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Application of Stochastic Frontier Production Function on Small Banana Growers of Kushtia District in Bangladesh

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Abstract: Agricultural productivity varies due to differences in production technology, differences in the setting in which production occurs and differences in the efficiency of the production process. Efficiency measurement has been the concern of researches with an aim to investigate the efficiency levels of farmers engaged in agricultural activities. Identifying determinants of efficiency levels is a major task in efficiency analysis. Moreover, estimates on the extent and sources of inefficiencies could help improve the efficiency or develop new technology to raise the banana productivity. Thus the main objective of this paper is to estimate the efficiency of the small banana grower in Kushtia district of Bangladesh. In this study, econometric frontier models were estimated under the specification of the Cobb-Doulas production function model. Primary data for this study were collected by the use of well structured questionnaire. Among the elasticities, the elasticity for land used for banana production is the largest (0.3498). The second largest elasticity is cost on fertilizer which is 0.2417 and the elasticity for the cost on labor is lowest (0.0495). From the results of the study, it is revealed that age and education level of the farmers has a positive effect on technical efficiency. This paper recommend that the Government should take an effective step to control the price system and price spread of the market and make sure that the producers can get their reasonable price and also the consumer can also get the product in a reasonable price. Government also should take necessary steps to improve the knowledge of a farmer to the modern cultivation technique and encouraged them to adopt the new technology to increase the production.

Keywords: Banana, Stochastic Frontier, Efficiency, Bangladesh

1. Introduction:

Banana (*Musa paradisiaca*, family Musaceae) is a central fruit crop of the tropical and subtropical regions of the world grown on about 8.8 million hectares [1]. It is possibly the world's oldest cultivated crop [2]. Farmers in Southeast Asia and Papua New Guinea first domesticated bananas. Recent archaeological and palaeoenvironmental evidence at Kuk Swamp in the estern Highlands Province of Papua New Guinea suggests that banana cultivation there goes back to at least 5000 BCE, and possibly to 8000 BCE [3]. It is likely that other species were later and independently domesticated elsewhere in Southeast Asia. Southeast Asia is the region of primary diversity of the banana. Areas of secondary diversity are found in Africa, indicating a long history of banana cultivation in the region [4]. The banana fruit is variable in size, color and firmness, but is usually elongated and curved, with soft flesh rich in starch covered with a rind which may be green, yellow, red, purple, or brown when ripe. The fruits grow in clusters hanging from the top of the plant. As a diet, banana is an affluent source of carbohydrate with calorific value of 67 calories per 100g fruit and is one of the most well-liked and widely traded fruits across the world [5, 2]. Banana is mainly cultivated for it's ripen fruits, cooked vegetables and leaves in India and many other countries including Bangladesh [6]. It is the second largest produced fruit after citrus, contributing about 16% of the world's total fruit production [7]. Banana is highly nutritious [8] and is more easily digestible than many other fruits including apple [1].

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 800840 metric tons in an area of 130589 acres whereas in Kushtia the total production of banana was 103166 metric tons in an area of 8262 acres in 2010-11 [9]. Also in

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Bangladesh, several studies have been conducted to analyze the banana production [10, 11, 12, 13, 14, 15, 16, 17, 18]. Production functions are widely used to analyze efficiency in terms of output for a given level of inputs. In most microeconomic analyses, production functions are estimated under the assumption that producers are rational profit maximizers that operate on their production frontiers. However, Farrell [19], Aigner et al. [20], Meeusen and Van den Broeck [21], and Battese and Coelli [22] support the view that producers differ in the measured output that they produce from a given bundle of measured input, or, alternatively, in the input requirements to produce a given output. Stochastic frontier analysis (SFA) acknowledges such efficiency differences among farmers. Producers operating on their production frontier are referred to as technically efficient and producers operating below that frontier are called technically inefficient. Stochastic frontier production functions have been used extensively in the past two decades to analyze technical efficiency.

