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Contents

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Estimation of Technical Efficiency and It's Determinants in the Tea Small Holding Sector in the Mid Country Wet Zone of Sri Lanka

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ABSTRACT

Sri Lanka is the world leader in made tea production and the small holding sector dominates national production by accounting for 60% of the island's tea production. However, given the high cost of production, there is a belief that it is very difficult to increase profitability without increasing costly inputs such as labour. With this background, in this study technical efficiency of the tea small holdings sector in the Mid Country Wet Zone of Sri Lanka was estimated in order to identify the potential to increase production without incurring any additional costs for inputs. The sources of inefficiency and the robustness of measured technical efficiency in various functional specifications was also investigated.

The primary data collected during the period September - January 2001 relevant to sixty small holder tea producers in the Mid-country Wet Zone was used for the study. Maximum likelihood estimates of the stochastic frontier model were estimated for green leaf yield as a function of land extent, family labour, hired labour, fertilizer, chemicals, and dolomite, using Cobb-Douglas and translog models. The determinants of technical efficiency such as age of farmer, experience, education, occupation type of crop (VP/Seedling) and type of clone were investigated, following the Battese and Coelli (1995) specification.

According to the Cobb-Douglas specification, extent of land, family labour, hired labour, fertilizer and dolomite showed significant effects on yield. The coefficients for land, family labour, hired labour and fertilizer had positive values of 1.11, 0.027, 0.067 0.029 and 0.004 respectively. The mean technical efficiency of the tea small holdings sector in the Mid Country Wet Zone was found to be 64.60 per cent. The result for the inefficiency model indicates that age of farmer, education, occupation, type of crop (VP or

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seedling) and type of clone have significant effects on efficiency. The coefficients for age, education, occupation and type of crop showed negative values. However contrary to expectations, type of clone and experience showed positive values. The estimation with the translog model yielded different technical efficiencies, which indicates the fact that technical efficiency estimations are highly sensitive to the functional form specified.

Introduction

The plantation sector occupies around 40 per cent of the total land cultivated in Sri Lanka and provides employment for about 15 per cent of the total labor force. Furthermore, it accounts for over five per cent of the GNP and yields 18 per cent of Sri Lanka's export earnings (Ekanayake, 1995). Three main plantation crops dominate the export agricultural sector; namely tea, rubber and coconut. These crops still occupy their position as the largest net foreign exchange earners of the Sri Lankan economy.

Tea is pre-eminent among Sri Lanka's plantation crops and it is one of the most important industries in the country in terms of employment and foreign exchange earnings. The tea plantations are categorized into two major production sectors, the estate sector and the small holding sector according to the extent cultivated. A tea small holding is defined by statute as an area of land in tea cultivation less than 4 hectares. There are about 200,000 tea small holdings in Sri Lanka covering an extent of 88,000 hectares approximately. This is about 42 per cent of the total tea land extent. In year 2000, the tea small holdings were able to produce 184 million kilograms of made tea which is 60 per cent of total made tea production (Central Bank, 2000).

Though the performance of the plantation estate sector is relatively stagnant, the small holdings sector has performed better during the past few decades. The area under the small holdings has increased from 56,266 hectares in 1985 to 88,000 hectares in 2000, while production has increased from 58.5 million kilograms of made tea to 164 million kilograms of made tea during the same period (MPI, 2000).

Small holding performances are relatively better, partially because they are predominantly located in the Low Country where soils are more fertile and climatic conditions are generally more favorable. Hence, it is reasonable that the tea small holdings should be given priority as far as the development of the tea industry in Sri Lanka is concerned. In addition, there are about 1.5 million dependents who are directly or indirectly involved in the tea small holdings sector. Therefore, upgrading the living conditions of the small holders will significantly enhance the development of a large fraction of the population of the country.

