Ranjan Kumar Kundu *et al*, International Journal of Advances in Agricultural Science and Technology,
Vol.7 Issue.5, May-2020, pg. 20-27 ISSN: 2348-1358
Impact Factor: 6.057
NAAS Rating: 3.77

A Stochastic Frontier Modeling of Boro Rice Farmers in Bogura District of Bangladesh

Ranjan Kumar Kundu; Md. Rakib Pervej; Most. Mira Khatun; Provash Kumar Karmokar*
Department of Statistics, University of Rajshahi-6205, Bangladesh
**E-mail:* sprovash@yahoo.com

Abstract
Due to its importance in the agricultural area, technical efficiency has enhanced in this study to recognize the contribution of the assigned factors of the farmers of Bogura district, Bangladesh following multistage sampling technique. To accomplish its goals stochastic frontier model exploits using authors surveyed cross-section data of 98 farmers collected in 2017-2018 cropping year. The maximum likelihood estimate of parameters and the efficiency scores of individual farmers are calculated using stochastic frontier approach. Although the model captures the mean efficiency, 0.803 it is evident that maximum 45.93% farmers belong to the efficiency group 80-90 percent and 18.37% belong to the groups, 60-70 and 70-80. Besides these, 15.30% farmers expose to the efficiency group greater than or equals to 90 and rest 1.02% farmers to the group less than 60. Furthermore negatively skewed pattern of the farmers' technical efficiencies are observed by the density curves. The empirical evidence suggests that the production frontiers of seed cost and irrigation cost is positive and statistically significant for Bogura district indicating that an increase of these variables could increase Boro production. Thus it is recommended that Boro farmers need to take care about seed and irrigation cost as well as their systems to improve the production which could be an important message for the marginal farmers and concerning authorities for the betterment of the food reservation of the country.

Keywords*:* Stochastic frontier approach, Production function, Technical efficiency, Marginal farmers, Multistage sampling

1. Introduction
Bangladesh is the fourth largest rice producing country in the world followed by China, India and Indonesia (FAO, 2015). According to the statistics of per-capita rice consumption the country holds fourth position in the world. Rice is cultivated three times in a year and depending upon the time of plantation and harvesting period, rice is classified into three varieties, Aus, Aman and Boro. Aman rice is planted in monsoon and is harvested in mid to late autumn. But, Aus rice is planted during May-June and its harvesting period from August to September. On the other hand, the variety Boro contribute significantly in the country as its production is high and duration is relatively less than Aman. The Boro rice is planted in November - December and is harvested in March-April.
To increase the total production of rice the government of Bangladesh takes various supportive activities so that the increased production may help to ensure the food security of the country. From the inception of the independence in 1971, production of rice increased over three folds. Applications of modern technology in the field of agriculture can enhance total production of rice significantly. Investment in research is essential for developing appropriate new technologies that is required for boosting up production of rice. In last three decades due attention was placed on rice research and farming innovations by the government for increasing the total production to address the growing needs of the country. Increased rice production is related to attain the Government's 'Vision 2021' to be the middle-income country and also for achieving the Sustainable Development Goals. Out of all crops, rice is the driving force of Bangladesh agriculture. In fact, food production in Bangladesh is dominated by such single crop (rice). Boro alone contributed to the highest share of total rice production since 1998-99 to date, which accounts for over 60% of total production. Therefore, increase of Boro rice production would be a significant possible way to prevail over food insufficiency in the country. The

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average yield of rice is 4.62 ton/hectare in Bangladesh whereas the yield in some other rice producing countries of the world such as Australia, South Korea, Japan and China are 10.29, 7.22, 5.44 and 6.94 ton/hectare, respectively (FAO data, 2016). In Bangladesh rice is considered as the center of food security and, at the same time source of socio-political stability as rice farming is the main economic activity of millions of rural poor.

