Research Journal of Applied Sciences, Engineering and Technology 12(6): 628-637, 2016
DOI:10.19026/rjaset.12.2710
ISSN: 2040-7459; e-ISSN: 2040-7467

Submitted: March 21, 2015 Accepted: April 22, 2015 Published: March 15, 2016

Research Article

Climatic Change and Environmental Effects on Rice Productive Efficiency

[1]Ismail Hossain, [2]Md. Azizul Baten and [3]Kashfi Rayan
[1]Monitoring and Evaluation Division (M&E), Directorate of Primary Education (DPE), Mirpur-2, Dhaka-1216, Bangladesh
[2]Department of Decision Science, School of Quantitative Sciences, Universiti Utara Malaysia, 01610 UUM Sintok, Kedah, Malaysia
[3]Department of Economics, American International University of Bangladesh (AIUB), Dhaka-1213, Bangladesh

Abstract: This study is concerned with the productive efficiency among rice crops (Aus, Aman and Boro) and identifies the impact of climatic and environmental effects on rice production using a translog stochastic production frontier model in Bangladesh. The result shows that the translog production function fits the study better than the Cobb-Douglas production and there is a comprehensible impact on input variables of rice productive efficiency. The γ -estimate associated with the variance of the technical inefficiency effect is found large and significant (90%). The mean technical efficiency of the three types of rice during the period 1980 to 2008 is found to be 78, 71 and 80%, respectively. The loss of technical efficiency from the optimum level has occurred, because of lack of proper combination of related input variables. Among the inputs rainfall and good seed are recorded to be the most significant factor in rice production. The square effect of Area is found statistically significant with a negative value at 1% level of significance. The interaction effect of Area and Seed has been statistically significant. It is also observed that the interaction effect among the inputs and environmental factors exist in rice production. The explanatory variables are found decreasing the level of inefficiency and the climatic factors played the essence rule in rice productive efficiency in Bangladesh.

Keywords: Climatic change, environmental effect, productive efficiency, rice crops, translog stochastic frontier model

INTRODUCTION

Climate is one of the major controlling factors for well-being of the residents of the world. But **c**limate variability and change, its impacts and vulnerabilities are growing concern worldwide. Climate and agriculture are interrelated processes, both of which take place on a global scale (Fraser, 2008). The climate in Bangladesh has been changing and it is becoming more unpredictable every year (Sikder, 2010). Global warming induced changes in temperature and rainfall are already evident in many parts of the world, as well as in Bangladesh (Ahmed and Alam, 1999). The overall effect of changing climatic condition on agriculture will depend on the balance of these effects. Assessing the effects of global climate condition change on agriculture would ensure to properly anticipate the weather extremes brought by global warming and adapt farming techniques to continue the growth of agricultural production.

Efficiency measures are also important because of its vital role on rice productivity growth. 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 (Richard and Shively, 2007). A number of studies have examined the productive efficiency of different type of crops in Asia and other countries (Kalirajan, 1981; Erwidodo, 1990; Kalirajan and Shand, 1989; Ekanayake, 1987; Hanley and Spash, 1993; Mythili and Shanmugan, 2000; Shanmugam, 2000; Squires and Tabor, 1991; Ahmad *et al*., 1999; Ajibefun *et al*., 2002; Ali and Flinn, 1989; Battese, 1992; Battese and Coelli, 1992; Battese and Coelli, 1995; Travers and Ma, 1994; Fan *et al*., 1994; Wang *et al*., 1996a, 1996b; Xu and Jeffrey, 1998; Fan, 1999; Tian, 2000; Tian and Wan, 2000; Wadud and White, 2000; Constantin *et al*., 2009; Tan *et al*., 2010). The impacts of using advanced techniques on rice productive efficiency in developing countries have been conducted by Bordey

Corresponding Author: Ismail Hossain, Monitoring and Evaluation Division (M&E), Directorate of Primary Education (DPE), Mirpur-2, Dhaka-1216, Bangladesh, Tel.: +8801615555655

(2004), Chengappa *et al*. (2003) and Khuda *et al*. (2005). In this context, Stochastic Frontier Approach has found wide acceptance within the agricultural economics (Battese and Coelli, 1992, 1995).

Rice is a major source of livelihood of rural population in most Asian countries and there are about 4 billion people who consume over 90% of the world's rice production. Rice was selected in this study because of its prominent position in the national economy of Bangladesh. There exist few literatures in estimating stochastic frontier production and consequently dealing with technical inefficiency of rice production in Bangladesh (Rahman *et al*., 1999; Dev and Hossain, 1995; Banik, 1994; Rahman, 2002). Khan *et al*. (2010) examined the influenced of farmers' age, education and experience on technical efficiency of *Boro* and *Aman* production using Cobb-Douglas production function and they found that education was positively related to technical efficiency. However, none of these studies focused on the potential influence of climatic conditions to enhancing technical efficiency of rice production. Given this back drop, the present study assesses the effects of climatic conditions (Rainfall, Humidity and Temperature) in Bangladesh on rice productive efficiency followed by stochastic frontier model (Battese and Coelli, 1995). In spite of this, the country is languishing with food deficit and each year the country has been importing over one million metric tons of rice at the expense of hard-earned foreign currency (BBS, 2009). The government of Bangladesh usually imports additional rice every year to meet the population demands. An earlier Agricultural Research Strategy document prepared by the Bangladesh Agricultural Research Council (BARC) projected the required paddy production by 2020 at 52 million tons (34.7 million tons of rice), which would require a production growth of 2.2% per year (Azad *et al*., 2008). The average rice yield in Bangladesh was 2.81 tones/ha in 2008-2009 (BBS, 2010), which is much lower compared to those of other Asian countries such as China, South Korea, Indonesia, Japan and Vietnam (FAPRI, 2009). The impacts of climate change on food production are global concerns and they are very important for Bangladesh (Basak *et al*., 2010). Rice production in Bangladesh is a major concern in recent years due to changing climatic conditions and environmental effects because there is a significant amount of rice production may hamper for climatic change and environmental effect. A number of studies have been examined the productive efficiency in its domain of agricultural production. But a few studies of the impact of climatic change and environmental effects on rice production using translog frontier production are available in the literature. For example, Tan *et al*. (2010) showed the impact of land fragmentation on rice producers' technical efficiency in South-East China. But no studies are found to estimate the productive efficiency with the impact of climatic change and environmental effects considering three rice crops (Boro, Aus and Aman) except Hossain *et al*. (2012). However, Hamjah (2014) conducted a study to measure the efficiency regarding the climatic and hydrological effects on cereal crop productions in Bangladesh but not in the rice crops. Baten *et al*. (2012) conducted a study on efficiency of rice growing farmers in selected area of Mymensingh district in Bangladesh with the environmental awareness but not considering the impact of climatic change on rice production.