Although Sri Lanka is the leading tea exporter in the world, the local tea industry has been facing severe problems during the last two decades. Some of these problems are declining production and productivity, increasing cost of production, fall in export prices and a reduced share of the world market (Manikam, 1995). The Tea Small Holding Development Authority (TSHDA), which is the main institution dealing with the tea small holders, has implemented several programs to develop the tea small holdings sector, and thereby expected better performances from the sector. Subsidy schemes (new planting, replanting, infilling), credit schemes (fertilizer credit) and the extension service are some of these programs.

Despite such efforts, the performances of tea small holdings were not satisfactory. Although the average yield is higher (2,216 kilograms of made tea per hectare) than the estate sector (1,630 kilograms of made tea per hectare), the yield tends to vary enormously among holdings. For example, in the Yatinuwara Secretariat Division, the yield tends to vary approximately from 500 kilograms of made tea per hectare to well over 5,000 kilograms of made tea per hectare.

In view of the growing competition in the world tea market and high production costs, production efficiency will become an important determinant of the future of Sri Lanka's tea industry. Developing and adopting new production technologies could improve productive efficiency. In addition the industry could maintain its economic viability by improving the efficiency of existing operations with a given technology. In other words, the industry's total output can be increased without increasing the total cost by making better use of available inputs and technology.

Following the above discussion, this study examined the individual as well as industry level efficiency of tea small holdings. It will enhance identification of the sources where improvements can be made. The relationship between efficiency level and various firm specific factors can provide useful policy relevant information. The main objective of this study is to estimate the technical efficiency of tea small holdings and determinants of inefficiency in the Mid Country Wet Zone. Specific objectives of the study are:

- To identify the factors causing technical inefficiency of tea small holdings, by examining the relationship between efficiency level and various firm specific factors.
- To study the robustness of technical efficiency estimates with respect to different functional form specifications.

Methodology

The Yatinuwara Divisional Secretariat area was selected for the study due to several reasons. There are a large number of tea small holdings in the area. Close proximity to the university, which saves time and financial facilities are the other reasons. The Yatinuwara Divisional Secretariat area is situated in the Kandy District and belongs to the Mid Country Wet Zone. The agro-ecological zone is WM 2 and the major soil type available is Red Yellow Podzolic. There are about 90 Grama Niladhari Divisions in the area and the tea small holdings are spread over 70 GN division. There are approximately 4000 tea small holdings in the Yatinuwara Divisional Secretariat area. Yatinuwara DS is divided in to three Tea Inspector (TI) ranges, namely Gannoruwa, Danture, and Manikdiwela. These TI ranges are administrated by the Regional Office of Tea Small Holdings Development Authority (TSHDA), Gannoruwa.

Since the primary observations and discussions with TSHDA officials indicated that there is no variability within the study area, a random sample of 60 farmers were selected from the whole Yatinuwara DS. The tea small holdings register available at the extension office in Giragama and Gannoruwa was used as the sampling frame.

Aigner, Lovell and Shemidt (1977) and Meeusen and Van den Broeck (1977) independently proposed the estimation of a stochastic frontier production function, where noise is accounted for by adding a symmetric error term (u_i) to the non negative term to provide,

$$Ln\,(Y_i) = f\,(x_i;\,\beta) + \varepsilon_i\,;$$
$$\varepsilon_I = v_i - u_i\,; \quad i = 1,\ldots,N$$

Where Y_i denotes production level, x_i is input level and β is a vector of unknown parameter to be estimated.

ε_i is the composed error term. v_i is independently and identically distributed random errors $N(0,\sigma_v^2)$. These are the factors outside the control of the firm. U_i is non-negative random variables which are independently and identically distributed as $N(0,\sigma_u^2)$ i.e. the distribution of u_i is half normal. $|u_i| > 0$ reflects the technical efficiency relative to the frontier. $|u_i| = 0$ for a firm whose production lies on the frontier and $|u_i| > 0$ for a firm whose production lies below the frontier.

According to Battese and Coelli (1995), technical inefficiency effects are defined by;

$$U_i = Z_i\ \delta + W_i,$$
$$I = 1,\ldots,N$$

Z_i is a vector of explanatory variables associated with the technical inefficiency effects.