In recent years the government of Bangladesh undertakes pragmatic and multidimensional steps to increase domestic production of rice for attaining self-sufficiency and to develop a good reserve for emergency crisis management. Some of these interventions are providing subsidies in agricultural inputs like chemical fertilizers, irrigation equipment, fuels, insecticides, pesticides, etc. and at the same time making these items readily available to the farmers. Besides, the government has put emphasis on training of farmers and transfers of technologies, and also the procurement of domestic rice for encouraging the grower. As a result, the domestic production of rice increased significantly and the country is at the doorstep for attaining self-sufficiency in rice production. In the production chain the northern area of the country has a enormous role and among these area Bogura is district contributing positively in the Boro rice production. Under these initiatives how farmers feeling well in their production system as well as how they get involves themselves with their experiences and other capabilities is matter of investigation. As such the stochastic frontier model have been used to estimate the technical efficiency and disseminate its sources with inefficiencies (if any) of Boro producers of Bogura district.

2. Review of Literatures

Globally, a great deal of empirical studies has led to analyze technical efficiency and identified different factors which are associated with production and its efficiencies on various crop in agricultural sector. Ahmed *et al.*, 2017 carried out a study to estimate technical efficiency and determine the empirical factors influencing rice yield in Niger state, a major rice producing state in Nigeria, and Hainan of China using Cobb-Douglas production function analysis. Rani & Singh, 2015 conducted a comparative study to estimate the farm level technical efficiency of rice production in irrigated and rain-fed environment of Uttrakhand state, India. Okeke *et al.*, 2019 conducted a study on the smallholder rice farmers to assess scores of technical efficiency, its determinants and the extent of their variability across three agro- ecological zones of Cameroonian. Zahri *et al.*, 2018 conducted a study to comparing rice farming appearance of tidal swamp area and coastal area in South Sumatra, Indonesia. Addai & Owusu, 2014 analyzed the technical efficiency of maize farmers maize farmers of the Bekwai Municipality, Nkoranza South District and Gushiegu District of the Forest,Transitional and Savannah Zone respectively using a translog stochastic production frontier function for the 2010 crop year. Kaura *et al.*, 2010 analyzed the technical efficiency in wheat production across different regions of the Punjab State, based on the cross sectional data collected from semi-hilly, central and south-western regions for the year 2005-06. Piya *et al.*, 2012 presented a study focused on comparing the technical efficiency and identifying factors affecting technical efficiency of rice farms in Dhading and Chitwan districts of Nepal.

In Bangladesh few studies on the agricultural sector are found to be conducted in searching the required potentials (see Rana & Bapari, 2018; Mitra & Yunus, 2018; Katungwe *et al.*, 2017; Hossain & Majumder, 2018; Rabbani *et al.*, 2017; Hasan *et al.*, 2016; Hasnain *et al.*, 2015; Sadika *et al.*, 2012; Hossain and Rahman, 2012; Alam *et al.*, 2012). In this connection we intended by the present study to investigate the technical efficiencies of the study area of Bangladesh.

3. Study Area, Data and Methodology

Bogura district is located between 24°32' and 25°07' north latitudes and in between 88°58' and 89°45' east longitudes and among the northern region of Bangladesh, Bogura district (see Figure 1) is predominantly an agricultural area where a lot of rice is grown. The district comprises of 12 administrative upazilas, namely, Bogura sadar, Gabtali, Sherpur, Kahaloo, Shajahanpur, Shibgonj, Dhunat, Nandigram, Sonatola, Adamdighi, Dupchanchia and Sariakandi.