Only a few studies have been carried out on the efficiency of rice production in Bangladesh, even though rice production is very important for ensuring food security considering the country's vulnerability to climate change.

Have farmers concerned the impact of climatic change on rice production? How have the policies undertaken by governments impacted rice production and a farmer's technical efficiency? So, it is important to evaluate the impact of climatic change and environmental effects on rice production in Bangladesh. This study also attempts to investigate the effect of other inputs such as area, seed and variety of fertilizer in rice production. This study may assist policy makers to design and formulate policy to increase rice production in Bangladesh. How have the policies undertaken to be aware of farmers regarding the effect of climatic conditions on rice production in Bangladesh. This study partly sought to answer of the question. This study has the following specific objectives:

- To measure productive efficiency of the three types of rice crops.
- To determine the effect of interaction among inputs and environmental factors in rice crops production.
- To investigate the influence of climatic and environmental effects on rice productive efficiency in Bangladesh.

MATERIALS AND METHODS

Sources of data:

- Rice production, Seed, Area, The average daily wage rate per man without food data and The Wage rate for Bullock: Bangladesh Bureau of Statistics (BBS).
- Fertilizer data for rice crops (Boro, Aus and Aman): Bangladesh Agriculture Development Corporation (BADC).
- Meteorological data such as rainfall, temperature and humidity: Meteorological Department in Bangladesh (BMD).

The list of variables considered in this study is shown below in Table 1.

Table 2 showed the summary statistics of output, input and explanatory variables used in this study.

Likelihood ratio test for the model selection: The Likelihood Ratio (L-R) test is an important aspect of the process that helps to determine whether the frontier

Table 1: Variable definitions

Variable	Symbol	Measurement units
Production	Y	Production is measured at thousand metric tons
Area	ARE	Area is measured in hectares
Seed	SEE	Seed is measured in thousand metric tons
Fertilizer in Urea	FEU	Fertilizer in urea is measured in metric tons
Fertilizer in TSP Fertilizer in TSP	FET	Fertilizer in Triple Supper Phosphate (TSP) is measured in Metric tons
Explanatory variables		
Rainfall	RAN	Rainfall is measured in Millimeter
Temperature	TEM	Temperature is measured in Celsius
Humidity	HUM	Average humidity in percentage in each crop is considered
Daily average wage rate of agricultural labour without food	WRL	The average daily wage rate per man without food is included and it is measured in Taka
Wage rate of Bullock pair in a day	WRB	The Wage rate for Bullock is enclosed in Taka

Table 2: Summary statistics of output, input and explanatory variables

Rice crops	Variable	Description	Mean	S.D	Min.	Max.
Boro	Y	Production	8402.072	4511.977	2630.00	17809.0
	ARE	Area in hectares	2846.610	1070.765	1160.00	4716.24
	SEE	Seed in metric tons	7730.517	10034.40	453.000	35089.0
	FEU	Urea in metric tons	1656.169	695.2758	519.000	2762.78
	FET	TSP in metric tons	300.0857	135.0942	24.1440	514.761
	RAN	Rainfall(Millimeter)	56889.83	7218.524	42264.0	69905.0
	TEM	Temperature (Celsius)	28.92727	0.585520	27.9241	30.4137
	HUM	Humidity in %	74.44744	2.624497	69.7707	78.1535
	WRL	Wage rate for a labour	65.96552	49.24101	16.0000	190.000
	WRB	Wage rate for Bullock	101.1034	47.95485	30.0000	190.000
Aus	Y	Production	2220.815	610.5243	1500.00	3289.00
	ARE	Area in hectares	1912.976	791.2642	905.995	3158.10
	SEE	Seed in metric tons	505.9655	273.0404	207.000	1580.00
	FEU	Urea in metric tons	1656.169	695.2758	219.000	2013.00
	FET	TSP in metric tons	300.0857	135.0942	17.0000	200.000
	RAN	Rainfall(in millimeter)	1845.000	325.0000	3004.00	2652.00
	TEM	Temperature in Celsius	31.95895	0.389689	31.1801	32.5039
	HUM	Humidity in %	84.79060	1.003597	82.8541	86.7835
	WRL	Wage rate for a labour	51.94828	34.65476	10.0000	150.000
	WRB	Wage rate for Bullock	82.62069	38.98756	15.0000	145.000
Aman	Y	Production	8421.304	1662.365	5574.00	11613.1
	ARE	Area in hectares	5671.858	276.0041	5047.86	6052.40
	SEE	Seed in metric tons	4364.828	3175.421	629.000	13619.0
	FEU	Urea in metric tons	1545.000	255.0000	171.000	2562.00
	FET	TSP in metric tons	125.0000	110.0000	16.0000	155.000
	RAN	Rainfall in millimeter	1025.000	2514.000	2500.00	1562.00
	TEM	Temperature in Celsius	30.95308	0.355718	30.2010	31.9125
	HUM	Humidity in %	82.53776	2.288341	76.1155	85.4697
	WRL	Wage rate for a labor	55.79310	35.64445	15.0000	150.000
	WRB	Wage rate for Bullock	94.03448	49.70519	23.0000	200.000

is really necessary for estimating the efficiency levels of the firms. If the three rice crops (Boro, Aus and Aman) share the same technology, then the stochastic frontier production model is enough to estimate the efficiency of the crops. The L-R test with the null hypothesis associated with the stochastic frontier models for rice crops is calculated here. The LR Statistic is defined by:

$$\lambda = -2\{\ln[L(H_0)/L(H_1)]\} = -2\{\ln[L(H_0)] - \ln[L(H_1)]\}. \quad (1)$$

where,

In $[L(H_0)]$ = The value of the log likelihood function for the stochastic frontier estimated under null hypothesis

In $[L(H_1)]$ = The value of the log-likelihood function for the stochastic production function under alternative hypothesis.

