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Analysis of Technical Efficiency and Constraints to The Climate Change Adaptation Practices of Rice Production in Pabna District, Bangladesh

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Abstract

The present world stresses with the development challenges industrialization, urbanization etc. as long as climate change. Developing nations, like Bangladesh is the worst victim of this reality due to their insignificant contribution to climate change. Possible prerequisite adaptation options are therefore needed to minimize potential future loss. Data collected from two drought-prone regions namely Dashuriya and Muladuli, from Ishwardi, Pabna Bangladesh are based on farm household survey. The study examines the impact of farmers' adaptation options on rice production efficiency and the barriers the farmer faced. Multinominal logit Model (MNL) is used to determine the farmer's decisions on adaptations options. Stochastic Frontier employed to analyze the efficiency level of different adaptation options and finally principle component analysis (PCA) applied to scrutinize the barriers that the farmer faced during adapting climate change adaptations strategies. The result revealed that sex, age, household size, and years of schooling, farm size, extension contact, and credit availability significantly influenced the farmers' preferences toward adapting climate change adaptation where training based education and farm size have positive impact on adaptation choice and age has significantly negative impact to choose the adaptation strategies. Stochastic frontier production model is used to estimate the production efficiency. The mean efficiency of the production model is 0.77 after effectively implemented climate change adaptation. Labor, farm size and irrigation statistically significant at 1% level of significance in the stochastic frontier production analysis. The study additionally uncovered the factor analysis and depicted that constraining factors into five categories namely public, institutional and labor constraints, neighborhood norms and conventional beliefs constraint, high production cost and poor alarming system constraint, limited information of adaptation and credit accessibility constraint and limited agricultural extension and service explain up to 62.239% of the variance. Farmers should be empowered by government and non-governmental organizations to promote input-based adaptation to minimize 23% of inefficiencies in the study area.

Keywords: Adaptation strategies, Bangladesh, Climate changes, Stochastic frontier, Technical efficiency, Barriers.

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1. Introduction

The livelihood of major people of developing nations like Bangladesh is significantly dominated by the agriculture sector. This sector is one of the sources of foreign exchange earnings (Mohammed-Lawal, A. and Atteh 2006) as well as production input for the country's agro industries. Despite the sectors contributes 14.97% only to the GDP of Bangladesh's economy, the majority of people (39.7%) still depend on agriculture for their livelihoods (Phillipoet al. 2015, BBS, 2017). The sector influence by local and global market fluctuation and policies of agriculture, trade policies, technological accessibility and extension, regulation of land use and carrying capacities, pest, soil quality with the uncertainty of climatic variability (Kurukulasuriya and Rosenthal, 2003). Further, the performance of the agricultural sector shows strong associations with the climate change like rainfall, temperature change etc. (Alemayehu and Bewket, 2016) which makes it one of the important drivers of the agricultural sector.

Climate change recognizes as a global threat by its potential impacts (Stern, 2006; IPCC, 2007b; IPCC, 2014). Agro-based communities in developing countries like Bangladesh are expected to be hardest hit by this climate change (Maskrey*et al.*, 2007). The average temperature of Bangladesh has risen during the last two decades and projected temperature will increase by 0. 4º C and 0.73º C on average at the year of 2050 and 2100 respectively (Karmakar and Shrestha 2000). The world has already experienced the vulnerable and exposure impacts of extreme climatic events like excess rainfall, flooding, increasing salinity, drought, storm etc. due to climate change. According to the climate risk index 2020, Bangladesh hit hardest for hazardous damaging effects of climate change due to occurring more frequent and more severe climatic events. This poses a serious threat to sustainable development in the context to their social, economic and environment (Zhuang, 2009; Mirza, 2011).

