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Stochastic Frontier Model with Distributional Assumptions for Rice Production Technical Efficiency

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ABSTRACT

Efficiency in agricultural production is indicative of the efficiency level of farm households in their farming activities. Farmers in developing countries do not make use of all the potential technological resources, thus making inefficient decisions in their agricultural activities. Herein, technical efficiency in relation with the production of three types of rice crop (Boro, Aus and Aman) was evaluated, with some determinants of technical efficiency identified, in Bangladesh. It was attempted, throughout this study, to access the status of technical efficiency in rice production in Bangladesh for panel data while using the Stochastic Frontier Production Model with either of truncated normal or half-normal distributional assumptions. Both time-variant and time-invariant inefficiency effects models were estimated, one at a time. Collected data from agricultural sector pertaining to three main rice crops in Bangladesh for the period of 1980 to 2008 were made used of throughout the study. The results revealed that technical efficiency gradually increased over the reference period with the half normal distribution being found preferable to the truncated normal distribution as regards the technical inefficiency effects. The value of technical efficiency was found high for *Boro* rice while low for *Aus* in comparison with *Aman* rice in Bangladesh for both distributions in either of time-variant or invariant ones. It was observed that the most efficient rice production system has occurred for the case of *Boro* with a technical efficiency of 0.98. Yearwise mean technical efficiency increased during the reference time periods.

Keywords: Bangladesh rice production, Cobb-Douglas stochastic frontier model, Panel data, Time variant and Time invariant efficiencies.

INTRODUCTION

Rice is a major source of subsistence of rural populations in most Asian countries. There are about 4 billion people consuming over 90 percent of the world's rice production. Rice was selected as the subject in the present study because of its prominent position in the national economy of Bangladesh. The share of agriculture to GDP in Bangladesh is about 18.64 percent (BER, 2008-09). About 80 percent of total cultivable land is diverted to rice production (McIntire, 1998). Since 1999-2000, *Boro* rice has contributed to more than half of the total rice production in Bangladesh. From 1980's to 2000's, the production of *Boro* has increased from 19 to 48 percent while the production of *Aus* and *Aman* types being decreased (from 25 to 7 percent and from 56 to 45 percent respectively (Ahmed, 2004)). Currently *Boro* occupies about 41 percent of total rice area and contributes to some 56 percent share of total rice production in Bangladesh. On the other hand, *Aman* rice occupies 50 percent of total rice land and contributes to some 38 percent of total production and while *Aus* rice taking about 9

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percent of total rice area, contributing by 6 percent to rice production (Dev *et al.,* 2009). A rate of per hectare of low technical efficiency in the production of Modern Variety (MV) rice was observed in Bangladesh (Sharif and Dar, 1996). Given the importance of rice production, yet it is surprising that there have been only a few studies carried out on the efficiency of rice production in Bangladesh. Have farmers promoted their production efficiently along with the progress in available technologies? How have the policies undertaken by governments impacted rice production and a farmer's technical efficiency. These are some of the questions the present study partly sought to answer.

Efficiency measures are important because of their vital role in productivity promotion. The efficiency of rice production has been of longstanding interest to the economists and policymakers in Asia, because of the strong relationship between rice production and food security in the region (Richard *et al.,* 2007). A number of studies have examined the productive efficiency in its domain of agricultural production (Travers and Ma, 1994; Fan *et al.,* 1994; Wang *et al.,* 1996a, 1996b; Xu and Jeffrey, 1998; Fan, 1999; Tian and Wan, 2000). Some impacts of the advanced techniques in rice production efficiency in developing countries have been touched upon (Bordey, 2004; Chengappa *et al.,* 2003; and Khuda, 2005). In this context Stochastic Frontier approach has found its wide acceptance within the agricultural economics context (Battese and Coelli, 1992, 1995). Some literature have focused on the Stochastic Frontier model with distributional assumptions by which efficiency effects can be separated from stochastic elements in the model and for this reason a distributional assumption has to be made (Bauer, 1990). Stochastic Frontier analysis employs a composed error model in which inefficiencies are assumed to follow an asymmetric distribution, usually the half-normal, while random errors are assumed to follow a symmetric distribution, usually the standard normal (Aigner *et al.,* 1977).

Most past studies have used the half-normal and truncated normal distributions as assumptions about inefficiency effects model because of the ease of estimation and interpretation (Kirkley *et al.,* 1995). Hasan *et al.* (2012) considered the Cobb-Douglas Stochastic frontier in which the technical inefficiency effects are defined by a model with truncated and as well with half-normal distributional assumptions with either one of time-variant or time-invariant inefficiency effects being estimated. However, there are no priority reasons for choosing one distributional form over the other, realizing the fact that all are of advantages and disadvantages (Coelli *et al.,* 1998). The most proper way to permanently get rid of the problem is to increase rice production up to its' optimum level. If one knew the existing efficiency level in rice production in Bangladesh, through an employment of the inputs for rice production, then policy makers could take viable measures as to increase production up to its maximum level. However, there exist few literature items in estimating stochastic frontier production and consequently dealing with technical inefficiency in rice production in Bangladesh as undertaken by (Rahman *et al.,* 1999; Deb and Hossain, 1995; Banik, 1994; Rahman, 2002; Islam *et al.,* 2011a, b; Backman *et al.,* 2011; Islam *et al.,* 2012). The novelty considered here is the distributional assumptions of stochastic frontier model. The objective is to assess the technical efficiency of rice production over time, and to observe the time varying inefficiency effects as regards area, seed and fertilizer concerning rice productive systems.

MATERIALS AND METHODS

Data Sources and Variables Construction

Data Set

The data on rice production in Bangladesh is obtained from the yearbook of agricultural statistics of Bangladesh , prepared by the Bangladesh Bureau of Statistics (BBS) every year. The dependent variable namely, rice production and such independent variables as area, seed, the level of fertilizer, rainfall, wage rate per labor without food and wage rate of a bullock pair for each crop are collected from yearly book of agriculture statistics of Bangladesh. For the present study, 29 time periods from 1980-1981 to 2008-2009 are taken into consideration. Such meteorological data as rainfall, temperature, and humidity are collected from the meteorological department in Bangladesh. The yearly distributions of fertilizer data for each rice crop (Boro, Aus and Aman) are collected from Bangladesh Agriculture Development Corporation.

