Role of human capital in efficiency increases: evidence from a data envelopment analysis of rubber smallholdings in Gampaha district

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Abstract

This study was carried out to analyze the present level of technical efficiency of rubber smallholders in Gampaha district and primary data were collected from 100 smallholder rubber farmers. Data Envelopment Analysis (DEA) was utilized to estimate technical efficiency levels. A double censoring Tobit model was estimated to assess factors affecting technical efficiency. Farmer specific and tapper specific factors were considered as covariates in the Tobit model. Findings reveal that, levels of human capital of owner farmers as well as latex extractors account for variations in technical efficiency levels. This highlights the importance of directing extension services not only towards the owner farmers, but also towards hired latex extractors to reap benefits of the present price hikes in the rubber sector.

Key words: data envelopment analysis, rubber smallholders, technical efficiency, Tobit model

Introduction

The spiraling prices of petroleum and its consequent impact on production cost of synthetic rubber has further impressed the long-term prospects for natural rubber (Sivakumaran, 2010). In next six years, the country will need around 150,000 metric tons of rubber per year just to meet the escalating demand from local rubber based industries. Considering the global demand for raw rubber exports, ideally 200,000 metric

tons of natural rubber is to be produced per annum by 2016 in Sri Lanka (Rodrigo *et al.*, 2011). The three main strategies to meet this increasing demand may be replanting existing stands with modern high-yielding clones, increasing area of new plantings and enhancing yield productivity of existing stands of mature rubber lands (Sivakumaran, 2010). In the short term, concentrating on the latter is prudent. In attempting to enhance the productivity

of existing lands, one crucial aspect is increasing efficiency with which farmers use their inputs in obtaining outputs. In literature, this is measured in terms of technical efficiency and a vast body of literature surrounds techniques and applications of technical efficiency analysis (for example, see Bravo-Ureta and Pinheiro (1993) and Murillo-Zamorano, 2004).

One important aspect of studies on technical efficiency analyses is the role of human capital in determining levels of efficiency of farmers. In most cases, the level of human capital is measured in terms of farmer education, experience and contacts with extension service. After reviewing 30 studies from 14 different developing countries, Bravo-Ureta and Pinheiro (1993) report that these variables show a positive and statistically significant impact on technical efficiency. Therefore, there is no doubt that human capital play a vital role in technical efficiency increases.

Extension is the major tool that is used to develop human capital in smallholder farmers. In most instances, extension efforts are directed towards owner farmers with the intension of increasing efficiency in smallholder rubber cultivation. Directing extension efforts towards owner farmers is prudent as they are the decision makers with respect to the classical questions in production economics; what to produce, how to produce and how much to produce. However, even with small-

holder farmers, the main activity in rubber cultivation is carried out by hired labor. As extension service is usually government supported and runs on scarce funding available to the government agencies that provide extension, it is prudent to ask, where should the extension service be directed to have the most desired outcome? However, previous studies on technical as well as allocative efficiency of rubber cultivation (Edirisinghe, *et al.* 2010, Bogahawatte, 1999 and Talgaswatta, 1995) have not inquired into this issue. Therefore, this study looks at the role of human capital of owner farmers as well as latex extractors in improving technical efficiency in smallholder rubber cultivation.

Methodology

Sample selection

This study covered rubber smallholders in all Rubber Development Officer's (RDO) divisions in Gampaha district; Weliveriya, Meerigama, Minuwangoda, Dompe, Urapola, Thihariya, Pasyala, Radawana and Pepiliyawala. A multi stage sampling scheme was used to obtain the sample. Three to five Grama Niladari (GN) divisions were selected from each RDO division and individuals were selected randomly from each selected GN division. Total sample size was restricted to 100 considering the limitations on expenses and time.

Data collection

Data were cross sectional in nature, and they were collected through a pre-tested questionnaire, during the month May 2011 *via*. face to face interviews and telephone conversations. Data included information on production and socio economic characteristics of smallholder rubber farmers as well as latex extractors.

