AN ANALYSIS OF THE TECHNICAL AND ALLOCATIVE EFFICIENCY OF PADDY FARMING: THE CASE OF MAHAWELI SYSTEM H[1]

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Abstract

This study estimates the technical and allocative efficiency of paddy farming in Sri Lanka. Household-specific technical efficiencies were computed using cross-sectional data collected from the household survey conducted in 2014 using a Stochastic Frontier approach. The Cobb-Douglas functional form was adopted for the frontier production function and the distributional assumption made for the inefficiency term was half normal. The results of this study show that the estimated mean technical efficiency of the farmers is 78.32 percent, suggesting there is a scope of 21.68 percent to increase paddy productivity using present technology. The estimated Returns to Scale is 0.2806, which implies that a proportional increase in all factors of production leads to a less than proportional increase in paddy productivity. Age, schooling, alcohol consumption, agricultural training, farmers' attitudes, and the distance between the land and the main watercourse are significant determinants of technical efficiency. According to the analysis of allocative efficiency, there exists inefficiency in allocating resources, where land and machinery resources are underutilised while labour is over utilised.

Key Words: *Technical Efficiency, Allocative Efficiency, Stochastic Production Frontier, Paddy Farming*

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INTRODUCTION

Rice is the staple food of a majority in Sri Lanka and it contributes a largest percentage of the population's total calorie requirement. Therefore, the long term sustenance and growth of paddy cultivation is very important to maintain and protect the nutritional level of Sri Lankan people.

Paddy is the leading crop when aspects including cultivated area, employment, and source of nutrition are considered. Even though paddy is the leading agricultural crop in Sri Lanka, paddy farmers are suffering from a large spectrum of problems such as unsatisfactory yield, insufficiency of profit etc. Since the rice represents the biggest proportion (34.23% of average per capita monthly food consumption[2]) of the total food consumption, changes in paddy production influence the living standard of Sri Lankan people to a great extent.

RESEARCH PROBLEM AND OBJECTIVES

According to the database of the International Rice Research Institute (IRRI), the average yield of paddy production of Sri Lanka for 2015 was estimated at 3.96 tons per hectare. This is a very small value compared with other countries those who cultivate paddy. The average yield of paddy per hectare estimated for 2015 for Australia, Vietnam, China, Indonesia, Japan, United States, India, Bangladesh and Taiwan, were 10 tons, 5.85 tons, 6.89 tons, 4.77 tons, 6.63 tons, 8.38 tons, 3.57 tons, 4.4 tons, and 6.28 tons respectively[3]. Average yield of paddy production for Australia was 6.0 tons in year 1960. Therefore, the current average yield of paddy in Sri Lanka at present is even less than the average paddy yield acquired by Australia in 1960. Further, values of paddy production index[4] in Sri Lanka recorded from 2009 to 2014 are 137, 115, 104.1, 102.8, 123.6 and 90.4 respectively, which reveal the poor trend of paddy productivity in recent years.

An increase in the productivity of paddy farming may be significant not only to get a better harvest but also to improve the standard of living of employees in paddy farming. This objective can be achieved by improving the technical and allocative efficiencies of paddy farmers which provides an opportunity to produce the maximum harvest without an increase in inputs. Based on these facts, the research problem of this study can be stated in the following manner: how do we improve the productive performance of

[2] Calculation by the author based on information taken from "Household Income and Expenditure Survey-2012/13 which conducted by Department of Census and Statistics. Sri Lanka (http://www.statistics.gov.lk/hies/hies201213buletineng.pdf)

[3] IRRI data base

[4] Central Bank reports from 2009 to 2014

paddy farmers in Sri Lanka in order to increase the paddy production? This study is based on this main question. Against this backdrop, the aim of this study is to analyse and empirically determine the technical and allocative efficiencies of paddy farmers in major paddy growing areas in Sri Lanka.

This study aims at achieving the following objectives:

1. To identify the main factors affecting the technical efficiency of paddy farming in Sri Lanka
2. To estimate the prevailing technical efficiency of paddy farming in Sri Lanka
3. To determine the allocative efficiency of each production input for paddy farming in Sri Lanka

A REVIEW OF LITERATURE

Technical and Allocative Efficiency

The credit for introducing a formal definition for economic efficiency goes to the study by Koopmans (1951). According to this study, a point of production is efficient if the output is maximised at the given level of inputs.