Description of the Variables

Dependent Variable

Production (Y): Total *Boro* (Local, HYV and Hybrid Boro)*, Aus* (Local and HYV Aus) and *Aman* (broadcast, local transplant and HYV Aman) have been estimated at thousand metric tons.

Independent Variables

Area:

The total areas under *Boro, Aus* and *Aman* rice have been estimated in hectares. Here we have considered the total area of cultivated land where specifically *Boro* is the cultivated crop. In this study all the varieties of each crop were taken into consideration.

Seed:

Seed is the very important input item in increasing a crop's production. Therefore it is recommended that the farmers use pure, healthy seeds as per the minimum certification standards of standard percentages. In fact seeds from the foundation of farming highly good quality seeds are of the have genetic purity, physical purity, health standards and the required moisture percentage in accordance with the minimum seed certification standards. For this study the required amount of seed is considered of each variety of crop and is measured in thousand metric tons.

***Fertilizer in Urea*:**

Fertilizer (in urea) is a kingpin in enhancing crop production. The total amount of fertilizer (in urea) used in each crop is considered separately with the unit in metric tons.

***Fertilizer in TSP*:**

Triple Supper Phosphate (TSP) is the major fertilizer applied to agricultural land in various proportions for every crop, including rice production in Bangladesh. The unit of fertilizer (in TSP) is metric tons.

Rainfall:

The primary need for agricultural production in vast parts of the world is rainfall. In this study, total rainfall is considered for *Boro* rice in millimeters, during the February-July session. Total rainfall considered for *Aus vs. Aman* rice consisted of precipitations during March-June *vs.* July-December respectively (Table1).

Analytical Framework

There are two methods employed in literature to estimate technical efficiency. The first one is an econometric approach which aims at developing stochastic frontier models as based on Aigner *et al.* (1977). The second is Data Envelopment Analysis (DEA), which uses either a nonparametric approach or mathematical programming method that is useful for multiple-input and multiple-output production technologies. The econometric approach is stochastic and parametric. It is of the potential to separate the effects of noise from the effects of inefficiency and confound the effects of misspecification of functional form (of both technology and inefficiency) with inefficiency, but generate acceptable results only for a single output as against multiple

Table 1. Summary Statistics of output **vs.** input variables.

Rice firm	Variable	Description	Mean	Std deviation	Min	Max
Boro	Y	Production	8402.0720	4511.9770	2630.00	17809.05
	ARE	Area in hectares	2846.6100	1070.7653	1160.00	4716.25
	SEE	Seed in metric tons	7730.5172	10034.400	453.00	35089.00
	FEU	Urea in metric tons	828.0847	347.63791	259.50	1381.39
	FET	TSP in metric tons	300.0428	135.54711	12.07	257.38
	RAN	Rainfall in millimeter	56889.8276	7218.5235	42264.00	69905.00
Aus	Y	Production	2220.8150	610.52430	2630.00	17809.05
	ARE	Area in hectares	1912.9761	791.26425	1160.00	4716.25
	SEE	Seed in metric tons	505.9655	273.04035	453.00	35089.00
	FEU	Urea in metric tons	656.1693	695.27582	199.50	981.35
	FET	TSP in metric tons	212.0857	102.09422	08.07	137.50
	RAN	Rainfall in millimeter	56889.8276	7218.5235	42264.00	69905.00
Aman	Y	Production	8421.3044	4511.9770	2630.00	17809.05
	ARE	Area in hectares	5671.8581	1070.7653	1160.00	4716.25
	SEE	Seed in metric tons	4364.8276	10034.400	453.00	35089.00
	FEU	Urea in metric tons	556.1793	237.6597	160.50	1181.40
	FET	TSP in metric tons	211.8157	67.0371	10.009	193.42

inputs. On the contrary, the mathematical programming approach is non-stochastic and non-parametric. It cannot separate the effects of noise and inefficiency during the calculation of technical efficiency and is less sensitive to the type of specification error (Kebede 2001), but could be useful in being applied to farms with multiple-input and multiple-output productions.

Since rice production in Bangladesh is an example of single output and multiple-input production, the study focuses on the use of an econometric approach for an assessment of technical efficiency as based on the stochastic frontier production model. A stochastic frontier model is considered as followed by Battese and Coelli (1992) with a simple exponential specification of time-varying firm effects which incorporates for panel data associated with observations on a sample of N firms over T time periods. The model is defined by:

$$Y_{it} = f(x_{it};\beta)\exp(V_{it} - U_{it}); i = 1,2,...,N \quad t = 1,2,...,T \tag{1}$$

Where, Y_{it} represents the production for the *i*-th firm at the t-th period of observation; $f(x_{it};\beta)$ represents a suitable function of a vector, x_{it} stands for vector inputs and firm-specific variables associated with the production of the *i*-th firm in the *t*-th period of observation. the vector, β, is an unknown parameter; V_{it}'s are assumed to be independent and identically distributed N(0, σ_v^2) random errors. The model used here incorporates a simple specification of the time-varying inefficiencies following Battese and Coelli (1992) as:

$$U_{it} = \eta_{it}U_i = \{\exp[-\eta(t-T)]\}U_i \tag{2}$$

Where, η is an unknown scalar parameter to be estimated determining whether inefficiencies are time varying or time invariant. The terms U_i's are assumed to be independent and identically distributed non-negative truncations of the $N\left(\mu,\sigma^2\right)$ distribution and are non-negative random variables associated with the technical inefficiency of production; and finally η

