ESTIMATING TECHNICAL EFFICIENCY OF VEGETABLE FARMERS IN ANURADHAPURA DISTRICT IN SRI LANKA¹

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Abstract

Promotion of technical efficiency is an important policy goal for the entire agricultural sector. This study aims at delivering empirical evidence on the level of technical efficiency of Vegetable farmers by analysing farm level data covering approximately 450 vegetable farmers in Anuradhapura district in Sri Lanka. The study focuses only commercial level vegetable farmers who cultivate only different type of vegetable varieties in their farms. The empirical results indicate that more than 80 % of the sampled farmers were less than 55% technically efficient. It was also found that farming experience, household size, agricultural extension services and level of educational attainment reduces technical inefficiency, while farmers' age increases technical inefficiency. Policies that would improve farmer's educational status through adult education and agricultural extension services would increase technical efficiency of vegetable farms in the long term.

Key Words: *Technical efficiency; Vegetable farmers; Stochastic frontier production*

JEL Codes: *C2, C22, Q12, Q13, Q16*

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INTRODUCTION

Technological innovation and the more efficient use of existing technologies are the main strategies of achieving higher level of output in agriculture (Hoang and Coelli, 2009). However, in developing countries most new agricultural technologies have only been partially successful in improving productivity. This is often due to a lack of ability or desire to adjust input levels by the producers because of their familiarity with traditional agricultural systems or because of institutional constraints (Binam et al., 2004). These considerations suggest that the best option to assist developing countries to raise productivity is increasing efficiency. If farmers are not effectively using existing technology, then efforts designed to improve efficiency may be more cost-effective than introducing new technologies. The presence of shortfalls in efficiency means that output can be increased without requiring additional conventional inputs and without the need for new technology. If this is the case, empirical measures of efficiency are needed to determine the magnitude of the gains that could be obtained by improving performance in agricultural production with a given technology. In this research farmers' ability to select a production system and its relationship with farm level technical efficiency is investigated.

There are several important reasons for measuring the farm level technical efficiency of agricultural production. Firstly, if farmers are not making efficient use of existing technologies, then efforts designed to improve efficiency would be more cost effective than introducing a new technology as a means of increasing output. Secondly, measuring efficiency leads to sustainable resource savings, which has important implications for both policy formulations and farm management. Thirdly, it is only through measuring efficiency and separating its effects from the effects of the production environment that one can explore hypotheses concerning the sources of efficiency differential. Fourthly, identification of sources of inefficiency is important to the institution of public and private policies designed to improve performance of agriculture.

Vegetable is an important sector in Sri Lanka as it contributes around 11% to the total agriculture production. Vegetables are cultivated more than two million family units in the island. Sri Lanka total vegetable cultivated land area is approximately 150,000 hectares. It is 10.1% from the total agricultural land. This research project aims at delivering empirical evidence on the level of technical efficiency of vegetable farmers by analysing farm level data covering approximately 450 vegetable farmers in Anuradhapura district in Sri Lanka. The study focuses only commercial level vegetable farmers who cultivate different type of vegetables varieties in their farms. To the best of my knowledge, this is one of the first attempts that investigates farm level technical efficiency of vegetable farmers in Sri Lanka.

REVIEW OF THE LITERATURE

There have been many studies on technical efficiency in agriculture (Kalirajan, 1991; Ureta and Pinheiro, 1993; Ureta and Evenson, 1994; Amarasinghe and Weerahewa, 2001; Gunaratne and Thiruchelvam, 2002; Vicente, 2004; Mkhabela, 2005; Udayanganie *et al.* 2006; Singh, 2007; Amarasuriya *et al.* 2010; Sekhon *et al.* 2010; Shantha *et al.* 2012; Akande, 2012; Nsikak *et al.* 2013). Kalirajan (1991) examines farm-specific application of the new rice technology by using a micro-level panel data from a South Indian district. The results show a wide variation in the efficient use of the technology by the sample farmers. Extension and education were identified as two major constraining factors. Ureta and Pinheiro (1993) investigated efficiency level of developing countries' agriculture. In this study a total of 30 studies from 14 different countries are examined. The results of this study suggest that there is a considerable room to increase agricultural output without additional inputs and given existing technology. This study reveals that farmer education and experience, contacts with extension, access to credit, and farm size are directly related with farm level technical efficiency. With the exception of farm size, the results reveal that these variables tend to have a positive and statistically significant impact on technical efficiency.