> ......A possible point (...) in the commodity space is called efficient whenever an increase in one of its coordinates (the net output of one good) can be achieved only at the cost of decrease in some other coordinates (the net output of another good)......[5]

Ferrell's (1957) study laid a sturdy foundation for efficiency and productivity analysis. In this study, the overall economic efficiency (EE) is divided into two components: technical efficiency (TE) and allocative efficiency (AE). It appears that Ferrell's explanation of efficiency was greatly influenced by Koopmans' work. Technical efficiency is the ability to produce a commodity using a combination of inputs located on the Production Possibilities Frontier. Allocative efficiency is the ability to produce a commodity using the combination of inputs which corresponds to the minimum cost of production. In other words, allocative efficiency is the ability to produce a given level of output by using the optimum combination[6] of inputs. The explanation of technical and allocative efficiency based on Farrell's work is elaborated below.

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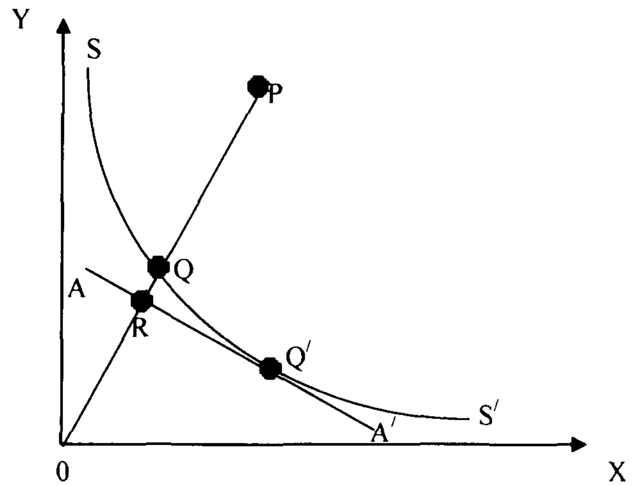
[5] Koopmans, T.C. (1951), Cowles Commission for Research in Economics, Monograph, pp. 60. This is considered as the first publication that gives a formal definition for efficiency in literature.

[6] Optimum combination of inputs is the most efficient input combination or combination of inputs at the minimum cost of production.

Figure 1: Technical Efficiency and Allocative Efficiency



Source: Farrel, M.J. (1957), p. 254.

SS' is the iso-quant[7] curve which shows different alternative combinations of inputs; X and Y, required to produce one unit of output. AA' is the iso-cost curve which shows maximum combinations of input which can be bought at the existing budget of the producer. Farrell (1957)'s explanation of efficiency is based on constant returns to scale. Technical efficiency is achieved at any combination of inputs which is located on the iso-quant curve. Allocative efficiency is achieved if the unit of output is produced by using any combination of inputs which is located on the iso-cost curve. Therefore, both technical and allocative efficiencies are fully achieved if the unit of output is produced by using the combination of inputs at point Q'. It is assumed that the combination of inputs at point P is used to produce a unit of output and hence, technical inefficiency (TIE) of input combination P is measured by the distance between Q and P. Technical inefficiency and technical efficiency as a ratio are measured by the fractions $QP/0P$ and $1-QP/0P$ respectively. Technical inefficiency decreases and technical efficiency increases as the bundle of inputs reach from P to Q. Minimum-cost input combination in producing one unit of output is indicated by Q' and therefore allocative inefficiency (AIE) is measured by the distance between R and Q. Allocative inefficiency and allocative efficiency as a ratio is measured by the fractions $RQ/0Q$ and $1-RQ/0Q$ respectively. Allocative inefficiency decreases and allocative efficiency increases as the bundle of inputs grow from Q to R[8]. Based on Farrell's

[7] SS' is a unit iso-quant curve which connects different alternative combinations of inputs corresponding to the production of one unit of output.

[8] Reaching of the bundle of inputs from Q to R is implied that reaching of the bundle of inputs towards Q'. Q' is the minimum costly combination of inputs.

study, overall or economic efficiency is the product of technical and allocative efficiencies. This explanation is formulated in the form of the following equations.

$$Technical Inefficiency\ (TIE) = \frac{QP}{0P} \qquad (01)$$

$$Technical\ Efficiency\ (TE) = 1 - \frac{QP}{0P} = \frac{0Q}{0P} \qquad (02)$$

$$Allocative\ Inefficiency\ (AIE) = \frac{RQ}{0Q} \qquad (03)$$

$$Allocative\ Efficiency\ (AE) = 1 - \frac{RQ}{0Q} = \frac{0R}{0Q} \qquad (04)$$

$$Economic Efficiency\ (EE) = TE\ X\ AE = \frac{0Q}{0P}\ X\ \frac{0R}{0Q} = \frac{0R}{0P} \qquad (05)$$

Measurements of Technical Efficiency

Various approaches to efficiency analysis have been used by two parallel traditions, the econometric methods (Aigner et al., 1977, Battese, 1992) and the non-parametric Data Envelopment Analysis (DEA) methods (Silkman, 1986; Sengupta, 1989).