being an unknown scalar parameter. This model is such that the non-negative firm effects, U_{it} decrease, remain constant or increase as *t* increases. If η is positive, then $-\eta(t-T)=\eta(T-t)$ is positive for $t<T$ and so $\exp\{[-\eta(t-T)]\}>1$, which implies that the technical inefficiencies of firms tend to improve their level of technical efficiency over time. If η is zero, then the technical inefficiencies of rice production remain constant, however, if η is negative, then $-\eta[(t-T)]<0$ and thus the technical inefficiencies of industries increase over time. Further, if the T-th time period is observed for the *i*-th firm then $U_{iT}=U_i,\quad i=1,2,...,N.$ Thus the parameters, μ and σ^2, define the statistical properties of the firm effects associated with the last period, for which observations are obtained. In this study, the model is assumed for the firm effects, U_i, is a generalization of the half-normal distribution which was proposed by Stevenson (1980). To permit greater flexibility in the nature of technical efficiency, a two parameter specification can be defined from (2) as follows, $\eta_{it}=1+\eta_1(t-T)+\eta_2(t-T)^2$, where η_1 and η_2 are unknown parameters. This model permits firm effects but the time-invariant model is the special case in which $\eta_1=\eta_2=0$. Given the model (l)-(2), it can be demonstrated that the technical efficiency of the *i*-th firm at the *t*-th time period would be:

$$TE_{it}=\exp(-U_{it})\,\mathrm{T} \qquad (3)$$

The parameters of the stochastic frontier model (1) here will be estimated using Maximum Likelihood Estimation (MLE). The total variation in output from the frontier level of output in terms of stochastic frontier model attributed to technical efficiency is defined by $\gamma=\sigma_u^2/\left(\sigma_u^2+\sigma_v^2\right)$. The variance parameter γ lies on the interval [0, 1]. In the truncated and half-normal distribution, the ratio of rice firm specific variability to total variability, γ, is positive and significant, implying that rice firm specific technical efficiency is important in explaining the total variability of output produced.

Empirical Stochastic Frontier Models

***Cobb-Douglas Stochastic Frontier Model*:**

There are several functional forms for estimating the relationship between inputs and output. Since the Cobb-Douglas functional form is preferable to other forms if there are three or more independent variables in the model (Hanley and Spash 1993), the Cobb-Douglas production function with five independent variables is applied in the present study. This paper devotes the Cobb-Douglas stochastic frontier production with the distributional assumption to assess the rice technical efficiency due to advantages over the other functional forms (Kalirajan and Flinn, 1993; Dawson and Lingard, 1989; Coelli and Battese, 1996). Since the panel data is used in this study and the sample is not very large, so try the Translog specification could not be tried. Following Battese and Coelli (1992) the model (1) can be expressed into the Cobb-Douglas stochastic frontier production functional form through the logarithm:

$$lnY_{it}=\beta_0+\ \beta_{ARE}ln\ AREAit+\ \beta_{SEE}lnSEED_{it}+\beta_{FEU}lnFERU_{it}+\ \beta_{FET}lnFERT_{it}+\ \beta_{RAN}lnRANF_{it}+V_{it}-U_{it}$$

(4) *i*=1, 2, 3; *t*=1, 2, 3……..29

Where, Y_{it}= Production in the *i*-th rice (Boro, Aus and Aman) production firm with *t*-th period; *AREAit* = Area in the i-th rice production firm with *t*-th period; $SEED_{it}$= Quantity of seed of the *i*-th rice production firm in the *i*-th rice with *t*-th period; $FERU_{it}$= Amount of fertilizer (in urea) in the *i*-th rice production firm with *t*-th period; $FERT_{it}$= Quantity of fertilizer (in TSP) in the *i*-th rice production firm with *t*-th period; $RANF_{it}$= Level of rainfall in the *i*-th rice production firm of the *t*-th period; $\beta_0\beta_{ARE}\beta_{SEE}\beta_{FEU}\beta_{FET}\beta_{RAN}$=

Unknown parameters to be estimated; *ln*= Refers to the natural logarithm; *i*= The number of rice types (Boro, Aus and Aman), and *t*= Time period.

The systematic error component V_{it} , which is assumed to be independently and identically distributed as $V_{it} \sim NID\left(0, \sigma_v^2\right)$ independent of U_{it} assesses the technical efficiency relative to the stochastic frontier. The important problem, however, is to specify an appropriate one-side distribution for U_{it}. Since U_{it} is the main focus of interest in the model, the focus in this study would be on distributional assumption as regards U_{it}.

***Half Normal Distribution in the Cobb-Douglas Stochastic Frontier Model*:**

In this study, it is assumed that the distribution of U_{it} belongs to the half–normal distribution, i.e., the inefficient component U_{it} is assumed to be half-normal $N\left(0, \sigma_u^2\right)$, then the density function of *U* will be

$$f(u) = \frac{2}{\sqrt{2\pi}\sigma_u} \exp\left\{-\frac{u^2}{2\sigma_u^2}\right\} \qquad u \geq 0.$$

Truncated Normal Distribution in the Cobb-Douglas Stochastic Frontier Model:

The half-normal distribution for the inefficient component U_{it} restricts the mode of the distribution to occur at *U*= 0. Stevenson (1980) suggests the use of truncated normal distribution for U_{it} so that the mode need not necessarily be zero. The density function of the truncated normal random variable is:

$$f(u) = \frac{\frac{1}{\sqrt{2\pi}\sigma_u} \exp\left\{-\frac{1}{2}\left(\frac{u-\mu}{\sigma_u}\right)^2\right\}}{\Phi\left({\mu}/{\sigma_u}\right)}, \qquad u \geq 0$$

Where, $\Phi(.)$ stands for the standard normal distribution function.

Tests of Hypothesis

A series of formal hypothesis tests are conducted to determine the distribution of the random variables associated with the existence of technical inefficiency and the residual error term. The case of null hypothesis *γ*= 0, expresses that the technical inefficiency effects are not present in the model. The half-normal distribution is a special case of the truncated normal distribution, and implicitly involves the restriction $H_0{:}\mu = 0$.The hypothesis that efficiency is invariant over time (i.e. η= 0) will be tested. These are tested through imposing restrictions on the model and using the generalized likelihood-ratio test statistic (λ) to determine the significance of the restriction. The generalized likelihood ration statistic is defined by:

$$\lambda = -2\{\ln[L(H_0)/L(H_1)]\} = -2\{\ln[L(H_0)] - \ln[L(H_1)]\}. \tag{5}$$

Where, $\ln[L(H_0)]$= The value of the log likelihood function for the stochastic frontier estimated under null hypothesis and $\ln[L(H_1)]$= The value of the log-likelihood function for stochastic production function under alternative hypothesies.

