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An Assessment of Technical Efficiency of Potato Production

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ABSTRACT. The purpose of this study is to investigate the technical efficiency and to find out the factors affecting technical efficiency of potato cultivation in Badulla district in Sri Lanka. The extent by which a farmer lies below its production frontier is regarded as the measure of technical inefficiency. A stochastic frontier production function and a model to explain technical efficiency were estimated to achieve the purpose of the study. Data was collected from 55 farmers using a structured questionnaire during 1999 yala season. Yield of potato was regressed as a function of land, labour, mechanical services, agrochemicals, and seed, rate. Technical efficiency was regressed as a function of age of the farmer, education level of the farmer, and farm assets. The two models were estimated in a single stage. According to the econometric results, labour and seed rate significantly affect the potato production in yala. Production technology exhibits decreasing returns to scale. The average level of technical efficiency of farmers was found to be 72%, indicating that the production would increase by 28%, if all the farmers achieved the technical efficiency level of the best farmer. However, the average yield of the best farmer too is far below the potential yield. The results of the model for the inefficiency effects indicate that educated farmers tend to be more efficient than the others.

INTRODUCTION

During the period of import restrictions potatoes became a very remunerative crop. As a result, most potato farmers did not adhere to proper agricultural practices and neglected crop rotation programs which led to lower yields. Yield levels had declined by almost half from about 16 metric tons ha^{-1} to about 10 metric tons ha^{-1} over the last 2 decades (Central Bank of Sri Lanka, 1998). The cost of production of local potatoes, which is around Rs. 26 kg^{-1}, is extremely high compared to other countries. It was argued that the main reasons for the high cost of production are lower yields which could be due to technical inefficiency, lower fertility of soil, high cost of seed potato which accounts for more than 50% of the total cost of production, and high wage rates. The prices of many inputs are higher in Sri Lanka compared to India as they are not subsidized.

With the objective of bringing down potato prices, import licensing on potato was removed and the import duty on potatoes was reduced from 35-20% in 1996. The price advantage enjoyed by the potato farmers in the highly protected market disappeared with the increased imports from India and Pakistan resulting a marked decline in the extent and

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production of potatoes by around 70% and an exit by a large number of farmers from the industry (Department of Census and Statistics, 1997).

It is hypothesized that farmers remained in the industry are technically efficient. The purpose of this study is to investigate the technical efficiency of potato farmers who remained in the industry even after trade liberalization. If the farmers are technically inefficient, the improvement in the efficiency of input use particularly in the case of fertilizer and pesticides can increase farm profitability as well as reduce health and environmental losses due to potato cultivation. By increasing efficiency, output can be increased by simply increasing its efficiency without absorbing further resources.

The information generated from such a study will provide a better understanding of the existing production system and serves as an important guideline to the relevant authority in the formulation of an appropriate agricultural program for this particular production group. In view of the above situation, this paper attempts to investigate the resource use efficiency in potato production with the following specific objectives.

1. to estimate technical efficiency of potato farmers based on stochastic frontier approach; and
2. to identify the determinants of technical efficiency.

MATERIALS AND METHODS

Conceptual framework

Fig. 1 and 2 diagrammatically show how technically efficiency (TE) is measured using a production frontier function.

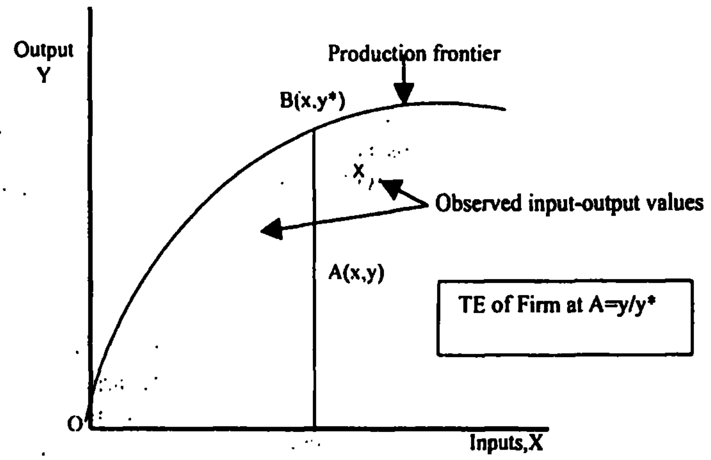

Fig. 1. Technical efficiency of firms in input-output space.