Analytical method

First, an efficiency analysis was carried out. Then, estimated efficiency scores were related to socio economic characteristics of owner farmers as well as latex extractors in order to understand what determines efficiency. This two stage estimation is criticized in literature because of endogeneity bias it may create. The argument for this criticism is that although it is assumed in the first stage that estimates of technical efficiency are independently distributed, in the second stage these efficiency estimates are assumed to have a functional relationship with explanatory variables. However, Barnes (2006) notes that even in the alternative one stage procedure, the Stochastic Frontier analysis, also suffers from bias due to assumptions regarding adopting a functional form in estimation (Barnes, 2006).

Efficiency analysis entails an estimation of an efficiency frontier. To estimate efficiency frontiers, many methods are available. These can be “Classical

Stochastic Frontiers”, “Bayesian Stochastic Frontiers” or “Data Envelopment Analysis (DEA)”. The Classical Stochastic Frontier Analysis differs from the Bayesian by the statistical paradigms. However, DEA, which is also a classical technique, differs in terms of assumptions about the data generation process (Balcombe, *et al.*, 2006). There are merits and demerits of all these methods. For example, stochastic frontier analysis imposes explicit functional form and distributional assumptions on data. Non parametric methods such as DEA do not impose any assumptions about the functional forms and therefore, is not subject to the problems of assuming an underlying distribution for the error term (Kaliba, 2004). However, it has the limitation of not having a random error term. There is no universal method to choose between the two popular methods of estimation of technical efficiency (*i.e.* DEA and SFA). Those studies that compare DEA and SFA in estimating technical efficiency report that the choice of the method used does not have much influence on the results, especially in ranking of firms on efficiency (Coelli and Perelman, 1999; Resti, 1997; Iráizoz *et al.*, 2003).

DEA involves the use of linear programming methods to construct a non-parametric frontier over the data and calculate efficiencies relative to this surface. Firms that operate on the frontier are technically efficient and the

firms beneath the frontier are technically inefficient. Technical efficiency of one firm is measured relative to the most efficient firm in the sample, and it can be defined as the capacity of an economic unit to produce the maximum possible output from a given bundle of inputs and a given technology. Technical inefficiency is the amount by which outputs could be increased without requiring extra inputs. The DEA solves a linear programming problem given as;

$$\begin{aligned} \text{Max } \varphi, \lambda \quad & \varphi \\ \text{Subject to} \quad & x_k - X\lambda \geq 0 \\ & -\varphi y_k + Y\lambda \geq 0 \\ & \lambda \geq 0 \end{aligned}$$

Where, X represents the input matrix, Y represents the output matrix and λ is a $N \times 1$ vector of constants. x_k is the input vector of the k^{th} farmer and y_k is the output of the k^{th} farmer. The optimal solution to this problem (φ^*) represents the proportional increase in output that could be achieved by the k^{th} farmer, while holding the input levels constant. This DEA is an output oriented model, where, φ^* is the technical efficiency score (Coelli *et al.*, 2005).

Data Envelopment Analysis Programme (DEAP) version 2.1 was used to construct the piece-wise linear programme given above (Coelli, 1996). Output oriented Constant Returns to Scale model (CRS) was used in estimating of technical efficiency using the production data; output

(kg/Year), total number of tappable trees, the fertilizer amount applied (kg/Year), total cost for chemicals (Rs./Year) and the total number of tappers. Output oriented CRS model is an appropriate specification since most farmers are interested in expanding output given their inputs. However, when CRS is assumed, the same value is given for the estimated technical efficiency score (Coelli *et al.*, 2005).

The censored regression (Tobit) model

In DEA, a farmer on the efficient frontier is given a score of one and any farmer that lies below the efficient frontier is given a score between zero and one. Thus, a double censoring Tobit model is applicable (Kaliba, 2004). Tobit models are appropriate because of two reasons. First, the calculated relative productive efficiency measures are censored between zero and one or in other words it can be scaled to be between zero and 100%. Second, the Tobit model enables calculation of both the marginal effect of the explanatory variable on the efficiency measure and the probability of improvement for inefficient farms. Because the estimated efficiency measures are bounded between zero and one, a two limit (double bounded) Tobit is suitable (Greene, 1993)

$$\begin{aligned} TE &= y^* \quad \text{for } 0 \leq y^* \leq 1 \\ TE &= 0 \quad \text{for } y^* < 0 \\ TE &= 1 \quad \text{for } y^* > 1 \\ y^* &= \beta'X + u \quad \text{for } 0 \leq y^* \leq 1 \end{aligned}$$