Hypotheses of the L-R Test: The following hypotheses require testing with the generalized likelihood ratio test:

$$\lambda_{LR} =- [L(H_0) - L(H_1)]$$

where $L(H_0)$ and $L(H_1)$ are the maximum values of the log likelihood functions under the null and alternative hypothesis, respectively. The null hypothesis is rejected when $\lambda_{LR} > \chi_c^2$. The following hypotheses will be tested: H_0: $\beta_{ij} = 0$, the null hypothesis identifies an appropriate functional form between the restrictive Cobb-Douglas and the Translog production function. It specifies that the second-order coefficients of the Translog frontier are simultaneously zero. H_0: $\gamma = 0$, the null hypothesis specifies that the technical inefficiency effects in firm are zero. H_0: $\gamma = 0$ the null hypothesis means that there is no change in the technical inefficiency effects over time.

Parametric stochastic frontier model:

Model-1: In this framework, the output (rice production) is treated as a stochastic production process and the specification of Battese and Coelli (1995) model may be expressed as:

$$Y_{it} = exp(X_{it}\beta + V_{it} - U_{it}) t = 1,2,\dots,N;\ i = 1,2,\dots,T \quad (2)$$

where,

Y_{it} = The production at the t-th observation for the i-th firm;
X_{it} = The (1 X k) vector of values of known functions of inputs of production in the i-th firm at the t-th observation,
β = A vector of unknown parameters for the stochastic frontier.
V_{it} = Assumed to be iid N (0, σ_v^2) random errors, independently distributed of the U_{it}.
U_{it} = Non-negative random variables which are assumed to account for technical inefficiency in production and to be independently distributed as truncations at zero of the N(μ, σ_u^2) distribution defined as:

$$U_{it} = Z_{it}\delta + W_{it} \quad (3)$$

where, Z_{it} is a (1×p) vector of explanatory variables which may influence the inefficiency of rice producing in Bangladesh, the random variable W_{it} follows truncated normal distribution with mean zero and variance $^{\sigma 2}$, such that the point of truncation is $-Z_{it}\delta$ and δ is a (p×1) vector of parameters to be estimated. Parameters of the stochastic frontier given by Eq. (2) and inefficiency model given by Eq. (3) are simultaneously estimated by using maximum likelihood estimation method. After obtaining the estimates of $U_{it}$the technical efficiency of the t-th observation inthe i-th rice firm is given by:

$$TE_{it} = EXP(-U_{it}) = EXP(-Z_{it}\delta - W_{it}) \quad (4)$$

Model-2: A stochastic frontier production model with time-varying inefficiency used in panel data can be defined as:

$$\ln(Y_{it}) = \beta_0 + \sum_i^n \beta_i \ln X_{it} + \frac{1}{2}\sum \beta_{ii} \ln X_{ii}^2 + \sum_i^n \sum_j^m \beta_{ij} \ln X_i \ln X_j + uit - vit \quad (5)$$

where,

Y_{it} = The value of the output in the i- th firm in the t- th period
X_{it} = The input variables in the i- th firm in the t- th period
$\beta_0, \beta_i, \beta_{ij}$ = The unknown parameters to be estimated

The systematic error component, v_{it}, is assumed to be independently and identically distributed random error having normal distribution with mean zero and variance σ_V^2, i.e N(0,σ_V^2) and u_{it} stands for technical inefficiency and can be predicted by the following equation:

$$TE_{it} = \frac{Y_{it}}{exp(X_{it}'\beta + v_{it})} = \frac{exp(X_{it}'\beta + v_{it} - u_{it})}{exp(X_{it}'\beta + v_{it})} = exp\ (-u_{it}) \quad (6)$$

u_{it} is measured as the ratio of observed output to the corresponding stochastic frontier output. It takes a value between zero and 1. The technical inefficiency effect, u_{it} in the stochastic frontier model (2) can be specified as $u_{it} = z_{it}\delta + w_{it}$ (4) Where, the random variable w_{it} is defined by the truncation of the normal distribution with zero mean and variance σ^2, such that the point of truncation is $-z_{it}\delta$, i.e.$w_{it} > -z_{it}\delta$. These assumptions are consistent with u_{it} being a non-negative truncation with N($z_{it}\delta$, σ_v^2) distribution (5). The technical efficiency of production for the i-th firm at the t-th observation is defined as:

$$TE_{it} = exp(-u_{it}) = exp(-z_{it}\delta - w_{it})$$

Empirical stochastic frontier model:

Model-1: The stochastic frontier production function to be estimated is:

$$lnY_{it} = \beta_0 + \beta_{ARE} ln\ ARE_{it} + \beta_{SEE} lnSEE_{it} + \beta_{FEU} lnFEU_{it} + \beta_{FET} lnFET_{it} + \boldsymbol{\varepsilon_{it}} \quad (7)$$

where,

i = 1, 2, 3; t = 1, 2, 3……..29
Y_{it} = Production in the i-th rice (Boro, Aus and Aman) with t-th period.
ARE_{it} = Area in the i-th rice with t-th period
SEE_{it} = The quantity of seed of the -th rice in the i-th rice with t-th period
FEU_{it} = The amount of Urea is used in the i-th rice with t-th period
FET_{it} = The amount of TSP is used in the i-th rice with t-th period
$\beta_0, \beta_{ARE}, \beta_{SEE},, \beta_{FEU}, \beta_{FET}$ = Unknown parameter to be estimated
ln = Refers to the natural logarithm
i = The number of rice (Boro, Aus and Aman)
t = Time period

