# Analysis of Factors Affecting the Technical Efficiency: A Case Study

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*Abstract*— The measurement of the production efficiency in agricultural production is very important since it gives useful information for making decisions, resource allocations, and for formulating agricultural policies and institutional improvement. This paper attempts to estimate the individual banana farmer's technical and scale efficiency in Kushtia district of Bangladesh by input and output-oriented Data Envelopment Analysis (DEA) model considering the variable returns to scale (VRS) assumption. The result specifies that the average technical efficiency (TE) and scale efficiency (SE) for banana farmers in Kushtia district is about 87% and 97% respectively for both input and output oriented VRS. Also, Tobit regression shows the variation of TE is related to farm-specific attributes such as age, experience, education of farmers and firm size. All of these factors provide a positive impact on farmer's efficiency. Therefore, this study suggests that the existing inefficiency may be reduced through training, policy interventions, adoption and spread of improved agricultural mechanization.

*Keywords*— Production Efficiency, Variable Returns to Scale, Tobit Regression, Banana, Bangladesh.

## I. Introduction

Banana is a very popular fruit and cultivated almost everywhere in Bangladesh round the year. However, the foremost banana growing areas are Rangamati, Barisal, Rangpur, Dinajpur, Noakhali, Faridpur, Tangail, Kushtia and Khulna. Total production of banana in Bangladesh was around 801 thousand metric tons in an area of approximately 131 thousand acres whereas in Kushtia the total production of banana was about 103 thousand metric tons in an area of 8262 acres in the year 2010-11 (BBS, 2012). Banana is not only important source of nutrition but also an important source of cash income to producers and traders. Moreover, a large number of people were involved in the production and marketing of banana. So, the farmers and intermediaries could be more benefited financially if production and marketing of banana are to be well expanded.

Efficiency or performance analysis is a relative concept (Coelli, et al., 1998). It relates to production analysis and measures the production with a ratio. Technical Efficiency (TE) relates to the degree to which a farmer produces maximum output from a given bundle of inputs or uses the minimum amount of inputs to produce a given level of output when the technology exhibits constant returns to scale but is likely to differ otherwise. These two definitions of TE are known as output-oriented and input-oriented efficiency measures, respectively (Farrell, 1957). Kumbhakar, Ghosh and McGuckin (1991) and Battese and Coelli (1995) were the first to suggest that determining the factors responsible for inefficiency is an essential component of efficiency analysis. Modern efficiency measurement begins with Farrell (1957) who drew upon the work of Debreu (1951) and Koopmans (1951) to define a simple measure of firm efficiency which could account for multiple inputs. He proposed that the efficiency of a firm consists of two components namely technical efficiency and allocative efficiency.

Wadud and White (2000) compared the efficiency of Stochastic Frontier Analysis (SFA) and Data Envelopment Analysis (DEA) of rice farm household in Bangladesh. They suggest that technical inefficiency effects are modeled as a function of farm-specific socioeconomic factors, environmental factors and irrigation infrastructure. Balcombe, *et al.*, (2008) examine the sources of technical efficiency for rice farming in Bangladesh. Hossain, *et al.*, (2015) estimate the efficiency of the small banana grower in Kushtia district of Bangladesh with the help of Cobb-Douglas type stochastic frontier production function. They showed that among the elasticities, the elasticity for land used for banana production is the largest (0.3498) and the elasticity for the cost of labor is lowest (0.0495). Their results revealed that age and education level of the farmers has a positive effect on technical efficiency. Hossain, *et al.*, (2016) identify the ARIMA (0,2,1) model to forecast the banana productions in Bangladesh. A number of dessert banana varieties in Bangladesh, but their performance is not equally well in all regions due to the difference in varietal adaptability and microclimatic variation (Ahmad, *et al.*, 1973; Ahmed, *et al.*, 1974). The market price of banana has greatly fluctuated in the different month which directly affects the farmer's income (Haque, 1984). Mohiuddin, *et al.* (2014) suggest that the banana waste utilization will be of help to the farmers, entrepreneurs, planners, scientists as well as Bangladesh government to take proper initiatives in socio-economic improvement of Bangladesh.

The measurement of the production efficiency in agricultural production is very important since it gives useful information for making decisions, resource allocations, and for formulating agricultural policies and institutional improvement. Identifying determinants of efficiency levels is a major task in efficiency analysis. So, the objectives of this research is to estimate the individual banana farmer's technical and scale efficiency in Kushtia district of Bangladesh by input and output oriented DEA model considering the variable returns to scale (VRS) assumption. Then, Tobit model is used to run a regression of the inputs and farm-specific characteristics as independent variables against the efficiency scores.