Based on the work of Farrell (1957), the DEA method was originally developed by Charnes et al. (1978). DEA method is based on linear programming techniques in which convex shape frontier is estimated by connecting observed efficient production units. It should especially be noted that in this method there is no functional form imposed on the production frontier and there is no any assumption made on the error term. But it requires the assumption of the convexity of production possibility set (Banker et al., 1986). In this method, the deviation of a combination inputs from the frontier is considered an inefficiency.

With the development of efficiency analysis regard to DEA, different methods have been introduced by researches in order to minimize its inherent weaknesses. Bootstrap method (Efron, 1979) and robust method (Cazals et al., 2002) are some of extensions to DEA which allow limited statistics tests.

The second approach is the parametric approach in which the frontier is estimated with specifications of a functional form. In this approach, the Stochastic Frontier method is the most popular and it was proposed for the first time by Aigner et al. (1977). The beauty of this method is that, the error term consists of two components: random error component and inefficiency component. The Stochastic Frontier Production Function according to parameterisations of studies such as Battese and Corra (1977) and Battese (1992) is specified below.

$$y_i = f(x_i, \beta) + v_i - u_i = f(x_i, \beta) + \varepsilon_i \tag{06}$$

Where y_i is the vector of output, x_i is the vector of inputs, β is the vector of parameters and ε_i is the error term. $\varepsilon_i = v_i - u_i$ and v_i are assumed as the random error which is two sided. u_i is the nonnegative technical inefficiency component. v_i is assumed to be symmetric and independent from u_i. Both v_i and u_i are assumed to be distributed independently from x_i.

Stochastic Frontier was extensively estimated through Cobb-Douglas and Translog production functions in empirical analysis.

According to the above analysis, it is clear that both parametric and nonparametric approaches consist of inherent advantages and disadvantages. Both approaches are rapidly improving through the findings of research which focus on eliminating its weakness.

Methods for Identifying Technical Efficiency Determinants

This section is specially focused to discover the methods related to Stochastic Frontier Production Function. According to literature, generally, two approaches have been used in analysing the determinants of technical efficiency through the Stochastic Frontier Production Function. The first one is called the two-step approach and in this approach at the first step, Stochastic Frontier Production Function is estimated to determine technical efficiency estimates. At the second step technical efficiency estimates are regressed on selected technical efficiency determinants. The two-step approach has been used by authors such as Pitt and Lee (1981), Kalirajan (1981), Parikh and Shah (1995), and Ben-Belhassen (2000) in their relevant studies.

In the one-step approach, parameters of the Stochastic Frontier and technical inefficiency determinants are estimated in one step. The one step approach has been used in research such as those by Ajibefun (1996), Coelli and Battese (1996), and Lyubov and Jensen (1998) to analyse the factors affecting technical efficiency. In the model developed by Kumbhakar (1991) and Reifschneider and Stevenson (1991), inefficiency effects are estimated as an explicit function of certain factors specific to the firm, and all the parameters are estimated in one step using the maximum likelihood procedure. Following this one step approach, Huang and Liu (1994) developed a non-natural Stochastic Frontier Production Function, in which the technical inefficiency effects are estimated as a function of a number of factors specific to the firm. Battese and Coelli (1995) also proposed a Stochastic Frontier Production Function for panel data in which technical inefficiency effects were specified in terms of explanatory variables, including a time trend to take into account the changes in efficiency over time.

Measurements of Allocative Efficiency

Allocative efficiency is the second component of overall economic efficiency. Allocative efficiency is not as commonly addressed by researchers as technical efficiency. In literature, it is clear that there are three alternative approaches to allocative efficiency analysis.

I. Computation of an allocative efficiency index through, marginal value product and marginal factor cost (price) of resources. Oniah et al. (2008), Suresh and Keshava Reddy (2006), Ogundari and Ojo (2008) are some of the researchers who applied this methodology for allocative efficiency analysis.

Allocative efficiency of each input is determined by comparing marginal value product and unit factor price (UFP). Theoretically marginal value product of an input should equal to its unit cost in order to be allocatively efficient. Marginal Physical Product (MPP)[9] and Marginal Value Product (MVP)[10] are estimated. Input elasticities are estimated from the estimated Cobb-Douglas production function. MVP of each input divided by relevant UFC is called allocative efficiency index. A particular input is underutilised if the index is greater than one and overutilised if the index is less than one.

