DOI: http://doi.org/10.4038/jrrisl.v99i0.1887

Journal of the Rubber Research Institute of Sri Lanka (2019) **99**, 47-56

Poverty alleviation through improvement in technical efficiency in the smallholder rubber sector: case study from Kegalle District of Sri Lanka

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Abstract

Growth and development of the agriculture sector play an important role in the alleviation of poverty. There is a long-lasting debate on whether improvement in efficiency levels leads to eradicate poverty. Further, some studies unveiled that farm and farmer characteristics have a significant influence on poverty. Hence, this study attempts to examine the relationship between technical efficiency and poverty and the effect of farmer's characteristics on poverty levels among the smallholder rubber farmers in Kegalle District.

Data were collected from 195 smallholder rubber farms in Kegalle district through a questionnaire survey. Cobb-Douglas Stochastic Frontier Analysis (SFA) was employed to determine the Technical Efficiency (TE) of the farmers and Poverty Gap Index (PGI) was calculated to measure the depth of poverty in the sample. Correlation analyses were conducted to analyze the relationship between poverty and technical efficiency. Generalized Linear Model (GLM) was employed to determine the farm and farmer characteristics affecting poverty.

The estimated mean technical efficiency of smallholder rubber farmers in Kegalle district was 63%, implying that the natural rubber production could be increased further by 37% through better use of existing resources and technology. Correlation analysis indicated that TE has a significant negative correlation (r=-0.147, P=0.04) with poverty, indicating that improving TE will help to alleviate poverty.

Results of GLM model indicated that years of education of the farmer and the farm size have a strong negative influence on poverty while family size and age of the farmer have a positive association with poverty. Hence, policymakers should give more consideration to these factors in poverty alleviation programmes.

Key words**:** Cobb-Douglas Stochastic Frontier Analysis, correlation analysis, generalized linear model, poverty, smallholders, technical efficiency

Introduction

Natural Rubber (NR) is one of the major contributors to the Sri Lankan economy which generates an export revenue of more than US$ 1 billion according to the statistics. About 68% of NR is provided by the smallholder sector in Sri Lanka. Kegalle District has the highest NR land area followed by Ratnapura, Kalutara, Gampaha, and Colombo districts. The

NR production of the country has recorded as 82,000 tonnes in the year 2017, which has been in a slightly up and down movement (Anon, 2017a).

The NR production of the country remains as quite steady state during the last few years, yet considerably low with respect to the area under tapping. This is one of the major concerns in the Sri Lankan rubber sector. The overall productivity in the country is around 800 kg/ha/year, which is far behind the countries like Vietnam, India and Malaysia where the yields average around 1680, 1431 and 1400 kg/ha/year, respectively (Anon., 2016a; Anon., 2016b).

The low productivity may lead to loss of a considerable amount of potential income, which makes the smallholder rubber sector an uncompetitive venture (Kumarasinghe *et al*., 2012). Further low rubber prices and low productivity levels of rubber lands push small scale rubber farmers into poverty (Anon., 2016c). In attempting to enhance the productivity of existing lands, one crucial aspect is increasing efficiency which can be measured in terms of technical efficiency (Kumarasinghe *et al*., 2012). Technical efficiency can be defined as the ability of firms to produce the maximum possible output level from a given set of inputs and technology (Kumbhakar *et al*., 2015).

Socio-economic characteristics of households have a significant influence on the poverty status of the household. Age, farm size, farm experience, years spent in school, family size, gender and dependency ratio are the key socio-economic variables that should be critically considered in the poverty alleviation programmes (Umeh *et al.*, 2013; Omoregbee *et al*., 2013).

As most of the rural people depend on agriculture for their livelihood, farm productivity improvement through increasing technical efficiency is one of the major policy decisions taken to alleviate poverty. At a given level of inputs, a producer is said to be technically inefficient if he is unable to produce the maximum possible output level. Hence, improvement in technical efficiency will increase farm income and reduce poverty (Islam and Haider, 2018).