δ is a vector of unknown parameter to be estimated. W_i is unobservable random variables, which are assumed to be identically distributed, obtained by truncation of the normal distribution with mean zero and unknown variance σ^2, such that U_i is non-negative.

Stochastic frontier production functions can be estimated using either the maximum likelihood method or using a variant of the COLS (corrected ordinary least squares) method suggested by Richmond (1974). But here we will consider the maximum likelihood method because availability of software such as the Frontier Programme (Coelli, 1994) has automated the maximum likelihood method.

According to Battese and Corra (1977), the variance ratio parameter γ which relates the variability of u_i to total variability (σ^2) can be calculated in the following manner;

$$\gamma = \sigma_u^2/\sigma^2$$

where $\sigma^2 = \sigma_u^2 + \sigma_v^2$;

so that $0 \leq \gamma \leq 1$

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).

The following model specifications were used in the analysis.

Cobb-Douglas Model

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

Where Ln denotes logarithms to base e

Y= out put (kg of green leaf)
X_1 = extent of land (ac)
X_2 = family labour (man days)
X_3 = hired labour (man days)
X_4 = fertilizer (kg)
X_5 = chemical (cost)
X_6 = dolomite (cost)

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

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

Z_1 = age of farmer (years)
Z_2 = experience (years)
Z_3 = education (years)
Z_4 = occupation, a dummy variable equal to one if the small holders are involved in tea holding only, zero otherwise.
Z_5 = type of clone, a dummy variable equal to one if only clone TRI 2023 is grown, zero otherwise.
Z_6 = type of crop (VP or seedling), a dummy variable equal to one if VP tea is grown, zero otherwise.
W_i = unobservable random variables

Translogarithmic Model

$$Y_i = \beta_0 + \Sigma^6_{j=1} \beta_j X_{ji} + \Sigma^6_{j<=} \Sigma^6_{k=1} \beta_{jk} X_{ji} X_{ki} + V_i - U_i$$

Inefficiency model and variables are the same as the Cobb- Douglas model.

Results and Discussion

The summary statistics related to the variables used for the analysis are depicted in Table 1.

Cobb-Douglas production function results

The OLS as well as ML estimates of the estimated Cobb-Douglas model are presented in Table 2.

The estimate of γ is 0.99, which indicates that the vast majority of error variation is due to the inefficiency error u_i (and not due to the random error v_i). This indicates that the random component of the inefficiency effects does make a significant contribution in the analysis. The one sided LR test of γ=0 provides a statistic of 37.22 which exceeds the chi-square five per cent critical value of 15.51. Hence the stochastic frontier model does appear to be a significant improvement over an average (OLS) production function.

The estimated ML coefficient of extent of land showed a positive value of 1.11 which was significant. Therefore, increment of land extent by one per cent will increase output by a larger proportion (1.11 per cent). The estimated ML coefficients for family labour, hired labour, fertilizer and chemicals showed positive values of 0.027, 0.067, 0.029 and 0.004 respectively. All these values were significant. This indicates that increment of the inputs, family labour, hired labour, fertilizer and chemicals by one per cent will increase output by 0.027 per cent, 0.067 per cent, 0.062 per cent and 0.004 per cent respectively. However contrary to expectation, the coefficient for dolomite showed a negative value of 0.109, which was significant.

The mean technical efficiency of the tea small holding sector was found to be 61.06 per cent, which indicates that the output could be increased by 39 per cent if all farmers achieved the technical efficiency level of the best farmer. Table 3 shows distribution of technical efficiencies of tea small holdings in Yatinuwara DS. Technical efficiency ranges from as low as 15 per cent to as high as 99 per cent.

