EFFICIENCY OF MAIZE PRODUCTION IN BANGLADESH: A STOCHASTIC FRONTIER APPROACH

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ABSTRACT

In the recent years, maize has emerged as an economically viable crop to the farmers of Bangladesh. This study estimates the technical efficiency of maize production under two different cropping patterns: Rabi season maize and Kharif season maize, and compares the efficiency of production between two cropping patterns. For this purpose, primary data have been collected from maize farmers from Thakurgaon district of Bangladesh as this area encompasses the highest concentration of maize cultivation. The Translog Stochastic Frontier production function is applied to estimate the technical efficiency of both seasons' maize. The results show that mean technical efficiency is found as 87.5% in the case of Rabi season maize, whilst it is 92% for Kharif season maize. It is also found that efficiency of maize production in Rabi season is positively influenced by fertilizer and irrigation while it is negatively influenced by farm size. On the other hand, farm size shows positive effect and irrigation shows negative effect on Kharif season maize production. An inefficiency effect model estimated by the Maximum Likelihood method shows that variables like education, household size, own land holding, access to credit and total income are negatively related to technical inefficiency of maize production in the Rabi season. In reverse, own land holding has positive relationship while farming experience, access to extension service and total income have negative relationship with technical inefficiency of maize production in the Kharif season.

Keywords: Maize, Technical efficiency, Rabi, Kharif, Translog stochastic frontier production function, Bangladesh.

INTRODUCTION

Bangladesh is a developing country with agriculture as the mainstay of the economy (Chowdhury *et al.* 2013). Agriculture sector has been playing a vital role in the socio-economic advancement and sustainable economic development of the country through gradual improvement of the rural as well as the whole economy by ensuring food security and alleviating poverty. It covers 15.35% share of the total GDP of Bangladesh in the FY 2015-16 (GoB, 2016). Agriculture not only provides food to the people but also creates the largest source of employment for the people of the country. More than 60 percent of total population depend on agriculture directly or indirectly, and 45.10 percent of its total labor force (GoB,

2016) is employed in this sector. It is the major source of livelihood for the 16 million households of Bangladesh (Kajal et al., 2013).

Agriculture sector is mainly dominated by crop subsector and rice is the main food crop in Bangladesh. In FY 2014-15, the total amount of food crop production in Bangladesh was 38.42 million mt. in which rice production alone was 34.71 million mt. This indicates the importance of rice in Bangladesh agriculture. Compared to rice, production of other food crops- maize and wheat, were 2.36 million mt, and 1.34 million mt., respectively (BBS, 2016). Although the total production of food is increasing in Bangladesh, the country still faces significant food security challenge as the production of food crops is not diversified. This leads to suffering of people from extremely high rate of chronic and acute malnutrition in the country, especially among the women and children (Rich et al., 2015). Lack of crop diversity results in shortage of some specific food crops which the country needs to import from abroad (Chowdhury et al., 2013). For example, Bangladesh imported a total of 2.79 million mt. food crop in FY 2015-16 (BBS, 2016).

In this circumstance, it has been increasingly realized that for the betterment of Bangladesh economy a real breakthrough in crop diversity is necessary (Baksh, 2003). Maize may be helpful to improve this situation although it is relatively a new crop in Bangladesh (Rahman et al., 2013). During the 1970-80s, a few thousand hectares of land was cultivated for maize production (Ali et al., 2009). After the establishment of BARI (Bangladesh Agricultural Research Institute) in 1976, researchers and government felt the potentiality of maize production in Bangladesh (Ali et al., 2008). According to CIMMYT (2009), maize is very well-suited to the country's fertile alluvial soil and can be grown almost any time, except for the rainy season. From 2000, maize became a lucrative cash crop particularly to the farmers of northern and western part of Bangladesh boosted by huge and expanding market demand for it. Thus, the area under maize cultivation has quickly increased to 804 thousand acres of land in FY 2014-15 from 72 thousand acres in FY 2003-04 (BBS, 2012 & 2015). The advantages of maize lie in its higher yield rate and higher profitability compared to the other two major cereal crops: *Boro* (irrigated) rice and wheat (BBS, 2012). Widespread use of fertilizer along with modern irrigation facilities has ensured high yield of maize production with a national mean yield of around 6.58 t/ha (BBS, 2012).