II. Computation of allocative efficiency through estimation of the cost function or implicit cost function. Schmidt and Lovell (1979) and Greene (1980) were pioneer in this methodology for allocative efficiency analysis.

Allocative efficiency was first time measured through the Cobb-Douglas Cost Frontier by the study Schmidt and Lovell (1979). This study explained the way of measuring cost efficiency through the implicit cost function. The implicit cost function should be derived through duality from the Cobb-Douglas Cost Frontier. The Cost Frontier

[9] MPP = APP * Input elasticity

[10] MVP = MPP * Output price

method introduced by Schmidt and Lovell (1979) was further expanded to the translog functional form by study Greene (1980).

III. Computation of allocative efficiency through estimation of the Input Distance function.Estimation of the Input Distance function was introduced by the study Coelli et al. (2003).

Estimation of the Input Distance function was introduced by the study Coelli et al. (2003). According to this study, the specialty of the Input Distance approach can be summarised as follows:

1. This is a strong solution for systematic deviations from cost minimisation behaviour
2. It does not suffer from simultaneous equations bias when firms are cost minimising firms or shadow cost minimising firms.
3. The Input Function Approach especially for multiple products

METHODOLOGY

Sample Selection and Data Collection

The Mahaweli development area is the population of the study and the masterplan of Mahaweli development area has been taken as the sample frame. The Irrigation areas proposed in the Master Plan are divided into 13 irrigation systems. Seven of these are Systems A, B, C, D-1 & D-2, E, F and G, located in the basins of the Mahaweli Ganga and MaduruOya. The remaining six systems, H, I, L, M, K and J are in the North-Central Part.

Data collection was carried out in the study area based on a household survey conducted during the months of August and September, 2014. Data collection has been done with a primary objective targeted to meet the objectives of this study using a structured questionnaire.

Households are selected using the cluster sampling method. Thirteen (13) irrigation Systems of Mahaweli development area are considered as first stage clusters. From these Systems, System H was selected randomly. System H consists of eight blocks, namely:Madatugama, Galkiriyagama, Galnewa, Meegalewa, Nochchiyagama, Tambuttegama, Talawa and Eppawala. These eight blocks were considered as second stage clusters in this study. From these eight clusters, Madatugama, and Meegalewa were selected randomly to the sample. According to the Mahaweli officers, Madatugama is above the average and Meegalewa is below the average in water abundance. Due to limited resources, two villages from Meegalewa namely Mahawelithanna and Thammitagama and one village from Madatugama namely

Unduruwa North were selected randomly as third stage clusters. 97 households in Mahawelithanna, 78 in Thammitagama, and 115 in Undyruwa North were investigated. Therefore this sample survey consisted of 290 households.

Secondary information on the study area was obtained from extension officers in the study area, relevant publication of Mahaweli Authority, Central Bank of Sri Lanka and popular data bases such as IRRI[11]. A structured questionnaire was formulated for primary data collection.

Paddy cultivation of sample area is done by most farmers only in Maha season due to insufficiency of water in Yala season. Therefore analysis of the study is based on Maha season. Total sample size was used for certain parts of the analysis such as summary statistics. Only 285 households have been used to estimate Stochastic Frontier Production Function (SFPF) due to the incompleteness of some variables such as education level, attitudes, and alcohol consumption.

Location and Physical Environment

The System H covers the area in the Kala Oya basin westwards up to the Anurdhapura-Puttalm road, on the North, the Kalawewa Right bank Yoda Ela (Nava Jayaganga) and on the South, the Left bank Balaluwewa, Yoda Ela of Kalawewa-Usgala-Siyamblangamuwa Ganga right up to Rajangane served by its Left bank Canal. Land under the Kandalama and Dambulu Oya reservoirs also fall within System H, as do the older settlement areas in Rajangane, the Kagama-Kattiyawa and Usgala-Siyambalangamuwa.

Model Specifications

The Stochastic Frontier Production Function which has been used by the study is specified below.

$$Y_i = f(X_i; \beta) + \varepsilon_i \qquad (07)$$

$$\varepsilon_i = Vi - Ui \qquad (08)$$

Where Y_i is the production of i^{th} household, f is a fitted functional form for the frontier, X_i is a vector of inputs used by the i^{th} firm/household; β is a vector of unknown parameters, V_i is a random variable which is assumed to be independently and

[11] International Rice Research Institute

identically distributed and independent of U_i, and U_i is a random variable that is assumed to account for technical inefficiency in production. Following Battese and Coelli (1995), U_i is assumed to be independently distributed as truncation (at zero) of the normal distribution.