The technical inefficiency effects are assumed to be defined by:

$$\mathbf{u_{it} = \delta_0 + \delta_1 RAN_{it} + \delta_2 TEM_{it} + \delta_3 HUM_{it} + \delta_4 WRL_{it} + \delta_5\ WRB_{it} + W_{it}} \quad (8)$$

where,

RAN_{it} = Rainfall in the it-th rice with t-the period
TEM_{it} = The average temperature in the i-th rice with t-th period

Table 3: Maximum-likelihood estimates of stochastic frontier Model -1 and Model -2 with rice productive efficiency effects Bangladesh

Variable	Parameter	Model -1 Coefficient	S.E	T-ratio	Model -2 Coefficient	S.E	T-ratio
CONSTANT	β_0	2.2790*	0.1273	17.9017	-0.9556@	0.9217	-1.0367
ARE	β_1	0.8393*	0.0305	27.4484	3.5341*	0.8197	4.3114
SEE	β_2	0.1402*	0.0171	8.1775	-1.4673@	0.7421	-1.9771
FET	β_3	-0.5553*	0.3874	-14.331	0.0460@	0.7602	0.0606
FEU	β_4	-0.0176***	0.0089	-1.9585	-0.1634@	0.4359	-0.3749
ARE^2	β_{11}				-0.6662*	0.1702	-3.9136
SEE^2	β_{22}				-0.0608@	0.0666	-0.9130
FER^2	β_{33}				0.0439@	0.1959	0.2245
FET^2	β_{44}				-0.0505@	0.2399	-0.2105
ARE*SEE	β_{12}				0.7426**	0.2912	2.5497
ARE*FEU	β_{13}				-0.0933@	0.3808	-0.2451
ARE*FET	β_{14}				-0.0820@	0.4963	-0.1652
SEE*FEU	β_{23}				-0.2085@	0.2543	-0.8202
SEE*FET	β_{24}				0.0639@	0.2762	0.2313
FER*FET	β_{34}				0.1293@	0.1395	0.9271
Inefficiency effect model							
CONSTANT	δ_0	-0.9131@	0.7468	-1.2227	-0.1792@	1.4858	-1.2066
RAN	δ_1	1.7773*	0.6402	2.7758	0.6836@	0.8243	0.8292
TEM	δ_2	-0.4414	0.4292	-1.0284	0.3992@	0.6662	0.5993
HUM	δ_3	0.0893@	0.1116	0.8003	0.1790@	0.4208	0.42551
WRL	δ_4	-0.8291*	0.0915	-9.0580	-0.4607@	0.4308	-1.0695
WBR	δ_5	0.1285@	0.1073	1.1972	0.0151@	0.2335	0.0650
Sigma	σ^2	0.0019*	0.0003	5.5070	0.0044*	0.0007	5.5336
Gamma	γ	0.8462*	0.0645	13.1115	0.9984*	0.0025	384.5901
log likelihood	164.3071	137.7343					
Mean efficiency	0.8286	0.8893					

*, **, *** Significance level at 1%, 5%, 10%, @ Means insignificant and S.E = Standard

HUM_{it} = The average humidity in the i-th rice with t-th period

WRL_{it} = In the i-th rice with t-th period the average wage rate of human labour without food

WRB_{it} = The wage rate of bullock pair in daily in the i-th rice with t-th period

$\delta_0, \delta_1, \delta_2, \delta_3, \delta_4 \& \delta_5$ = Unknown parameter to be estimated

Model-2: The formulation of the stochastic frontier Translog production model is defined as:

$$
\begin{aligned}
lnY_{it} &= \beta_0 + \beta_1 \ln(ARE_{it}) + \beta_2 \ln(SEE_{it}) + \beta_3 ln(FEU_{it}) + \beta_4 ln(FET_{it}) \\
&+ .5[\beta_{11} ln(ARE_{it}^2) + \beta_{22} \ln(SEE_{it}^2) + \beta_{33}(lnFEU_{it}^2) + \beta_{44} ln(FET_{it}^2)] \\
&+ \beta_{12} ln(ARE_{it}) * ln(SEE_{it}) + \beta_{13} ln(ARE_{it}) * ln(FEU_{it}) + \beta_{14} ln(ARE_{it}) \\
&* ln(FET_{it}) + \beta_{23} ln(SEE_{it}) * ln(FEU_{it}) + \beta_{24} ln(SEE_{it}) * ln(FET_{it}) + \\
&+ \beta_{34} ln(FEU_{it}) * ln(FET_{it}) + v_{it} - u_{it}
\end{aligned}
\tag{9}
$$

where,

Y_{it} = The production in the *i*-th rice firm with *t*-th period

ARE_{it} = The Area in the *i*-th rice firm with *t*-th period

SEE_{it} = The quantity of seed in the *i*-th rice firm with *t*-th period

FEU_{it} = The amount of Urea is used in the *i*-th rice firm with *t*-th period

FET_{it} = The amount of TSP is used in the *i*-th rice firm with *t*-th period

ln = Refers to the natural logarithm,

β_i's = Unknown parameters is to be estimated;

$v_{it} \sim N(0, \sigma^2_v)$ and

$u_{it} \sim$ Truncations at zero of the $N(\mu, \sigma^2_u)$ distribution.

RESULTS AND DISCUSSION

Maximum-likelihood estimates of the stochastic frontier model with efficiency effects on rice production: In this section, Maximum Likelihood Estimates (MLE) of the parameters was reported in the context of rice productive efficiency of Bangladesh followed by stochastic frontier Model-1 and Model-2. The estimates of parameters were obtained by grid search in the first step and then these estimates were used to estimate the maximum likelihood estimates of the parameters of stochastic frontier model. The estimates of parameters in the model were presented in the Table 3. The results showed that the maximum-likelihood estimates of the coefficients of Area and Seed input were found to be positive values and significant at 1% level of significance for Model -1 and the coefficient of Fertilizer (Urea and TSP) found to be negative at 1% and 10% level of significance respectively. For Model -2, the square effect of the input variable *Area* was found statistically significant with a negative value at 1% level of significance.