Amarasinghe and Weerahewa (2001) speculated an assessment of technical efficiency of potato production in Sri Lanka. 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. The results of the model for the inefficiency effects indicate that educated farmers tend to be more efficient than that of others. Gunaratne and Thiruchelvam (2002) investigated the technical efficiency of paddy production under major and minor irrigation schemes in Anuradhapura district. The results suggest that increasing technical efficiency is the most appropriate means of enhancing paddy production in the irrigation schemes. Given the importance of the minor tanks in paddy production in Sri Lanka, major attention should be paid to raising their level of technical efficiency.

Krasachat (2004) measured technical efficiency in Thai agricultural production during the period 1972 to 1994. Empirical results of this study suggest that there are significant possibilities to increase efficiency levels by increasing farm size. In addition, the availabilities of new land as well as the diversity of climate and natural resources may influence on technical efficiency in Thai agricultural production. Vicente (2004) measured levels of technical, allocative and economic efficiency in agricultural crop production for Brazil in 1995. The issues of having moderate technical inefficiency and strong allocative inefficiency are identified in this study. Accordingly, if full technical efficiency were achieved, the crop production would increase by more than 30% over that obtained in 1995.

According to Mkhabela (2005) farm level efficiency can be significantly increased by the factors such as farm visits by extension officers, participation in farmer training, less

sloping lands, more experience, and higher diversity of the vegetable system. Udayanganie *et al.* (2006) assesses the technical efficiency of paddy production in one of the major irrigation schemes in Sri Lanka with special emphasis on the usage of agrochemical inputs and determinants of technical efficiency. The results of the production function show negative relationships between yield and the cost of pesticides indicating an over use of pesticides. Among the determinants of inefficiency, the importance of credit and extension services are highlighted. Singh (2007) speculated about technical efficiency of wheat cultivation in Haryana. The estimates of technical efficiency in this study have indicated that small-size farms are more efficient than medium and large-size farms, negating thereby the myth that large-size farming is more profit/business oriented.

According to Amarasuriya *et al.* (2010) technical efficiency was significantly affected by season, ownership, experience, off farm income and a constraint index. Sekhon *et al.* (2010) analysed the technical efficiency in crop production and regional variation while Khai and Yabe (2011) identified factors such as intensive labour in rice cultivation, irrigation and education as the most important in increasing technical efficiency levels in agriculture. Shantha *et al.* (2012) investigates the economic and technical efficiency of paddy farming in a minor irrigation scheme in Sri Lanka. Accordingly, the average technical efficiency of selected farmers given by the Cobb Douglas model is 69.08% per cent. This indicates that there is scope of farther increasing the output by 30.2% without increasing the level of input.

Technical efficiency and total factor productivity (TFP) growth of agricultural holdings in the EU-15 region was measured by Akande (2012) using Data Envelopment Analysis (DEA) and agricultural data for a period of 11 years. The results of this study revealed that the Western European region was more efficient with the highest average technical efficiency of 95% while Central European region shared the same technical efficiency level of 85% with southern European region. The Northern European region was found the least technically efficient (84%). The annual average TFP growth rate observed for all the regions in the EU-15 countries was between 3% and 4%.Nsikaket *al.* (2013) identified the sources of technical efficiency among subsistence maize farmers. Results reveal output from maize production could be increased by 29% using available technology and land, labour, inorganic fertilizer and planting materials were found to have positive and significant impact on technical efficiency. Other variables which were identified as sources of technical efficiency include age, technical assistance, credit and market.

The review of these studies suggest that the best option to assist developing countries to raise productivity is increasing efficiency. If farmers are not effectively using existing technology, then efforts designed to improve efficiency may be more cost-effective than introducing new technologies. The presence of shortfalls in efficiency means that output can be increased without requiring additional conventional inputs and without the need

for new technology. If this is the case, empirical measures of efficiency are needed to determine the magnitude of the gains that could be obtained by improving performance in agricultural production with a given technology. In this research farmers' ability to select a production system and its relationship with farm level technical efficiency is investigated.

