)	297.75	21.36	331	253
Gross income (Rs/ac)	204,058.6	108,132.3	502,205	23,820
Labour cost (Rs/ac)	90,798.16	52,359.38	258,300	16,605
Fertilizer cost (Rs/ac)	1,290.875	2,182.314	9,660	0
Cost of weeds control (Rs/ac)	9,709.901	7,431.28	45,000	2,666.67
Machinery cost (Rs/ac)	3,576.858	1,865.238	8,750	200
Raw material cost (Rs/ac)	2,547.055	2,629.515	16,800	505.55
Acid cost (Rs/ac)	1,073.057	559.5715	2,625	60
Total cost of production (Rs/ac)	108,995.9	57,586.86	293,000	22,507.5
Profit (Rs/ac)	95,062.74	96,654.57	439,160.55	-144,410

Stochastic Frontier Analysis

The maximum likelihood estimates (MLE) of the stochastic frontier production function for rubber production in the study area are shown in Table 04. Accordingly, all the variables except fertilizer and weed controlling in the Cobb-Douglas production function have a statistically significant effect on the rubber production. Here, the MLE coefficients are the elasticities which are directly related to the inputs of the rubber product. This implies that when the effect of all other inputs used in the rubber production are held constant, a 1% increase in the cost of felling, land area, labour, and raw material, will increase rubber yield by 0.153%, 0.492%, 0.219% and 0.958%, respectively. The ratio of the standard error of u to that of v which is the λ is 3.6317, exceeded one in value and it is statistically different from zero at the one

percent significant level. This is an important parameter of log likelihood in the half normal model and correctness of the specific distributional assumption. If λ equals 0, it means that there is no technical inefficiency effect and all deviations from the frontier are due to statistical noise. However, in this study since λ is significantly different from zero it suggested the existence of an inefficiency effect for small scale rubber farming at production stage.

Table 4: Maximum Likelihood Estimates for Parameters of the Stochastic Frontier Production Function.

Variable	Units	Parameter	Coefficient	t-ratio
Number of Tapping trees ($\ln X_1$)		β_1	0.153**	1.99
Extent of land ($\ln X_2$)	Acres	β_2	0.4918***	11.35
Labour ($\ln X_3$)	Hours	β_3	0.2195***	5.54
Fertilizer ($\ln X_4$)	Kg	β_4	0.011	1.50
Raw material cost ($\ln X_5$)	Rs.	β_5	0.958***	17.72
Weeds controlling ($\ln X_6$)	Rs.	β_5	-0.019	-0.84
Constant		β_0	-4.022***	-14.95
Sigma-Squared (u)		σ_u^2	0.06905	
Sigma-Squared (v)		σ_v^2	0.005235	
Sigma-squared ($\sigma^2 = \sigma_u^2 + \sigma_v^2$)			0.07428	3.212
Gamma ($\gamma = \sigma_u^2/\sigma^2$)			0.9295	2.981
Lambda ($\lambda = \sigma_u/\sigma_v$)			3.6317	

Notes: 1. Likelihood-ratio test of sigma u=0: chibar2 (01) = 18.94 Prob >= chibar2 = 0.000

2. ***, ** and * denote significance levels $p < 0.01$, $p < 0.05$ and $p < 0.1$, respectively.

The strength of the inefficiency and random effect can be separately observed using the value of the gamma (γ). It is the ratio of the variance of firm-specific technical inefficiency (u_i) to the total variance of output. The gamma (γ) estimate is 0.93, which implies that the most error variables are caused by a technical inefficiency error but not by random error.

Returns to Scale

The analysis of the returns to scale can be done based on the estimates of the stochastic frontier production function in Table 04. Determining the scale benefit of rubber production can be done by summarizing the input coefficients other than the weed control and fertilizer factors. The sum of the coefficients is 1.8229, which is greater than 1, indicates increasing returns to scale on rubber production in the

Kalutara District. That is, output increases faster than the increase in inputs. Increasing all the inputs except weed control and fertilizer by 100% can increase the production of rubber (rubber yield per acre) by 182%.

Technical Efficiency

Table 5 shows how the statistical distribution of the TE levels of rubber growers in the selected sample has occurred. The TE of the sample varies from 36.2% to 97.95%. Overall, the average TE of SRPOs is estimated to be 82.86%, indicating that the growers in the sample are already utilizing about 82.86% of their technical capabilities on average. It also indicates that about 17.14% of the technical potential has not been met. The majority of farmers (87.5%) have higher than 70% TE levels. In addition, 26.67% of farmers have reached a TE level of more than 90%.

Table 5: Statistical Distribution of Technical Efficiency

Efficiency (%)	Number of Growers	Percentage of Total (%)
Less than 50	3	2.50
51-60	3	2.50
61-70	9	7.50
71-80	29	24.17
81-90	44	36.67
91-100	32	26.67
Total growers	120	100.00
Mean TE	0.8286	

Under the given technology, some farmers were able to reach the maximum technical efficiency levels and some growers appeared to be relatively inefficient. Therefore, it is important to identify the factors that contribute to this inefficiency. The estimated coefficients of the inefficiency model are reported in Table 6. The model consists of eight explanatory variables. Four of the coefficients of these variables are statistically significant, while the coefficients of the other variables are not. When the level of education of the farmers increases, the farmer becomes technically efficient. However, when the number of family members and the distance from home to the farm increase, it is clear that the plantations become technically inefficient. As the negative sign of the coefficient of the gender dummy indicates, on average, the males' contribution to technical efficiency is less than that of females'.