Bangladesh has long history of producing almost all agricultural crops. Although farm households produce almost all agricultural crops as they need, some regions in Bangladesh are advantageous or dominant to produce certain crops than other regions. Farm households in these regions are producing those crops which are environmental friendly and ensure more income or profit to them. But farm households are not strict to certain crops; they are always trying to produce new crops which ensure them promising income. Thus land use patterns have been changing over the years [23]. In view of the slow growth and increasing instability in production, the banana production of Kushtia district could be benefitted to a great deal from its inefficiency studies. Efficiency measurement has been the concern of researches with an aim to investigate the efficiency levels of farmers engaged in agricultural activities. Identifying determinants of efficiency levels is a major task in efficiency analysis. Thus, the main objective of this paper is to estimate the efficiency of the small banana grower in Kushtia district of Bangladesh with the help of Cobb-Douglas type stochastic frontier production function. Moreover, estimates on the extent and sources of inefficiencies could help improve the efficiency or develop new technology to raise the banana productivity in Kushtia district. This necessitates efficiency analysis of the small banana grower across different regions of the Kushtia district, which in turn, will help in formulating the policy measures to mitigate various constraints in the banana production of Bangladesh, particularly in Kushtia district. The study in hand is oriented towards the goal of achieving higher productivity by improving technical efficiency of the banana farmers in Kushtia district of Bangladesh.

The present paper is organized as follows. After this introduction Section 2 describes the methodology which includes sample size and sampling methods, Stochastic Frontier & Efficiency measurements and models & variables. In Section 3 we discuss the results obtained in this study. Finally, Section 4 makes conclusion of this research.

2 Methodology

2.1 Sample Size and Sampling Methods:

This is a field study research which has been made on the basis of a survey. A well structured questionnaire has been developed after an intensive review of the literature and practical experience. The target population of the study is the small banana growers of Islamic University thana of Kushtia district in Bangladesh. Purposively we select the target area. The sample unit of this study is the individual farmer (small banana grower). The sample size is 200 farmers. The sample size is determined by the formula, $n = \frac{z^2 pq}{d^2}$, where $n =$ the desired sample size, $z =$ the standard normal deviate, $p =$ the proportion in the target population estimated to cultivate the banana, $q = 1 - p$ and $d =$ degree of accuracy desired (precision level of the estimate). From a pilot survey of the target area we estimate as $p = 0.746 \approx 0.75$. We also consider $z = 1.645$ for 90% confidence level and $d = 0.10$. By using these information, we have, $n = 202.952$. Non-probability convenience sampling procedure has been used to collect primary data from small farmers who cultivate banana less than two acres of land. Research was conducted in 10 villages from the Islamic University thana of Kushtia district and interviewed 20 farmers form each village. Data collection was conducted on June-July of 2014. Collected data was analyzed by IBM SPSS 22 and FRONTIER 4.1.

2.2 Stochastic Frontiers and Efficiency Measurement:

The measurement of the efficiency of production has been an important area of research over the last two decades. For this purpose stochastic frontier production function has been used. Coelli [24] observed that thirty out of forty studies on application of frontier models to agriculture have used stochastic frontier production function. The advantage of using stochastic frontier models are: (1) It introduces a disturbance term representing statistical noise, measurement error and exogenous shocks beyond the control of production units which would other-wise be attributed to technical inefficiency, (2) It provides the basis for conducting statistical tests of hypothesis regarding the production structure and the degree of inefficiency. The estimation of frontier function and efficiency can be completed either in one stage or in two stages. The two-stage analysis of explaining levels of technical efficiency (or inefficiency) was criticized by Battese and Coelli [22] as being contradictory, in the assumptions made in the separate stages of the analysis. In this

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paper, we follow the Battese and Coelli [22] approach of modeling both the stochastic and the technical inefficiency effects in the frontier, in terms of observable variables, and estimating all parameters by the method of maximum likelihood, in a single-step analysis.