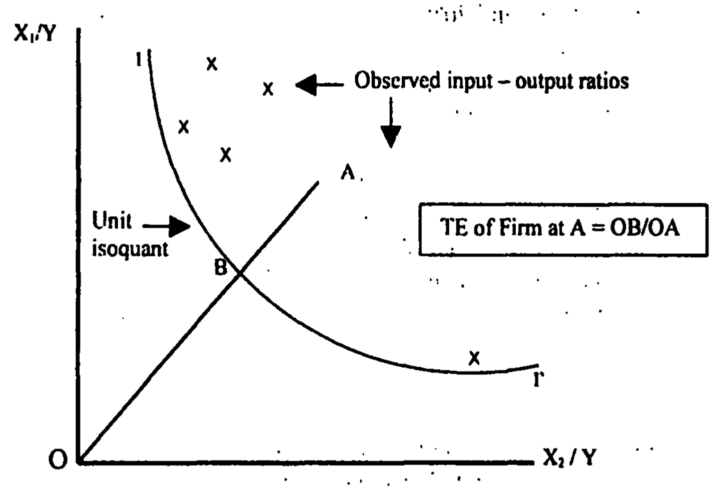

Fig. 2. Technical efficiency of firms in relative input space.

A general presentation of Farrell's concept of the production function (or frontier) is depicted in Fig. 1. The horizontal axis represents the (vector of) inputs, X, associated with producing the output, Y. The observed input-output values are below the production frontier, given that firms do not attain the maximum output possible for the inputs involved, given the technology available. A measure of the technical efficiency of the firm which produces output, y, with inputs, x, denoted by point A, is given by y/y*, where y* is the frontier output associated with the level of inputs, x (see point B).

Fig. 2 depicts the situation in which firms use two inputs of production, X_1 and X_2, to produce their output, Y, such that the points, defined by the input-per-unit-of-output ratios, (X_1/Y, X_2/Y), are above the curve. The unit isoquant defines the input-per-unit-of-output ratios associated with the most efficient use of the inputs to produce the output involved. The deviation of observed input-per-unit-of-output ratios from the unit isoquant was considered to be associated with technical inefficiency of the firms involved. Farrell (1957) defined the ratio, OB/OA, to be the technical efficiency of the firm with input-per-unit-of-output values at point A.

The frontier production function is built based on the concept of efficiency adduced by Farrel (1957). The intercept is adjusted by shifting the function until no residual is positive and one is zero. This is done by adding the largest error term of the fitted model to the intercept, thus yielding the frontier production function. The frontier may be specified to be either deterministic or stochastic. In the deterministic and stochastic frontier models, inefficiency is introduced *via* the disturbance term. In the deterministic frontier models, all variation in firm performance is attributed to variation in firm efficiencies relative to the common family of frontiers. Deterministic frontier is estimated by means of a Linear Programming methodology. The essential idea behind the stochastic frontier model is that the error term is composed of two parts. A symmetric component permits random variation of the frontier across firms, and captures the effects of random error outside the firm's control. A one-sided component captures the effects of inefficiency relative to the stochastic frontier. Stochastic frontier uses the maximum likelihood technique for estimation purposes.

Theoretical model

Stochastic production frontier can be written as;

$$Y_i = f(X_{ij}) + \varepsilon_j ; \quad \varepsilon_j = V_j - U_j$$

where, Y_i is production, X_{ij} is input level and ε_j is the composed error term. Factors outside the control of the farm are represented by V_j and the random variables which are under the control of the farm are represented by U_j. Most empirical studies assume that V_j is identically and independently distributed as $N(0, \sigma^2_v)$. A one sided component $| U_j | > 0$ reflects technical inefficiency relative to the stochastic frontier. Thus, $| U_j | = 0$ for a farm whose production lies on the frontier, and $| U_j | > 0$ for one whose production is below the frontier. Assume that U_j is identically and independently distributed as $| N(0, \sigma^2_u) |$; *i.e.*, the distribution of U_j is half-normal.

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

$$\gamma = \sigma^2_u / \sigma^2, \quad \text{where } \sigma^2 = \sigma^2_u + \sigma^2_v ;$$

So that $0 \leq \gamma \leq 1$.

If $\gamma \rightarrow 0$, the difference between a farmer's yield and the efficient yield is mainly due to statistical error. On the other hand if $\gamma \rightarrow 1$, the difference is attributed to the farmer's less than efficient use of the technology.