Accordingly, the technical efficiency of i^{th} firm/household, denoted by TE_i, is defined by the ratio of the mean production for the i^{th} household given by values of the inputs, X_i, and its technical inefficiency effect U_i to the corresponding mean production if there were no technical inefficiency of production Battese and Coelli, specified below:

$$TE_i = \frac{Y_i}{Y^*} = \frac{E(Y_i \mid u_i, X_i)}{E(Y_i \mid u_i = 0, X_i)} = E\left[\exp(-U_i)/\varepsilon_i\right] \qquad (09)$$

Where $E(Y_i \mid u_i, X_i)$ is the maximum achievable level of output; $E(Y_i \mid u_i = 0, X_i)$ is the output lies on the frontier. TE takes values on the interval (0, 1), where TE = 1 indicates a fully efficient household and TE = 0 a fully inefficient household. The variance of the parameters $V_i(\sigma_V^2)$, $U_i(\sigma_U^2)$ and the overall model variance (σ_V^2) were used to measure the total variance of output from the frontier under these relationship;

$$\sigma^2 \equiv \sigma_U^2 + \sigma_V^2 \qquad (10)$$

$$\gamma \equiv \sigma_U^2 / \sigma^2 \qquad (11)$$

where, γ is the total variation of output from the frontier, which can be recognized to technical inefficiency.

Considering these factors, Cobb-Douglas form Stochastic Frontier can be specified for this analysis as follows.

$$\ln Y_i = \beta_0 + \Sigma_i \beta_i \ln X_{ij} + V_i + U_i \qquad (12)$$

In the production function, five inputs of production, labour, machinery hours, Fertiliser, seed, pesticideare included. The choice of the variable is made because these inputs are conventional inputs used in the paddy production. The maximum likelihood method was applied for the estimation of parameters, using FRONTIER 4.1 computer program developed by Coelli (1994). The equation (12) can be expanded in the following way of this study.

$$\ln Y_i = \beta_0 + \beta_1 \ln X_{1i} + \beta_2 \ln X_{2i} + \beta_3 \ln X_{3i} + \beta_4 \ln X_{4i} + \beta_5 \ln X_{5i} + v_i - u_i \quad (13)$$

Where,

Y_i = Paddy output in kilo grams per hectare

X_{1i} = Total human labour hours (Labour) employed by a farmer

X_{2i} = Total machinery hours (Machinery) employed by a farmer

X_{3i} = Total amount of fertiliser used in by a farmer kilograms

X_{4i} = Total amount of seed in kilograms (Seed) used by a farmer

X_{5i} = Total amount of pesticide/herbicide used in litters (Pesti./herbi.) by a farmer

ln = Natural logarithm

i = 1, 2,...N, N = 285.

U_i is a random variable that is assumed to account for technical inefficiency in production. U_i is assumed to be independently distributed as $N(0,\sigma_U^2)$ i.e. the distribution of U_i is half normal.

Average paddy production per hectare is used as the dependent variable in estimating Stochastic Frontier Production Function.

The inefficiency model based on Battese and Coelli (1995) specification was

$$U_i = \delta_0 + \delta_1 Z_1 + \delta_2 Z_2 + \delta_3 Z_3 + \delta_4 Z_4 + \delta_5 Z_5 + \delta_6 Z_6 + \delta_7 Z_7 + \delta_8 Z_8 + \delta_9 Z_9 + \delta_{10} Z_{10} + \delta_{11} Z_{11} + \delta_{12} Z_{12} + \delta_{13} Z_{13} + \delta_{14} Z_{14} + W_i \quad (14)$$

Where,

Z_1 = Age of the household head

Z_2 = Number of years of schooling achieved by the household head

Z_3 = Family size (number of members in the family)

Z_4 = Dummy variable 1, indicating if the farmer is consuming Alcohol frequently: Yes = 1, No = 0

Z_5 = Dummy variable 2. indicating if the farmer has participated in agricultural trainings within the year: Yes = 1, No = 0

Z_6 = Dummy variable 3. indicating if the farmer has received agricultural extension services within the year: Yes = 1, No = 0

Z_7 = Dummy variable 4. indicating if the farmer has access to the formal credit facilities: Yes = 1, No = 0

Z_8 = Distance between paddy land and residence in meters

Z_9 = Distance between land and main water channel in meters (B Ela)

Z_{10} = Commitment 01 (Number of observations in the paddy field by the farmer per day)

Z_{11} = Commitment 02 (Dummy variable 5), indicating whether paddy cultivation has been destroyed more than once due to same reason: Yes = 1, No = 0

Z_{12} = Commitment 03 (Number of times a farmer discuss about his farming activities with family members per day)

Z_{13} = Dummy variable 6. indicating whether main livelihood of the household head is paddy farming: Yes = 1, No = 0

Z_{14} = Attitude (Value of attitude index)

According to the study by Somatunga et al. (2014), "Drinking alcohol can cause damage to physical, mental, psychological and spiritual well being of a person". This study further revealed that 34.23% of males in Sri Lanka between 25-64 years age group are drinking alcohol. Among drinkers, 15.8% of males have drinking frequency of 1-4 days a week. With this background, alcohol consumption is considered as a determinant efficiency in this study.

