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Technical Efficiency of Boro Producers and Its Distribution: An Evidence from Natore District, Bangladesh

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ABSTRACT

As an agrarian country, Bangladesh people mostly depend on rice for their food and nutrition. To achieve self-sufficiency it is very important to be concerned about rice production. Because of its notably high production rate Boro rice has become a very popular variety in Bangladesh. Thus, in attaining national food security it is expecting to pay necessary attention to the farmers and the concerned authorities to enhance rice productivity and efficient utilization of resources may be the best way in this regard. Evidence from the stochastic production frontier analysis shows that the traditional input variables, Fertilizer cost, Seed cost, Irrigation cost, Land size are significant and playing a major role in Boro rice production which therefore suggested that taking care of these variables could increase Boro rice. Technical efficiency and its distribution is the parameter to measure the impact of input variables to the output variable at a glance and hence the aim of the study was to justify how efficient the Boro farmers of the study area? Accordingly, the authors have estimated the technical efficiency and its distribution following a multistage sampling using 88 respondents during cropping season 2018-2019 by employing the stochastic frontier model. The estimates of parameter gamma are 0.62 and 0.93 for Singra and Baraigram upazilla respectively. These indicate that 62 percent of the total variations in Boro rice output among the producers are due to technical efficiencies for the Singra upazilla and 93 percent of the variations are due to the differences in technical efficiencies of the producers of Baraigram upazilla. Priorities on farming experiences and adopting better technologies were given and it was recorded that on basis of the study variates and data there are about 84% of farmers achieved a high level of technical efficiency with the range 90–100% for the district Natore. Even if the technical efficiencies recorded 16% in the range of below 90 may be increased to the higher level by nourishing and providing the best facilities from the concerning authorities, the overall efficiency and its level for the study area was very satisfactory. As such the result of the study is remarkable to the concerning authorities of the country for their policy decision purpose and it could be helpful for the betterment of the farmers.

Keywords: Stochastic Frontier Analysis, Technical Efficiency, Cobb-Douglas Production Function, Boro Rice.

Introduction

Although Bangladesh has attained in achieving near self-sufficiency in food production and has reduced hunger by a significant margin, the severity of hunger remains somehow according to the global report. According to Global Hunger Index (GHI) 2019, Bangladesh ranked 88th in the index, with a score of 25.8, among 117 qualifying countries around the world. Even if a lot of changes have made in the last decades due to the policies against the poverty and the steps in favour of the farmers' interest of the current government of Bangladesh insufficient diet and some sort of food shortage are seen also. It is noted that a large portion of the people are undernourished due to lack of adequate supply of food and the prevalence of malnutrition, 14.7% were found in 2016-18 (FPMU, 2020). Due to the prolonged pandemic of Covid-19, an agricultural system of the agrarian countries has to face already threat and it may become impossible to achieve food production targets in the future. As a result, there will be a long-term or short-term adverse effect on food security around the world. According to the estimation of World Food Program, the Covid-19 could double the number of people in low and middle-income countries facing acute food insecurity.

The present government of Bangladesh confers food security and nutrition the highest importance by setting targets of self sufficiency on rice production by 2030 as a part of SDGs, which aims to end hunger and all forms of malnutrition by 2030 as a top international policy priority. Thus, as the staple food the contributory role of the farmers in attaining the national food security of Bangladesh is expecting to the concerning an authority of Bangladesh, the fourth largest consumer and producer of rice in the world. In Bangladesh, three ecotypes of rice namely, Aus, Aman, and Boro are grown intensively all over country in three different seasons. Among all types of rice, Boro has become very popular and is emerging as a new cropping system in Bangladesh, because of its notably high production rate and enormous economic benefits.