METHODOLOGY AND DATA

Empirical model of estimating technical efficiency in this study is based on the stochastic production function proposed by Battese and Coelli (1995). The model of Battese and Coelli (1995) is used in accordance with the original models of Aigner et al. (1977) and Meeusen and van den Broeck (1977). In the first phase of the empirical analysis, technical efficiency effects for a cross section of farmers is modeled in terms of input variables in the production process. The general form of the stochastic frontier production can be defined by:

$$Y_i = f(x_i, \beta) \exp(V_i - U_i) \quad i = 1, 2, \dots, N \quad (1)$$

Y_i refers to the output obtained by farm i , x_i is the vector of different inputs used and β is a vector of parameters to be estimated. The model is such that the possible production, Y_i , is bounded above by the stochastic quantity, $f(x_i, \beta) \exp(V_i)$. Therefore, the term stochastic frontier is used. The error components V_i are assumed to be independently and identically distributed as $N(0, \sigma_v^2)$. This is associated with random factors such as random errors, errors in the observation and measuring of data, which are not under the control of the farm (Coelli et al., 2005). The error components, U_i are non-negative truncations of the $N(0, \sigma_u^2)$ distribution that can be half normal, truncated normal, exponential distribution or gamma distribution. The truncated normal frontier model is due to Stevenson (1980) while the gamma model is due to Green (1990). The log-likelihood functions for these different models can be found in Kumbhakar and Lovell (2000). We used Cobb-Douglas production function and the estimation was performed using Frontier version 4.1 (Coelli, 1996). Accordingly, the stochastic frontier model to be estimated is defined by:

$$\ln Y_i = \beta_0 + \sum_{i=1}^4 \beta_i \ln X_i + V_i - U_i \quad (2)$$

where $\ln$ represent the natural logarithm. The subscript i , indicates the i^{th} farmer in the sample ($i = 1, 2, \dots, n$).

$\ln Y_i$ represents the natural logarithm of the value of farm output

$\ln X_i$ represents the natural logarithm of the total area of land (in acres) under cultivation

$\ln X_2$ represents the natural logarithm of labour in man dates

$\ln X_3$ represents the natural logarithm of capital expenditure

$\ln X_4$ represents the natural logarithm of other cost: raw materials

β_j 's are unknown parameters to be estimated

V_i 's are assumed to be independent and identically distributed normal random errors having zero mean and unknown variance; σ_v^2 ; U_i 's are non-negative random variables, called technical inefficiency effects, which are assumed to be independently distributed such that U_i is defined by the truncation (at zero) of the normal distribution with mean, μ_i and variance σ_u^2 . The model for the technical inefficiency effects specifies that the technical inefficiency effects of the stochastic frontier are a function of socio-economic and institutional factors (age, education, household size, number of separate plots, agricultural extension services, credit access, membership of a farm organization, land ownership...etc.). Some of these variables are assumed to be directly related to farmers' management skills, while the others could impact on their technical efficiency through availability of labour for timely management of farming activities or incentives for increasing efficiency in farms. This can be written as:

$$U_i = \alpha_0 + \alpha_1 Z_{1i} + \alpha_2 Z_{2i} + \alpha_3 Z_{3i} + \alpha_4 Z_{4i} + \alpha_5 Z_{5i} + \alpha_6 Z_{6i} + \alpha_7 Z_{7i} + \alpha_8 Z_{8i} + \alpha_9 Z_{9i} + g_i \quad (3)$$

Z_{1i} is the age of the responded in years (AGE)

Z_{2i} is the formal education of the responded in years (EDU)

Z_{3i} is the household size (HS)

Z_{4i} is extend of irrigated area (RFH)

Z_{5i} is farming experience in years (FE)

Z_{6i} is agricultural extension services contacts(AEC):Dummy variables if Yes 1, else 0.

Z_{7i} is credit access : Dummy variables if Yes 1, otherwise 2.