The estimated coefficients in the inefficiency model are of particular interest to this study and are depicted in Table 4. The age coefficient appeared to be negative and significant which indicates that older

Table 1: Summary statistics for variables in the stochastic frontier production functions for tea small holdings

Variable	Sample mean	Standard deviation	Minimum value	Maximum value
Out put (green leaf-kg)	8,626.45	14,790.15	150	80,000
Extent (Ac)	1.34	1.53	0.25	07
Fertilizer (kg)	837.90	1,135.33	50	5600
Family labour (man days)	90.67	110.05	10	572
Hired labour (man days)	477.56	746.43	05	3,600
Chemicals (cost)	1,243.49	122.63	250	4,200
Age of farmer (years)	49.50	10.74	25	72
Experience (years)	12.50	8.72	04	40
Age of plantation (years)	8.87	4.06	04	50

Table 2: OLS estimates and maximum likelihood estimates for parameters of the stochastic frontier (Cobb-Douglas model) for tea small holdings

Variable	Parameter	Coefficient		Standard error		t ratio	
		OLS	MLE	OLS	MLE	OLS	MLE
Constant	$ß_o$	7.96	9.08	0.4908	0.014	16.22*	640.33*
Land	$ß_1$	0.978	1.11	0.1122	0.009	8.71*	120.93*
Family labour	$ß_2$	0.019	0.027	0.0185	0.002	1.09	12.15*
Hired labour	$ß_3$	0.088	0.067	0.0157	0.008	5.59*	8.12*
Fertilizer	$ß_4$	0.035	0.029	0.0253	0.007	1.39	4.08*
Chemical	$ß_5$	-0.018	0.004	0.0111	0.001	-1.63	3.65*
Dolomite	$ß_6$	-0.017	-0.072	0.1046	0.003	-0.166	-32.81*
σ^2			0.6303				
γ			0.99				
Log likelihood		-39.46	-20.85				
LR test			37.22				

* Significant at 5 per cent probability level

Table 3: Distribution of technical efficiencies (based on Cobb-Douglas specification)

Technical efficiency %	Number of farmers
10 - 20	2
20 –30	2
30 – 40	7
40 – 50	11
50 – 60	9
60 – 70	6
70 – 80	7
80 – 90	9
90-100	11

farmers are more efficient than younger ones. Coefficients of education, occupation and type of crop (VP/seedling) showed negative values. The negative and significant coefficient for education suggests that the educated farmers are more efficient than others. Those farmers who are involved only in tea holdings as full time farmers are found to be more efficient than others. This may be because they devote more time on the tea holding. The inefficiency increases with experience according to results. This can be explained by most of the experienced farmers used to grow seedling tea and they tend to ignore advises given by TSHDA. The small holders who use VP tea are found to be more efficient. This may be because VP tea is highly responsive to fertilizer and high yielding compared to seedling tea. The positive coefficient for clone indicated that the producers who use clone TRI 2023 appeared to be inefficient. Although the Tea Research Institute recommends this clone for the area, the small holdings who use this clone are found to be inefficient.

Translog production function results

A stochastic translog production frontier was estimated as a test of robustness in the choice of functional form. The form of this model encompasses the Cobb-Douglas form, so test of preference for one form over the other can be undertaken by analyzing significance of cross terms in the translog form. The ML estimates are given in Table 5.

Coefficient of land, dolomite, chemical square and dolomite square showed significant effect on output. But the coefficient of land and chemical square were negative. The mean technical efficiency obtained from the translog function was 83.10 per cent. None of the parameters in the inefficiency model showed significant effect on inefficiency (Table 6).

Robustness of technical efficiency estimates

Technical efficiency estimates obtained by Cobb-Douglas and translog models differ very much. If the estimates are close, it could be shown in the Figure 1 as a 45-degree line. The mean technical efficiency obtained from the Cobb-Douglas model is 61.06 per cent while the translog model showed a mean technical efficiency of 83.10 per cent.