ISSN: 2348-1358
Impact Factor: 6.057
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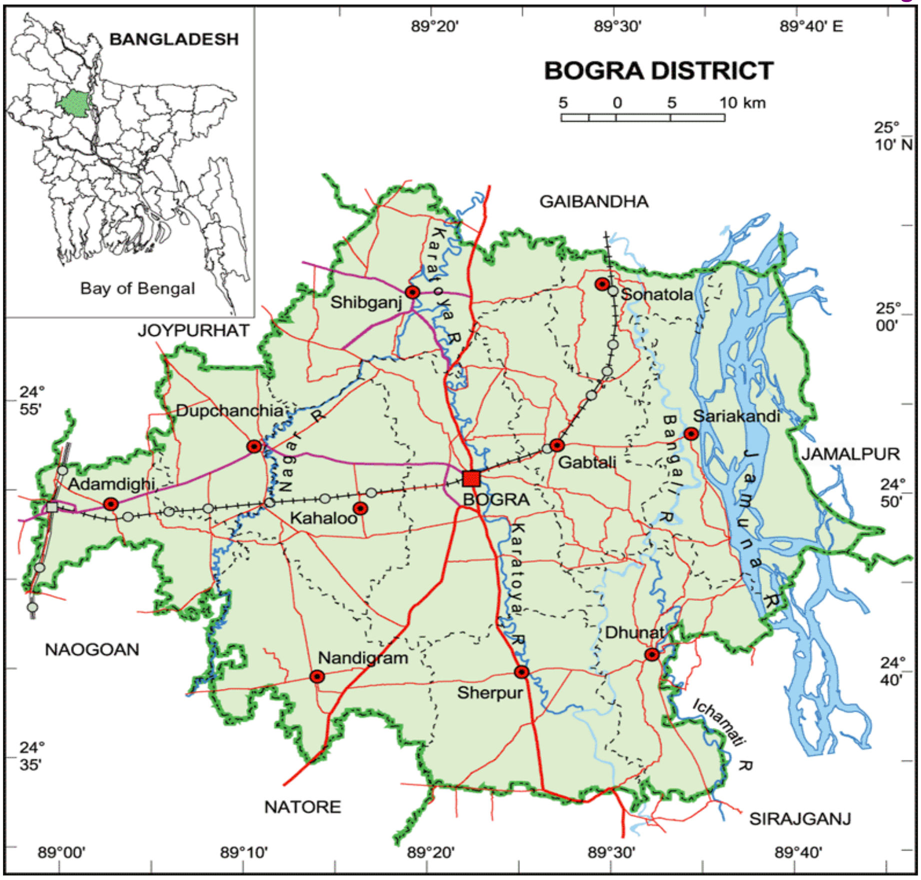

Figure 1. Map of the Bogura district of Bangladesh
(Source: http://www.banglapedia.org)

A multistage sampling technique was employed to collect the data. Bogura district was selected among the districts of northern areas purposively and in the second stage two upazilas were randomly selected. In the first stage Bogura districts was chosen based on its potential to rice production and the population is all Boro rice producers in the districts. From each upazila two villages were randomly selected from a list of major Boro rice producing villages. Finally, 10% farmers from each village were taken as respondent using simple random sampling technique on basis of the up-to-date list of farmers provided by the respective upazila agriculture office. The lists of respondents are given in Table 1.

Table 1: Population and sample parameters of Boro Producers

Selected Parameters of the marginal farmers			
Upazila	Village	Enlisted	Selected
Sonatola	Balua	237	24
	Madhupur	268	27
Kahalu	Durgapur	212	21
	Murail	261	26
Total farmers selected for interviewed		98	

The sampled farmers were interviewed personally either at their farms or at residence with the help of well-structured questionnaire designed for the study in January to April 2018. The demographic, institutional and socioeconomic variables were included in the questionnaire.

3.1 Stochastic Frontier Modeling

The Stochastic Frontier Model (SFM) captures the stochastic part of the data sets make it popular among the practitioners in the econometric area of research. The Stochastic Frontier Analysis (SFA) is parametric approach