Z_{8i} is member of a farm organization : Dummy variables if Yes 1, otherwise 2.

Z_{9i} is the land ownership (LO); Dummy variable if owned 1, otherwise 0.

The econometric estimation strategy requires some of the assumption about functional forms and distribution of error components. Given functional and distributional assumptions, maximum-likelihood estimates (MLE) for all parameters of the stochastic

frontier production and inefficiency model will be simultaneously estimated using the program, FRONTIER 4.1. The technical efficiency of a farmer is between 0 and 1 and is inversely related to the level of the technical inefficiency effects (Battese and Coelli, 1995). Technical efficiency can also be predicted using the FRONTIER program, which calculates the maximum-likelihood estimator of the predictor for Equation 1 that is based on its conditional expectation, given the observed value of $(V_i - U_i)$ (Battese and Coelli, 1988). More details about obtaining maximum-likelihood estimator is given by Coelli et al. (2005).

The farm household data covering three Divisional Secretariats (DS) in Anuradhapura district is used for the analysis. When selecting the sample, ten villages from each DS division are selected purposively. Then approximately 17 vegetable farmers from each village is selected randomly. We assigned random numbers to represent each farm household address and used this number to select the households for the interview (e.g. each third number). The survey was carried out during a three months period at middle of 2013. Total number of sample is 510, however after dropping a few incomplete questionnaires 450 households data could be used in the analysis. A questionnaire designed to gather the information was validated in a pilot survey and a number of focus group discussions. The final questionnaire was then adjusted. The gathering of data was carried out carefully by a trained group of researchers under the close supervision of the research team. The interviews took place in the interviewee's home. The participants were informed about the purpose of the study and gave verbal consent. A field supervisor reviewed the quality of the data gathered and entered it into a database for analysis. It was confirmed that the survey questions were clearly understood by respondents and obtained appropriate information regarding inputs and outputs of the vegetable cultivation.

RESULTS AND DISCUSSIONS

The descriptive statistics shows that the majority of the sample respondents are male (94 %). The mean age was 45 years. This implies that majority of the farmers were youth and in an economic active age that can make positive contribution to agricultural production. Most respondents (91%) are married. The household size of most respondents (99%) ranged between 1 and 6 members and approximately 41% of families include four members. A large household size also means more mouth to feed, such that for a given farm size large households could produce a smaller market surplus (Minot et al, 2006). The literacy level among the farmers in the study area is quite high. Most of the farmers have completed grade 11 at school. Approximately 35% of respondents have passed ordinary level exam, 4% have passed advanced level exam and 1% are degree holders. Further, 89% of farmers' main occupation is farming. Average family income is Rs.14, 851 per month and average spending for foods is 49 % of their total income. Majority of the respondents (65%) had more than 10 years of farming experience, and this shows that the managerial ability of the farmers can be inferred to be reasonably good. Approximately 84% of the sample respondents cultivated more

than 4 varieties of vegetables. Most farmers were cultivating vegetable varieties such as brinjal, long beans, Bittergards, Pumpkins and different types of Cowpea.

As the first step of the analysis, we obtained the estimates of the production function and these estimates indicate the relative importance of factor inputs in vegetable production. The results are reported in Table 1 and it shows that the coefficients of all factors have the expected signs and magnitudes. Land appears to be the most important factor of production with the coefficient values of 0.29 and Labour appears as the second most important factor while capital is the third most important factor for vegetable farms in study area. The parameter $\gamma = \sigma_u^2/\sigma^2$ lies between zero and one with a value equals zero implying that technical inefficiency is not present and the ordinary least square estimation would be an adequate representation and a value close or equal to one implying that the frontier model is appropriate. The values of γ are 0.81 and it is statistically significant at one per cent level of significance which implies that more than half of the residual variation is due to the inefficiency effect.