There is a longstanding discussion about the effect of technical efficiency and factor productivity on poverty alleviation. Many scholars show evidences in favour of an inverse relationship between efficiency and poverty, while some of the studies indicate that technical efficiency is not sufficient in poverty reduction or there is no significant relationship between technical efficiency and poverty (Gelaw, 2013; Asogwa *et al*., 2012; Islam and Haider, 2018).

There is little empirical evidence of the relationship between technical efficiency and poverty among the smallholder rubber farmers in Sri Lanka to guide agricultural policies that aimed towards alleviation of poverty among the rural farmers. Further, it is important to identify the farm and farmer characteristics of smallholder rubber farmers that affect poverty. Hence this study attempts to examine the relationship between technical efficiency and poverty among the smallholder rubber farmers and the smallholder rubber farm and farmer characteristics that affect the poverty in Kegalle District, which can be exploited as a basis for poverty alleviation strategy.

Methodology

Study area

The study area lies between 80° 20' E Longitudes and 7° 14' N Latitudes. Kegalle District was purposefully selected for the study as it is one of the major rubber growing areas in Sri Lanka where rubber market channels are well established. This district has an extent of 28,765 ha of rubber which is around 30% of the total rubber extent in Sri Lanka. The number of smallholdings in this area is about 24,309 with a total extent of 16,959 ha. (Anon, 2016b). Contribution to total poverty from the Kegalle District is 7.2% and the number of poor people in the District is 60,435 out of 869,000 total population. Hence, around 6% of the total population in Kegalle District is suffering from poverty. Further, the Head Count Index (HCI) and Poverty Gap Index (PGI) in Kegalle District are 7.1% and 1.1%, respectively (Anon., 2017b).

Sample selection and data collection

Randomly selected 195 smallholdings stratified according to the number of holdings in each Divisional Secretariat (DS) were used in the survey. The farmers were interviewed through a structured questionnaire to collect primary data.

Frontier analysis

The frontier production function methodology has been extensively used in production economics to estimate technical efficiency due to its strong theoretical background (Kumbhakar *et al*., 2015). The stochastic frontier approach was selected for this study, as this method allows for statistical noise (Bravo-Ureta *et al*., 2007). The Cobb-Douglas functional form was used to estimate the production function as it satisfies homogeneity condition and allow to estimate returns to scale and elasticity coefficients relatively easier (Coelli *et al*., 1998). The following Cobb-Douglas production function was used in the analysis.

$$\text{Ln } Y_i = \beta 0 + \beta 1 \ln (X_{1i}) + \beta 2 \ln (X_{2i} + \beta 3 \ln (X_{3i}) + \beta 4 \ln (X_{4i}) + Vi - Ui$$

Where,

Y_i - Dry rubber production of the i^{th} firm (kg/year),

X_{1i} - Extent of the Land (ha)

X_{2i} - Labour (Man Days/year)

X_{3i} - Quantity of fertilizer used (kg/year),

X_{4i} - Chemicals used (L/year)

V_i - Error component which stands for the random output variations

U_i - Technical inefficiency relative to the stochastic frontier

In order to determine the farm and farmer-specific attributes influencing the technical inefficiency of smallholder rubber farmers, the following model was formulated and estimated together with the stochastic frontier model in a single-stage maximum likelihood estimation procedure.

$U_i = \delta_0 + \delta_1 Z_1 + \delta_2 Z_2 + \delta_3 Z_3 + \delta_4 Z_4 + \delta_5 Z_5 + \delta_6 Z_6$

Where,

Z_1= Education (Years)

Z_2= Labour involvement from family (number)

Z_3= Experience (years)

Z_4= Dummy for Adoption of Extension Services (1-Yes, 0-No)

Z_5= Dummy for Management of the Farm (1-Owner, 0-Care Taker)

Z_6= Dummy for Method of Harvesting (1-By family, 2-Hired Labour)

The software FRONTIER 4.1 was used to estimate technical efficiency values and determinants of efficiency jointly as described by Coelli (1996). The 'zeros' in the Cobb-Douglas model was handled as described by Battese (1996).