Jondrow *et al.* (1982) have shown that the individual farm measures of technical efficiency can be estimated from the error term ε_j. They demonstrated that the conditional mean of U_j given ε_j is equal to:

$$E (U_j | \varepsilon_j) = \sigma_u \sigma_v / \sigma - [f^*(\varepsilon_j \lambda / \sigma) / 1 - F^* (\varepsilon_j \lambda/\sigma) - \varepsilon_j \lambda/\sigma] \quad \text{where, } \lambda = \sigma_u / \sigma_v$$
$j = 1, \ldots n$,

Where f^* and F^* are the standard normal density distribution and the standard normal distribution function respectively. The measure of technical efficiency (TE) can be computed as follows;

$$TE_j = \exp (- E [U_j / \varepsilon_j])$$
So that $0 \leq TE_j \leq 1 \quad j = 1,\ldots,n$

The parameters of the stochastic frontier production function model are estimated by the method of maximum likelihood, using the computer program, FRONTIER Version 4.1 (Coelli, 1994).

Econometric model

In this study. the Battese and Coelli (1995) stochastic frontier was specified for cross sectional data where the model for the technical inefficiency effects involves farmer-specific variables[1]. Frontier function gives maximal output attained with respect to those farms in sample or over all possible sample points, given a set of input quantities, whereas OLS provides estimates of the average function. The stochastic Cobb-Douglas production frontier to be estimated in the Battese and Coelli (1995) model specification is:

$$\ln Y_i = \beta_0 + \sum_{i=1}^{m} \beta_i \ln X_i + (V_i - U_i) \quad (1)$$

where the subscript i refer to the i-th farmer;
ln represents the natural logarithm;
V_i is assumed to be independently and identically distributed random errors, having N(0, σ_v^2) distribution; and
The U_i is non-negative random variables, called technical inefficiency effects, associated with the technical inefficiency of production of the farmers involved.

It is assumed that the inefficiency effects are independently distributed and U_i arise by truncation (at zero) of the normal distribution with mean, μ_i, and variance, σ^2, where μ_i is defined by:

$$\mu_i = \delta_i Z_i \quad (2)$$

where Z_i are variables which may influence the efficiency of a firm.

The stochastic frontier production function, defined in equation (1), is a linearised approximation of a Cobb-Douglas production function. In the stochastic frontier, output (Y) is the yield in each farm (kg/ac). The inputs denote: land (X_1) measured in acres, labour (X_2) measured in man days, mechanical services (X_3) measured in rupees, agrochemicals (X_4) measured in rupees, and seed rate (X_5) measured in kg/ac. The estimates were obtained using the computer program, FRONTIER Version 4.1 (Coelli, 1994). The selected farm characteristics (Z_i) were farmer's age (AGE) measured in years, education level (EDU) measured in years of schooling, and value of farm assets (FA), which composed of sprayers, water pumps, and two and four wheel tractors and valued in rupees, as other researchers have used[2].

Data

The data used in this study were obtained from the interviews conducted with the farmers. A structured questionnaire was used for interviews. Fifty-five potato farms were

1 The one-stage approach is less objectionable from a statistical point of view and is expected to lead to more efficient inference with respect to the parameters involved.

2 Current value of farm asset was measured in rupees since it is difficult to assess the capacity of capital goods.

chosen at random from the four major potato-growing areas in the Badulla district, namely Uva Paranagama, Keppetipola, Boralanda and Dambawinna. To get more reliable set of data, data on fertilizer, pesticides, mechanical services, and labour inputs were collected from each farm in every two weeks during the period of *yala* season (July - October), 1999.

The dependent variable, yield, was measured in kg/ac. The land variable is the extent of land measured in acres. The labour variable combines family labour, hired labour and exchange labour. The labour variable was incorporated in terms of man-day equivalents by taking 8 h of work as a day. In computing equivalent man-days of work per farm, a woman-day and a child-day were considered to be 0.75 and 0.5 of man-days, respectively. The variable representing mechanical services is an important variable in the context of technical change. This was measured in terms of the cash expenditure on mechanical services[1]. The expenditure on agrochemicals which constitutes fertilizer, insecticides, and fungicides was measured in rupees[2]. The variable, seed rate was measured in kg/ac.

RESULTS AND DISCUSSION

Table 1 presents the Ordinary Least Square estimate of the average function and Maximum Likelihood estimates for the parameters in the stochastic frontier and inefficiency model.