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which is based on econometric estimation of a production frontier with one output and multi-inputs. Most studies that have measured technical efficiency in agriculture were used the stochastic frontier method because of the above-stated advantages. This frontier production function accounts both the random error and inefficiency component specific to every producer. Following the pioneer (Debreu, 1951; Koopmans, 1951 and Farrell, 1957) of the SFA to measure empirically the efficiency of production units, the general form of the stochastic production frontier production can be expressed as

$$Y_i = f(X_i, \beta)\exp(v_i - u_i); \qquad i = 1,2,3,.........,N \tag{1}$$

where Y_i is the output of Boro rice (kg) of the ith farmer, X_i is a 1×k vector of inputs used by the ith farmer, β is a 1×k vector of unknown parameters to be estimated, $f(X_i, \beta)$ is suitable functional form of Cobb-Douglas function. The two sided systematic error term, v_i's $(-\infty \le v_i \le \infty)$ are identically and independently normally distributed random error [v~N$(0, \sigma_v^2)$]. The one sided efficiency component $(u_i \ge 0)$ captures the inefficiency in production relative to the stochastic frontier (Coelli *et. al*., 2005). Following half-normal distribution of u_i (u~N[μ, σ_u^2]) the technical efficiency of individual farmer, (TE_i) can be obtained as the ratio of the observed output (Y_i) to the corresponding frontier output (Y^*) conditioned on the level of inputs used by the farmer. Mathematically it is expressed as-

$$TE_i = \frac{Y_i}{Y^*} = \frac{f(X_i, \beta)\exp(v_i - u_i)}{f(X_i, \beta)\exp(v_i)} = \exp(-u_i) \tag{2}$$

The technical efficiency lies between 0 to 1.
The specified empirical model of the Cobb-Douglas production function for Boro rice producers of the study region have been analyzed using this model

$$\ln y_i = \beta_0 + \sum_{j=1}^{6} \beta_j \ln X_{ij} + v_i - u_i$$

$$\ln Y_i = \beta_0 + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 + \beta_4 \ln X_4 + \beta_5 \ln X_5 + \beta_6 \ln X_6 + v_i - u_i \tag{3}$$

where β_0 = Intercept; Y_i the output of ith farmers (in Kg.); X_1 =Labour cost Tk. /decimal; X_2 =Fertilizer cost Tk. /decimal; X_3 =Seed cost Tk. /decimal; X_4 =Cutting cost Tk. /decimal; X_5 = Irrigation cost Tk. /decimal; X_6 =Land size decimal.

4. Discussion of Results

Socio–economic variables of Boro Rice producer's are important and it is related to the stochastic frontier analysis also. Thus the descriptive statistics of the socio-economic characteristics of the Boro rice farmers are presented in Table 2.

Table 2: Socio-economic characteristics of the Boro farmers

Characteristics	Percentage	Characteristics	Percentage
Marital status		Gender	
Single	4	Male	97
Married	95	Female	3
Widowed	1	Age	
Religion		< 30	11
Muslims	86	30-49	63
Hindus	12	50-70	26
Christianity	2	Farming experience	
Household size		< 10	15
1-4	28	11-20	67
5-7	45	21-30	13
8+	27	31-40	5

ISSN: 2348-1358
Impact Factor: 6.057
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It is seen from the Table 2 that 97% of the farmers are male and rest 3% are female. Maximum 86% of the farmers are Muslim while 12% are Hindu and rest 2% are from Christian community. The marital record says that 95% belong to the married group and 4% belong to unmarried and 1% is widow. The age statistics tells that maximum 63% of the farmers belongs to the age group 30-49 while minimum 11% belongs to the lowest age group <30 but 26% belongs to the age group 50-70. Among the farmers, 45% have household size within 5 to 7 persons and 27% farmers have maximum household size, eight or more. The farming experience is one more issues that are important for cultivating are considered accordingly. It is found that there are about 67 farmers have previous experience from 11 to 20 years. Next to this 15% have previous experience less than 10 years and only 5% farmers have 5 years previous experience.

The FRONTIER 4.1 program in R environment has been used to estimate the Maximum Likelihood Estimators of the parameters of (3) for Boro rice farmers of Bogura district and the results are presented in Table 3.

