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Technical Efficiency of Boro Rice Production in Jhenaidah District of Bangladesh: A Stochastic Frontier Approach

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Abstract: Rice is the dominant food crop in Bangladesh. Like *Aman* and *Aus* varieties, *Boro* rice also grows in leaps and bounds in the country. The production of *Boro* rice during the dry season is welcomed as increasing use of irrigation in the country is expected to raise *Boro* rice production for achieving food self sufficiency. This study estimates the technical efficiency of *Boro* rice farms and determines the important factors affecting the level of technical inefficiency of the farms. This study mainly uses primary data for the analysis, collected from 112 rice producing farms of *Jhenaidah* district using multistage random sampling technique. The Cobb-Douglas stochastic production frontier approach is employed to estimate the technical efficiency of *Boro* rice farms. An inefficiency effect model is also used to determine the factors that affect the level of inefficiency of the *Boro* rice farms. The empirical results of the Cobb-Douglas stochastic production frontier approach show that the technical efficiency of Boro rice production is on average 0.92. This indicates that the level of technical efficiency in the study area is high. It also finds that cost of labor, irrigation, seed and ploughing are the important factors which affect increasing efficiency of *Boro* rice production. The results from the estimated inefficiency effect model reveal that farm size, age, education, training and credit facility are the significant factors which are negatively related to technical inefficiency of *Boro* rice production. This study suggests that steps to increase education, training and credit facilities are instrumental to reduce technical inefficiency of rice production in the study area.

Keywords: Technical Efficiency, Cobb-Douglas Stochastic Production Frontier, Rice Production, Bangladesh

1. Introduction

Agriculture is a crucial sector for economic growth and development of Bangladesh [31]. Despite gradual decrease in the direct contribution of the sector to the GDP of the country over time, economic development is enhanced by its indirect contribution [20]. It provides food for the people as well as raw materials to the agro based industries that help forming capital. It is also the largest source of employment and income generation of the people in Bangladesh. About 47.5% of the labor forces of the country are presently engaged in agriculture sector. Bangladesh earned US$ 899 million by exporting agricultural product in the fiscal year 2013-14[5]. In addition to the exports of traditional agricultural commodities, (e.g., raw jute, jute goods, tea, frozen foods), the government of Bangladesh has taken steps to increase exports of non-traditional agricultural commodities [4].

Rice, wheat, jute, pulses, vegetables, oil seeds, sugarcane and potato are the major crops grown in Bangladesh, among which rice is the most important food grain as it supplies two-third of total calorie and about one-half of the total protein intake of an average person in the country [8], [18]. It is grown in almost all ago-ecological zones of Bangladesh during the three crop seasons namely *Aus*, *Aman* and *Boro*[25], [13]. In Bangladesh, about 82% of total agricultural produce comes in the form of rice [3]. The volume of rice production in the fiscal year 2013-14 is 342.65 lac metric tons of which *Aus* is 23.26 lac metric tons, *Aman* is 130.23 lac metric tons and *Boro* is 189.16 lac metric tons. Thus, *Boro* is the single largest crop in Bangladesh with respect to volume of production [5], [9]. It is also observed that the productivity of *Boro* rice production is higher than *Aus* and *Aman* rice production [13].

Although the overall rice production in Bangladesh has been increased due to adoption of modern agricultural technologies, the country still needs to import a small amount of fine quality rice from other countries every each year [25]. Moreover, the country occasionally faces shortfall of rice by small amounts due to climatic reasons. The amount of rice import in fiscal year 2013-14 is 2.96 lac metric tons [5]. With increase in population and rise of per capita income of the people, demand for rice increases every year. However, the rate of growth of rice production lags behind the rate of increase in demand in the country [15]. Rice production could not keep pace with its demand due to certain production inefficiencies. Production inefficiency in rice production is believed to exist for several reasons such as low level of education, lack of extension services and training facilities. Another most important reason of production inefficiency is the lack of proper utilization of modern technologies and this is happening due to the existing fragmented state of agricultural land. Therefore, the main objective of this paper is to estimate technical efficiency and determine the factors affecting the technical inefficiencies of rice production in Bangladesh focusing on the *Boro* variety of rice. The measurement of efficiency is an important issue to make effective management decision of resource allocation and formulate different kinds of policies for the improvement of rice production in the country [20].

2. Literature Review

There are many empirical studies e. g. [30], [26], [32], [17], [21], [2], [10], [1], [6], [7], [33], [22], [19], [28], [4] and [11] conducted to measure technical efficiency of rice production. Most of these studies used production function techniques suited to cross section data. There are few studies in Bangladesh that measured technical efficiency of rice production. Studies such as [15], [13], [20], [27] and [9] examined technical efficiency of rice production in Bangladesh. They used Stochastic Frontier approach to determine the level of technical efficiency. The study, [15] showed that the mean technical efficiency of rice farming in Naogaon district of Bangladesh is 0.80, and in that case technical inefficiency is negatively influenced by factors like age, education, farming experience and agriculture policy. [20] investigated technical efficiency using the Cobb-Douglas Production frontier approach and found that the mean technical efficiency was 0.95. [13] found that labor cost, fertilizer and pesticide cost, and irrigation cost are the significant factors affecting the level of technical efficiency of rice production. [29] found that education is positively related to technical efficiency. Moreover, [27] examined that how land fragmentation and resource ownership affect productivity and technical efficiency of rice production. There are few studies which explore farm level technical efficienc of *Boro* varieties in Bangladesh, focusing on specific study area. The present study is an endeavor to fulfill this gap in the literature.