The adjusted R^2 value of 0.79 and LR test value of 35.48 testified to the adequacy of the model used. Seed rate and labour were found to have significant impacts on potato production. Among them, seed rate had the highest input elasticity of 1.4245. Thus, output could be increased at a larger proportion by increasing seed rate. The second most important variable in increasing potato production was the labour having the output elasticity of 0.1375. Thus, labour intensification would increase the production significantly. Mechanical services, and agrochemicals showed negative, however insignificant effects on production. Shortage of water in *yala* season would perhaps explain the response of agrochemicals. Farmers were operating at decreasing returns to scale of 0.5632 as indicated by the sum of the output elasticities of the Cobb-Douglas production function.

The estimated δ-coefficients in Table 1 associated with the explanatory variables in the model for the inefficiency effects are worthy of particular discussion. We observe that the level of education of the farmers has a negative significant effect upon the inefficiency. That is, farmers with greater years of formal education tend to be efficient in potato production. The coefficient of age is estimated to be negative. That is, the older farmers tend to have smaller inefficiencies than younger farmers. However, the coefficient of age was found to be insignificant. The coefficient of farm assets is estimated to be negative. This implies that the farmers those who posses farm assets like tractors, water

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1 Machinery variable was measured in terms of expenditure on mechanical services since it is difficult to measure the capacity of machinery.

2 Agrochemicals were measured in rupees to overcome the aggregate problem.

pumps, and sprayers tend to be efficient. However, the coefficient of farm assets was found to be insignificant.

Table 1. Maximum-likelihood estimates for parameters of the stochastic frontier and inefficiency models.

	Parameter	Average Function Coefficient	t-ratio	Stochastic Frontier Coefficient	t-ratio
Stochastic frontier					
Intercept	β_0	1.7482	1.4383	-0.7432	-0.6865
Land	β_1	0.5122*	1.7159	0.1414	0.7090
Labour	β_2	0.1663	0.8691	0.1375**	1.9893
Mechanical services	β_3	-0.0281	-0.2156	-0.0829	-0.9249
Agrochemicals	β_4	-0.2869*	-1.7908	-0.3141	1.3825
Seed rate	β_5	1.0229***	3.5051	1.4245***	9.1131
Inefficiency model					
Age	δ_1			-0.0039	-1.0545
Education	δ_2			-0.0771**	-5.3455
Farm assets	δ_3			-0.3043E-6	-0.4689
RTS				0.5632	
Adjusted R^2		0.79			
LR test				35.48	
γ				0.9610***	28.1602
σ^2				0.1196	2.7572

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

The technical inefficiency coefficient γ associated with the variances in the stochastic frontier is estimated to be 0.9610. Although this parameter cannot be interpreted as the proportion of the variance of the inefficiency effects relative to the sum of the variances of the inefficiency effects and the random variation, it indicates that the random component of the inefficiency effects does make a significant contribution in the analysis of potato production.

In the stochastic frontier model, the average Timmer technical efficiency index was 72% (Table 2). Thus, output could be increased by 28%, if all farmers achieved the technical efficiency level of the best farmer. With respect to the least efficient farmer, output could be increased by 58%. Other studies have reported similar type of results of technical efficiency with other crops in Sri Lanka. Karunaratne and Herath (1989) estimated frontier production function for paddy and chilli farmers in Mahaweli system H to investigate resource use efficiency. Farmers were found to be more efficient during *yala* than during *maha*. The average Timmer technical efficiency index for *yala* and *maha* paddy farmers was 55%, and 43% respectively, while it was only 72% for the chilli growers. The average Timmer technical efficiency index for tail end farmers was higher than for head end farmers during *maha*. In a study to investigate the effects of green revolution on resource productivity in rice cultivation in Kandy and Anuradhapura districts, Herath (1983) reported that inefficient use of most resources according to traditional efficiency estimation criteria.

Table 2. Technical efficiency of farmers.

Technical efficiency (%)	Number of farmers
< 50	81
50-59	05
60-69	13
70-79	07
80-89	11
90-100	11
Maximum	0.9993
Minimum	0.4251
Average	0.7271

SUMMARY AND CONCLUSIONS

Stochastic frontier production function was estimated for potato production in the Badulla district. The production frontier involves the inputs of land, labour, mechanical services, agrochemicals, and seed rate. The results of the stochastic frontier model indicated that labour, and seed rate have positive and significant effects on potato production. Output elasticities of labour, and seed rate were 0.1375, 1.4245 respectively. Agrochemical use and mechanical services indicated negative but insignificant effects on production. The average technical efficiency level was 72% indicating that output could be increased by 28%, if all farmers practice the best farmer's technique. The results of the model for the inefficiency effects indicated that educated farmers tend to be technically efficient and technical inefficiency can be reduced by providing rural education and extension services for expansion and propagation on modern techniques of production.

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