RESULTS AND DISCUSSION

Estimation of Cobb-Douglas Stochastic Frontier Model

The Ordinary Least Square (OLS) estimates of the parameters of Cobb-Douglas production function were obtained through grid search in the first step and then used to estimate the maximum likelihood estimates of the parameters of Cobb-Douglas stochastic frontier production model. Table 2 shows that the maximum-likelihood estimate of the parameter with time varying inefficiency effects for rainfall input are -0.0797 and -0.0593 for the truncated *vs.* half normal distributions respectively. For both distributions the coefficient of rainfall was found to be insignificant. These results also confirmed that rainfall bears low output elasticity. On the other hand, area input is significantly

Table 2. Maximum-likelihood estimates of the Cobb-Douglas Stochastic Frontier model. Distributions with Time variant efficiency effects, rice production.

Variable	Parameter	Truncated-Normal			Half-Normal		
		Coefficient	SE[a]	*T*-Ratio	Coefficient	SE	*T*-Ratio
Constant	β_0	1.9975^{***}	0.4998	3.996	2.0362^{***}	0.4451	4.5752
Area	β_{ARE}	1.0495^{***}	0.0400	26.188	1.0306^{***}	0.0409	25.152
Seed	β_{SEE}	0.0346^{*}	0.0191	1.8078	0.03354^{*}	0.01796	1.672
FERU	β_{FEU}	-0.3560^{***}	0.0839	4.2431	-0.3258^{***}	0.07369	4.4222
FERT	β_{FET}	0.0284^{***}	0.0098	2.8981	0.0306^{***}	0.01037	2.9529
RANF	β_{RAN}	-0.0797^{b}	0.0706	1.1291	-0.0593^{b}	0.06327	-9374
SIGMA	σ^2	0.0241^{***}	0.00274	9.7927	0.3696^{b}	0.3721	.9935
GAMMA	γ	0.9643^{***}	0.0068	140.4	0.9975^{***}	0.0022	437.75
MU	μ	0.3055^{***}	0.0368	8.2940	0	0	0
ETA	η	0.0262^{***}	0.0035	7.2927	0.02007^{***}	0.0055	3.6441
Ln-Likelihood		172.7100			172.171		
Mean efficiency		0.532134			0.45149		

***; **, *: Significance level at 1; 5, 10%.

[a] Standard Error, [b] Means insignificant.

different from zero at 1 percent level of significance for both distributions. Here it is to be mentioned that the coefficient of area is highly significant at 1% level. The coefficient for seed is statistically significant at 10 percent level in the truncated normal distribution and in half normal distributions. So, there is an overall indirect impact of their technical inefficiencies on rice production. The coefficient of fertilizer (in urea) is found to be negative but significant at 1 percent level in both distributions. This means that there exists a negative response to rice production. The coefficient of fertilizer (in TSP) is found to be positive and significant at 1 percent level. This means that there exists a positive response on its side to rice production. The large difference was identified in the variance parameters arising from the two distributions. This difference in variance parameters could be due to the specification of the distribution of the error term. For the truncated and for half-normal istribution, $\gamma = \sigma_u^2 / \left(\sigma_u^2 + \sigma_v^2\right)$, is estimated at 0.964 and 0.995 levels respectively, which could be interpreted as follows: 96 *vs.* 99 percent of random variations for truncated *vs.* half-normal distribution in rice production are due to inefficiency. These can be interpreted that 96 *vs.* 99 percent of the variations in output among the rice crops are due to the differences in technical efficiency for either of the distributions respectively. It is evident that the estimates of σ^2 amount to 0.0241 and 0.371 for truncated and half-normal distributions respectively. They are observed significant in case of truncated normal but insignificant for the half-normal case; indicating the correctness of the assumptions of truncated and half-normal distributions. The estimates for the parameters of time varying inefficiency model, indicate that the technical inefficiency effects tend to increase over time since the estimate for the η parameter is found positive (i.e. $\eta =$ 0.02). Also the parameter μ is positive indicating that the distribution of the inefficiency effects is not more concentrated around zero, as compared with half-normal distribution.

From Table 3, it becomes evident that the coefficient of area is significant at 1% level for half normal distribution while this coefficient for the truncated normal distribution is found as insignificant. This means that the inefficiency effects of area bears an indirect effect on the rice production in Bangladesh. The coefficients of seed and fertilizer are observed as significant in case of half normal distribution while they are found insignificant in case of truncated normal distribution. Hence there is an indirect effect observed on the rice production. The coefficient of rainfall is recorded as insignificant, meaning that rainfall has not influenced the rice production of the crop rice. The coefficient of seed is found highly significant at 1% level in case of half-normal distribution while it is observed insignificant in case of truncated normal. The ratio of rice specific variability to total variability, γ, associated with the variance of the technical inefficiency effects is observed relatively low. For the truncated *vs.* half-normal distribution, γ is estimated at levels 0.21 and 0.97 respectively. These can be interpreted that 21 and 97 percent of the random variations having occurred in rice production are due to the differences in technical efficiency for either one of the distributions. The estimated value of μ is found statistically insignificant for the truncated-normal distribution. The η parameter is restricted to zero in the model with time invariant inefficiency effects.

Yearwise Technical Efficiency of Rice: Results from Truncated Normal *vs.* Half-Normal Model

Yearwise mean efficiencies of three types of rice crop in Bangladesh, by two distributions with time variant, are displayed in Table 4 and in Figure 1. It can be observed that the mean efficiency for *Boro* rice and for truncated normal distribution is indicated 0.6035 while for the half-normal distribution the mean efficiency is 0.5166. For both distributions, the technical efficiency increased over time. In other words, the overall average levels of efficiency of *Boro* rice increased over the period 1980-2008. It is also shown that

Table 3. Maximum-Likelihood Estimates of the Cobb-Douglas Stochastic Frontier Model with time invariant Efficiency Effects, Rice Production.