3. Methodology

3.1. Study Area and Data Collection

The present study is based on primary data that are collected from *Jhenaidah* district of Bangladesh. Agriculture is the main livelihood strategy of the people of *Jhenaidah* district and the district is dominated by rice farming. The survey has been conducted in 2016 on the 2014-15 production years. The survey has been conducted with great care which covers different socio-economic information of 112 small, medium and large farmers. The selection of the respondents has been made using the multistage simple random sampling procedure.

At the first stage, two out of six *upazilas* under *Jhenaidah* district are selected using simple random sampling. The *upazilas* are *Kotchandpur* and *Kaligonj*. There are 6 and 11 *unions* under *Kotchandpur* and *Kaligonj upazilas,* respectively. At the second stage, using random sampling technique, from each *upazila* two *unions* are chosen which are Elangi and Bolabaria*union* of *Kotchandpur upazila* and Triechandpur and Rakhalgachi of *Kaligonjupazila*. At the third stage, two villages under each union are selected using random sampling technique. Finally, a list of farmers of the selected villages are collected from the *upazila* agriculture office and chosen 14 respondents from each village using simple random sampling technique which accounts a total of 112 respondents.

3.2. Method of Analysis

Technical efficiency is the maximum possible output obtained from a given set of inputs [24]. According to [12], within a given level of inputs and technology the maximum possible output of a firm can be shown by the frontier production function. The present study uses stochastic frontier production function for measuring technical efficiency of *Boro* rice farming in the study area.

3.3. The Empirical Model

In the stochastic frontier approach, two functional forms of production function are often used to estimate technical efficiency. These are Cobb-Douglas production function and translog production function. In the present study, Cobb-Douglas production function is used to estimate the technical efficiency of rice farms. The model used in this study is defined by the following equation.

$$\ln Y_i = \beta_0 + \beta_1(\ln X_1) + \beta_2 \ln(X_2) + \beta_3 \ln(X_3) + \beta_4 \ln(X_4) + \beta_5 \ln(X_5) + \beta_6 \ln(X_6) + V_i - \mu_i$$

Where, Y_i = Total market value of *Boro* rice output of i^{th}

farm; X_1 = Total cost of labor (Taka, Bangladeshi currency); X_2 = Total cost of fertilizer (Taka); X_3 = Total cost of irrigation (Taka); X_4 = Total cost of seed (Taka); X_5 = Total cost of pesticide (Taka); X_6 = Total cost of ploughing (Taka); V_i = random variable associated with disturbances in production which captures the randomness outside the control of the farmers; μ_i = stochastic disturbance term that represents farm specific or socioeconomic characteristics related to production efficiency that captures randomness under the control of the farmers. To identify the socioeconomic and farm level characteristics that contribute to inefficiency of the farms, the inefficiency effect model is constructed as follows.

$$\mu_i = \delta_0 + \delta_1 Z_1 + + \delta_2 Z_2 + \delta_3 Z_3 + \delta_4 Z_4 + \delta_5 Z_5 + \delta_6 Z_6 + \delta Z_7 + \delta_8 Z_8 + \delta_9 Z_9 + \omega_i$$

Where, μ_i represents the inefficiency that is related to different exogenous or farm specific socioeconomic factors of rice production; δ's are unknown parameters to be estimated; Z_1= total farm size; Z_2 = household size; Z_3= age of the household head; Z_4= education; Z_5= experience of the farmer; Z_6= training; Z_7 = land fragmentation; Z_8 = extension services; Z_9 = credit facility; ω_i = stochastic disturbance term.

3.4. Explanation of the Variables used in the Model

Farm output is defined as the total market value of produced *Boro* rice in 2014-15 production year. Labor cost includes the total cost incurred by both family and hired labor employed in the production. Fertilizer cost includes the cost of buying organic and inorganic fertilizers. Irrigation cost is calculated as the total cost of irrigation for rice farms in the *Boro* season. Seed cost includes the cost of using both local and improved varieties of seeds. Pesticide cost includes total cost of pesticide used in the production. Total ploughing cost is measured by the cost of ploughing the *Boro* plots by power tiller and bullocks. The measurement of variables and the summary statistics of the explanatory variables used in the stochastic frontier model are shown in Table1:

Table 1. *Summary Statistics of the Variables Used in the Stochastic Frontier Model.*

Varia-bles	Unit	Min.	Max.	Mean	Std. Deviation
Output	Taka/bigha	14000	21000.0	18112.5	1670.6
Labor Cost	Taka/bigha	2080	4250.0	2892.0	509.5
Fertilizer Cost	Taka/bigha	1880	3400.0	2820.3	229.1
Irrigation Cost	Taka/bigha	1000	2500.0	2070.2	345.9
Seed Cost	Taka/bigha	300	560.0	437.6	62.8
Pestici-de Cost	Taka/bigha	300	600.0	533.9	76.6
Ploughi-ng Cost	Taka/bigha	520	1000.0	761.5	96.9

Source: Field survey data

It is also mentioned in different literature that there are some important factors that affect the technical inefficiency of *Boro* rice farms in the study area. In order to identify that factors, the inefficiency effect model uses the following variables which are shown in Table2.