2.3 Model and Variables:

The study used the primary data which were collected from 200 small banana growers of Islamic University thana of Kushtia district in Bangladesh. The Cobb-Douglas (CD) production function was found to be an adequate representation of the data, given the specifications of the corresponding translog frontier model. The stochastic frontier model is defined by:

$$\ln(Y_i) = \beta_0 + \beta_1 \ln(X_{1i}) + \beta_1 \ln(X_{1i}) + \beta_1 \ln(X_{1i}) + \beta_1 \ln(X_{1i}) + \beta_1 \ln(X_{1i}) + \beta_1 \ln(X_{1i}) + V_i - U_i \quad \ldots \quad \ldots \quad (1)$$

Where ln represents the natural logarithm (base, e); the subscript, i denotes the i-th farmer in the sample, $i = 1, 2, 3, \ldots, 200$; Banana production, (Y_i) represents the total banana production (in Taka, note that Taka is the currency of Bangladesh) for the farmer; banana area (X_{1i}) represents the total area of banana (in bigha, 1 acres=3bigha); cost on seed (X_{2i}) represent the total cost for seed to produce single time banana (in Taka); cost on labor (X_{3i}) represent the total cost for labor to produce single time banana (in Taka); cost on irrigation (X_{4i}) represents the cost of irrigation water applied to produce single time banana (in Taka); cost on fertilizer (X_{5i}) represents the cost on fertilizer applied to produce single time banana (in Taka); cost on transport (X_{6i}) represents the cost on transportation for marketing the banana produced single time (in Taka), the $\beta_k; k = 1, 2, \ldots, 6$ are unknown parameters for the production function; the V_i's are random errors associated with measurement errors in the production of banana reported, or the combined effects of input variables not included in the production function, whereas V_i's are assumed to be independently and identically distributed $N(0, \sigma_V^2)$ random variables; the U_i's are non-negative random variables, associated with technical inefficiency of production of the farmers, assumed to be independently distributed, such that the technical inefficiency effect for the i-th farmer, U_i, is obtained by truncation (at zero) of the normal distribution with mean m_i, and variance, σ^2, such that $m_i = \delta_0 + \delta_1 Z_{1i} + \delta_2 Z_{2i} + \delta_3 Z_{3i} + \delta_4 Z_{4i}$ ... ... (2), where, Z_{1i} represents the age of farmers in years; Z_{2i} represents the experience of a farmer to produce in years; Z_{3i} represents the age of land producing banana in years; Z_{4i} represents the education of farmers in years of schooling; and the δ's are unknown parameters to be estimated. The stochastic frontier model used in this study is estimated using the computer program, FRONTIER 4.1, written by Coelli [25]. The parameters of the frontier model are estimated, such that the variance parameters are: $\sigma_S^2 = \sigma_V^2 + \sigma^2$ and $\gamma = \frac{\sigma^2}{\sigma_S^2}$, where the γ parameter has a value between zero and one.

3 Results and Discussion

The annual production, yield and harvested area of banana in Bangladesh for different year have been shown in the following figure:

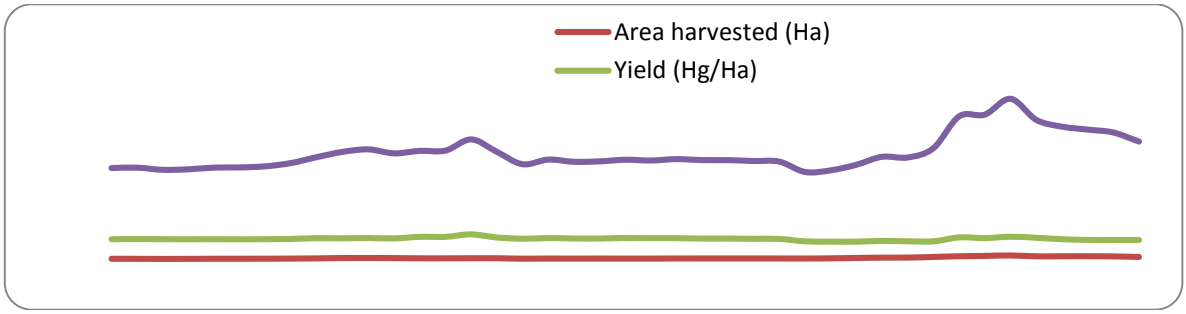

Figure 1: The annual production, yield and harvested area of banana in Bangladesh for different years.
Data source: http://faostat.fao.org