Where y^* is the inefficiency score, TE is the technical efficiency score, β is the parameter vector and u a $N(0, \sigma^2)$ distributed error term. The vector of regressors, X , includes, Smallholder's age (Years), Smallholder's gender (Dummy: Male=1, Female=0), smallholder's education (Years), membership in a rubber society (Dummy: Yes=1, No=0), number of extension agent visits, tapper's age (Years), tapper's education (Years) and dummy variable representing use of hired labor (Hired = 1, otherwise 0). These variables included in the Tobit model were carefully selected. Because our interest is to compare the impact of levels of human capital of owners as well as latex extractors on efficiency, two variables were incorporated (Tappers age and education) related to levels of human capital of latex extractors apart from those that relate to human capital of owner farmers. The Tobit model was estimated using STATA 11 computer software.

Results and Discussion

Table 1 depicts the summary statistics related to variables used in DEA and obtained technical efficiencies are given in Table 2. Results revealed that smallholders' technical efficiency levels varied from 8% to 100% and 77% of

farmers ranged between 20-70% of technical efficiency levels. The mean technical efficiency of rubber smallholding sector in Gampaha district was found to be 49.8 %, which indicates that the output could be increased by 50.2% if all farmers achieved full technical efficiency (Table 2). This value is considerably less than what previous studies reported for other districts in the country (Edirisinghe, *et al.*, 2010; Talgaswatta, 1995), but these researches concentrated on traditional rubber growing districts such as Kalutara, Kegalle and Ratnapura. Considering the mean level of output recorded in the present sample (1100 kg/ha/year), increases that could be made if full efficiency is reached is substantial. As these increases in output could be made without any change in the cost structure of farmers, the impact on farmer income will be invaluable. On the other hand, not using scarce resources that farmers own to maximum is a waste of such resources in a time where opportunity cost of resources (such as land) is extremely high.

Table 3 reports results of the Tobit regression where farmer specific variables are related to the estimated efficiency levels in order to identify determinants of technical efficiency.

Table 1. *Summary statistics for variables used in the analysis*

Variable	Sample mean	Min value	Max value
Output (kg/year)	1100	135	6950
Tappable trees/farm	380	45	1450
Fertilizer (kg/year)	117	0	720
Chemical cost (Rs/year)	2401	0	20130
Total no. of tappers	1.5	1	5
Farmer age (years)	56.94	28	81
Farmer education (years)	11.33	0	18
Extractor age (years)	52.27	28	88
Extractor education (years)	8.2	0	13
Extension visits	2.84	0	12
% of male farmers in the sample		73	
% of society members in the sample		43	
N		100	

Table 2. *Distribution of technical efficiencies*

No. of smallholders	Technical efficiency (%)
1	0-10
6	11-20
16	21-30
17	31-40
14	41-50
16	51-60
14	61-70
7	71-80
1	81-90
8	91-100
Mean technical efficiency	49.8

In the Tobit regression, a positive coefficient implies that any increase in the value of a variable would lead to an increase in the level of the latent

variable, which is the technical efficiency. Similarly a negative coefficient implies that any increase in the value of the variable would lead to a

decrease in the level efficiency. Therefore, from the point of view of reducing inefficiency in rubber cultivation, variables with positive coefficients are of interest. We find that all variables except membership of the rubber society report positive signs. The coefficients reported in the Tobit regression relates to the latent variable (y^*) and not the actual technical efficiency itself. This is of no interest as the latent variable is unobserved. The slope coefficient for the observed technical efficiency (TE) estimates can be obtained from

$$\frac{\partial E(TE|X)}{\partial X} = \beta \times Prob[0 < y_i^* < 1]$$

Where β is the coefficient from Tobit regression and $Prob[0 < y_i^* < 1]$ is the probability of the latent variable (y^*) falling between the two censoring limits. The marginal effects obtained in this manner are reported in Table 4.