Variable	Parameter	Truncated-Normal			Half-Normal		
		Coefficient	SE[a]	*T*-Ratio	Coefficient	SE	*T*-Ratio
Constant	β_0	1.0955^b	0.98	1.115695	-0.0936^b	0.4321	-0.2166
Area	β_{ARE}	0.4787^b	0.698	0.6857	0.8003^{***}	0.0445	17.9686
Seed	β_{SEE}	0.2875^b	0.385	0.7467	0.1095^{**}	0.0233	4.6917
FERU	β_{FEU}	-0.0856^b	0.48	-0.17791	0.1757^{***}	0.0335	5.2392
FERT	β_{FET}	0.0119^b	0.56	0.0209	0.0217^b	0.0142	1.5298
RANF	β_{RAN}	0.0692^b	0.41	0.1664	0.0613^b	0.0887	0.6912
SIGMA	σ^2	0.0039^b	0.00	0.4317	0.0725^b	0.0587	1.2354
GAMMA	γ	0.2151^b	0.96	0.2219	0.9760^{***}	0.0198	49.218
MU	μ	0.0581^b	0.86	0.0674	0	0	0
ETA	η	0	0	0	0	0	0
Ln-Likelihood			116.3383			144.3026	
Mean efficiency			0.9235			0.8114	

***; **, *: Significance level at 1; 5, 10%.

[a] Standard Error, [b] Means insignificant.

Table 4. Yearwise efficiencies of *Boro* rice production by two distributions, time variant.

Yearwise efficiencies of rice in Bangladesh by two distributions, time variant						
CROPS	*Boro* Rice		*Aus* Rice		*Aman* Rice	
Year	Truncated normal	Half-Normal	Truncated-Normal	Half-Normal	Truncated normal	Half-Normal
1980-1981	0.4833	0.4187	0.3601	0.3099	0.3714	0.3231
1981-1982	0.4974	0.4261	0.3698	0.3172	0.3810	0.3304
1982-1983	0.5065	0.4333	0.3794	0.3245	0.3906	0.3378
1983-1984	0.5155	0.4406	0.3891	0.3319	0.4003	0.3452
1984-1985	0.5244	0.4478	0.3987	0.3392	0.4099	0.3525
1985-1986	0.5332	0.4551	0.4083	0.3466	0.4194	0.3599
1986-1987	0.5420	0.4622	0.4179	0.3540	0.4290	0.3673
1987-1988	0.5060	0.4694	0.4274	0.3614	0.4385	0.3747
1988-1989	0.5592	0.4765	0.4369	0.3687	0.4479	0.3821
1989-1990	0.5677	0.4836	0.4464	0.3761	0.4573	0.3894
1990-1991	0.5761	0.4906	0.4558	0.3835	0.4667	0.3968
1991-1992	0.5843	0.4976	0.4651	0.3909	0.4760	0.4042
1992-1993	0.5925	0.5045	0.4744	0.3983	0.4852	0.4115
1993-1994	0.6006	0.5114	0.4837	0.4056	0.4944	0.4188
1994-1995	0.6086	0.5183	0.4929	0.4129	0.5035	0.4262
1995-1996	0.6165	0.5251	0.5020	0.4203	0.5125	0.4334
1996-1997	0.6242	0.5319	0.5110	0.4276	0.5214	0.4407
1997-1998	0.6392	0.5386	0.5200	0.4349	0.5303	0.4479
1998-1999	0.6394	0.5453	0.5288	0.4421	0.5391	0.4551
1999-2000	0.6469	0.5519	0.5376	0.4493	0.5478	0.4623
2000-2001	0.6542	0.5584	0.5463	0.4565	0.5564	0.4695
2001-2002	0.6614	0.5649	0.5549	0.4637	0.5649	0.4766
2002-2003	0.6685	0.5714	0.5635	0.4709	0.5733	0.4836
2003-2004	0.6755	0.5778	0.5719	0.4780	0.5816	0.4907
2004-2005	0.6824	0.5841	0.5802	0.4850	0.5898	0.4977
2005-2006	0.6892	0.5904	0.5885	0.4920	0.5979	0.5046
2006-2007	0.6959	0.5966	0.5966	0.4990	0.6059	0.5115
2007-2008	0.7024	0.6028	0.6048	0.5060	0.6138	0.5184
2008-2009	0.7089	0.6088	0.6125	0.5129	0.6216	0.5252
Mean	0.6035	0.5166	0.4905	0.4123	0.5009	04254

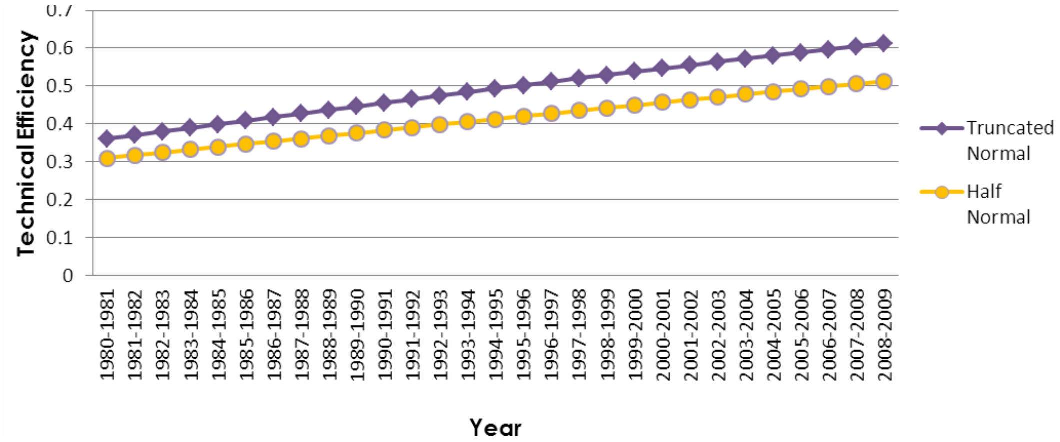

Figure 1. Yearwise technical efficiency of *Boro* rice for Truncated *vs.* Half Normal distributions.