The life and livelihood of Bangladesh is highly dependent on rice. The progress of industrial twentieth century made surplus production of rice (2.3%) higher than population growth (Gautam; 2008). However, rice productivity and production gains are facing a major challenge with the start of second generation problems, such as soil depletion, ground water depletion, and particularly, climate change. The available forecasts are inconsistent and vary from 10% to 15%, somewhere 7-10% yield losses for rising per degree temperature (Tao and Zhang, 2013; Peng *et al.*, 2004; Krishnan *et al.*, 2007). To get rid of this climatic risk, farmers use several adaptation strategies. Such declining or variations of rice production require farmers' adaptability to avoid these negative impacts. However, farm-level adaptations practices vary from one region to another and farm to farm regarding production efficiency. Choosing the right adaptation strategies to enhance production efficiency under changing climate. So, it is very important to learn about the production efficiency of climate change adaption strategies of the farming communities of Bangladesh. It is, therefore, acknowledging the farmer's perception about the risk of climate change to implement adjustment practices effectively. Eyasmin*et al*. (2017) revealed that 95% household heads perceived increasing temperature, 97% perceived changing precipitation and 98% perceived other climatic variability such as drought, river erosion, famine, storms etc. in the *Pabna district*, Bangladesh. The several strategies including changing sowing dates, fast matured rice varieties, drought-tolerant rice varieties, use of mineral or natural fertilizers, approaching near-water cultivation, mixed cropping, improved irrigation, switch toshallow tube-well, the building of embankments, inclusion of plants in rice farms, crop rotation, short-duration species selection, conserving rainwater etc. tracked to promote farm productivities, reliability and stimulate profits as producing unit (Eyasmin, *et al.* 2017; Gosh and Hossain 2016; Ghosh, *et al.* 2015; Masud*et al.*, 2014; Sarkar *et al.* 2013; Bilow*et al.*, 2010; Timmer, 1980; Abdulai and Huffman, 2000). Moreover, technical efficiencies stimulate farm productivities by accomplishing possible potential profit which allows fixed factors and farm price. Since climate change proof as to the cause of technical inefficiencies and the adaptation strategies affect the technical efficiencies. This justifies further study on how rice production efficiency affects by technical efficiency of climate change adaptation practices in Bangladesh linked with socio-economic variables. This study thus sheds light on our understanding about the technical efficiency of climate change adjustment strategies on rice production and the barriers to taking the initiatives that help to region-based policy implications in Bangladesh particularly in *Ishwardi Upazila* at *Pabnadistrict* Bangladesh.

2. Methodology

2.1 Sampling Procedure

A cross-sectional survey is performed to collect information of random 200 farming households through using a multistage random sampling method in the *Pabna District* at the year 2017 including requiring data for analysis. Since time and other resources limit the researcher to select purposively one *Upazila- Ishwardi*, two unions (Dashuriya, Muladuli) and four villages *(*AthalShimul, Dashuriya, Ramnathpur, and Muladuli and 50 from each)for this study. AsIshwardi Upazila has experienced extreme weather of high temperature and low level of rainfall that the Upazila suffers severe drought. Moreover, rice farming is major livelihood source of Pabna District that captures the attention to perform the study.

2.2 Multivariate Discrete Choice Model

The MNL log it model carried out in order to evaluate the determinants of farmer's decision since it is commonly used and easier to assess in decision making studies involving multiple choices. Utility related adjustment practices calculated through farmers' adaptation. According to Greene (2000), a random utility paradigm drive the unordered choice model, if the i^{th} household choose the technique of *j*, the utility of technique *j* is given by

$U_{ij} = \beta_j X_{ij} + \varepsilon_{ij}$…………… (1)

Where

U_{ij} is the utility of i^{th} farmer after adapting j^{th} choice of adaptation strategy,

$X_{ij}$is a feature vectors to indicatesthe choice decision of adaptation strategies,

β_j is the parameters to comprise the changes ofX_{ij} onU_{ij}.

$\varepsilon_{ij}$are assumed to be distributed independently and identically.

If farmers decide to alter adaptation strategy j, then U_{ij} explain maximum potential utilities.

This implies

$U_{ij} > U_{ik} \forall k \neq j$………… (2)

Where U_{ik} is the utility of technology k for i^{th} farmer.

Each adjustment strategy is implemente dsignificantly as a potential decision to maximize their utility in the context of possible alternatives in equation (2) (Dorfman, 1996). The preference of j relies on X_{ij}, which includes household-specific aspects and patterns of a farm among other factors. Following Greene (2000) random variable Y_i reveals how the rice farmer made decision to prefer adaptation. The decision based on assumption of a set of discrete, mutually exclusive farmer's choices of adaptation strategies or measures.

2.3 Stochastic Frontier Model

A stochastic frontier production function shows a comparison of recorded output with attainable output to measure technical efficiencies. Therefore, modelling, estimation and application of stochastic frontier model has place as popular in economic analysis for the past two decades (Ojo, 2003). Though, the model applied to analyze agricultural data of United States (Aigner *et al.*1977) and pastoral zone of Eastern Australia (Battese and Corra1977). Moreover, these three models constructed the composed error structure that developed in a production frontier context.

The model can be expressed as:

$y = f(x, \beta)\exp(\epsilon_i - \epsilon)$ …………………… (3)

Where

y = scalar output,

x = input vector,

β = vector of technology parameters.

The effects of statistical noise replicated by the first error component $\epsilon_i \sim N(0, \sigma_{\epsilon_i})$ and the effects of technical inefficiency captured by the second error component $\epsilon \sim N(0, \sigma_\epsilon)$.