Table 1: Maximum-likelihood estimates for parameters of the production function

Variable	Coefficient
Constant	0.271 (3.28)*
Land	0.298 (4.85)*
Labour	0.252 (3.61)*
Capital	0.175 (3.74)*
Row Material	0.062 (2.13)*
Model Variance	0.752 (6.02)*
Variance Ratio	0.813 (10.01)*
Log Likelihood function	-266.083
Number of observation	450

Note: i. t ratios are given in the parenthesis. * denotes significant variables at 1% level

Source : Authors' Estimations

As we use the log variables in the model, these coefficients provide the elasticities directly. All elasticities are positive indicating that, as these inputs are increased, output increases. Returns to scale are determined by summing all values of elasticities. If the sum is less than one decreasing returns are indicated; if greater than one increasing returns to scale are indicated. By adding coefficients of elasticities together the returns to scale is shown to be 0.78. This implies there is decreasing returns to scale for vegetable farms in study area.

As the second step of the analysis, we examine the distribution of technical efficiency of farmers. The result shown in Table 2 imply that more than 80% of the sampled farmers were less than 55% technically efficient. From the distribution, the most efficient farmers in terms of resource use have an index of 87% and the least efficient farmers have a resource use efficiency of 28 per cent. The average resource-use efficiency of the sample is 0.52. This implies that about 48 per cent higher levels of production could be achieved without additional resource for vegetable farmers in the study area. A wide variation of the technical efficiency level among vegetable farmers in different districts is evident by these figures in table 2.

Table 2: Distribution of TE among different groups

Efficiency-range	Number of farms	Percentage (%)
0.00 - 0.40	122	27.11
0.41 - 0.45	102	22.67
0.46 - 0.50	79	17.56
0.51 - 0.55	55	12.22
0.56 - 0.60	31	6.89
0.61 - 0.65	24	5.33
0.66 - 0.70	13	2.89
0.71 - 0.75	5	1.11
0.76 - 0.80	8	1.78
0.81 - 0.85	6	1.33
0.86 - 0.90	5	1.11
0.91-1.00	0	0.00

Note: No farmer is found less than 20 % level of TE. Therefore, first range is taken as 0 to 0.4.

Source : Authors' Estimations

Next, the average efficiency levels for different land size was estimated. The purpose of this analysis is to investigate whether there is a direct link between farm level efficiency and farm size. The average estimates of technical efficiencies by farm-size categories are presented in Table 3. It is clear that producers in larger vegetable farms are

relatively less efficient than the producers in smaller farms. This implies that there is a significant difference of mean technical efficiency between different farm sizes. As the average technical efficiency has opposite relationship with land size, small scale vegetable farms seems more efficient than large vegetable farms in study area.

As the final step of the analysis, the variables of the inefficiency model were estimated to explain the determinants of inefficiency of production among farmers in study area. The sign of the variables in the inefficiency model is very important in explaining the observed level of TE of the farmers. A negative sign would imply that the variable had the effect of reducing technical inefficiency, while a positive coefficient would indicate increasing inefficiency. The results are presented in Table 4 and indicate that all the included variables except age had the expected sign.

Table 3: Land Size and Average Efficiency Level

Farm size (acres)	Number	Efficiency Average
0.00-0.50	202	0.515
0.51-1.00	178	0.428
1.10-1.50	24	0.399
1.51-2.00	26	0.386
2.10-2.50	20	0.324

Note: Most of the vegetable farms are small scale farms. In the study area approximately 85 % of the farmers cultivate less than one acre.

Source : Authors' Estimations

It is clear that the estimated coefficients of the inefficiency function provide explanations for the relative technical efficiency levels among individual farms. Most of the coefficients of explanatory variables in the inefficiency model are found to have expected signs. The age coefficient is positive, which indicates that the older farmers are more inefficient than the younger ones. This variable is significant at 5% level. The positive coefficient of age suggests that age led to technical inefficiency of the farmers. A possible explanation could be that the general ability to supervise farming activities decreases as farmers advanced in age. The negative estimate for education variable implies that farmers with greater years of schooling tend to be less inefficient. The relationship is relatively strong, because the coefficient is very high relative to its estimated standard error. The coefficient of education is significant at 1% level. It can therefore be assumed that farmers with greater years of formal schooling tend to be more technically efficient.