within the year 1981 the technical efficiencies related to *Boro* rice amounted to only 48.33 and 41.89% percent for truncated *vs.* half-normal distributions respectively. In year 2009, the technical efficiencies for *Boro* rice are found to be 70 *vs.* 60% for truncated *vs.* half normal distributions respectively. The technical efficiency being increased means that the production of *Boro* rice was growing rapidly. This implied that during the year 2009, 70 and 60 percent of potential output are being realized by *Boro* as according to truncated normal and half-normal distributions respectively. (Tables 2-3)

The truncated normal distribution exhibited higher technical efficiency estimates in comparison with the half normal distribution. Yearwise mean efficiency of *Aus* rice in Bangladesh through two distributions of time variance are displayed in Table 4 and in Figure 2. In case of truncated normal distribution, the mean efficiency is recorded with the value (0.4905) while for the half-normal distribution the mean efficiency is 0.412376. However, technical efficiency increased for both distributions. In other words, the overall mean efficiency increased over the period 1980-1981 to 2008-2009. It was also revealed that for the first five years, technical efficiency was observed to vary from 31 to 39 percent for either one of the distributions. For truncated and half normal distributions, the technical efficiencies for the year 2009 are recorded 61.25 *vs.* 51.29 percent respectively, so one can conclude that a better technical efficiency is recorded for *Aus* with truncated normal distribution. It is also deducted that the technical efficiency being one the increase, would mean that the *Aus* rice production would also be growing rapidly. In addition, this implied that 61.25 *vs.* 51.25 percent of potential output were being realized through *Aus* rice production according to truncated normal *vs.* half-normal respectively. The truncated normal distribution showed higher technical efficiency estimates than the half normal distribution. Here both *Boro* and *Aus* rice production with truncated normal demonstrated higher technical efficiencies.

The yearwise mean efficiency for *Aman* rice in Bangladesh and through two distributions with time variant is displayed in Table 4 and in Figure 3. It is observed that the mean technical efficiency for truncated normal distribution bears a value of 0.5009 while for the half-normal distribution the mean efficiency amounts to 0.4254. The technical efficiency increased according to either of the distributions. In other words, the overall mean efficiency increased over the years 1980-1981 to 2008-2009. In the case of *Aman,* it was also revealed that the first five years of technical efficiency varied from 32 to 40 percent for either one of the distributions. For truncated *vs.* half normal, the technical efficiencies for the year 2009

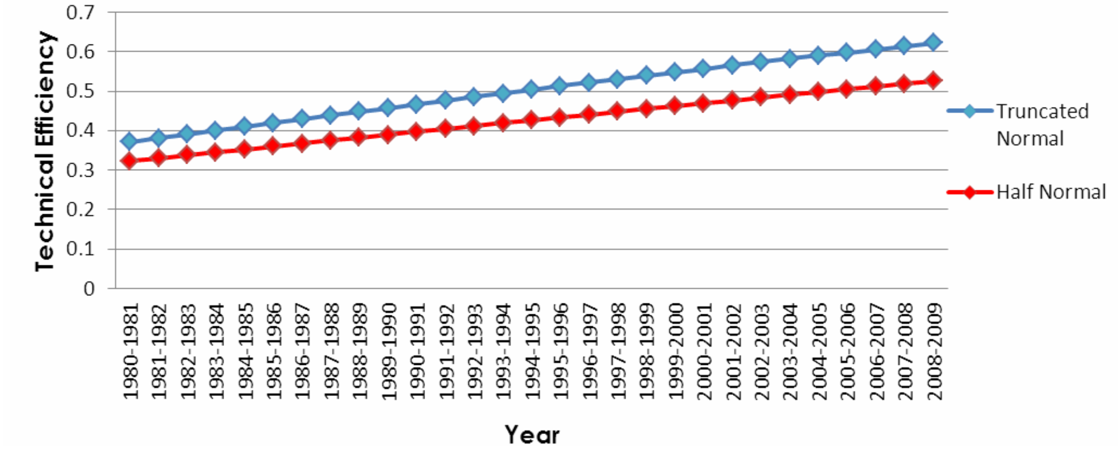

Figure 2. Yearwise technical efficiency of *Aus* rice for Truncated *vs.* Half Normal distributions.

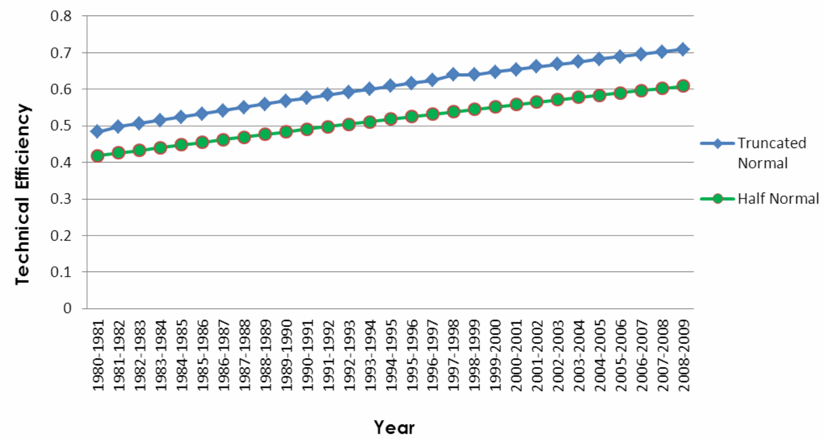

Figure 3. Yearwise technical efficiency of *Aman* rice for Truncated *vs.* Half Normal Distributions.

are found to be 62.16 *vs.* 52.52 percent respectively. *Aman* rice production is extended rapidly due to its technical efficiency being increased. This implies that 62 *vs.* 52 percent of potential output is being realized by *Aman* rice according to the truncated normal distribution *vs.* half-normal distributions respectively. The truncated normal distribution showed higher technical efficiency estimates than the half normal distribution. So one can conclude that the better technical efficiency is found for *Aman* rice with truncated normal distribution. From the overall analysis it is concluded that the technical efficiency for each rice crop indicated a better efficiency when truncated normal applied, and for *Boro* rice, a higher technical efficiency in comparison with the other types of rice crops was observed.