The stochastic frontier model can be written as the form of a generalized production function

$y = f(x_i, \beta) + (V_i - U_i)$

$= f(x_i, \beta) + \varepsilon_i$ …………….. (4)

The frontier production function $f(x_i, \beta)$ measured how any particular input vector x_i played role to attain highest potential output measurement. The V_i and U_i is the frontier deviation of actual output. The V_i is the random factors related to symmetric noise rather monitoring by the farms or farmers that distributed identically with zero mean and constant variance $V_i \sim N(0, \sigma_v)$. The independent and identical distribution of U_i is a non-negative deviation of the frontier production function due to controllable factors with half-normal, truncated normal distribution and gamma density (technical inefficiency). (Meeusen & Van den Broeck, 1977; Aigner *et al.*, 1977; Stevenson, 1980; Greene, 1980).

The Maximum Likelihood Estimation (MLE) model used to develop a maximization technique of stochastic frontier production model on the base of following assumption (Olowofeso & Ajibefun, 1999; Koutsoyiannis 1977).

(i) The population distribution of Y's is assumed known and particularly y_i normally distributed.
(ii) each ε_i is different from any other value ε_j by random sampling (or, similarly, y_i is autonomous of y_j; and
(iii) The random sampling is representation of population by its simple explanation of results. The assumption is particularly crucial for small sampling. As normality test is mandatory for the ML estimation, while normality test is not required for b's estimation process but for significancein OLS.

A farmers' or producers' Technical efficiency (TE) is expressed by the fraction of the observed output (y) to the corresponding frontier output (y*), with subject to the level of inputs used by the farm. Thus, in the context of Stochastic Frontier Production Function (SFPF), the technical efficiency (TE) of a firm or production unit i can be written as:

$$TE = {y_i}/{y^*} = {lny_i}/{lny^*}$$
$$= {f(x_i, \beta) + (v_i - u_i)}/{f(x_i, \beta) + v_i}$$
$$= \exp(-u_i) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (5)$$

So that $0 \leq TE \leq 1$

Following Jondrow*et al.* (1982), the density function of u and v can be written as:

$$f(u) = 1\sqrt{({1}/{2n})({1}/{\sigma_v}) \exp\left({-u^2}/{2{\sigma_u}^2}\right)}; u \geq 0 \ldots\ldots \quad (6)$$

$$f(v) = 1\sqrt{}({1}/{2n})({1}/{\sigma_v}) \exp\left({-v^2}/{2{\sigma_v}^2}\right);\ -\infty \leq v \leq \infty \ldots\ldots \quad (7)$$

The joint density of (V-U) can be expression as density function of y, given as:

$$(y) = 1 \Big/ \left[\sigma\sqrt{{1}/{2n}}\right] \exp\left({-\omega^2}/{2\sigma^2}\right) [1 - F\{({\omega}/{\sigma})^{\gamma}/{1-\gamma}\}] \quad \ldots\ldots (8)$$

Where, $F({\omega}/{\sigma})^{\gamma}/{1-\gamma})$ is the function of cumulative distribution of the standard normal variable.

$\omega = v - u$

$\sigma^2 = {\sigma_u}^2 + {\sigma_v}^2$; and

$\gamma = {\sigma_u}^2 / ({\sigma_u}^2 + {\sigma_v}^2)$…………………. (9)

And the interval γ lies between 0 to 1

The likelihood function of the sample would be;

$$(y;\theta) = \pi \left[1 \Big/ \left[\sigma\sqrt{1/2n}\right] \exp\left(-\omega^2/2\sigma^2\right) \left[1 - F\left\{(\omega/\sigma)\, \gamma / 1-\gamma\right\}\right]\right]$$
……………………… (10)

Where,θ is the parameter of σ^2 *and* γ

Observed U is derived from the conditional distribution of u at a given (v-u) (Jondrow*et al*., 1982; Kalirajan & Flinn, 1983). The conditional mean of U can be written by given (v-u), the frequency distribution for v and a half- normal distribution for u

$E(u/(v-u) = \int uf(u/v-u)\delta u$…………….. (11)

Where,the density function of u is $f(u/v-u \big/ f(v-u)$ by given (v-u), is equivalent to

$f(u/v-u) = 1\sqrt{2\pi\sigma}/\sigma_u\sigma_v \exp[-{\sigma_u}^2/$
$2{\sigma_u}^2{\sigma_v}^2(u + {\sigma_u}^2/\sigma^2)^2]\; 1 \big/ -F(\omega/\sigma)\,\gamma/1-\gamma)$ ....(12)

Where, the standard normal distribution function $f(u/v-u)$. Now,

$$E(u/v-u) = \left(-\sigma_u\sigma_v/\sigma\right)\left[\left(f(u/v-u)/1 - F(\omega/\sigma)\,\gamma/1-\gamma\right) - v-u \Big/ \sigma\sqrt{\gamma/1-y}\right]$$ … (13)

Where, $f(u/v-u)$ and $F(\omega/\sigma)\,\gamma/1-\gamma)$ are the standard normal and cumulative normal density functions corresponding.