Our interest in this research was to evaluate the impact of human capital of the owner farmer as well as the latex extractor (labor) on efficiency. The regression included two key variables representing human capital: Education and Age (experience). Results show positive and significant coefficients in education level of owner farmers as well as the latex extractors. The two

marginal effects of farmer and labour education levels are almost similar. Thus, level of human capital of both farmer and the labourer is equally important in achieving high efficiency. Further, age (which represent experience) show statistical significance in the case of labour, but fail to show significance in the case of farmer. Age may represent experience in latex extraction in the labour force. This statistical significance is very much true because in the case of rubber cultivation, efficiency may well lie in the manner latex is extracted. Unskilled latex extraction leads to low yields at present as well as in future as barks of trees get damaged in the long run. Because a rubber plantation has approximately a 30 year economic life span, proper latex extraction will lead to efficient production in the long run. However, the negative and significant sign of the dummy variable for hired labour indicate that still, farmers who own and operate their rubber lands are more efficient than farmers who own but use labour in operation. This is as expected. Variable relating to extension effort, which was introduced in to the model to capture the effect of extension effort on efficiency does not show statistical significance. However, the expected positive sign was observed.

Table 3. *Results of Tobit model*

Variable	Coef.	Std. Err.	P> t	[95% C.I.]	
Farmer age	0.0008	0.0021	0.7020	-0.0034	0.0050
Farmer education	0.0209**	0.0122	0.0890	-0.0033	0.0451
Extension visits	0.0048	0.0085	0.5710	-0.0120	0.0216
Labour age	0.0060*	0.0021	0.0060	0.0018	0.0102
Labour education	0.0154**	0.0088	0.0850	-0.0022	0.0329
Farmer gender	0.0036	0.0540	0.9470	-0.1036	0.1108
Society membership	-0.0668	0.0460	0.1500	-0.1582	0.0246
Hired dummy	-0.1160*	0.0554	0.0390	-0.2261	-0.0059
Constant	-0.1259	0.2345	0.5930	-0.5917	0.3399
Prob > F	0.0295				
Log pseudo likelihood	-182.01				

*Significant at 5 percent level **Significant at 10 percent level

Table 4. *Calculated slopes of coefficient of the Tobit model*

Variable	dy/dx	Std. Err.	P> z	[95% C.I.]	
Farmer age	0.0008	0.0020	0.7010	-0.0032	0.0048
Farmer education	0.0201**	0.0115	0.0810	-0.0025	0.0426
Extension visits	0.0046	0.0081	0.5690	-0.0113	0.0205
Labour age	0.0058*	0.0020	0.0040	0.0019	0.0096
Labour education	0.0147**	0.0084	0.0800	-0.0018	0.0313
Farmer gender	0.0035	0.0518	0.9470	-0.0981	0.1050
Society membership	-0.0641	0.0439	0.1450	-0.1502	0.0220
Hired dummy	-0.1113*	0.0527	0.0350	-0.2146	-0.0080

*Significant at 5 percent level **Significant at 10 percent level

Conclusions

Results obtained from DEA showed that the average technical efficiency of rubber smallholding sector in Gampaha district was 49.8%. This indicates that there are possibilities for further increases in output by 50.2% without any increase in levels of inputs. Increases in efficiency therefore will have a marked impact on smallholder income in the context of present hikes in natural rubber prices.

Higher and similar size of the coefficient for education of both smallholder as well as the tapper provides important insight about the importance of improved human capital in increasing efficiency levels and hence farmer income. In previous studies, only factors specific to the owner farmer has been considered in providing policy implications on how to increase efficiency. This paper deviates from the typical, and have included factors specific to laborers, whom is an important entity in rubber production. Findings reveal that developing human capital in the tapper community is also important as developing the farmer community. The present extension effort, which usually targets owners of rubber smallholdings, should be directed towards the tapper community as well to reap benefits of higher prices as well as full potential of high yielding clones available.

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