The predicted coefficient of household size was negative and significant at 1% level of significance. The negative coefficient is in agreement with the hypothesized expected

sign and implies that as the number of persons (adult) in a household increases, efficiency also increases. This is because more adult members in a household mean that additional quality labour would be available for carrying out farming activities in a timely fashion, thus making the production process more efficient (Shehu et al., 2007). Variable related to the irrigated area is not significant. Possible explanation is that most farmers use rainwater for cultivating vegetables in the study area. The coefficient of experience of farming is significant at 5% level. It can therefore be assumed that farmers with greater years of experience in vegetable farming tend to be more technically efficient.

Table 4: Maximum-likelihood estimates for parameters of the inefficiency model

Variable	Coefficient
Constant	1.725 (1.96)
Age	0.012 (1.75)* *
Education	-0.215 (-3.29)*
HH size	-0.028 (-2.76)*
Irrigated land area	0.004 (1.57)
Experience	-0.024 (-1.78) **
Extension services	-0.259 (-3.76)*
Credit	-0.069 (-3.17)*
MFO	-0.045 (-1.63)***
Land ownership	-0.012 (-1.61)***

Note: *t* ratios are given in the parenthesis. * denotes significant variables at 1% level and ** indicates significant at 5% level while *** denotes significant variables at 10% level of significant.

Source : Authors' Estimations

The predicted coefficient of household size was negative and significant at 1% level of significance. The negative coefficient is in agreement with the hypothesized expected sign and implies that as the number of persons (adult) in a household increases, efficiency also increases. This is because more adult members in a household mean that additional quality labour would be available for carrying out farming activities in a timely fashion, thus making the production process more efficient (Shehu et al., 2007). Variable related to the irrigated area is not significant. Possible explanation is that most farmers use rainwater for cultivating vegetables in the study area. The coefficient of experience of farming is significant at 5% level. It can therefore be assumed that farmers with greater years of experience in vegetable farming tend to be more technically efficient.

The coefficient of extension contact is negative and significant, suggesting that such contact increases farm level technical efficiency because farmers are able to use modern techniques of farming involving land preparation, planting, application of agro-chemicals (for example, fertilizer) and harvesting. The coefficients of availability of agricultural credit and becoming a member of a farm organization were also statistically significant and had the expected signs. Credit access can remove farmers' financial constraints and thereby increase the farm level efficiency. It can also be assumed that being a member of a farm organization helps farmers improve managerial skills as it provides training programs with necessary information during the crop season. The results also show that land ownership has a negative impact on inefficiency. This implies that farmers who cultivate their own land are more efficient than those who cultivate land that is leased. This is because farmers who own land have added motivation to cultivate more efficiently as they have an incentive to maintain their land for long-term benefits.

CONCLUSIONS

This research is one of the first attempts to use the stochastic production frontier approach to investigate the technical efficiencies among vegetable farmers in Sri Lanka. The study provides an economic analysis of farm household efficiency among vegetable farmers. Econometric analysis of survey data shows that land size, labour, capital expenditure and expenditure on raw materials are important inputs and are strongly associated with the total output. The analysis reports evidence of farm level technical inefficiency and its determinants. Results of this study show the potential for large gains in real output if technical efficiency is increased. The results depict a wide gap between farmers who are relatively poor in their efficiency performance (25%) and those who are highly efficient (more than 85%). In particular this study shows that the output value of farms in the study area can be increased with the current levels of inputs and technology if less efficient farmers are encouraged to follow the resource utilization pattern as well as farm types that have already been adopted by the most efficient farmers.

The overall findings of this research will help implement policies to reduce technical inefficiency among vegetable farmers in Sri Lanka. It also helps to increase awareness and generates support for investment in increasing technical efficiency in the vegetable farming sector. This type of study can provide an economic analysis of farm household efficiency among commercial vegetable farms in Sri Lanka, where vegetable farming generates a large part of household income. The results show the potential of encouraging the methods of increasing more efficient farms in the country. Econometric analysis of survey data 1 provides the information of current technical efficiency level as well as the factor which determine the technical efficiency in these farms. These determinant factors, in turn, can be used to make policies in order to reduce technical inefficiencies among vegetable farmers in the country.

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