Estimates of $E(u/v-u)$ are derived by assessing Equation (13) at the ML estimates of γ, σ_u *and* σ_v. Technical efficiency of each farmer is computed as follows:

$TE = \exp E(u/v-u)$ …………………….. (14)

2.3.1 Model Specification of Stochastic Frontier Production Function

Cobb-Douglas and average form of stochastic frontier production function consistent with the data of the study after testing the generalized log-likelihood which meets up the analytical requirements as well. The formation can be written as:

$lnQ_i = \beta_0 + \sum \beta_i \ln(X_i) + (V_i - U_i)$………………… (15)

Where,

$\beta_i = Parameters\ Estimates$

$Q_i = The\ value\ of\ rice\ production(Tk.)$

$X_1 = Capital\ used\ by\ the\ farmer\ (Tk.)$

$X_2 = Labor\ ued\ in\ the\ production\ (Man\ per\ days)$

$X_3 = Farm\ Size$ for rice farming (decimals)

$X_4 = Fertilizer\ used\ in\ production\ (kg)$

$X_5 = The\ value\ of\ Irrigation(Tk.)$

$X_6 = The\ value\ of\ Pesticides(Tk.)$

$V_i = Random\ error\ term\ that\ are\ assumed\ to\ be\ independentidentically\ distributed\ N(0, {\sigma_v}^2) random\ variabes$

$U_i = Non - negative\ Technical\ inefficiency\ effects$

TECHNICAL INEFFICIENCY EFFECT MODEL

$U_i = \delta_0 + \sum_{i=1}^{9} \delta_i Z_{ji}$ ……………………… (16)

Where,

$U_i = Inefficiency\ effect$

$\delta_i = Coefficients\ of\ climate\ change\ adaptation\ strategies\ and\ socio - economic\ Factors$

$Z_{ji} = climate\ change\ adaptation\ Strategies\ and\ socio - economic\ factors$

$Z_1 = Age\ of\ the\ respondents\ (years)$

$Z_2 = Level\ of\ education\ (years\ of\ schooling)$

$Z_3 = Experience\ of\ rice\ farming\ (years)$

$Z_4 = Land\ fragmentation\ (No. of\ plot)$

$Z_5 = Off\ farm\ Income\ from\ off\ farm\ activities$

$Z_6 = Years\ of\ awarness\ of\ climate\ change$

$Z_7 = Extension\ Contact\ (1\ if\ access\ contact\ 0\ otherwise)$

$Z_8 = Access\ of\ credit\ for\ rice\ farming\ (1\ if\ access\ credit\ 0\ otherwise)$

To explain the inefficiency effect, following hypothesis of the functional formneed to be tested;

H_0: $\gamma = \delta_0 = \delta_1 = \cdots = \delta_9 = 0$, null hypothesis claims the absence of technical inefficiency effects i.e. the rice farmers are completely efficient technically. If null hypothesis is accepted average production function will be better to explain the data than the frontier function that assumes the existence of inefficiency in rice production.

The generalized likelihood-ratio statistic is used to perform above test of hypothesis that defined by;

$$\lambda = -2\ln\left[\frac{L(H_0)}{L(H_1)}\right] = -2\ln[L(H_0) - L(H_i)]$$

Where, L (H_0) is the likelihood function for the average production function with limiting parameter by null hypothesis, and the likelihood function for the generalized frontier model is L (H_1). If the null hypothesis is accepted, the parameters of H_1 and H_0 are equal with degrees of freedom by approximately a Chi-square distribution λ and then the number of parameters omitted from the model.

2.4 Factor Analysis Model

Factor Analysis (FA) model examined a large number of variables of several new dimensions. The model shows covariance among the unobservable, random variables in a matrix way (Johnson and Wichern, 1992; Hair, *et al.*1995). The model shows a strong correlation of variables within a particular group and lower relationship to other's group (Makhura, Goode & Coetzee, 1997). That's why variables are restricted to select, however, relaxation of restriction implies to explain the patterns of relationships only.

The matrix form of factor analysis model is:

$x = Af + e$.. (17)

Where,

x is the vector of n observable variables

f is the vector of m unobservable factors,

Ais called the loading matrix of the order $n \times m$

e is the error vector of $n \times l$

As indicated earlier, FA model aim in account to covariance between the explanatory variables in terms of a smaller number of factors. Therefore, the process further applies to identify the constraints of climate change adaptation practices in rice production. The model factor analysis of constraint specified as:

$$Q_1 = a_{11}X_1 + a_{12}X_2 + \cdots + a_{1n}X_n$$
$$Q_2 = a_{21}X_1 + a_{22}X_2 + \cdots + a_{2n}X_n$$
$$Q_3 = a_{31}X_1 + a_{32}X_2 + \cdots + a_{3n}X_n$$

. . . .