According to Worldometer the current population of Bangladesh is more than 164 million. The population in Bangladesh is projected to increase 185 million in 2030 and 202 million in 2050 for medium variant population growth (UN Population Division, 2017). To feed this extra population, Bangladesh must increase rice production substantially and this will require sustainable intensification of production. Considering the current trends, it is anticipated that most of the additional rice will come from augmentation of the Boro rice production (Mojid, 2019). Therefore, attempts should be made to increase the productivity of Boro rice. The best option and the most effective way is to improve Boro rice productivity. In this ground it needs to pay attention on Boro production and its concerning issues for the farmers. Efficiency is a very important factor of productivity growth, especially in developing agricultural economies where resources are meager and opportunities for developing and adopting better technologies are dwindling (Mukwalikuli, 2018). Measurement of technical efficiency (TE) provides useful information on competitiveness of farms and potential to improve productivity, with the existing resources and level of technology (Atamja *et al*., 2019).

In the recent past, a good number of studies have been conducted on rice farming and its productivities considering the technical efficiency of producers in worldwide (see Konja *et al*., 2019; Meenasulochani *et al*., 2018; Kerdsriserm *et al*., 2018; Mkanthama *et al*., 2018; Lema *et al*., (2017); Kabore, 2016). Although studies on technical efficiency of rice production in Bangladesh are mostly scarce some efforts are seen in the literature for Bangladesh under Stochastic Frontier Production methodologies in the rice production areas.

Among them Rana and Bapari (2018) attempted to study on TE of Boro rice production for Pabna district, Hasan *et al*., (2016) for Jhenaidah district and Hossain and Rahman (2012) for Naogaon district using the Cobb-Douglas stochastic production frontier approach. Hasnain *et al*., (2015) also analyzed the technical efficiency of Boro rice farm in Meherpur district of Bangladesh using the Translog Stochastic Frontier Production function approach. In this ground, we were intended to determine the technical efficiency of Boro rice producers in Natore district of Bangladesh. And hope that the evaluated technical efficiencies and identified factors may have contributory effect on the productivity of Boro rice production in the study area.

Materials and method

Description of the study area

The study was carried out in Natore district (Figure 1) of northern region in Bangladesh. Geographically, the district is located between 24°25' and 24°58' north latitudes and between 88°01' and 88°30' east longitudes. The district is well known as a major rice producing districts in the country and its total area is 1900.19 Sq.km. The district comprises of seven administrative upazilas, namely, Natore Sadar, Singra, Gurudaspur, Baraigram, Bagatipara, Lalpur, Naldanga. Among them we have selected the upazillas Singra and Baraigram for data collection with the help of appropriate sampling methodology.