Yearwise Mean Technical Efficiency: Results from Truncated *vs.* Half-Normal Model

The yearly mean efficiency for three types of rice in Bangladesh is displayed in Table 5 and Figure 4. It can be observed that the highest mean efficiency was found for the truncated normal in 2009 with an efficiency score of 64.77 percent while the lowest mean efficiency occurring in 1981 with an efficiency score of 40.66 percent. In 2009 the mean efficiency increased by 24 percent

Table 5. Yearwise mean technical efficiency of rice production through two distributions, time-variant.

Year	Efficiency for Truncated-Normal	Efficiency for Half-Normal
1980-1981	0.4066	0.3506
1981-1982	0.4161	0.3579
1982-1983	0.4255	0.3652
1983-1984	0.4349	0.3725
1984-1985	0.4443	0.3799
1985-1986	0.4537	0.3872
1986-1987	0.4629	0.3945
1987-1988	0.4722	0.4018
1988-1989	0.4813	0.4091
1989-1990	0.4905	0.4164
1990-1991	0.4995	0.4236
1991-1992	0.5085	0.4309
1992-1993	0.5174	0.4381
1993-1994	0.5262	0.4453
1994-1995	0.5350	0.4525
1995-1996	0.5436	0.4596
1996-1997	0.5522	0.4667
1997-1998	0.5607	0.4738
1998-1999	0.5691	0.4808
1999-2000	0.5774	0.4878
2000-2001	0.5856	0.4948
2001-2002	0.5937	0.5017
2002-2003	0.6018	0.5086
2003-2004	0.6097	0.5155
2004-2005	0.6175	0.5223
2005-2006	0.6252	0.5290
2006-2007	0.6328	0.5357
2007-2008	0.6403	0.5424
2008-2009	0.6477	0.5490
Mean	0.5321	0.4521

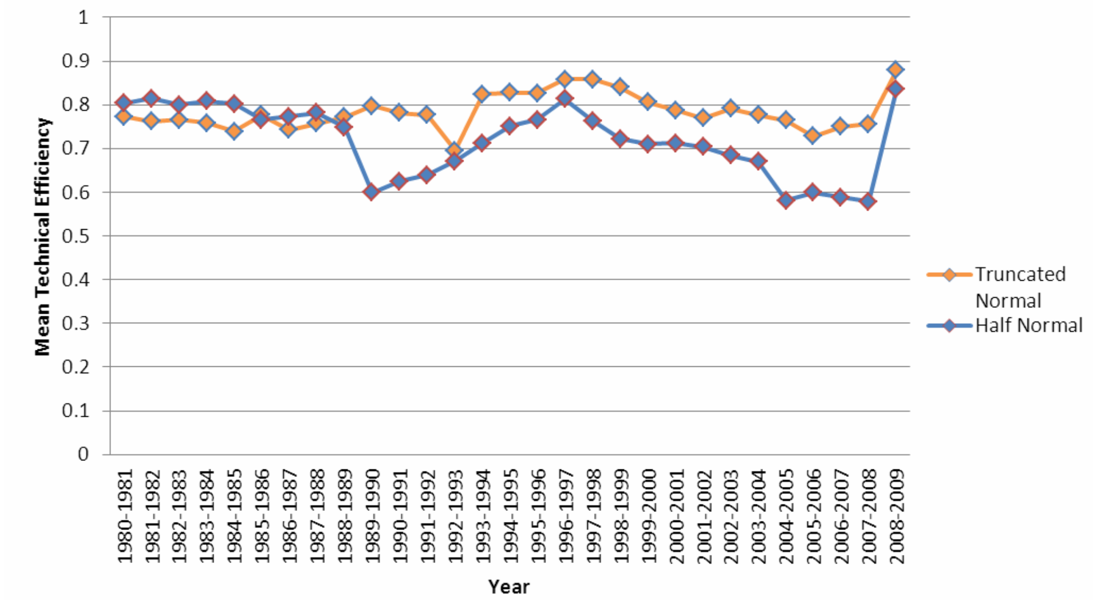

Figure 4. Yearwise mean efficiencies of rice production through two distribution methods.

in comparison with 1981. In other words, the overall mean efficiency increased over the period of years 1980-81 to 2008-09. Time is observed as an important element in increasing efficiency. It is also revealed that the mean technical efficiency of rice production in case of truncated normal during the period 1980-81 to 2008-09 is found to be 0.5321. This implies that 53 percent of potential output is being realized by the three types of rice crops. For the half normal distribution, it was observed that the highest mean efficiency is recorded for 2009 with an efficiency score of 54.9% while the lowest recorded in 1980 with a score of 35%. The overall mean efficiency during the reference period is recorded 0.4521 percent only. In 2009 the mean efficiency increased by 19 percent from 1981. Finally it was concluded that the technical efficiency of rice production in Bangladesh was more accurately appraised with truncated normal distribution as compared with half normal distribution.

Cropwise Technical Efficiency: Results from Truncated Normal *vs.* Half-Normal Model with Time Invariant

Cropwise technical efficiency with respect to either one of truncated normal *vs.* half-normal model and with time-invariant is displayed in Table 6. The mean technical efficiencies for either one of the truncated *vs.* half-normal distributions are found to be 0.92 and 0.81%. This shows that mean technical efficiency of rice crop gained about 0.92% of its maximum attainable return for the truncated normal distribution,

Table 6. Cropwise technical efficiency: Results from Truncated-Normal *vs.* Half-Normal model with time-invariant.

Rice crop	Efficiency for Truncated-Normal	Efficiency for Half-Normal
BORO	0.9869	0.9851
AUS	0.8553	0.6944
AMAN	.92771	0.7547
Mean efficiency	0.9258	0.81145

whereas about 0.81% of the maximum attainable return for the case of half-normal distribution. For the truncated normal distribution, there is a variation in the technical efficiencies among the different type rice crops as rice production in Bangladesh is concerned, namely: it ranged from a low of 0.8553 for *Aus* to a high of 0.9869 for *Boro* rice. This was while for the half-normal distribution it ranged from a low of 0.6944 for *Aus* to a high of 0.9851 for *Boro* rice. In case of both truncated normal *vs.* half normal distributions, the value of technical efficiency is found high for *Boro* rice while low for *Aus* rice in comparison with *Aman* rice crop in Bangladesh. The greater technical efficiencies are observed in case of truncated normal distribution as compared with the half-normal distribution.