Table 4: Year wise efficiency of rice in Bangladesh by translog stochastic

	Model -1				Mdel-2			
Year	Boro	Aus	Aman	Overall	Boro	Aus	Aman	Overall
1980-1981	0.6581	0.5920	0.6228	0.62430	0.8404	0.7669	0.9053	0.8375
1981-1982	0.6531	0.5971	0.5787	0.60963	0.8247	0.7812	0.8178	0.8079
1982-1983	0.6801	0.5910	0.5977	0.62293	0.8396	0.7381	0.7410	0.7729
1983-1984	0.7023	0.6367	0.6221	0.65370	0.8686	0.8314	0.7597	0.8199
1984-1985	0.7310	0.6645	0.6756	0.69037	0.8956	0.8783	0.7945	0.8561
1985-1986	0.7354	0.6446	0.6761	0.68537	0.8989	0.7727	0.7922	0.8213
1986-1987	0.7442	0.6846	0.7810	0.73660	0.8941	0.8312	0.9366	0.8873
1987-1988	0.7732	0.7182	0.7110	0.73413	0.9105	0.8890	0.8109	0.8701
1988-1989	0.7848	0.7199	0.7203	0.74167	0.8969	0.8458	0.7953	0.8460
1989-1990	0.8527	0.7029	0.8019	0.78583	0.9979	0.7710	0.8820	0.8836
1990-1991	0.8444	0.7143	0.7927	0.78380	0.9726	0.7894	0.8731	0.8784
1991-1992	0.8667	0.7581	0.8379	0.82090	0.9676	0.8177	0.9258	0.9037
1992-1993	0.8088	0.7822	0.8374	0.80947	0.8702	0.8409	0.9111	0.8741
1993-1994	0.8728	0.7700	0.8327	0.82517	0.9599	0.7989	0.8820	0.8803
1994-1995	0.8393	0.7632	0.8213	0.80793	0.8954	0.7773	0.8561	0.8429
1995-1996	0.8740	0.7999	0.8507	0.84153	0.9311	0.7905	0.8608	0.8608
1996-1997	0.9044	0.8391	0.8693	0.87093	0.9704	0.8216	0.8800	0.8907
1997-1998	0.8926	0.7776	0.8193	0.82983	0.9440	0.8136	0.8105	0.8560
1998-1999	0.9429	0.8012	0.8293	0.85780	0.9733	0.8002	0.8325	0.8687
1999-2000	0.9498	0.8824	0.9106	0.91427	0.9621	0.8591	0.8894	0.9035
2000-2001	0.9741	0.9395	0.9555	0.95637	0.9822	0.9212	0.9766	0.9596
2001-2002	0.9647	0.9524	0.9540	0.95703	0.9621	0.9156	0.9679	0.9485
2002-2003	0.9828	0.9449	0.9604	0.96270	0.9868	0.9213	0.9493	0.9525
2003-2004	0.9847	0.9539	0.9858	0.97480	0.9631	0.9289	0.9946	0.9622
2004-2005	0.9948	0.9383	0.9744	0.96917	0.9830	0.9214	0.9355	0.9466
2005-2006	0.9911	0.9824	0.9881	0.98717	0.9369	0.9805	0.9582	0.9585
2006-2007	0.9929	0.9838	0.9919	0.98953	0.9335	0.9735	0.955	0.9540
2007-2008	0.9973	0.9918	0.9881	0.99240	0.9718	0.9739	0.9183	0.9547
2008-2009	0.9953	0.9935	0.9921	0.99363	0.9925	0.9981	0.9814	0.9907
Average	0.861666	0.797241	0.826848	0.828585	0.931917	0.853379	0.882531	0.8893
Mean efficiency	0.8286				0.8893			

Hence, it can be said that the square effect of Area had depressing effect on the rice production of Bangladesh. The interaction effect of Area and Seed was observed as positive and significant at 5% level of significance.

It can be concluded that the interaction effect of *Area and Seed* had a positive impact on the rice production in Bangladesh. The interaction effects of *Area and Fertilizer (Urea), Area and Fertilizer (TSP) and Seed and Fertilizer (Urea)* were recorded with negative values and it can be realized that these three interaction effects have reverse effect on rice production in Bangladesh for Model-2.The coefficient of *squared Seed and Fertilizer (TSP*) were also negative and moreover *Fertilizer (Urea)* was found to be insignificant for Model -2 which implied that the extra seed and fertilizer actually decreased the technical efficiency in rice production. Hence, concerned rice growing households need to be aware of their rice cultivation methods regarding this outcome. For Model-1 one of the climatic factors, *Rainfall* was observed to be a significant inefficiency variable with positive value and also WRL was significant with a negative value at 1% level of significance. On the other hand these two inefficiency variables in Model-2 were insignificant.