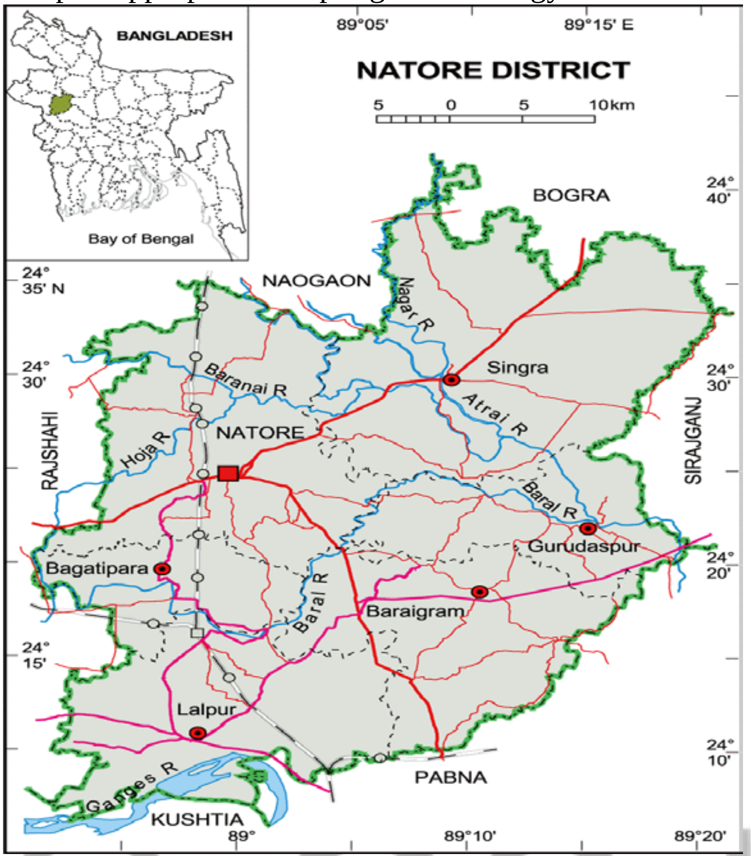

Fig. 1. Map of Natore district showing the study area
(Source: http://www.banglapedia.org)

Sampling, Sample Size and Data

A multistage sampling technique was used to select the respondents in this study. At the first stage, two out of seven upazilas under Natore district are selected using simple random sampling. Secondly, from each upazila two unions are chosen and in the third stage, two villages under each union are selected using random sampling technique. In the final stage, farmers from each of the villages have been selected using proportional sampling and using 10% of the sample frame (884) have been taken as the sample size. Thus, 88 Boro producers have selected and the data have been collected with the help of well-prepared semi-structured questionnaire through direct face to face interviewing during cropping season 2018-19 for this study.

Empirical model

The parametric and the non-parametric approaches are well known in the literature of technical efficiency have been found to measure the efficiency in agricultural sector. In this study, stochastic production frontier model of parametric approach following Battese and Coelli, (1995) have used to estimate the technical efficiency of Boro rice farmers in the study area. The general form of stochastic model is

$$y_i = f(x_i, \beta)\exp(v_i - u_i); \qquad i = 1,2,3,..........,n \qquad (1),$$

where y_i is the output of the ith farmer, x_i is a vector of k inputs (or cost of inputs) used by the ith farmer, β is a vector of k unknown parameters to be estimated and $f(x_i, \beta)$ represents suitable functional form. $v_i - u_i$ is the composite error term defined as $\varepsilon_i = v_i - u_i$. And v_i represent random errors assumed to be independent and identically distributed as $N(0, \sigma_v^2)$ and u_i represents the technical inefficiency effects assumed to be non-negative truncated of the half-normal distribution $N(\mu, \sigma_u^2)$. The technical efficiency of individual farmers is defined in terms of the ratio of the observed output (y_i) to the corresponding frontier output (y_i^*), conditional on the level of input used by the farmer. As such, the technical efficiency of the farmer may be expressed as

$$TE_i = \frac{y_i}{y_i^*} = \frac{f(x_i,\beta)\exp(v_i - u_i)}{f(x_i,\beta)\exp(v_i)} = \exp(-u_i) \qquad (2).$$

It is well established that the TE varies from 0 to unity ($0 \le TE_i \le 1$).

The Cobb-Douglas functional form of the production function developed by C. W. Cobb and P. H. Douglas in 1928 is widely used in representing the relationship of inputs and outputs. The empirical model of the Cobb-Douglas production function for Boro rice producers in its logarithmic form is specified as follows

$$\ln y_i = \beta_0 + \sum_{j=1}^{6} \beta_j \ln x_{ij} + \varepsilon_i \qquad (3),$$

where y_i =Output of Boro rice (kilograms) is produced by the *i*-th farmer; β_0 = Intercept, common to all producers, *x* is a set of six input categories namely: x_1 = Land area under Boro rice in bigha; x_2 = Seed cost used by the *ith* farmer in Tk/bigha; x_3 = Labour cost used by the *ith* farmer in Tk/bigha; x_4 =Fertilizer cost used by the *ith* farmer in Tk/bigha; x_5 = Pesticide cost used by the *ith* farmer in Tk/bigha; x_6 = Harvesting cost used by the *ith* farmer in; ε_i = Random error.

Description of variables used in model

The input and output variables that were incorporated in the Cobb-Douglas production functions are defined briefly as follows.