## II. Methods and Materials

### A. Data and Variables

In this study, we consider the secondary data which was collected

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by Hossain, *et al.* (2015). They have conduct a survey to collect the data set with the help of well-structured questionnaire that has been developed after an intensive review of the literature and practical experience. The target population of their study was the small banana growers of Islamic University thana of Kushtia district in Bangladesh. Purposively they have selected the target area. The sample unit of this study was the individual farmer (small banana grower). They have collected information from 200 farmers. Non-probability convenience sampling procedure has been used to collect the primary data from small farmers who cultivate banana less than two acres of land. Research was conducted in 10 villages under the Islamic University thana of Kushtia district and interviewed 20 farmers form each village. From the extensive literature review it is found that the efficiency of a farmer depends on some demographic variables as well as the characteristics of the firm. Thus, this paper considers farmer's efficiency as the dependent variable and age, experience, education of farmers and firm size as the independent variables in Tobit regression. The collected data was analyzed by DEAP Version 2.1. Also, STATA version 12 software were used to resolve the Tobit regression.

### *B. Data Envelopment Analysis (DEA)*

Data Envelopment Analysis is a non-parametric approach to frontier estimation. Boles (1966) and Afriat (1972) suggested mathematical programming methods which could achieve the task, but the method did not receive wide attention until a paper by Charnes, *et al.*, (1978) which coined the term *Data Envelopment Analysis* (DEA). Charnes, *el al.*, (1978) proposed a model which had an input orientation and assumed constant returns to scale (CRS). Later Banker, *et al.*, (1984) proposed a variable return to scale (VRS) model. This paper consider VRS model. According to Coelli, (1996) the input-oriented DEA model based on the variable returns to scale (VRS) is stated as follows:

$$\begin{aligned} &\min_{\theta,\lambda} \theta, \\ &\text{subject to } -y_i + Y\lambda \geq 0, \\ &\qquad \theta x_i - X\lambda \geq 0, \\ &\qquad N1'\lambda = 1 \\ &\qquad \lambda \geq 0 \end{aligned}$$

where, $N1$ is an $N \times 1$ vector of ones.

According to Coelli, *et al.*, (2002) the output-oriented DEA model based on the VRS is stated as follows:

$$\begin{aligned} &\min_{\varphi,\lambda} \varphi, \\ &\text{subject to } -\varphi y_i + Y\lambda \geq 0, \\ &\qquad x_i - X\lambda \geq 0, \\ &\qquad N1'\lambda = 1 \\ &\qquad \lambda \geq 0 \end{aligned}$$

where, $N1$ is an $N \times 1$ vector of ones and $1 \leq \varphi < \infty$ and $(\varphi - 1)$ is an increase in the ratio of output that can be achieved by farmers i[th], with a given quantity of inputs which is constant.

### *C. Tobit Regression*

The present study uses a censored regression (Tobit regression) to analyze the role of farm-specific attributes in explaining efficiency in production of banana. The Tobit model is used to run a regression of the inputs and farm-specific characteristics as independent variables against the efficiency scores. Tobit's model was introduced by Tobin (1958) involving a censored regression model of the economy (Fumio, 2000) and first analyzed in the econometric literature (Maddala and Lahiri, 2009). As the efficiency index derived from data envelopment analysis is bound between 0 and 1 values, thus it is suitable for use as a simulation analysis to identify the determinant of technical efficiency among farmers. Based on previous studies, to identify the influence of efficiency of farmers Deller and Nelson (1991) has been used Ordinary Least Square (OLS) to a regression model. Since the measurement of efficiency is censored with the value between 0 and 1, hence some arguments state that the estimation of OLS is inconsistent and inefficient (Amin and Featherstone, 2008). For that reason, this study used the Tobit Model to replace OLS (Ray, 2004). Tobit's model can be written as

$$y_i = \begin{cases} y_i^* \text{ if } y_i^* > 0 \\ 0 \text{ if } y_i^* \leq 0 \end{cases}$$

where, $y_i^*$ is a latent variable defined as $y_i^* = \beta x_i + \varepsilon_i$, and $y_i$ is a DEA efficiency index used as a dependent variable, $\beta$ is an unknown parameter vector associated with the farm-specific attributes, and $\varepsilon$ is an independently distributed error term that is assumed to be normally distributed with zero mean and constant variance, $\sigma^2$. A Tobit regression model applying the maximum likelihood approach to estimate parameters of the model.

## III. Results and Discussion

The performance of banana farmers in Kushtia district is conducted to determine its ability to provide maximum output with the given inputs. The inputs were used of this study including farm size, cost on fertilizers, cost on seedling, cost on irrigation, cost on transport and cost on labours. Therefore, the DEA efficiency score can be summarized to show how much the farmers maximize the production without addition of input that can be considered as the best technical efficiency. The technical efficiency is estimated by using the approach of maximizing the output subject to constant input and evaluated on the VRS (input-oriented and output-oriented). Scores for technical efficiency and scale efficiency of each farmer were estimated and presented in Table 1.

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**Table 1:** Frequency distributions of technical efficiency scores obtained with the DEA model.

| Efficiency Score | Input Oriented | | Output Oriented | |
|---|---|---|---|---|
| | TE | SE | TE | SE |
| 0.0-0.60 | 0 | 0 | 0 | 0 |
| 0.60-0.70 | 13 | 1 | 17 | 1 |
| 0.70-0.80 | 39 | 4 | 33 | 2 |
| 0.80-0.90 | 59 | 15 | 66 | 17 |
| 0.90-1.00 | 89 | 180 | 84 | 180 |

| Efficiency Score | Input Oriented | | Output Oriented | |
|---|---|---|---|---|
| | TE | SE | TE | SE |
| IRS | | 118 | | 67 |
| DRS | | 50 | | 91 |
| CRS | | 32 | | 42 |

TE = Technical efficiency; SE = Scale efficiency; IRS = Increasing return to scale; DRS = Decreasing return to scale; CRS = Constant return to scale.