Table 4: Determinants of inefficiency-Cobb-Douglas Model

Variable	Parameter	Coefficient	Standard error	t ratio
Constant	δ_0	2.97	0.8975	3.31*
Age of farmer	δ_1	-0.038	0.0113	-3.32*
Experience	δ_2	0.025	0.0012	2.17*
Education	δ_3	-0.145	0.0454	-3.19*
Occupation (D1)	δ_4	-0.467	0.0213	-2.19*
Clone (D2)	δ_5	-0.734	0.2854	2.572*
Type of crop (D3)	δ_6	-0.646	0.2832	-2.28*

* Significant at 5 per cent probability level

Table 5: Maximum likelihood estimates for parameters of the stochastic frontier (translog) for tea small holdings

Variable	Parameter	Coefficient	Standard error	t ratio
Constant	$ß_o$	5.4800	0.9943	5.5080
Land	$ß_1$	8249.8000	0.9688	8515.490*
Family labour	$ß_2$	0.0878	0.8699	0.1009
Hired labour	$ß_3$	0.8415	0.9329	0.9019
Fertilizer	$ß_4$	.0246	0.9118	0.0303
Chemical	$ß_5$	0.0212	0.8828	0.0240
Dolomite	$ß_6$	4124.7800	0.8685	4749.090*
Land sqr.	ß7	0.2044	0.5836	0.3503
Family labour sqr.	$ß_8$	0.9738	0.8360	1.1610
Hired labour sqr.	$ß_9$	0.3390	0.6919	0.4899

Table 5 (contd.): Maximum likelihood estimates for parameters of the stochastic frontier (translog) for tea small holdings

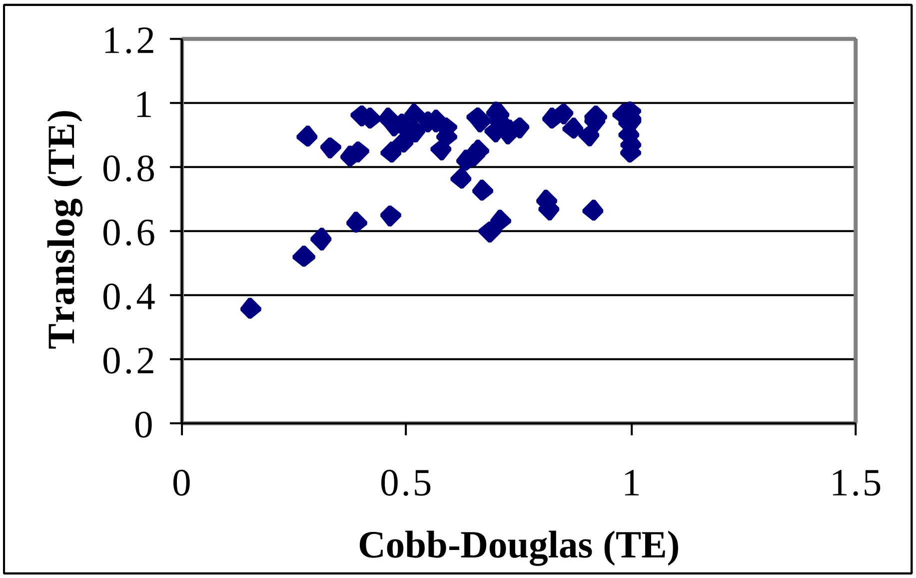
Variable	Parameter	Coefficient	Standard error	t ratio
Fertilizer sqr.	$ß_{10}$	0.0567	0.8106	0.0698
Chemical sqr.	$ß_{11}$	1.8590	0.5435	3.4210*
Dolomite sqr.	$ß_{12}$	3.0650	0.8651	3.5420*
Land * F. L.	$ß_{13}$	0.0569	0.1838	0.3090
Land * H.L.	$ß_{14}$	0.0215	0.2619	0.0820
Land * Fertilizer	$ß_{15}$	0.2920	0.6859	0.4250
Land * Chemical	$ß_{16}$	0.0080	0.1664	0.0453
Land * Dolomite	$ß_{17}$	0.3470	0.7957	0.4363
F. L. * H.L.	$ß_{18}$	0.0642	0.2420	0.2658
F. L. * Fertilizer	$ß_{19}$	0.0247	0.1944	0.1273
F. L. * Chemical	$ß_{20}$	0.0016	0.0299	0.0754
F. L. * Dolomite	$ß_{21}$	0.0270	0.2947	0.0957
H.L. * Fertilizer	$ß_{22}$	0.0037	0.1025	0.0356
H.L. * Chemical	$ß_{23}$	0.0038	0.0217	0.1781
H.L. * Dolomite	$ß_{24}$	0.0044	0.3409	0.1291
Fertilizer* Chemical	$ß_{25}$	0.0150	0.0810	0.1839
Fertilizer * Dolomite	$ß_{26}$	0.1560	0.1693	0.4858
Chemical * Dolomite	$ß_{27}$	0.0038	0.0575	0.0198
σ^2		0.0643		
γ		0.9918		
Log likelihood		28.11		
LR test		21.17		