Dependent variable: Output refers to the total quantity of Boro rice harvested during the cropping season, 2018-2019 and it is measured in kilogram per *bigha*.

Independent variables: the inputs that were used in Boro rice production include; labor cost, fertilizer cost, seed cost, cutting cost, irrigation cost, and farm size. The description of variables, unit of measurement and expected sign are given on the following table:

Table 1. Unit of measurement and expected signs of variables used in the model

Variables	Unit of Measurement	Expected sign
Land area	Cultivated area (in bigha)	+
Seed cost	Price of the seeds (BDT/bigha)	+
Labor cost	Wages of the hired labour (BDT/bigha)	+
Fertilizer cost	Price of fertilizers (BDT/bigha)	+
Pesticide cost	Price of the pesticide (BDT/bigha)	+/-
Harvesting cost	Harvesting amount (BDT/bigha)	+

Result and discussion

The data have been processed and preliminary statistics have been measured using Statistical Package for Social Sciences (SPSS) and maximum likelihood estimates of the parameters of the Cobb-Douglas stochastic frontier production function and its related computations have been executed by R programming convenient to FRONTIER VERSION 4.1(Coelli, 1996). The socio-economic characteristics may influence farmers' production oriented decisions as well as their overall technical efficiency in production (Muhammad-Lawal *et al.*, 2009) is important in any analysis. As such the characteristics age, sex, religion, marital status, family size, level of education, farming experience in Boro rice cultivation are presented in Table 2.

Table 2. Socio-economic characteristics of the sampled Boro rice farmers

Characteristics	Frequency	Percentage	Characteristics	Frequency	Percentage
Gender			Age		
Male	85	96.59	21-30	8	9.09
Female	3	3.41	31-40	17	19.32
Marital status			41-50	39	44.32
Single	4	4.54	51-60	17	19.32

Married	83	94.32	>60	7	7.95
Widowed	1	1.14	Education		
Religion			Up to primary (0-5)	53	60.25
Muslims	73	83	Up to SSC (6-10)	22	25
Hindus	11	12.5	HSC (11-12)	9	10.25
Christianity	4	4.50	Higher (>12)	4	4.5
			Farming experience		
Family size			1-10	13	14.77
1-4	25	28.41	11-20	58	65.91
5-7	40	45.45	21-30	12	13.64
7+	23	26.14	31-40	5	5.68

(Source: Field survey data, 2018)

As shown in Table 2 it can be noticed that Boro rice production in the study area was dominated by males (about 97%) followed by females with 3 percent. Among the respondents 95% were married, 4 percent single while rest 1% were widowed. Most of the Boro farmer selected from Muslims family (83%) and next to were Hindus (about 12.5%) but Christianity were found as 4.5%. Age is one of the important factors influence the decision making of individuals and it is also a risk covering parameter of farmers. Risk-taking attitude and innovativeness in adopting new technologies (Samarpitha *et al.,* (2016) may be affected by age. Table 2 revealed that among five age groups majority of farmers about 44% belong to the age group 41-50 and about 20% of the farmers belong to the age groups 31-40 and 51-60. Next to these about 8% farmers belong to old age (>60) group. In this study family size of the farmers was divided into three classes as small (members up to 4), medium (5 to 7 members) and large (7+ members). From the Table 2 it can be noticed that in Natore district majority (45 percent) of the farmers belonged to medium sized families than that of small (28 percent) and large (27 percent) families. Education heightens the managerial and technical skills of farmers. The majority of the farmers (60.25%) were educated up to primary level and one-fourth (25%) farmers were found in the level SSC. More than 10 percent of the farmers have attained HSC level while only almost 5% have attained a higher level of education. Experience is an important tool in order to operate agricultural activities. Farmers with many years of farming experience will most likely be familiar with the required skills needed for Boro production and therefore are more likely to have higher outputs. Consequently they are supposed to be more technically efficient. It is noticed that the majority (65.91%) of the respondents had an experience of 11 to 20 years, followed by 14.77% who had up to 10 years of experience while only 5.68% of the farmers had greater than 30 years of experience in Boro rice cultivation.