Three variables (from Z_{10} to Z_{12}) were included to reflect farmers' commitment to cultivate paddy. Farmer's positive and negative attitudes towards paddy culture are measured based on ABC model which is used human resources management which was introduced by LaPiere (1934).

- Affective component: this involves a person's feelings/emotions about the attitude object.
- Behavioural component: the way the attitude we have influences how we act or behave.
- Cognitive component: this involves a person's belief/knowledge about an attitude object.

Six questions have been used by the study to measure farmers' attitudes based on ABC model.

Affective Component

1. I am extremely proud to be a paddy farmer.
2. I feel freedom, independence, and sovereignty in cultivating paddy.

Behavioural Component

3. I expect introduce new technology and seeds to develop my paddy farming.
4. I expect to continue paddy farming blissfully.

Cognitive Component

5. I believe that, paddy farming will never be a successful livelihood in Sri Lanka.
6. I believe that, I am a paddy farmer because of past sins.

Farmers' opinions on the above were measured by five Likert scales. One mark was allotted to the most negative response and five to the most positive in each field. Therefore the minimum and maximum amount of marks of the attitude index are six (20%) and thirty (100%) respectively. The positive attitude of any farmer cannot be assumed to be zero since he is cultivating paddy. Based on this reason, attitude index has been constructed with 20 percent of minimum value of the study.

A multiplicative production function has been estimated in order to get estimates for the allocative efficiency analysis.

$$\ln Y_i = \beta_0 + \beta_1 \ln X_{1i} + \beta_2 \ln X_{2i} + \beta_3 \ln X_{3i} + \beta_4 \ln X_{4i} + \beta_5 \ln X_{5i} + v_i - u_i \quad (15)$$

Where,

Y_i = Total paddy output in kilo grams per household

X_{1i} = Total human labour hours (Labour) employed by a farmer

X_{2i} = Total machinery hours (Machinery) employed by a farmer

X_{3i} = Total amount of fertilisers used in kilo grams (Fertiliser) by a farmer

X_{4i} = Total amount of seed in kilo grams (Seed) used by a farmer

X_{5i} = Total amount of pesticide/herbicide used in litters (Pesti./herbi.) by a farmer

ln = Natural logarithm

i = 1, 2,...N, N = 285.

Marginal Value Product (MVP) and Unit Factor Cost (UFC) of each input have been statistically compared in analysing allocative efficiency.

RESULTS AND DISCUSSION

Summary Statistics of the Variables

Summary statistics of the variables based on household survey 2014 are given in Table 1. The average paddy production per household was 5953 kg with 3269.59 kg level of standard deviation. A huge standard deviation of the sample indicates the output disparity among the farmers.

Estimation of Parameters of Stochastic Frontier Production Function

The maximum likelihood estimates of the Stochastic Frontier Production Function for paddy production in the study area are reported by Table 2.

Fertiliser, Labour and Machinery are statistically significant in the Stochastic Frontier Production Function. Coefficients of all significant inputs of the model except labour are positive figures and it indicates positive relationship between quantity of inputs and paddy productivity.

The estimated coefficients of the inefficiency model are presented in Table 3. The inefficiency model of the study consists of 14 variables. Eight variables of the inefficiency model are statistically significant while other variables are statistically insignificant.

One of important variables included to the inefficiency model is farmers' attitudes towards paddy cultivation. Coefficient of attitudes of inefficiency model is -0.56. The minus value of coefficient implies a negative relationship between positive attitudes and inefficiency of paddy farming. In other words, there is positive relationship between positive attitudes and efficiency of paddy farming.

The average technical efficiency of 78.32 percent implies that on average farmers are capable in obtaining 78.32 percent of potential productivity from a given mix of inputs. Thus in the short run there is scope for increase in average paddy production per hectare by 21.68 percent, by adopting the technology and the techniques used by the frontier farmer, in paddy farming.