Table3. Maximum Likelihood Estimators of SFP function of Boro production

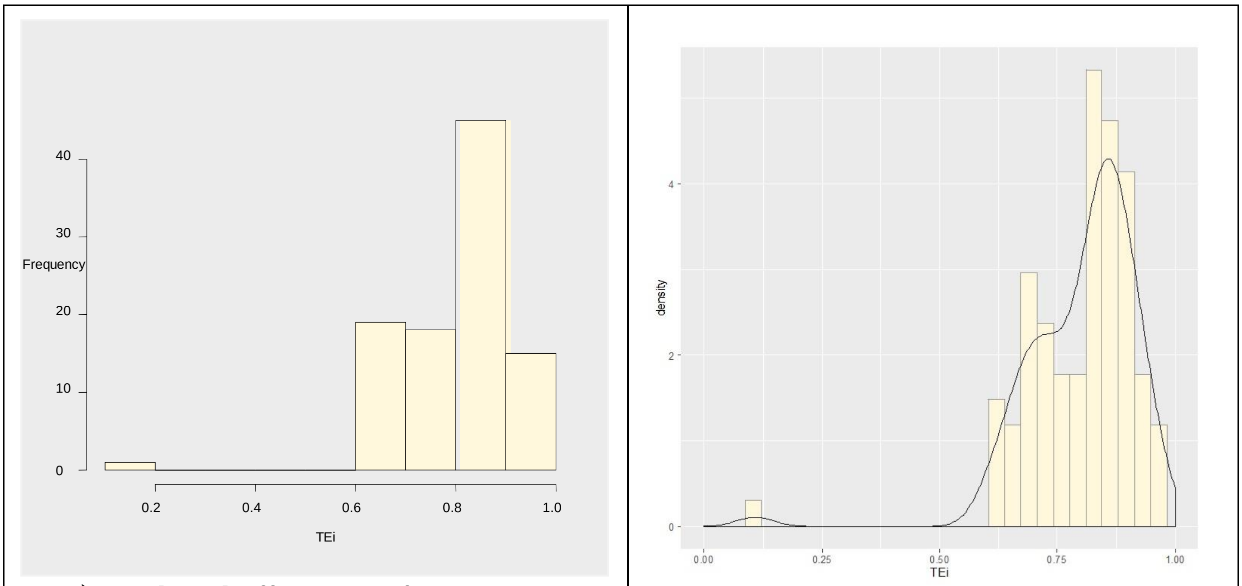
Variables	Parameter	Coefficients	Standard Errors	Z value	P value
Stochastic frontier					
Constant	β_0	0.628	0.320	1.963	0.050
Labor cost (X1)	β_1	0.136	0.189	0.718	0.473
Fertilizer cost (X2)	β_2	0.164	0.179	0.913	0.361
Seed cost (X3)	β_3	0.330	0.112	2.955	0.003
Cutting cost(X4)	β_4	0.004	0.097	0.041	0.967
Irrigation cost(X5)	β_5	0.309	0.084	3.661	0.000
Land size (X6)	β_6	–0.103	0.115	–0.893	0.372
Diagnostic Statistics					
Sigma squared (σ^2)		0.125	0.024	5.201	0.000
Gamma (γ)		0.945	0.041	23.007	0.000
Log likelihood function = 15.758					

From the Table 3, including the constant term three of the classical inputs are found to be significant. The positive value of the estimated coefficient of seed cost is significant at 5% error and it is found to be 0.330. This implies that increasing of 1% of the seed cost causes increase of the output by about 0.330 units if the other factors are constant. The estimated coefficient of labour cost (0.136) is also positive but statistically insignificant implies that output of Boro rice may increase with an incresion of labour cost considering other factors as constant. Similarly the coefficients for Fertilizer cost and Cutting cost (0.164 and 0.004) are found to be positive but insignificant. The coefficient of Land size under Boro rice production has surprisingly negative signs with an elasticity of -0.103 and is statistically insignificant. This implies that decreasing in the land area under Boro rice production would insignificantly decreases Boro rice output for keeping other variables constant. The irrigation cost is very important to the Boro production has been found as significant at 1% level of error with its estimate, 0.309 indicating that one unit increase of such cost caused incresion of the Boro production by 0.309 units.