Correlation analysis between poverty and technical efficiency

A correlation analysis was conducted to analyze the relationship between poverty and technical efficiency. Poverty or income gap index was calculated to measure the depth of poverty in the sample. This measures the extent to which individuals fall below the poverty line (the poverty gaps) as a proportion of the poverty line (Asogwa *et al*., 2012). The official poverty line by district, which is calculated by the Department of Census and Statistics Sri Lanka was considered in the calculations (Anon., 2016d). The poverty gap index (P) can be written as,

$$P = \frac{1}{N}\sum_{i=1}^{N}\frac{(z-yi)}{z}$$

where,

N -Total population

Z - Poverty line

y_i - Monthly income of the farm families

Determinants of poverty

Generalized linear model (GLM) was employed to identify the farm and farmer characteristics that affect poverty as a means of overcoming the assumptions of linearity and equal variance in Ordinary Least Square regression. Further GLM uses maximum likelihood estimation to estimate parameters which are more accurate compared to ordinary least squares (Nelder and Wedderburn, 1972). The following generalized linear model (GLM) was used to measure the effect of farm and farmer characteristics on poverty.

$Yi = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \beta_3 X_{3i} + \beta_4 X_{4i} + \beta_5 X_{5i} + \beta_6 X_{6i} + \varepsilon_i$

Where,

Y_i – Poverty gap index

X_1 – Gender

X_2 – Age (years)

X_3 – Dependency Ratio (sum of household members below 14 and above 65 divided by the total number of household members)

X_4 – Education (Years)

X_5 – Experience (Years)

X_6 – Family Size

X_7 – Farm Size (ha)

ε_i – error term

Results and Discussion

Analysis of technical efficiency

The summary statistics of the variables used in the stochastic frontier model and inefficiency model are presented in Table 1.

Table 1. *Descriptive statistics of variables used in the stochastic frontier model*

Variable	Mean	Standard deviation	Minimum	Maximum
Variables used in Production Model				
Dry rubber yield (kg/year)	1,048.05	671.46	150	3,500
Labour (Man days/year)	144.37	41.48	68	314
Fertilizer (kg/year)	119.06	146.29	1	641
Land area (ha)	0.86	0.51	0.20	2.02
Chemicals (L/year)	41.52	343.49	1	3,901
Variables used in inefficiency model				
Labor involvement from family (Number)	4	1.44	1	5
Experience (Years)	20.31	8.01	7	40

The majority of the farmers in the sample (42%) have studied up to ordinary level, while 27% of the farmers have primary education, 26% studied up to advanced level and about 6% of the sample farmers had higher education qualifications. The majority of the farmers (87%) have adopted the knowledge gathered from extension services. More than 90% of the rubber lands are managed by the owner of the land. While 44% of the farmlands are harvested by the family members, 56% of lands were harvested through hired labour. The mean experience level of farmers in the sample is 20 years which ranged from 7 to 40 years. The maximum likelihood (ML) estimates of the Cobb–Douglas stochastic frontier parameters and inefficiency model are given in Table 2.