Table 1: Summary Statistics of the Sample

Variable	Minimum	Maximum	Mean	Standard Deviation
Average harvest (kilograms) per household for Maha season	1210.00	14300.00	5953.70	3269.59
Average harvest (kilograms) per acre for Maha season	880.00	3200.00	2269.00	479.75
Price of paddy sold in the market (Rs.)	25.00	38.00	28.40	5.41
Size of the land cultivated for Maha season (acres)	0.50	5.00	2.56	1.14489
Quantity of seed (kilograms) per acre	23.47	88.00	55.0408	12.61153
Quantity of fertiliser (kilograms) per acre	30.00	416.67	156.07	60.04
Quantity of pesticide (litres) per acre	0.15	7.20	1.88	1.14
Number of family labour hours per acre	0.00	486.00	58.17	79.67
Number of hired labour hours per acre	0.00	297.60	85.87	57.15
Number of labour hours (family and hired) per acre	34.80	518.00	144.04	78.64
Number of machinery hours per acre	0.00	25.00	7.19	5.21
Cost of land (rent) per acre (Rs.)	10000.00	25000.00	15840.00	1426.62
Cost of labour per hour (Rs.)	100.00	150.00	125	19.65
Cost of machinery hours per hour (Rs.)	1900.00	2200.00	2002.78	435.87
Cost of fertiliser (Including transportation cost) per 1 kg (Rs.)	7.00	9.50	8.71	1.12
Distance between land and residence (metres)	50.00	5000.00	1238.50	1020.67
Distance between land and main water source (metres)	10.00	4000.00	696.08	725.65
Age of head of household	30.00	75.00	52.56	9.94
Education level of head of household	2.00	5.00	3.00*	0.93
Number of members in the family	2.00	7.00	4.11	1.19

Source: Household survey 2014.

* Median has been calculated to determine average of education level.

Table 2: Maximum Likelihood Estimates of the Stochastic Frontier Production Function

Variables	Units	Average per Acre	Standard Deviations of Coefficients	Coefficient	t-ratios
Constant			0.0008	0.0014	1.6572*
Labor (X1)	Hours	144.04	0.0566	-0.1141	-2.0143**
Machineries (X2)	Hours	7.19	0.0836	0.2285	2.7318***
Fertiliser (X3)	kg	156.07	0.0881	0.1626	1.8452*
Seed (X4)	kg	55.04	0.0033	0.0038	1.1326
Pesticide (X5)	Liters	1.88	0.0007	-0.0002	-0.2603

Source: Data analysis by the author.

Note: ***, ** and * indicate significance at 1%, 5% and 10% levels respectively.

Table 3: Estimation of Inefficiency Model

Variables	Coefficient	t-ratios
Age (Z_1)	0.3672	1.6903**
Schooling (Z_2)	-0.2525	-2.0142**
Number of members in the family (Z_3)	0.0159	0.0249
Alcohol / Dummy variable 01 (Z_4)	0.9129	3.5567***
Training / Dummy variable 02) (Z_5)	-0.2123	-1.6688*
Extension / Dummy variable 03 (Z_6)	0.6342	0.1437
Access to credit facilities / Dummy variable 03 (Z_7)	0.4129	0.9562
Distance 01 (Z_8)	0.2146	0.5543
Distance 02 (Z_9)	0.7125	2.8776***
Commitment 01 (Z_{10})	-0.3326	-1.8116*
Commitment 02 / Dummy variable 04 (Z_{11})	0.7142	0.4732
Commitment 03 (Z_{12})	0.1021	0.2191
Occupation / Dummy variable 05 (Z_{13})	-0.9124	-2.7817***
Attitude (Z_{14})	-0.5623	-2.9159****

Source: Data analysis by the author.

Note: ***, **, and * indicate significance at 1%, 5%, and 10% levels respectively.

Table 4: Diagnostic and Other Statistics of the Model

Variable	Value	t-ratios
$\chi^2_{0.05,21}$	34.8	
No. of observations	285	
Mean efficiency	0.7832	
Sigma-squared ($\sigma^2 = \sigma_U^2 + \sigma_V^2$)	0.3327	1.9804*
Gamma ($\gamma = \sigma_U^2/\sigma$)	0.8225	2.7365***
Log likelihood function	0.1982	
LR test	0.2941	

Source: Data analysis by the author.
Note: ***, ** and * indicate significance at 1%, 5% and 10% levels respectively.