Further the variance parameters sigma squared (σ^2) of the stochastic frontier production function is significant and noted as 0.125 which indicating a good fit and correctness of specified distributional assumption of the composite error term. Furthermore, the variance ratio denoted by gamma (γ) is a measure of the level of the inefficiency (if any) in the variance parameter has been found as 0.945. Thus at 1% level of significance there are about 94.5 percent of the variation in total Boro rice output are due to differences in technical efficiency and that the variation in output are not solely due to random effects. The farmers technical efficiencies are computed and their distribution are provided in Table 4. Also histogram for the efficiencies of farmers together with their density curves are shown in the Figure 2.

Table 4. Distribution of Technical Efficiency (TE)

TE	Frequency	Percentage
< 60	01	1.02
60-70	19	19.38
70-80	18	18.37
80-90	45	45.93
>= 90	15	15.30
Total	98	100.00



a) Technical Efficiencies of Farmers b) Estimated Densities of Farmers

Figure 2. Plot of Technical Efficiencies and Densities of Farmers

The mean technical efficiency of the stochastic frontier model is 0.803. The distribution of Technical Efficiencies is presented in the Table 4. It is found from the distribution that the maximum percentage 45.93% belongs to the efficiency group 80-90 and the groups, 60-70 and 70-80 accounts for efficiencies19.38% and 18.37% respectively. The group greater than or equals to 90 have 15.30% efficiency while the minimum efficiency, 1.02% is found for the less than 60 group. A quick comparison among the computed efficiency level of farmers with negative skewed behaviour has been noticed easily from the Figure 2.

5. Conclusion

As the aim of the study was to model the contributory variables to the Boro rice producers of Bogura district of Bangladesh, we have been fitted stochastic frontier model using the data set of 98 Boro rice farmers collected from Bogura district Bangladesh following well structured pretested questionnaire under multistage sampling technique.

The mean technical efficiency of the stochastic frontier model is found to be 0.803. The left skewed pattern of the technical efficiencies is evident with the maximum percentage of farmers, 45.93% within the efficiency group 80-90. It is remarkable from the empirical results that the production frontiers of seed cost and irrigation cost is positive and statistically significant for Bogura district indicating that increasing of these variables may increase Boro production. Any farmer who is fully technically efficient have value, one and farmers with values lying between zero and less than one are said to be technically inefficient. The parameter γ represents total variation of output from the frontier that is attributed to technical inefficiency and it lies between zero and one. In this study, the estimated γ is 0.945 which is close to one indicates that technical inefficiency may occur within the data set. Further the variance parameters sigma squared (σ^2) of the stochastic frontier production function is significant and noted as 0.125 indicating the correctness of specified distributional assumption of the composite error term. Effortlessly negative skewed behaviour of technical efficiencies of farmers confirms in this study.

As therefore, together with the other influencing factors, the concerning authority should take care about seed and irrigation cost as well as their management systems to improve and develop the production policy under the existing situation.

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Acknowledgement
The authors highly acknowledge the farmers of the study area for their cooperation and the Department of Statistics for providing the research platform with technical supports.

The Authors Biography

Ranjan Kumar Kundu is pursuing Ph.D. degree in the agricultural/econometric statistics from the Department of Statistics, University of Rajshahi, Bangladesh. At present, he is serving as Assistant Professor in the Department of Statistics, Bonpara Dregree College, Natore, Bangladesh.

Md. Rakib Pervej has completed M.Sc. from Department of Statistics, University of Rajshahi, Bangladesh and is interested to the research in the agricultural statistics.

Most. Mira Khatun had been awarded M.Sc. degree from Department of Statistics, University of Rajshahi, Bangladesh and doing research work focusing on both theoretical and applied area of Statistics.

Provash Kumar Karmokar is a Professor of the Department of Statistics, University of Rajshahi, Bangladesh. He did his PhD in Time Series and completed Post Doctoral from the Institute for Mathematical Research, UPM, Malaysia. He publishes more than 50 articles in different cited journals and achieves the best performance awards for his research contribution.