Table 6: Technical Efficiency Criteria Related to the Tobit Model
(Dependent Variable = TE)

Variable	Parameter	Coefficient	Standard Deviation	t-ratio
Age of cultivation (years)	α_1	-0.00148	0.0011	-1.34
Number of family members	α_2	-0.01344*	0.0069	-1.95
Rubber farming experience (years)	α_3	-0.00089	0.0007	-1.22
Number of years of education	α_4	0.00568*	0.0029	1.94
Gender (Male=1, Female=0)	α_5	-0.04138**	0.0199	-2.08
Use of rain cover (Yes=1, No=0)	α_6	0.00246	0.0309	0.08
Distance from home to cultivation (meters)	α_7	-0.00006***	0.00002	-2.73
Frequency of attendance of extension officers	α_8	-0.00121	0.0016	-0.76
Constant	α_0	0.93286***	0.0492	18.98

Note: ***, **, and * denote significance levels $p < 0.01$, $p < 0.05$ and $p < 0.1$, respectively

Allocative Efficiency

The output efficiency of each input of the average farmer is determined by comparing the MVP and the unit factor price/cost (UFC). Calculating MVP requires the average prices of MPP and output. Estimated input flexibility based on the Cobb-Douglas production function was used to calculate the MPP.

Table 07: MPP, MVP and UFC

Variable	APP (Kg)	Elasticity	MPP ¹	MVP ²	Unit Factor Cost (UFC)
Land	685.34 ³	0.4918***	337.05	100,356.64	2,500,000 ⁵
Labour	0.9284 ⁴	0.2195***	0.2038	60.68	123 ⁶

Notes: 1. MPP=APP*Input elasticity.

2. MVP=MPP*Output price. (The average price of a kilo of calculated dry rubber is Rs.297.75)

3. The average rubber yield per acre per year is kg.

4. Average yield per acre / Working hours per acre per year.

5. Average price per acre of land for all farmers.

6. Average labour cost per hour.

Table 7 shows the MPP, MPV and UFC. The input elasticities with respect to land, labour, number of tapping trees and raw materials are statistically significant whereas the elasticities related to the weed control and fertilizer are not. Therefore, the weed control and fertilizer factors have been removed from the AE Analysis. Also, since the raw material cost factor is made up of a combination of several

different costs, it is also omitted here as the unit cost cannot be calculated. It is not practical to calculate the unit cost of the variable the number of tapping trees, and therefore, it is also ignored in calculating the AE.

The results of AE analysis based on the MPP, MVP and UFC in Table 7 are reported in Table 8. The results indicate that the inputs land and labour employed by SRPOs in Kaluthara district have been overused as compared to their optimal levels.

Table 8: Allocative Efficiency of Each Input

Input	Standard Deviation of MVP	Standard Deviation of UFC	Comparison between MVP and UFC	Allocative Efficiency	Usage
Land	56842.24	1291110	MVP<UFC	Not achieved	Overuse
Labour	39.84	21.79	MVP<UFC	Not achieved	Overuse

Conclusion and Implications

The main objective of this study is to measure the EE of the SRPOs in the Kalutara District of Sri Lanka and to make necessary policy recommendations. According to the estimates obtained on the stochastic frontier production function, the average TE of the SRPOs of the Cobb-Douglas model is 82.86%. This indicates that the rubber production can be further increased by 17.14% without increasing inputs or reducing the technical inefficiency of rubber growers.

The gamma estimate of the ratio of the total output variability in rubber cultivation to the TE variance is 0.929 which means that 93% of the production variability of rubber cultivators is due to the changes in TE.

Inputs such as the number of tapping trees, land, labour and raw material have a significant positive impact on the rubber yield and the raw material cost is the most important factor for the rubber production. It was also observed that the interest of the SRPOs in the use of fertilizers was low. Therefore, the SRPOs have failed to get the expected rubber harvest from the rubber plantations. Rainy weather, price fluctuations and the decline in income from rubber cultivation can increase the risk of engaging in rubber cultivation. Therefore, government agencies should intervene and introduce a reasonable guaranteed price for rubber.

According to the results of the TE model, the variables such as the number of family members and distance from home to cultivation have significant negative

impacts and number of years of education has a significant positive impact on the TE. Gender was identified as the variable that has the greatest impact on the TE. Accordingly, female SRPOs' contribution to TE is greater than that of male SRPOs. Therefore, women-oriented programs should also be implemented to increase their efficiency.

The results of the AE analysis revealed that the land and labour have been overused in comparison to optimal use. Therefore, guidance should be given for the optimal use of the labour and land.

Accordingly, the necessary policy measures need to be implemented to establish new growers under the guidance of extension advisory services. There is a need to establish new growers, check whether the existing cultivators are functioning properly, and provide the necessary counselling services for replanting. At the same time, policies need to be formulated to develop the EE of the rubber growers by introducing technologies required to carry out the rubber production process. In addition, the referral systems for cultivators to cultivate weather-resistant clones through extension officers should be encouraged. Also, growers should be made aware of the new market opportunities available in Sri Lanka and assistance must be provided to adapt rubber production to match with these market opportunities.

Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and publication of this article.

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