The average harvested area, yield and production over the period 1972 to 2012 in Bangladesh were 42863.73 Ha, 158286 Hg/Ha and 678478.6 tonnes respectively. From Figure 1, the annual banana productions in Bangladesh increase dramatically after the year 2000 and continue up to 2007. In this study we are not able to identify the reason behind this. Again, after the year 2007 the annual banana production is decreasing though the yield and harvested area

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over the period almost same. After the year 2005, the yield and harvested area slightly increase and decrease after the year 2011.

The maximum likelihood estimates of the parameters of the stochastic frontier production function defined by equation (1) and (2) are presented in Table 1, along with their standard errors and t-values.

Table 1: Maximum likelihood Estimates for Parameters of Stochastic Frontier Production Function and Inefficiency Model for Banana Farmers in Kushtia District of Bangladesh

Variable	**Parameter**	**Standard error**	**t-value**
Constant	6.4678	0.7804	8.288302
ln of banana area	0.3498	0.0873	4.007471
ln of cost on seed	0.0925	0.0356	2.59807
ln of cost on labor	0.0495	0.0140	3.541024
ln of cost on irrigation	0.0837	0.0231	3.623108
ln of cost on fertilizer	0.2417	0.0643	3.756363
ln of cost on transport	0.1067	0.0240	4.439266
Inefficiency Model			
Constant	0.1394	0.0177	7.877153
Age	-0.0301	0.0129	-2.33671
Experience to produce banana	0.0324	0.0143	2.257748
Age of land producing banana	0.0294	0.0130	2.261518
Education	-0.0214	0.0101	-2.11087
Variance Parameters			
sigma-square	0.0335	0.0118	2.844298
gamma	0.8629	0.0839	10.2801
Log likelihood function			150.9281
Likelihood Ratio			15.9122

Note: A negative sign of the parameters in the inefficiency function means that the associated variable has a positive effect on technical efficiency, and vice versa.

Source: Field survey, 2014.

The estimate for the variance parameter, $\frac{\sigma^2}{\sigma_S^2}$, indicates that the variance, σ^2, associated with the inefficacy effect is about 86% of the two variances. Estimated output elasticities for all the inputs all differed from zero at the 5% significance level. Among the elasticities, the elasticity for land used for banana production is the largest (0.3498). This means a 10% increase in the land used for banana production will give rise to a 3.498% increase in output. The second largest elasticity is cost on fertilizer which is 0.2417. Among the elasticities, the elasticity for the cost on labor is lowest (0.0495). Socio-economic, demographic factors, farm characteristics, environmental factors and non-physical factors are likely to affect the efficiency [26, 27]. The results of technical inefficiency effects are also presented in the lower part of Table 1. From our results, it is revealed that age and education level of the farmers has a positive effect on technical efficiency. Also, experience of banana producing of a farmer and age of the land banana producing has negative effect on technical efficiency. Though in our study, experience of banana producing of a farmer has negative effect on technical efficiency but in general we expect it has positive effect on technical efficiency.

Table 2: Summery Statistics of Efficiency Estimates from the Stochastic Frontier Model

Statistic	**Efficiency Score**	**Statistic**	**Efficiency Score**
Mean	0.887719	Standard Deviation	0.070798
Minimum	0.651553	Kurtosis	0.689109
Maximum	0.980862	Skewness	-1.14221

The average technical efficiency for the sample is about 89 percent, with a minimum of about 65 percent and maximum 98 percent (Table 2). This implies that on average the respondents are able to obtain 89 percent of potential output from a given mix of production inputs. Thus, in the short run, there is a scope for increasing banana production

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in Kushtia district of Bangladesh by 11 percent, by adopting the technology and the techniques used by the best practice banana farms.