In the face of growing food consumption and changing food habit of the people, maize has potential role to play as a food crop in Bangladesh. People can consume maize by different ways and in terms of human consumption, maize occupies important position in the food chain after rice and wheat. Maize is also used in food baking and cattle feed industries in Bangladesh. Although the demand for maize is increasing day by day, its production is still below the required level. So, it is important to expand the area under maize cultivation for ensuring the food security and promoting sustainable development of agriculture in Bangladesh. This also demands the need of knowing more information about maize production along with the state of efficiency in production of this crop for policy purposes. However, in reality this sort of studies regarding maize production is very scant in our country. Therefore, this research takes care of the issue of technical efficiency of maize production in Bangladesh under different cropping seasons taking *Thakurgaon* area as the case study.

In Bangladesh, hybrid maize is grown mostly in the winter (*Rabi*) season (November-March) after the harvest of Transplanted. *aman* rice. Additionally, more area is coming under maize production in the post winter (*Kharif)* season (February-May), mainly after the harvest of potato (Ali et al., 2009). Following this, farmers in *Thakurgaon* District also cultivate maize in the above two seasons, *Rabi* and *Kharif* under two cropping patterns. Another cropping pattern is also found in the study area under which maize is cultivated after harvesting wheat or mustered but this is insignificant considering very low coverage of land and its amount of production. Therefore, this study mainly concentrated on the *Rabi* and *Kharif* season maize production ignoring the other pattern. It is interesting to note here that farmers use different level of inputs combinations in these two cropping patterns, and as a result production also varies significantly. Thus, the main objective of this paper is to assess the level of technical efficiency of maize production under two seasons- *Rabi* and *Kharif*, and to compare the results obtained for these two seasons, focusing on the context of *Thakurgaon* District of Bangladesh. The study also focuses on the factors affecting technical inefficiency existing in maize production in the study region.

LITERATURE REVIEW

There are a number of studies devoted to measure technical efficiency of maize production in the context of different countries. Ngeno et al. (2011), Esham (2014), Musaba and Bwacha (2014), Chirwa (2007), Ogunniyi and Ajao, (2011), Geta et al. (2013), Oppong (2003) and Boundeth et al. (2012) estimated the technical efficiency of maize production in Kenya, Sri-Lanka, Zambia, Malawi, Nigeria, Ethiopia, Ghana and Laos, respectively. The studies have used different approaches to obtain their objectives. Ngeno et al. (2011), Esham (2014), Musaba and Bwacha (2014), Islam et al., (2011), Boundeth et al. (2012), Oppong (2003), Ilembo and Kuzilwa (2014) used the stochastic frontier approach in their studies and they mostly used the Cobb-Douglas stochastic frontier production function form. Most of the studies used Maximum Likelihood method for estimating technical efficiency level of production. Oppong (2003) used both Maximum Likelihood and Seemingly Unrelated Regression methods to estimate efficiency in his study. In the study of Ngeno et al., (2011), Data Envelopment Analysis (DEA) approach was used with the application of Translog Stochastic Frontier function to analyze the technical efficiency. Ogunniyi and Ajao, (2011) employed both the Stochastic Frontier Analysis (SFA) and Data Envelopment Analysis (DEA) approaches in their study. Geta et al. (2013) used Normalized Translog Production function and the Tobit regression model to measure maize productivity and to determine efficiency factors, while the DEA method to measure the efficiency level.