* Significant at 5 per cent probability level

Table 6: Results of the Inefficiency model for translog function

Variable	Parameter	Coefficient	Standard error	t ratio
Constant	δ_0	0.0478	0.9992	0.0479
Age of farmer	δ_1	0.0060	0.1853	0.0358
Experience	δ_2	0.0230	0.1690	0.1371
Education	δ_3	0.0074	0.9383	0.0078
Occupation (D1)	δ_4	0.0698	0.9991	0.0699
Clone (D2)	δ_5	0.0417	0.9946	0.0419
Type of crop (D3)	δ_6	0.0495	0.9917	0.0494

Figure 1: Robustness of technical efficiency estimates.



Conclusions and Policy Implications

The primary objective of this study is to estimate the technical efficiency of tea small holdings in the Mid Country Wet Zone and to identify the factors causing inefficiency. According to the results obtained from the stochastic frontier estimation, the average technical efficiency of tea small holding sector given by the Cobb-Douglas model is 63.10 per cent. This indicates that there is scope of further increasing the output by 36.90 per cent without increasing the levels of inputs.

From the factors considered which affect technical efficiency, age of farmer, experience, educational level, occupation, type of crop and type of clone were significant at 5% level. According to the results, older farmers appeared to be more efficient than younger farmers. This may be due to their good managerial skills, which they have learnt over time. Therefore the younger farmers should be encouraged to work with elder farmers. Experience showed a positive relationship with inefficiency. This may be because most of the experienced farmers still do have seedling tea in their holdings. Another reason may be that they neglect adopting management practices recommended by TSHDA. Educated farmers are found to be more efficient than the uneducated. This may be because their knowledge, gained from education has provided them a background to take correct decisions. It would be easier for them to grasp the information provided them by the extension officers. Therefore it is necessary to increase educational facilities in the area. Farmers who are involved in the tea holding as full time farmers are found to be more efficient than the other farmers. This is obvious, as they devote more time on their holdings. Tea small holders should be encouraged to be involved in the tea holding as full time farmers. This could be a difficult task because they seek other employment as it is not secure to be involved in the tea holding as full time farmers. The reason is that price fluctuations and unfavorable climatic conditions drastically affect the tea industry. Therefore, the risk is great. Implementation of a solid guaranteed price scheme would be an appropriate solution.

The positive coefficient for clone indicates that the usage of clone TRI 2023 alone is inefficient. Although the TRI has recommended TRI 2023 as a suitable clone for the Mid Country, it showed a negative effect in terms of efficiency. Since the usage of clone TRI 2023 alone is inefficient, small holders should be encouraged to replace TRI 2023 with other clones such as TRI 2025, TRI 2021 and DG 39 etc. The small holders who use vegetatively propagated tea are found to be more efficient than others who use seedling tea. Tea small holders should be encouraged to replant their old seedling tea with improved VP tea. A good suggestion would be to increase the subsidy given for replanting.

It was found that the technical efficiency estimates are highly sensitive to the functional form specified because the Cobb-Douglas and translog models yielded different technical efficiencies. However, the Cobb-Douglas specification is used in the interpretation as it is widely accepted in the literature.

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