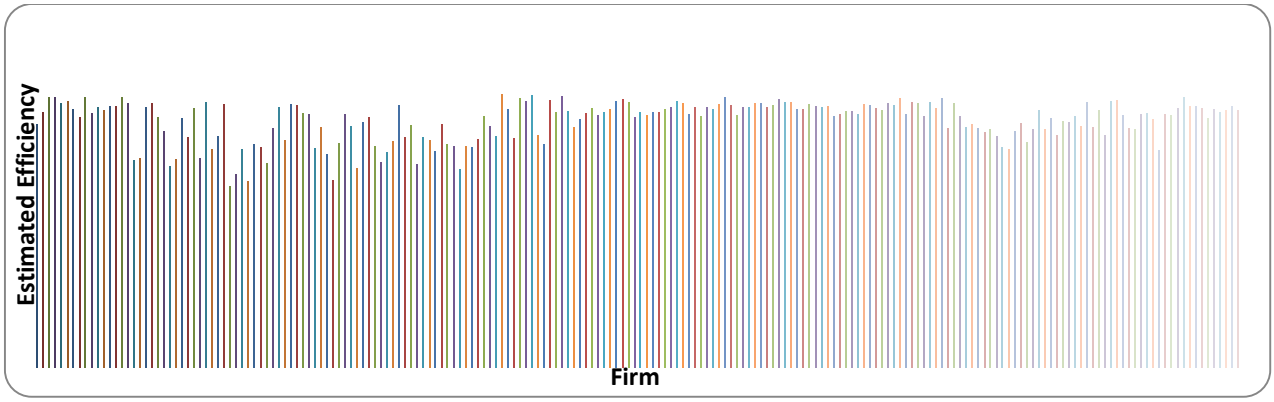

Figure 2: Estimated Efficiency of the Firms

It is observed that the estimated firm efficiency almost nearer to one. Only 6 percent of the firm has efficiency score less than 0.70. About 60 percent of the firm considered in this study operate with efficiency level greater than 0.90 (Figure 2).

Table 3: Frequency Distribution of Technical Efficiency Estimates from the Stochastic Frontier Model.

Efficiency Score	Number of Firms	Percentage of Firms
0.55-0.70	4	2
0.70-0.75	8	4
0.75-0.80	16	8
0.80-0.85	21	10.5
0.85-0.90	33	16.5
0.90-0.95	86	43
0.95-1.00	32	16

The frequency distribution of the efficiency estimates obtained from the stochastic frontier model in presented in Table 3. About 43 percent of the firms operate with efficiency level greater than 90 percent as can be seen from the table. Only 14 percent of the firms operate with efficiency level less than 80 percent.

4 Conclusion

Agricultural productivity varies due to differences in production technology, differences in the setting in which production occurs and differences in the efficiency of the production process. Efficiency measurement has been the concern of researches with an aim to investigate the efficiency levels of farmers engaged in agricultural activities. Identifying determinants of efficiency levels is a major task in efficiency analysis. Empirical studies suggest that farmers in developing countries fail to exploit fully the potential of a technology making inefficiency decisions. Policy makers have started to recognize that one important source of growth for the agricultural sector is efficiency gain through greater technical efficiency. It is observed that among the elasticities, the elasticity for land used for banana production is the largest (0.3498). The second largest elasticity is cost on fertilizer which is 0.2417 and the elasticity for the cost on labor is lowest (0.0495). Results of this study revealed that age and education level of the farmers has a positive effect on technical efficiency. Also, experience of banana producing of a farmer and age of the land banana producing has negative effect on technical efficiency. Though in our study, experience of banana producing of a farmer has negative effect on technical efficiency but in general we expect it has positive effect on technical efficiency.

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. Government should take an effective step to control the price system and price spread of the market and make sure that the producers can get their reasonable price and also the consumer can also get the product in a reasonable price. Government also should take necessary steps to improve the knowledge of a farmer to the modern cultivation technique and encouraged them to adopt the new technology to increase the production.

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