Table 2. *Maximum likelihood estimates of Cobb-Douglas Stochastic production frontier*

Variable	Coefficient	Std. Err	t-value
Stochastic production frontier			
Ln (labour)	0.731	0.104	7.025***
Ln (Fertilizer)	-0.014	0.012	-1.117
Ln (Land area)	0.333	0.054	6.171***
Ln (Chemicals)	-0.056	0.132	-0.424
Constant	4.473	1.154	3.876
Inefficiency effects			
Education	-0.211	0.066	-3.188**
Family members	0.000	0.024	0.003
Extension	0.110	0.098	1.125
Experience	-0.029	0.006	-5.12***
Management	0.044	0.111	0.399
Harvest	-0.009	0.041	-0.228
Constant	-0.665	1.352	-0.490
Variance parameters			
Sigma squared	0.12		
Gamma	0.66		
Log Likelihood function	-47.25		

*** significant at 1% level ** significant at 5% level

The estimate of γ is 0.66, which indicates that only 66% of the total variation in dry rubber output was due to technical inefficiency and this satisfied the theory that the true γ should lie between zero and one. The estimated ML coefficient of labour showed a positive value of 0.731 which is statistically significant at 1% level. Similar results were obtained by Basnayake and Gunaratne (2002) and Wijesuriya *et al.* (2012). The estimated ML coefficient of land area showed a positive value of 0.333 which was significant at 1% level. These findings are also in line with Basnayake and Gunaratne (2002), Barnes (2008), Wijesuriya *et al*. (2012) and Fatima *et al*. (2016). The ML estimates of fertilizer and chemicals are not statistically significant. However, an increment of number of labour units and land area by one unit will increase the dry rubber output by 0.731 percent and 0.333 percent, respectively.

The effect of farm and farmer specific factors on inefficiency was simultaneously estimated with the production frontier. The estimated coefficients in the inefficiency model are presented in Table 3. The coefficient for education is negative and statistically significant at 5% level indicating that the educated farmers are more efficient compared to others. This result is consistent with Bettese *et al.* (1996), Basnayake and Gunaratne (2002), Wijesuriya *et al.* (2012) and Fatima *et al.* (2016). The coefficient for experience was also found to be negative and statistically significant at 1% level. This suggests that experienced farmers are more efficient compared to less experienced ones. This result confirms that of Fatima *et al.* (2016).

Accordingly, experience and education are the key factors affecting the technical efficiency of rubber smallholders. The other variables; *viz*. labour involvement from family, adoption of extension services, type of management and method of harvesting are not statistically significant. The frequency distribution of the estimated technical efficiency of rubber smallholders is given in Figure 1.

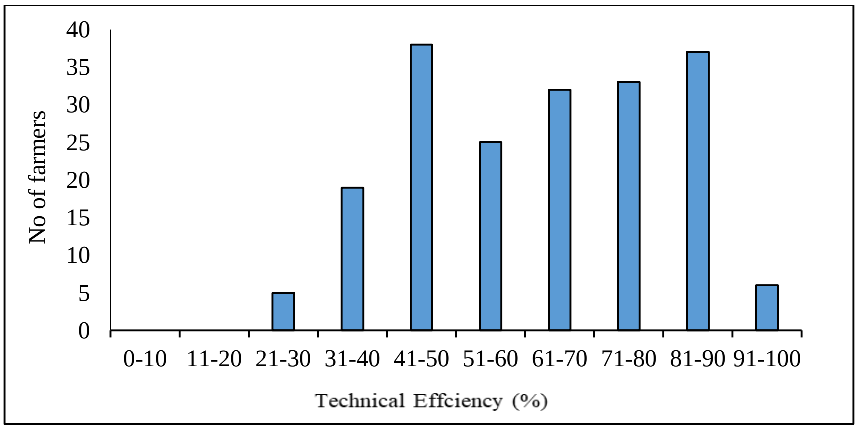

Fig. 1. Distribution of technical efficiencies (based on Cobb-Douglas specification)

The results revealed that the technical efficiencies estimated using Cobb-Douglas production frontier ranged from 21% to 92%. The mean technical efficiency in the sample is 63% indicating that 37% of the potential maximum productivity is lost due to technical inefficiency of the farmers in Kegalle District. Hence, there is a possibility to increase the TE further by 37%. Around 51% of farmers in the sample have TE higher than the average value of 63%. A relatively higher percentage of farmers was observed in the range of 41-50%. Whilst 3% of the farmers had efficiency levels higher than 90%, there were around 30% of the sample had technical efficiency of less than 50%.