Table 2. *Variables used in Estimation of the Inefficiency Effect Model.*

Variables	Unit of Measurement
Farm size	Area which is cultivated by a single *Boro* rice farmer (in bigha)
Household size	Number of family members
Age	Age of the farmer calculated in years
Education	Level offormal education of the farmer measured in the number of years
Experience	Length of growing rice activityby the farmer measured in the number of years
Training	1= if the farmer received any agricultural training, and 0 otherwise
Land fragmentation	Number of plots cultivated by the farmers
Extension service	1=if the farmer get any extension service, and 0 otherwise
Credit facility	Amount of money taken by the farmer from different institutions

4. Results and Discussion

The parameters of the Cobb-Douglas production frontier is estimated by using the Maximum Likelihood (ML) estimation method and the results are presented in Table 3. The obtained results revealed that the value of gamma is 0.60. This indicates that 60% difference exists between observed and maximum production frontier output.

The coefficients of labor cost, irrigation cost and seed cost are 0.78, 0.03 and 0.14, respectively, and they are statistically significant. These indicate that one percent increase in labor cost, irrigation cost and seed cost may increase the total value of *Boro* rice production by 0.78%, 0.03% and 0.14%, respectively. These results are similar to the obtained results found in [24] and [13]. On the other hand, the coefficients of fertilizer and pesticide cost are negatively significant to explain the technical efficiency of Boro rice production. This indicates that one percent increase in fertilizer and pesticide cost may cause to decrease the total value of rice by 0.43%

and 0.08%, respectively. These results are consistent with the results of [16], [20] and [13]. The other variable, ploughing cost, used in Cobb-Douglas production frontier, is found statistically insignificant to explain the technical efficiency of *Boro* rice production.

Table 3. *Maximum Likelihood Estimates of Cobb-Douglas Stochastic Production Frontier.*

Variables	Coefficient	Std. Deviation	*t*-ratio
Constant	0.46	0.723	0.639
ln labor cost	0.78^{***}	0.183	4.28
ln fertilizer cost	-0.43^{***}	0.05	-8.67
ln irrigation cost	0.03^{***}	0.012	2.51
ln seed cost	0.14^{***}	0.031	4.62
ln pesticide cost	-0.08^{***}	0.010	-8.08
ln ploughing cost	0.04	0.14	0.31
Inefficiency Model			
Constant	-0.01	0.10	-0.13
Farm size	-0.55^{***}	0.12	-4.50
Household size	-1.25	0.79	-1.58
Age	-0.51^{***}	0.18	-2.87
Education	-1.05^{***}	0.31	-3.40
Experience	-0.25^{*}	0.14	-1.77
Training	-0.71^{**}	0.34	-2.10
Land fragmentation	0.21	0.80	0.26
Extension service	-0.37	0.30	-1.25
credit facility	-1.52^{***}	0.55	-2.76
Sigma-squared	0.36^{***}	0.07	5.18
Gamma	0.60	5.45	0.11

Source: Author's own calculations; Note: *, **and *** indicate 1%, 5% and 10% level of significance

The results of inefficiency model show that the coefficients associated with age, education, experience and training are negative and they are statistically significant. This indicates that one percent increase in these variables may decrease the level of technical inefficiency of *Boro* rice production by 0.51%, 1.05% and 0.71%, respectively. This results are similar to the findings of [25], [9], and [11]. The coefficient of farm size is negatively related to technical inefficiency which indicates that a 1% increase in farm size may decrease the level of technical efficiency by 0.55% which contrasts to the result obtained by [15]. The coefficient associated with land fragmentation is positive. This implies that more and more land fragmentation may increase the level of inefficiency. The coefficient associated with credit facility is negatively related to technical inefficiency and statistically significant to explain inefficiency of the *Boro* rice farmers. This implies that one percent increase in credit facility may decrease the level of inefficiency by 1.52%. The variables like household size, experience and extension service are negatively related to the level of inefficiency but statistically insignificant.

5. Conclusion

The main objective of this study is to estimate the level of technical efficiency and determine the factors affecting on technical inefficiency of *Boro* rice production using Cobb-Douglas Stochastic frontier approach. It is observed that the *Boro* rice farms in the study area run their operation with less than full potentials as the mean technical efficiency of the farmers is found to be 92%. This implies that output of the farm can be increased by 8% under the given technology without increasing any additional inputs. The estimation results clearly suggest that farm size, age, education, training and credit facility are the crucial factors which can reduce the existing technical inefficiency in *Boro* rice production. Based on the results, the study suggests that government should take necessary steps to increase the education level, training facilities and extension services of the farmers as well as improve the credit facility of the farmers.

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