. . . .

. . . .

$$Q_n = a_{n1}X_1 + a_{n2}X_2 + \cdots + a_{nn}X_n$$

Where,

$Y_1, Y_{2,} \ldots\ldots, Y_n$
$= Observed\ constraints\ of\ rice\ farmers\ on\ adaptation\ of\ climate\ change$

$adaptation\ strategies$

$a_{11} \dots \dots . a_{nn} = factors\ loading\ or\ correlation\ coefficients$

$X_1, X_2 \dots \dots, X_n$
$= unobsved\ factors\ constrLainting\ rice\ farmers\ from\ adapting\ climate$

$change\ adaptation\ strategies$

3. Results

3.1 Influencing Factors of Adaptation Strategies Used by Rice Farmers

As estimation of MNL normalized by base category, no adaptation has taken as base category in this analysis. The variables of distance to input and an output market dropped from the model after the initial run due to its insignificant impact. The coefficients along with t values of MNL model are presented in table 1 where highly significant likelihood ratio (χ^2statistics;P < 0.0000) strongly explain the model. Moreover, the model represents the response of dependent variables in according to independent variables. Thus marginal effects of MNL has performed to explain actual magnitude of change in probabilities; shown in table 2.

Moreover, the MNL is run with and without the explanatory variables such as the age of household head, years of education, household size, farm size, extension contact, credit access which is represented in Table 2.

Table 1: Parameter Estimates of MNL Analysis of Influencing factors of Adaptation Strategies Used by Rice Farmers

Explanatory Variables	Coefficients					
	DTRV	CHEMFERT	ALTERTP	IRIGTION	CHANGPD	TESTNV
Sex (male) (1/0)	0.057	- 1.174	0.4923	0.4272	0.1336	-.55224
	(0.683)*	(1.126)**	(0.7240)	(0.6707)	(0.6738)	(0.6809)
Age of Household Head (years)	- 0.0093	0.0023	- 0.0145	0.0130	- 0.0024	- 0.0104
	(0.012)*	(0.012)	(0.0119)	(0.0139)	(0.0124)**	(0.0119)*
Years of Education (Number)	0.029	0.024	0.0218	- 0.0389	0.0062	0.0034
	(0.0308)	(0.0345)*	(0.0310)**	(0.0339)	(0.0309)	(0.03086)*
Household Size (Number)	- 0.095	- 0.192	0.0272	0.0336	-0.0436	-0.00216
	(0.075)	(0.0837)**	(0.0723)	(0.0837)	(0.0708)	(0.0694)**
Farm Size (decimals)	0.0019	0.0038	0.0010	0.000027	0.0004	0.0000502
	(0.0014)	(0.0019)**	(0.00096)	(0.00079)**	(0.0007)	(0.0008)***
Extension Contact (1/0)	0.429	0.474	0.1543	0.0444	- 0.5043	0.2166
	(0.325)***	(0.375)	(0.3133)	(0.3542)**	(0.3297)	(0.3135)*
Credit Access (1/0)	- 0.211	0.8924	0.473	0.1107	0.1291	0.1617
	(0.323)	(0.4109)***	(0.337)	(0.3585)**	(0.3328)**	(0.3251)
Constants	1.032	2.473644	- 1.4162	0.0171	- 0.1574	- 0.0060
	(0.8784)	(1.170192)	(0.9306)	(0.8732)**	(0.8768)	(0.8638)***

Number of Observation: 200

Prob $>\chi^2$ = 0.0000

Pseudo R^2 = 0.1181

Log pseudo likelihood = - 197.44765

Note: DRTV stands on drought tolerance rice variety, CHEMFERT stands for chemical fertilizer, ALTERTP stands on alternative tillage practices, CHANGPD stands on change in planting dates and TESTNV stands by testing new varieties IRGTION means irrigation

No Adaptation marked as base category. the robust standard errors shows in figure in parentheses

***, **, * implies 1%, 5%, and 10% level of significance respectively;

Source: Computed from Field Level Data, 2017

Table 2: Marginal Effects from MNL Analysis of Influencing factors of Adaptation Strategies Used by Rice Farmers