Poverty status of the smallholder rubber farmers in Kegalle District

The minimum expenditure per person per month in Kegalle District in 2016 was Rs.4,073.00. It was observed that there were only 35 households out of total 195 households in the sample were found below this official poverty line.

Farm and farmer characteristics affecting poverty

The results of the GLM is presented in Table 3.

This GLM has a reasonable model fit with a R^2 value of 33%. Results of the GLM indicate that years of education of the farmer and farm size has a significant negative relationship with the poverty gap index.

It suggests that increasing farm size and improving the education level of the farmer helps to reduce the poverty level of farmers. Further, family size and age of the farmer have a significant positive association with the poverty gap index. Hence, increased family size and age of the farmer tends to increase the poverty level of farmers. However, gender, experience and dependency ratio do not have a significant relationship with the poverty gap index.

Table 3. *Effect of household variables on Poverty Gap Index*

Variable	Coefficient	Std. Error	Z	P>|z|	[95% Conf. Interval]	
Gender	0.071	0.169	0.420	0.672	-0.260	0.403
Dependency Ratio	-0.046	0.059	-0.780	0.434	-0.161	0.069
Education	-0.171	0.069	-2.470	0.013**	-0.307	-0.036
Family Size	0.387	0.071	5.450	0.000***	0.248	0.525
Age	0.101	0.058	1.740	0.082*	-0.013	0.214
Farm Size	-0.206	0.078	-2.630	0.009***	-0.359	-0.052
Experience	-0.105	0.080	-1.310	0.191	-0.261	0.052
Constant	-0.056	0.155	-0.360	0.718	-0.360	0.248

*** Significant at 1% level, ** Significant at 5% level, *Significant at 10 % level

Correlation analysis between technical efficiency and poverty

According to the results of correlation analysis, there is a significant negative (r=0.1478, P=0.0402) relationship between technical efficiency and poverty gap. Thus, there exists an inverse relationship between poverty and technical efficiency. These results are in line with the results of Gelaw (2013), Asogwa *et al*. (2012a) and Asogwa *et al*. (2012b).

Conclusion

The mean technical efficiency level in the sample is around 63%. Further, the technical efficiency in the sample ranged between 21% and 92%. Therefore, there is a possibility to increase the output level by 37% without any increase in the level of outputs. From the farm and farmer specific characters, farmer's experience and education have a negative relationship with the technical inefficiency. This suggests that more experienced farmers are more efficient compared to the newcomers. Hence it is necessary to conduct farmer training programs especially focusing on the newcomers to improve their exposure to the rubber management practices. Further, farmers with higher educational levels are more efficient compared to those with low educational levels. This may be due to the increased knowledge levels through education which probably help them to take appropriate managerial decisions. Thus, improving education facilities in the area will help to increase the efficiency levels of the farmers.

According to the poverty analysis and the poverty level, there are 35 smallholders below the official poverty line. Poverty determinant analysis reveals that the farmer's education, farm size, age of the farmer and the family size of the farmer has a significant influence on the poverty level. Hence, policymakers should critically consider these factors in poverty alleviation programmes.

Results of correlation analysis indicate that technical efficiency has a significant negative correlation with poverty. Hence, this study unveils that improving the technical efficiency of the farm will reduce the poverty level of farmers. As the education level and the experience have a significant positive impact on the technical efficiency of the farmers, the awareness of farmers on rubber cultivation and management practices needs to be improved through effective means of technology transfer. Adoption of these practices will eventually increase the productivity of smallholder lands and reduce the poverty levels of the farmers.

Acknowledgements

The authors are grateful to the Head, Advisory Services Department and his staff for assisting in the collection of data and the smallholder farmers in Kegalle district for their support during the questionnaire survey.

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