In the inefficiency effect model, a positive coefficient value increases the level of inefficiency and vice-versa. In Model-1, the inefficiency variables, Temperature and WRL were found negative hence they contribute in decreasing the level of inefficiency and WRL ha d a significant effect on the level of efficiency. In Model-2, though *Temperature* had a positive value yet it was insignificant in increasing the level of inefficiency. For both models estimation of the effect of *Humidity* was statistically insignificant with positive values indicating that it contributed in increasing the level of inefficiency. On the other hand, WRL had negative values on both the models, which was found to be significant for Model-1 and insignificant in case of Model-2. The other important climatic factor *Rainfall*, was significant with a positive value in Model-1 but it is insignificant in Model-2.This indicate that the inefficiency level of rice production is linked with rainfall. Therefore the results suggest that *Rainfall*, *Humidity* and *Temperature*: these climatic factors are internally linked with other inputs affecting rice production even at a technical level. The value of γ was estimated at 0.84 and 0.99 respectively (Table 3) which was positive and significant at 1% level of significance for both the models. It can be interpreted as follows: 84% and 99% of random variation for Model-1 and Model-2 respectively, that exist in rice production can be explained through inefficiency and only one 1% due to stochastic random error. It was also observed that

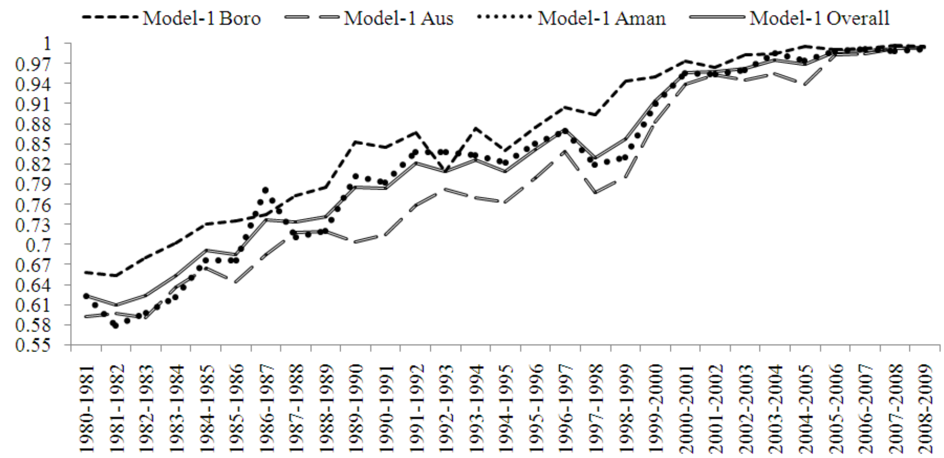

Fig. 1: Year wise TE of rice production (Model 1)

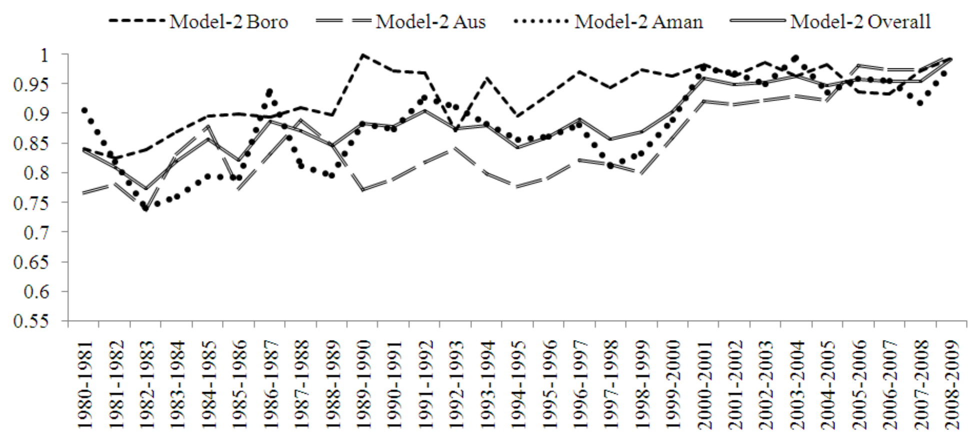

Fig. 2: Year wise TE of rice production (Model 2)

Table 5: Technical Efficiency (TE) in Model 1

Crops	Maximum TE	Minimum TE	Average
Aus	0.9935	0.591	0.7972
Aman	0.9921	0.5787	0.8268
Boro	0.9973	0.6531	0.8616

Table 6: Technical Efficiency (TE) in Model-2

Crops	Maximum TE	Minimum TE	Average
Aus	0.9981	0.7381	0.8533
Aman	0.9946	0.7410	0.8825
Boro	0.9979	0.8247	0.9319

Model-2 explained the maximum variation of the rice production efficiency in this study. The estimate of sigma was found significant for both models that indicated that the estimated factors are perfectly fitted for these models (Table 3 and 4).

Year-wise rice productive efficiency: This study used two models to estimate the technical efficiency of rice production. The first model, Model-1 used rice production as a stochastic production process where technical inefficiency was estimated as a functions of the parameters of the distribution. In Model 2, time-varying inefficiency is used on the same data, making it a dynamic model that showed how technical efficiency evolved over time (Desli *et al*., 2002).

Figure 1 show that in the last 29 years the overall rice production efficiency of the three crops increased at a steady state except for the years 1984-85, 1990-91, 1994-95 and 1997-98. In these years TE dropped from the steady trend. However, it is important to notice that since 1998-99 to 2008-2009 TE maintained an average value of 0.9 for all the rice crops (Aus 0.930, Aman0.957 and Boro 0.979). In addition, Table 5 summarizes the findings of TE for Model 1 that shows that TE of Aus and Aman rice has increased significantly over the years.

Figure 2 depicts the TE of rice production that evolved over time in Model 2, where TE was separated from fixed year specific effects that were not treated as parts of TE (Desli *et al.,* 2002).

In this Fig. 2 the TE of rice production shows more fluctuations compared to Fig. 1. Distinctively, the TE for Aus showed a volatile trend from 1980-81 (0.76) till 2000-01(0.92). However, it reached a steady growth after that period and achieved the highest TE (0.9981) among the crops in 2008-09. The summary of Fig. 2 is compiled in Table 6.