To identify the affecting factors of Boro rice productivity the stochastic frontier models have been estimated using the data set with all assigned variables using C-D production function for two Upazilla Singra and Baraigram of Natore district. The computed results are presented in Table 3 and Table 4.

Table 3. The ML estimates of SFP function for Boro rice in Singra upazila

Variables	Parameters	Coefficient	Std.err	t-value	Pr(>|t|)
Intercept	β_0	2.5434***	0.5034	5.0521	0.0000
Land	β_1	0.0186**	0.0081	2.2978	0.0270
ln(Seed)	β_2	-0.0005^{NS}	0.0617	-0.0089	0.9920
ln(Labor)	β_3	0.2461***	0.0818	3.0089	0.0040
ln(Fert)	β_4	0.0915^{NS}	0.0612	1.4954	0.1420
ln(Pest)	β_5	0.4795***	0.1129	4.2457	0.0000

ln(Harv)	β_6	0.0782 NS	0.0569	1.3731	0.1770
Variance parameters					
lambda	λ	1.2825	1.0692	1.1995	0.2370
sigma square	σ^2	0.0195			
sigma square,*v*	σ_v^2	0.0073			
sigma square,*u*	σ_u^2	0.0121			
log likelihood		38.7504			
Mean TE		0.9182			

(Note: ***significant at 1%; **significant at 5% and *significant at 10%.).
Source: Computed by author based on survey data 2018.

Table 4. ML estimates for C-D production function of Baraigram upazila

Variables	Parameters	Coefficient	Std.err	t-value	Pr(>|t|)
Intercept	β_0	2.3840***	0.4601	5.1809	0.0000
Land	β_1	0.0011NS	0.0043	0.2666	0.7910
ln(Seed)	β_2	0.2774***	0.0401	6.9187	0.0000
ln(Labor)	β_3	0.1213***	0.0425	2.8525	0.0070
ln(Fert)	β_4	-0.0101NS	0.0820	-0.1238	0.9020
ln(Pest)	β_5	0.2380***	0.0507	4.6910	0.0000
ln(Harv)	β_6	0.3245**	0.1223	2.6544	0.0120
Variance parameters					
lambda	λ	3.4948	2.1983	1.5897	0.1220
sigma square	σ^2	0.0125			
sigma square,*v*	σ_v^2	0.0009			
sigma square,*u*	σ_u^2	0.0115			
log likelihood		50.6529			
Mean TE		0.9196			

(Note: ***, ** and * are statistically significant at 1%, 5% and 10% respectively).
Source: Computed by author based on survey data 2018.

From Table 3, among six variables, land, labor, and pesticide are found to be positive and significant at different level and rest of the variables are found to be insignificant. The coefficients of labor and pesticide were significant at 1% level of significance, and the coefficient of land was significant at 5% level of significance. It informs that these were significantly different from zero and hence these variables were important in explaining Boro rice production in the study area. The positive production elasticity with respect to land, labor, and pesticide imply that as each of these variables increase, Boro rice output will increase. On average, as the farmer increases area allocated to Boro rice, amount of pesticide application and labor for the production of Boro rice by 1% each, they can increase the level of Boro rice output by 0.0186, 0.4795 and 0.2461percent, respectively. The estimated variance parameters sigma square, σ^2 is 0.0195 and lambda is ($\lambda = \sigma_u/\sigma_v$) 1.2825. Both of them are significantly different from zero and this indicates a good fit of the model and the correctness of the specified distributional assumptions. A lambda value is greater than 0 also implies that the variation in the observed output from the frontier output is due to technical inefficiency and random noise. However, the variation in output explained by technical inefficiency is relatively larger than the deviations in output from the pure noise component of the composed error term. Gamma, γ is also a measure of the level of the inefficiency in the variance parameter and it is estimated as 0.62 and is significant at 1% indicating that 62 percent of the total variations in Boro rice output are due to technical inefficiencies in Singra upazilla.