Returns to Scale

The analysis on Returns to Scale is based on estimates of Stochastic Frontier Production Function presented in Table 2. Returns to scale of the paddy production can be determined by taking the summation of all input elasticities except land. The value of the Returns to Scale is 0.2806 suggesting a possibility of increasing paddy productivity (paddy harvest per hectare) by 28.06 percent by increasing all inputs (excluding land) by 100 percent. T-test has been conducted to test whether Returns to Scale (0.2806) equals one. Null hypothesis is rejected[12] at one percent significant level suggesting decreasing Returns to Scale of paddy farming in Mahaweli development area.

Allocative Efficiency of Paddy Farming

Allocative efficiency of each input for an average farmer is determined by comparing Marginal Value Product (MVP) and Unit Factor Price/Cost (UFP). Theoretically MVP of an input should equal to its UFC in order to be allocatively efficient. Marginal Physical Product (MPP)[13] and MVP[14] are estimated. Estimated input elasticities based on multiplicative production function presented in Table 5 have been used in order to compute MPP.

[12] Calculated t-vale is -4.96

[13] MPP = APP * Input elasticity

[14] MVP = MPP * Output price. (Average price of paddy per kg is Rs. 28.40 which is computed by the survey)

Table 5: Input Elasticities based on Multiplicative Production Function

Input	Elasticity	Standard deviation	t-ratios
Land	0.8123	0.2934	2.7681***
Labour	-0.3986	0.2425	1.6435*
Machinery	0.2852	0.1349	2.1134**
Fertiliser	-0.3768	0.3649	-1.0326
Seeds	0.0123	0.0159	0.7724
Pesticide	0.1214	0.1361	0.8921

Source: Data analysis by the author.
Note: ***, ** and * indicate significance at 1%, 5% and 10% levels respectively.

Table 6 shows MMP, MPV and UFC. Input elasticities of land, labour and machineries statistically significant while input elasticities of fertiliser is insignificant. Therefore fertiliser has been removed from allocative efficiency analysis.

Table 6: MPP, MPV and UFC

Variable	APP (kg)	Elasticity	MPP in kg	MVP (Rs)	Unit Factor Cost (UFC) (Rs)
Land	2269.00	0.8123	1843.11	52334.32	15840.00[15]
Labour	15.75	-0.3986	-6.28	-178.35	125.00[16]
Machinery	315.58	0.2850	89.94	2554.29	2002.78[17]
Fertiliser	14.54	-0.3768	-5.48	-155.63	8.71[18]

Source: Calculations by the author based on household survey 2014.

[15] Average price (rent) of land per acre for all farmers which is computed by the survey

[16] Average cost of labour per hour which is computed by the survey

[17] Average machinery cost per hour which is computed by the survey

[18] Average fertiliser cost (Including transportation cost) per kg which is computed by the survey

Table 7: Allocative Efficiency of Each Input

Input	Standard Deviation of MVP	Standard Deviation of UFC	Comparison between MVP and UFC	Allocative Efficiency	Usage
Land	2645.2861	924.3518	MVP > UFP***[19]	Not achieved	Underuse
Labour	9.3492	7.6542	MVP < UFP***[20]	Not achieved	Overuse
Machinery	168.5381	243.7654	MVP > UFP***[21]	Not achieved	Underuse

Source: Calculations by the author based on household survey 2014.
Note: *** indicate significance at 1%.

CONCLUSIONS

Estimated value of overall technical efficiency in the area is 78 percent which implies that farmers in the sample are 78 percent technically efficient or 22 percent technically inefficient. In other words, there is scope to increase average paddy harvest per hectare by 20 percent in the short run with the existing utilisation of inputs.

The estimate of γ, which is the ratio of the variance of farm-specified technical efficiency to the total variance of output, is 0.82. This would mean that 82% percent of the variance in output among the farmers is due to the differences in technical efficiency.

Technical efficiency is significantly determined by the education level of farmers, agricultural training, age of farmers, alcohol consumption by farmers, location of the land, whether farming is the main livelihood, and the attitudes of farmers. Technical efficiency is negatively affected by age of farmers, alcohol consumption by farmers and distance between land and main water channel. Technical efficiency is positively affected by education level and participation to agricultural training programs by farmers. Further, the farmers those who are farming paddy as a main livelihood are more efficient than that of part time farmers. Analysis further revealed a strong positive relationship between positive attitudes and technical efficiency.

[19]T-Test of difference = 0 (vs ≠): T-Value = 666.49 P-Value = 0.000

[20]T-Test of difference = 0 (vs ≠): T-Value = 423.84 P-Value = 0.000

[21]T-Test of difference = 0 (vs ≠): T-Value = 31.42 P-Value = 0.000

The results of the study had shown allocative inefficiency for land, labour and machineries. The results of the study further revealed that, land and machinery resources are underutilised and labour resource is over utilised compared with optimum utilisation.

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