Table 1 shows the frequency distribution of farm-specific technical, and scale efficiency of banana farmers. No farmer in the study areas operates the farm below 60% of TE levels for both input-oriented and output-oriented VRS. About 45% of farmers operate their farms between 0.90-1.00 efficiency levels for input-oriented VRS whereas for output-oriented VRS it is 42%. In both input-oriented and output-oriented VRS, 50% farms have efficiency level between 0.70 and 0.90. In terms of scale economics, 118 farms were characterized by increasing return to scale, 32 farms had constant return to scale and fifty farms were characterized by decreasing return to scale for input-oriented VRS. The scenario is different for output-oriented VRS. Out of 200 farms, 67 had increasing return to scale, 42 farms had constant return to scale and 91 farms were characterized by decreasing return to scale.

**Table 2:** Summary statistics of Technical efficiency (TE) and Scale efficiency (SE) of banana farmers

| Statistics | Input Oriented | | Output Oriented | |
|---|---|---|---|---|
| | TE | SE | TE | SE |
| Mean | 0.8750 | 0.9661 | 0.8713 | 0.9703 |
| Standard Deviation | 0.1029 | 0.0539 | 0.1039 | 0.0498 |
| Minimum | 0.6320 | 0.6740 | 0.6190 | 0.6740 |
| Maximum | 1.0000 | 1.0000 | 1.0000 | 1.0000 |

Summary statistics for the measures of technical and scale efficiencies are presented in Table 2. Under input-oriented and output-oriented method, the estimated TE was found to be about 87%, which indicates that the output per farm can be increased on average 13%. Scale efficiency (SE) measures the optimality of the firm's size, or when it operates where average and marginal products are equal (Forsund and Hjalmarsson, 2004). The results reported in Table 2 also show that the average level of SE is around 97%, which indicate that the farm can reduce scale inefficiency by 3%.

**Table 3:** Estimate the effects of farm-specific variables on banana farming efficiency by using Tobit model

| Variables | Input Oriented | | Output Oriented | |
|---|---|---|---|---|
| | TE | SE | TE | SE |
| Constant | 0.0825 (0.1032)* | 0.9188 (0.000)*** | 0.1576 (0.0019)*** | 0.9658 (0.0000)*** |
| Age | 0.0084 (0.0034)*** | 0.0049 (0.1052)* | 0.0047 (0.0142)** | 0.0042 (0.0175)*** |
| Experience | 0.0689 (0.000)*** | 0.0461 (0.0198)** | 0.0498 (0.006)*** | 0.0398 (0.0103)** |
| Education | 0.0959 (0.0024)*** | 0.0357 (0.0051)*** | 0.0210 (0.0416)** | 0.0026 (0.0172)** |
| Firm size | 0.0237 (0.0089)*** | 0.0055 (0.0811)* | 0.0223 (0.0086)*** | 0.0173 (0.000)*** |
| Log likelihood | 169.07808 | 300.86644 | 171.23014 | 328.51373 |

***, **, and * indicate significant at 1% (P<0.01), 5% (P<0.05), and 10% (P<0.10) level respectively. P values are in parentheses. TE=Technical efficiency and SE=Scale efficiency

The results of the Tobit estimates are presented in Table 3. On the basis of log-likelihood test and individual p-value it may conclude that the variables considered in this study for measuring the efficiency of a farmer are significant i.e., the variables age, experience, education of farmers and firm size is found to be statistically significant and positively related to a farmers being technically efficient. These results are consistent to the results of Wadud and White (2000); Hossain, *et al*. (2015). The scenario is similar for all cases considered in this study. That is farmers that are more educated are likely to be more efficient compared to their less educated counterparts, perhaps because of their better skills, access to information and good farm planning. The experience of farmers also can lead to the proper management of farm activities in term of pesticide, fertilizer and technology application. A possible explanation of the positive coefficient of experience could be that the farmers have more valuable experience by hands-on learning and tends to affect use of inputs efficiently.

## IV. CONCLUSION

Production efficiency is an important factor of productivity growth in the agriculture-based economy of a developing country like Bangladesh. The result indicates the average TE and SE for banana farmers of Kushtia district are about 87%, and 97%, respectively for the both input and output oriented VRS. It can be said that, for the available technology, farmers could increase their banana production in Kushtia by only 13%. Tobit regression shows the variation of TE of farmers that is related to farmers-specific attributes such as age, experience, education and firm size also. All of these factors provide a positive impact on farmer's efficiency. Therefore, this study suggests that the existing inefficiency of farmers may be reduced through training, policy interventions, adoption and spread of improved agricultural mechanization. Increasing agricultural productivity and sustainability with the use of natural resources can also guarantee the achievement of a more optimal sustainable living in an effort to increase the farmers' income and lead to achieve Bangladesh's middle-income country.

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