Results Obtained from Test of Hypothesis

Formal tests of various hypotheses were conducted employing the Likelihood Ratio (L-R) test statistic presented in Table 7. The first null hypothesis, H_0: $\gamma = 0$ specifies that there are no technical inefficiency effects in the model. Since the hypothesis is rejected so it is concluded that there exists a technical inefficiency effect in the model. This implies that the technical inefficiency effects associated with rice production in Bangladesh are found to be significant. The technical inefficiency effects having a half-normal distribution, are tested through null hypothesis H_0: $\mu = 0$. This hypothesis is accepted in this study indicating that half normal is preferable to truncated normal distribution. The hypothesis H_0: $\eta = 0$ is rejected, indicating that the technical inefficiency effect varied significantly over time.

COCLUSIONS

The patterns of technical efficiency of rice production in Bangladesh is herein investigated making use of the Cobb-Douglas stochastic frontier production function. The model is estimated with the specification of the technical inefficiency effects models. Results indicate that rice production in Bangladesh is seen to be increased in time varying and in time invariant. The results indicated that the input variables included in the technical inefficiency effects have had significant influence on rice production, especially seed and fertilizer (in TSP) within the rice production system. From the results it is also understood that rainfall is observed as insignificant in rice production of Bangladesh. The time-varying inefficiencies' parameter, η, is found positive for the truncated normal and as well for the half-normal distributions. It is indicated that technical inefficiency increased over the reference period. Through the several tests, it is observed that the technical inefficiency effects are significant implying that technical inefficiency effects associated with the rice crops are significant. The half normal distribution is found to be

Table 7. Likelihood-ratio test of hypothesis of the Stochastic Frontier Product Function for rice production in Bangladesh.

Null hypothesis	Log-likelihood function	Test statistic	Critical value*	Decision
$H_0 : \gamma = 0$	107.1554	131.109	7.045	Reject H_0
$H_0 : \eta = \mu = 0$	144.3026	56.8148	2.706	Reject H_0
$H_0 : \mu = 0$	172.171	1.078	5.138	Accept H_0
$H_0 : \eta = 0$	116.3383	112.7434	5.138	Reject H_0

Notes: The critical values are significant at 5% level of significance.

preferable to the truncated normal distribution for the technical inefficiency effect and the technical efficiency rate is found as gradually increasing over time as regards rice production. Moreover, technical inefficiency effects are also positively influenced by seed within the production process. Policies that lead to provision of improved seed to the farmer could be beneficial in enhancing efficiency in rice production in Bangladesh. In this regard, suggestions are pertinent for government and policy makers that efficient utilization as well as a combination of fertilizer and improved seed can reduce the inefficiency effects in rice production.

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مدل مرزی ضمنی (Stochastic Frontier Model) همراه با فرضیات توزیعی (Distributional Assumptions) ، مورد : کارآئی فناوری در تولید برنج

ع. باطن ، و ا. حسین

چکیده

بازده یا کارآئی در کشاورزی نشانگر سطح کارآئی خانوارهای روستائی در زمینهٔ فعالیت کشاورزی و یا کشت و کارآنها است. کشاورزان در کشورهای در حال توسعه از تمامی عوامل و منابع بالقوهٔ کارآئی فناوری (Techinal Efficiency) استفاده نکرده و در نتیجه تصمیماتی ناکافی در رابطه با چگونگی فعالیتهایشان اتخاذ می‌نمایند. در تحقیق حاضر، بازدهی فناوری در ارتباط با تولید سه نوع برنج امان،آوس و برو (Aman, Aus, Boro) با عنایت به تعیین پاره‌ای از فاکتورهای تأثیرگذار بر بازدهی فناوری (در بنگلادژ) مورد بررسی قرار گرفت و پاره‌ای از فاکتورهای تأثیرگذار بر بازدهی یا کارآئی فناوری تعیین شدند. در خلال این مطالعه تلاش شد وضعیت بازدهی فناوری در محدودهٔ تولید برنج (با توجه به داده‌های موجود) و استفاده از مدل تولید مرزی ضمنی (Stochastic Frontier Production Model) با فرضیات توزیعی (Distributional assumptions) ، هریک از دو روش نرمال کوتاه (Truncated normal) یا نیمه نرمال (Half normal) مورد بررسی قرار گیرد. بعلاوه ، هریک از دو مدل تأثیر عدم بازدهی (Insufficiency effect models) اعم از وابسته و یا غیر وابسته به زمان (Time variant vs Time invariant) به طور جداگانه مورد بررسی قرار گرفتند. در خلال تحقیق، از آمار و اطلاعات جمع‌آوری شده از بخش کشاورزی در ارتباط با سه نوع عمدهٔ محصول برنج در بنگلادژ برای سالهای ۱۹۸۰ تا ۲۰۰۸ استفاده شد. نتایج نشان داد که بازدهی فناوری به تدریج در طی دوره مطالعه افزایش پیدا کرده و روش توزیع نیمه نرمال بر روش توزیع نرمال کوتاه شده (با عنایت به تأثیرات عدم بازدهی فناوری (Technical inefficiency effects) ارحجیت داشت. بازدهی فناوری برنج نوع *Boro* (در هریک از وضعیت‌های وابسته یا غیروابسته به زمان) با مقایسه با برنج *Aman* در سطح بالا و بازدهی فناوری برنج نوع *Aus* (در قیاس با *Aman*) در سطحی پائین قرار گفت. نهایتاً اینگونه مشاهده و نتیجه‌گیری شد که سیستم کارائی (توام با بیشترین بازدهی محصول و در رابطه با تولید برنج) در مورد Boro (با بازدهی فناوری ۰/۹۸) محقق شده است.