Explanatory Variables	Marginal Effects					
	DTRV	**CHEMFERT**	**ALTERTP**	**IRIGTION**	**CHANGPD**	**TESTNV**
Sex[b] (male)	0.0134	0.2181	- 0.11850	0.0832	- 0.0315	0.1361
(1/0)	(0.08)*	(1.05)	(- 0.68)	(0.64)**	(- 0.20)	**(0.82)***
Age of Household Head (years)	0.00217	- 0.000433	- 0.00349	**- 0.0025498**	- 0.0005	-0.00257
	(0.77)	(- 0.19)***	(- 1.23)	(- 0.95)	(- 0.20)*	(- 0.88)*
Years of Education (Number)	- 0.0067	0.045804	.0052569	.0075946	-.0014	**.0008488**
	(- 0.94)	(0.71)**	(0.71)**	(1.17)***	(-0.20)	(0.11)*
Household Size (Number)	0.022	.0356817	-.0065	**-0.0065545**	0.0103	**0.0005326**
	(1.30)	(2.410	(-0.380	(-0.40)	(0.62)	(0.03)
Farm Size (decimals)	- 0.0004	0.0007186	-0.00024	-5.34E-06	-0.000094	**.0000124**
	(- 1.34)	(- 2.12)**	(- 1.08)	(- 0.03)	(- 0.54)	(0.06)**
Extension Contact[b] (1/0)	0.0997	0.08815	0.0371	0.00865	0.1192	0.05342
	(1.34)**	(- 1.29)	(- 0.49)*	(0.13)*	(1.57)	(0.69)
Credit Access[b] (1/0)	0.049	0.1657626	-0.1139	0.0215645	0.0305	- 0.03988
	(0.66)	(- 2.29)**	(- 1.43)	(0.31)**	(0.39)**	(- 0.50)

(b) $\frac{dy}{dx}$ is for changing of dummy variables from 0 to 1,

Note: DRTV stands on drought tolerance rice variety, CHEMFERT stands for chemical fertilizer, ALTERTP stands on alternative tillage practices, CHANGPD stands on change in planting dates and TESTNV stands by testing new varieties, IRIGTION means Irrigation

No Adaptation marked as base category. the robust standard errors shows in figure in parentheses

***, **, * implies 1%, 5%, and 10% level of significance respectively;

Source: Computed from Field Level Data, 2017

From the Table 1 and 2, gender of the household slightly significant role in case of adapting drought tolerance rice varieties and chemical fertilizer. This shows that male dominant farmer appreciates using drought tolerance rice verities and using chemical fertilizer rather female by 1.43% and 21.81%. On the other hand, age of the household head has significant at 1% level of significance and negative correlation to the probability of choosing and using drought tolerance rice variety, changing planting dates and testing new varieties to cope up climatic risk in the study area. The result indicates the frugality of young farmer make them able to cope up climate change rather than their older counterparts by 28.3%. This may imply that older farmer has lower interest or understanding to climate change adaptation as rising age may discourage them less likely to invest in new technology as adaptation of drought-tolerant rice variety, changing planting dates and testing new varieties drop by 0.00217 (0.21%), 0.0005 (0.05%), and 0.00257 (0.25%), respectively. Meanwhile, the positive marginal values of education have positive impact on climate change adaptation. From the observation, higher education level rises probabilities of adapting chemical fertilize by 4.58%, alternative tillage practices by 0.52%, tested new varieties by 0.084%. The result is in line Shongwe, P. (2014), Uddin, M.N., Boklmann, W., and Entsminger, J. S. (2014). Household size seems to have no substantial impact on the choice of adapting adaptation options although the coefficient of the practices has positive sign. It is, therefore, insignificant, the greater the size of the household has better opportunity to adapting climate change. The significant variables of farm size and extension contact increase the chance of adapting climate change adaptation options. The farm size increase the chance of using chemical fertilizer irrigation and testing new varieties is 0.07%, 0.00053% and 0.0014% respectively. The Belay, A. *et al.* (2017), and Sarkar, R. (2011) found the same results as well. Therefore, extension contact/ services would expand the possibility of prefer and usage of drought tolerance rice variety, irrigation, and testing new varieties approximately 10%, 0.8% and 5.34% Furthermore, the use of mineral fertilizer, changing sowing dates as well as irrigation involving institutional support have significantly positive impacts on promoting adjustment practices by 0.1657 (16.57%), 0.02152 (2.15%) and 0.0305 (3.05%) respectively

3.2 Estimation For Stochastic Frontier Production Function

The Maximum Likelihood Estimation (MLE) involved in the estimation of technical efficiency of average output (Model 1) with the production frontier models (Model 2). The model for rice production preferred according to the generalizing log likelihood ratio statistics. Thus, estimated stochastic frontier models (Model 1 and 2) for rice production has shown in Table 4 in the study region. Table 3 represents the results of hypothesis test to test the better response of the data.

The statement on the purpose of absence of inefficiency effects as null hypothesis, H_o: $\gamma = \delta_0 = \delta_1 = \cdots = \delta_8 = 0$,which is rejected for the rice farmer.

Table 3: Generalized Log Likelihood-ratio Tests of Null Hypothesis

H_o: Rice farmers are efficient technically (γ=0)

	Log Likelihood Ratio				
Rice Farmers	Model 1	Model 2	λ	Critical Value*	Decision
Total Sample (200)	- 158.002	- 149.869	16.266	15.51	Reject H_o

Restricted parameter counted as Degree of freedom, here the number of restricted parameters were 8.