It is depicted from Table 4 that for Baraigram upazila that two variables, land and fertilizer have found insignificant in the model. The estimated coefficients of labor, seed and pesticide were positive and statistically significant at 1% level and the coefficient of harvesting cost also positive and statistically significant at 5% level. It means that there is a scope for increasing the production of Boro rice by increasing the level of these inputs. Negative coefficient value of fertilizer and positive coefficient value of land were not significant. In addition, the estimated sigma square, σ^2 is 0.0125 and lambda, λ is 3.4948 and are significantly different from zero. This indicates a good fit of the model and the correctness of the specified distributional assumptions of the composite error terms. The estimated gamma (γ) parameter is 0.93 which means that 93% of the variations in the Boro rice output among farmers in the study area are due to the differences in their technical efficiencies. It can also be explain as that the inefficiency component contribute 93% in the composite error term. In other word it also suggests that about 7% of the variation was due to uncertainty or random shocks beyond the farmers control.

Table 5. Frequency distribution of TE of Natore

Efficiency level	Frequency	Percentage
TE < 60	2	1.13
60-70	4	2.26
70-80	8	3.41
80-90	22	9.10
90-100	52	84.10
Total	88	100
Mean	0.824	
Minimum	0.645	
Maximum	0.984	
Standard deviation	6.44	

The distribution of technical efficiency among the Boro rice farmers in Natore district is presented in Table 4. The result indicate that technical efficiency for Boro rice farmers in the study area are recorded as mean 0.824, minimum 0.645 and maximum 0.984. This implies that the output could be increased by 17.6% if all Boro rice farmers could achieve technical efficiency at the same level of the best farmer in the study area. The results also revealed that approximately 84% of farmers achieved the high level of technical efficiency with a range of 90–100%. In addition, approximately 9% of the Boro rice farmers have technical efficiency with the range of 80–90%, while the proportion who had technical efficiency in the range at 70-80%, 60–70% and <60% was approximately 3%, 2%, and 1%, respectively.

Conclusions and Policy Recommendations

While Bangladesh is stepping to attain self-sufficiency in food production by reducing a significant margin of hunger it is very significant to pay attention to its staple food. Because of its notably high production rate and enormous economic benefits, Boro rice has become a very popular variety of rice and is emerging as a new cropping system in Bangladesh with a maximum share in the growing need of food of the country. Since Bangladesh has given importance by setting targets of self-sufficiency on rice production as a part of SDGs that aim to end hunger and all forms of malnutrition by 2030 we have been intended to investigate the Boro production system and its concerning issues for the producers of the study area. As such with the help of the author surveyed data of Natore district, Bangladesh we have fitted stochastic frontier model following Battest and Coelli, (1995) to estimate the technical efficiency and identify its influencing factors. The estimated variance parameters sigma square and lambda of model (1) were found to be 0.0195 and 1.2825 respectively. These parameters are significantly different from zero indicating that a good fit of the model and the correctness of the specified distributional assumptions of the model. The lambda value implies that the variation in the observed output from the frontier output is due to technical inefficiency and random noise. The test performed on the γ and it is estimated as 0.62 indicating that 62 percent of the total variations in Boro rice output among the producers are due to technical efficiencies for the Singra upazilla. And it is accounted for 93 percent of the variations due to the differences in technical efficiencies of the producers of Baraigram upazilla. As because efficiency is a very important factor in the productivity and developing agricultural economies it is very important to give the priorities to adopting better technologies. Together with this the farming experiences is also a key factor for the production of Boro rice. Therefore, the authors were interested in this variable and it is noted on basis of the study variates and data that approximately 84% of farmers achieved a high level of technical efficiency with a range of 90–100% for the district Natore. Finally, the technical efficiency of the Boro Producers of Natore district, Bangladesh would be remarkable to the producers and the concerning authorities of the country for their policy purpose.

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