Table 7: Generalized likelihood-ratio tests of hypothesis

Null hypothesis	Log likelihood	Test statistics λ	Critical value*	Decision
H_0: $\beta_{ij} = 0$	164.3071	53.1400	18.3	Reject H_0
H_0: $\gamma = 0$	-109.22	138.997	7.05	Reject H_0
H_0: $\eta = 0$	-42.568	5.68400	3.84	Reject H_0

All critical values are at 5% level of significance. *: The critical values are obtained from table of Kodde and Palm (1986)

By comparing the findings of the two models (Model -1 and Model-2), it was found that on average TEis higher in Model- 2 compared to Model-1. In Model- 1, the minimum TEs for Aus, Aman & Boro states were at 59, 57 and 65%, repectively. On the other hand minimum TEs for Aus, Aman & Boro in model 2 are 73, 74 and 82%. However, the maximum value of TE in the three crops for both models was close to 99%. Also, the average TEs for Aus, Aman & Boro for Model-1 were 79%, 82% and 86% and for Model -2 were 85%, 88% and 93% respectively. Hence, the overall mean efficiency of Model -1 was 82% and for Model- 2 was 88%. It is also important to note that the variations of TE for the three different crops were more prominent in the 1980's and 1990's. The fluctuations of TE reached a steady state after the year 2000-01 at 90% level. Hence, it is difficult to interpret the changes of environmental factors on rice production as the TE reached at highest level in the 21st century. Hence, in this study the interaction of environmental parameters within the models describes the effect of environmental factors on rice production rather than the changes in TE.

Results of tests of hypothesis and model selection: The null hypothesis which includes the restriction that γ is zero does not have a chi-square distribution, because the restriction defines a point on the boundary of parameter space. From Table 7, the null hypothesis, H_0: $\beta_{ij} = 0$ is rejected and it is in favor of the Translog production function, the second null hypothesis is H_0: $\gamma = 0$, which is rejected and so there was a technical inefficiency effect in the model. The third null hypothesis is H_0: $\eta = 0$, which is rejected indicating that the technical inefficiency effects varied significantly.

CONCLUSION

This study attempts to identify the impact of climatic and environmental factors on rice productive efficiency for three different rice crops of Bangladesh. The Cobb-Douglas production frontier model and the Translog Stochastic Frontier Model are formulated to see the impact of climatic and environmental effects on rice production during the time period of 1980-1981 to 2008-2009. It provides the estimates of rice productive efficiency and compares the efficiencies among three types rice crop in Bangladesh. The analysis estimated that the level of technical efficiency among the three rice crops: *Boro*, *Aus* and *Aman*are 0.86, 0.79 and 0.82 for Model-1 and 0.93, 0.85 and 0.882 for Model-2 respectively. In addition this study estimates the average production of the three crops considering human effort, agricultural inputs and environmental factors. The highest production in *Aman* is explained by its highest technical efficiency on average for the last 29 years. Also, about 84% and 99% variations in output are explained by the production's technical efficiency among three different rice crops by using the Model-1 and Model-2 in that order. Area has a direct influence to increase the level of TE for both models. The study also examined the interaction effect among the inputs factors and how they impact to the total production of output. In Model -1, FEU and FET both have negative influence to decrease the level TE while in Model-2, FEU and the square of FEU are the cause of increasing TE. In Model-1 model, Seed has direct influence to increase the TE while in Model-2 it has negative impact to decrease the level of TE.

REFERENCES

Ahmad, M., M. Rafiq and A. Ali, 1999. An analysis of technical efficiency of rice farmers in Pakistani Punjab. Bangl. J. Agr. Econ., 22: 79-86.

Ahmed, A.U. and M. Alam, 1999. Development of Climate Change Scenarios with General Circulation Models. In: Huq, S., Z. Karim, M. Asaduzzaman and F. Mahtab (Eds.), Vulnerability and Adaptation to Climate Change for Bangladesh. Springer Science+Business Media, Dordrecht, pp: 13-20.

Ajibefun, I.A., G.E. Battese and A.G. Daramola, 2002. Determinants of technical efficiency in smallholder food crop farming: Application of stochastic frontier production function. Q. J. Int. Agr., 41: 225-240.

Ali, M. and J.C. Flinn, 1989. Profit efficiency among basmati rice producers in Pakistan Punjab. Am. J. Agr. Econ., 71: 303-310.

Azad, M.A.S., B.A.A. Mustafi and M. Hossain, 2008. Hybrid rice: Economic assessment of a promising technology for sustainable food grain production in Bangladesh. Proceeding of the AARES 52nd Annual Conference. Rydges Lakeside, Canberra, ACT, Australia, February 5-8, pp: 1.

Banik, A., 1994. Technical efficiency of irrigated farms in a village of Bangladesh. Indian J. Agr. Econ., 49(1): 70-78.

Basak, J.K., M.A. Ali, M.N. Islam and M.A. Rashid, 2010. Assessment of the effect of climate change on boro rice production in Bangladesh using DSSAT model. J. Civil Eng., 38(2): 95-108.

Baten, M.A., I. Hossain and M.K.B.M. Nawawi, 2012. Technical efficiency of rice growing farmers in selected area of Mymensingh district in Bangladesh: A role of environmental awareness. Welfenia J., 19: 8.

Battese, G.E., 1992. Frontier production functions and technical efficiency: A survey of empirical applications in agricultural economics. Agr. Econ., 7: 185-208.

Battese, G.E. and T.J. Coelli, 1992. Frontier production functions, technical efficiency and panel data: With application to paddy farmers in India. J. Prod. Anal., 3: 53-169.

Battese, G.E. and T.J. Coelli, 1995. A model for technical inefficiency effects in a stochastic frontier production function for panel data. Empir. Econ., 20: 325-332.

BBS, 2009. Statistical Yearbook of Bangladesh. Ministry of Planning. Dhaka, Bangladesh.

BBS, 2010. Bangladesh Bureau of Statistics. Ministry of Planning, Dhaka, Bangladesh.

Chengappa, P.G., A. Janaiah and M.V.S. Gowda, 2003. Profitability of hybrid rice cultivation: Evidence from Karnataka. Econ. Polit. Weekly, 38: 2531-2534.

Constantin, P.D., D.L. Martin and E.B.B.D.R. Rivera, 2009. Cobb-Douglas, Translog stochastic production function and data envelopment analysis in total factor productivity in Brazilian agribusiness. J. Oper. Supply Chain Manage., 2(2): 20-34.