Source: Computed from field data, 2017

The Cobb-Douglas frontier model (Model 2) preferred as better option to estimate efficiency of rice farmer regarding the hypothesis test. The analysis is therefore based on the Cobb-Douglas frontier model as shown in Table 4. The results of Cobb-Douglas frontier model are compatible with the Sarker. *et al.* (2017) as lead functional form to estimate the risk watermelon in Bangladesh. Table 4 hypothesized adjustment practices and other farm specific household variable age, education, years of rice farming, fragmentation of land, off-farm income, years of perception of climate change, extension contact and availability of credit. The results reveals that 0.77 mean efficiency indicate the reduction of barriers can maximize the output by 23%

Table 4: Maximum Likelihood Estimates (MLE) of the Stochastic Frontier Production Function for Rice Farmers

		Model 1		Model 2	
Variables	**Parameters**	**Coefficients**	**t-ratios**	**Coefficients**	**t-ratio**
Production Model					
Constant	β_0	1.58 (0.5674)	28.889***	0.8559 (0.5952)	14.37***
Ln(Capital) (X_1)	β_1	0.2977 (0.0912)	3.26***	0.28147 (0.08768)	3.20***
Ln (Labor) (X_2)	β_2	0.0393 (0.0546)	0.72	0.0515 (0.0534)	0.965
Ln (Farm Size) (X_3)	β_3	0.5641 (0.07683)	7.34***	0.4892 (0.0796)	6.13***
Ln (Fertilizer) (X_4)	β_4	0.0718 (0.0639)	5.02**	0.06479 (0.06251)	4.36**
Ln (Irrigation) (X_5)	β_5	0.0151 (0.0510)	2.29***	0.0394 (0.051767)	2.11***
Ln (Pesticides) (X_6)	β_6	- 0.0061 (0.0450)	- 0.13	- 0.0112 (0.0428)	- 0.61

Technical Inefficiency Model				
Constant	Z_0	---	0.344 (0.162)	2.6**
Age	Z_1	---	0.01878 (0.00625)	3.00*
Years of Schooling	Z_2	---	0.01307 (0.01549)	2.69*
Years of Rice farming	Z_3	---	- 0.0218 (- 0.01236)	- 1.76
Fragmentation of Land	Z_4	---	0.05175 (0.03796)	13.6***
Off-farm Income	Z_5	---	1.413E-06 (7.22E-06)	2.00*
Years of perception of Climate Change	Z_6	---	- 0.00192 (0.0135)	- 2.078**
Extension Contact	Z_7	---	- 0.4933 (0.3354)	- 6.47***
Accessibility of Credit	Z_8	---	- 0.0322 (0.150)	- 2.13**
Variance Parameters				
Total Variance	σ^2	0.2936	0.3692 (0.0948)	3.89***
Gamma	λ	0.05	0.4716 (0.2032)	2.32***
Log Likelihood Function	Llf	- 158.002	- 149.869	

*, **, *** stands for level of significance at 10%, 5%, 1% respectively;

Figures in parentheses are the robust standard errors

Source: Computed from field data, 2017

From the table 4, age and education level are significant at 10%, credit access is significant at 5% and land fragmentation and extension contact are significant at 1% level of significance. However, years of farming rice and observation of climate change (years) are not significant.

The positively significant sign of age indicates that the degree of inefficiency is lower to the younger farmer than older one which is observed similarly among sorghum production (Bushara, M.O. *et al.* 2016). Moreover, the positive coefficient of degree of education continues to increase the inefficiency level. Rather, this could conflict in the absence of practical and vocational education (e.g. agricultural education) that is persistent of (Kuria *et al.* 2003; Abedullah and Ahmad 2006); Abedullah*et al.*2007; Maganga, 2012; Ojo 2012).

Raise in land partitions reflect the extent of inefficiency that would relevant the positive coefficient of fragmentation of land at the study region. The finding is in line of Al-Amin, A.K.M.A. *et al.* (2016). However, the negative sign of extension contact may lead more inefficiency after getting extension. The service is more effective after training that provide practical example (Coelli*et al.* 2002), though inefficient farmers would have benefited from extension services(Balcombe *et al.* 2007; Rahman *et al.*, 2009; Coelli*et al.*, 2003; Rahman, 2003 and Myint and Kyi, 2005). The negative coefficient of credit access leads to lower inefficiency after getting more credit. This implies that more working capital positively affected the farming because of high cost of input. The similar findings explored by Binam*et al.*, (2004) and Bozoglu and Ceyhan (2007).