Desli, E., S.C. Ray and S.C. Kumbhakar, 2002. A Dynamic Stochastic Frontier Production Model with Time-varying Efficiency. Economics Working Papers, Department of Economics Working Paper Series, University of Connecticut, Connecticut, pp: 200-315.

Dev, U.K. and M. Hossain, 1995. Farmers' education, modern technology and technical efficiency of rice growers. Bangl. J. Agr. Econ., 18: 1-13.

Ekanayake, S.A.B., 1987. Location specificity, settler type and productive efficiency: A study of the Mahaweli project in Sri Lanka. J. Dev. Stud., 23: 509-521.

Erwidodo, 1990. Panel data analysis on farm-level efficiency, input demand and output supply of rice farming in West Java, Indonesia. Ph.D. Thesis, Michigan State University, East Lansing.

Fan, S., G. Cramer and E. Wailes, 1994. Food demand in rural China: Evidence from rural household survey. Agr. Econ., 11: 61-69.

Fan, S., 1999. Technological Change, Technical and Allocative Efficiency in Chinese Agriculture: The Case of Rice Production in Jiangsu. Technological change, technical and allocative efficiency in Chinese agriculture: The case of rice production in Jiangsu, Environmental and Production Technology Division (EPTD), International Food Policy Research Institute, Washington DC, USA.

FAPRI, 2009. The Agricultural Outlook. Iowa State University, University of Missouri-Columbia, Ames, Iowa, U.S.A.

Fraser, E., 2008. Crop Yield and Climate Change. Retrieved from: http://www.vulnerable foodsystems.com. (Accessed on: September, 14 2009)

Hamjah, M.A., 2014. Measuring climatic and hydrological effects on cereal crop production in Bangladesh using multiple regression and measuring efficiency using stochastic frontier model. Math. Theory Model., 4(4).

Hanley, N. and C.L. Spash, 1993. Farm management research for small farmer development. Food and Agriculture Organization of the United Nations, Rome.

Hossain, M.K., T.A. Masron, A.A. Kamil, A. Mustafa and M.A. Baten, 2012. Influence of environmental constraints on rice productive technical efficiency in Bangladesh. Proceeding of the International Conference on Management, Economics and Finance. Hilton Hotel, Kuching, Sarawak, Malaysia, pp: 478-485.

Kalirajan, K.P., 1981. An econometric analysis of yield variability in paddy production. Can. J. Agr. Econ., 29: 283-294.

Kalirajan, K.P. and R.T. Shand, 1989. A generalized measure of technical efficiency. Appl. Econ., 21: 25-34.

Khan, A., F.A. Huda and A. Alam, 2010. Farmhouse hold technical efficiency: A study on rice producers in selected areas of Jamalpur District in Bangladesh. Eur. J. Soc. Sci., 14(2): 262-271.

Khuda, B., H. Ishtiaq and M. Asif, 2005. Impact assessment of zero-tillage technology in rice-wheat system: A case study from Pakistani Punjab. Electron. J. Environ. Agr. Food Chem., 4(6): 1132-1137.

Kodde, D.A. and F.C. Palm, 1986. Wald criteria for jointly testing equality and inequality restrictions. Econometrica, 54: 1243-1248.

Mythili, G. and K.R. Shanmugan, 2000. Technical efficiency of rice growers in Tamil Nadu: A study based on panel data. Indian J. Agr. Econ., 55: 15-25.

Rahman, K.M.M., 2002. Measuring Efficiency of Producing Rice in Bangladesh: A Stochastic Frontier Analysis. WissenschaftsverlagVauk Kiel KG. ISBN 3-8175-03571, 8: 215.

Rahman, K.M.M., P.M. Schmitz and T.C. Wronka, 1999. Impact of farm-specific factors on the technical inefficiency of producing rice in Bangladesh. Bangl. J. Agr. Econ., 22(2): 19-41.

Richard, T.Y. and E.G. Shively, 2007. Technical change and productive efficiency: Irrigated rice in the Philippines. Asian Econ. J., 21(2): 155-168.

Shanmugam, K.R., 2000. Technical efficiency of rice growers in Bihar. Indian J. Appl. Econ., 8: 377-389.

Sikder, M.T., 2010. The impacts of climate change on the coastal belt of Bangladesh: An investigation of risks & adaptations on agricultural sector. Proceeding of the International Conference on Environmental Aspects of Bangladesh (ICEAB, 2010), pp: 26-28.

Squires, D. and S. Tabor, 1991. Technical efficiency and future production gains in Indonesian agriculture. Dev. Econ., 29: 258-270.

Tan, S., N. Heerink, A. Kuyvenhovenb and F. Qu, 2010. Impact of land fragmentation on rice producers' technical efficiency in South-East China. NJAS-Wagen. J. Life Sc., 57: 117-123.

Tian, W.M., 2000. Technical Efficiency of China's Grain Production'. In: Yang, Y.Z. and W.M. Tian (Eds.), China's Agriculture at the Crossroads. Macmillan, Basingstoke, pp: 148-165.

Tian, W. and G.H. Wan, 2000. Technical efficiency and its determinants in China's grain production. J. Prod. Anal., 13: 159-174.

Travers, L. and J. Ma, 1994. Agricultural productivity and rural poverty in China. China Econ. Rev., 5(1): 141-159.

Wadud, A. and B. White, 2000. Farm household efficiency in Bangladesh: A comparison of stochastic frontier and DEA methods. Appl. Econ., 32: 1665-1673.

Wang, J., E.J. Wailes and G.L. Cramer, 1996a. A shadow-price frontier measurement of profit efficiency in Chinese agriculture. Am. J. Agr. Econ., 78(1): 146-156.

Wang, J., G.L. Cramer and E.J. Wailes, 1996b. Production efficiency of Chinese agriculture: Evidence from rural household survey data. Agr. Econ., 15: 17-28.

Xu, X. and S.R. Jeffrey, 1998. Efficiency and technical progress in traditional and modern agriculture: Evidence from rice production in China. Agr. Econ., 18: 157-165.