3.3 Barriers of Undertaking adjustment Practices Faced by Rice Farmers

The varimax-rotated principal component analysis is used to evaluate the key factors restricted rice farmers in adapting to climate change in the study area. From the result, five (5) categories were derived from the responses of the respondents. The criterion of Kaiser(1960) was used to identify the number of factors of principle components. Eigen values of less than was used to explaining the number of corresponding components. The variable with factor loadings of 0.40 and above 10% variance were used to include variable and less than 0.40 factor loading were discard (Madukwe, 2004). These factors are after discarding and rotation; five categories namely public, institutional and labor constraints accounted 17.283% of the variance, neighborhood norms and conventional beliefs constraint was 15.245%, high production cost and poor alarming system constraint weighted by 12.833%, limited information of adaptation and credit accessibility constraint was 8.76% and limited agricultural extension and service was counted by 8.116%. 62.239% of variation retained to explain 17 limiting factors.

Table 5: Varimax Rotated Barrier Factors of Rice Farmers on Climate Change Adaptation

	Components*					
Constraints	**Factor 1**	**Factor 2**	**Factor 3**	**Factor 4**	**Factor 5**	**Communality**
Inadequate access to supporting institutional facilities	0.805					0.69
Poor access to information to climate change adaptation strategies	0.891					0.811
Neighborhood norms, customs, culture and traditional belief against adaptation		0.756				0.611

Inherited system of land ownership		0.862				0.774
Traditional practice		0.813				0.707
Illiteracy of rice farmer			0.779			0.674
The high cost of fertilizer			0.422			0.566
The high cost of irrigation facilities			0.662			0.565
Tedious nature of climate change adaptation strategies				0.738		0.681
Lack of credit facilities provided by the govt.				0.752		0.579
Lack of study on adaptation				0.776		0.607
Poor access to climate-related data				0.511		0.327
Lack of govt. policies					0.520	0.521
Lack of insurance					0.498	0.435
**Non-availability of storage facilities			0.630	0.40		0.643
Percentage (%) of total variance	17.283	15.528	12.833	8.762	8.11	

*Factor1= public, institutional and labor constraints; Factor 2 = neighborhood norms and conventional beliefs constraint; Factor 3 = high production cost and poor alarming system constraint; Factor 4 = limited information of adaptation and credit accessibility constraint; Factor 5 = limited agricultural extension and service. ** Constraints that loaded under more than one factor

Source: Computed from field data, 2017

The table 5 describes particular factors that increased the limitation on public, institutional and labor constraints (factor 1) by poor accessing institutional facilities (0.805), poor access to the observation of climate change (0.891) among the rice farmers in the study area. The challenges posed a serious to cope up climate changes, however, as they are not alert for current development potentials. Moreover, the inability to adjust in terms of limited resources such as inaccessibility of climatic information creates a significant gap to be efficient production. The prediction of climatic variable helps the farmer to plan useful and effective. Islam, M. M. (2014) found that institutional constraints are one of the major constraints in Bangladesh that restricted the farmers and become more vulnerable (Ozor*et al.* 2010).

Neighborhood norms and conventional beliefs constraint under factor 2 loaded highly against adaptation (0.756), inherited land ownership system (0.862) and conventional practices (0.813). Variables associated with high production cost and poor alarming system constraint under factor 3 (high cost of inputs constraints) are high input cost of fertilizer (0.779), high cost of irrigation facilities (0.662), and illiteracy of the rice farmers (0.779). Factor 4 limited perception of climate change adaptation by complexity of undertaking adjustment practices (.738), limited credit facilities (0.752), poor study on adaptation (0.776) and lower accessibility of climate-related data (0.511). Poor local policies (0.520), insurance facilities (0.498) includes high loaded factor 5 of limited agricultural extension and services.

5. Conclusion

The study is the evaluation of the micro or farm level rice production efficiency along with the impact of climate change adaptation strategies. The above analysis more or less shows the magnitude and direction of the impact on climate change adaptation strategies on rice production efficiency and the barriers the farmer actually faced in *Ishwardi Upazila* in *Pabna District*. As climate change adaptation strategies specially affect agricultural production as well as rice production efficiency. So, climate change adaptation strategies are a crucial matter in rice production efficiency.

This has a policy implication worth thinking about and planning before damage occurs.

- Bangladesh government must consider structuring and actualizing adjustment strategies which are the best viability impacts for the misuse of environmental change and attention to the barriers the farmers faced.
- Try to focus on food security by proper access of climate related information, enhance the training and vocational education, and extend and effective irrigation infrastructure to implement adaptation strategies effectively that farmers easily adapt the adjustment practices.
- Strengthening qualitative research need to be pursued, as well as the farmers has decided to implement or expand the utilization of more adaption strategies.
- New technologies and improvement should take place against adjustment barriers in farming.
- Tenure status and access to subside was found to encourage using new adaptation strategies.

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