Most of the studies done in contexts of different countries found technical inefficiency existing in maize production and they observed varying findings with regard to the level of technical efficiency and the factors that cause technical inefficiency in production. Using both the SFA and DEA approaches Ngeno et al. (2011) obtained mean technical efficiency level as 85% in the case of Kenya. Esham (2014) obtained an efficiency level of 72% in Sri Lanka and observed that there was considerable potential for improvement in maize productivity within the present level of technology. Musaba and Bwacha (2014) found an average level of technical efficiency of 79.6% in Zambia and observed that farmers with cooperative membership showed higher efficiency in maize production. Boundeth et al. (2012) have found that the mean technical efficiency is 65% in maize production in Laos. Ogunniyi and Ajao (2011) obtained moderately higher level of technical efficiency in maize production in Nigeria and observed that SFA gave higher score for efficiency than the DEA approach. However, Chirwa (2007) estimated the technical efficiency level of the smallholder maize producers of Malawi and found that the level of technical efficiency was very low, which is equal to 46.23% only. Geta et al. (2013) found the mean technical efficiency in Ethiopian maize producers as low as 40% implying that there was substantial opportunity to raise the efficiency among smallholder maize farmers.

Empirical studies also emphasized on investigating the determinants of technical inefficiency in maize production. From the review of the major empirical literature, variables such as age, education, training of the farmer, farm size, seed type, use of fertilizer and pesticides, own land holding, farmers' involvement with club or association, etc. are reported to have significant effect on efficiency of maize production (Esham, 2014; Musaba et al., 2014; Geta et al., 2013; Rahman et al., 2013; and Boundeth et al., 2012; Islam et al., 2011; Rahman et al., 2008; Chirwa, 2007; Oppong, 2003). Esham (2014) found that the seed, hired labor and land size were found to positively influence maize production. Oppong (2003) observed that access to credit and education, hybrid seed, male farmers and farm size were positively related to the technical efficiency. In contrast, Musaba and Bwacha (2014) found that seed types, rotation practices and education level of the farmers have negative effect on technical efficiency. Ngeno et al. (2011) found that quantity of seed, use of tractor and pesticide are negatively related to efficiency of the maize farmers. The results of the study of Chirwa (2007) revealed that inefficiency of the maize production declines as the hybrid seeds are used and when the households are with membership in a farmer's club or association. In Sadiq et al. (2009) the positive and significant value for education reveals that higher education increases inefficiency of production. Geta et al. (2013) found the factors that significantly affect the technical efficiency were agro-ecology, oxen holding, farm size and use of high yielding maize varieties.

Studies on technical efficiency of maize production in Bangladesh are mostly scarce. Rahman et al. (2013) estimated the profitability and technical efficiency of maize production in the selected areas of Bangladesh using the Cobb-Douglas stochastic frontier production function. The study found the estimated average level of technical efficiency of the respondents was very high (96.90%), implying that only 3.10% technical inefficiency was existed. They also found that farmers' age, education and training received have significant positive effect on maize production. Hasan (2008) estimated the costs, returns and economic efficiency of maize production in comparison to Boro rice in Bangladesh. The results based on the Cobb-Douglas stochastic frontier production function showed that average yield of maize was 6.27 ton/ha, and the mean technical efficiency was 84% at Dinajpur and 80% at Panchagarh districts, respectively. It was found that the most significant constraints of maize production in the study area were high seed price, low grain price, and unavailability of fertilizers at time when required. Using Stochastic Cost Frontier function Rahman and Rahman (2014) found that maize ranks first in terms of yield (7.98 t/ha) and return (BCR=1.63) as compared to rice and wheat. The economic efficiency of maize production is also estimated high, 87%, although a substantial 15% cost reduction is still possible by eliminating technical and allocative inefficiency.

Moniruzzaman et al. (2009) found the net return of maize production to be Tk 25,575 per hectare and benefit cost ratios were calculated as 1.58, 2.10 and 2.85 on total cost, variable cost and cash cost basis, respectively. The study observed that lack of capital and high price of TSP were the main constraints to efficiency of maize production. Karim et al. (2010) found net return from one kilogram of maize production was found as Tk.3.68. The major problems for hybrid maize production as found in this study are timely unavailability of seeds, high price of fertilizer, low price of yield at harvesting period etc. Rahman et al. (2015) a Probit regression model to evaluate the determinants of choice of maize growing season and its economic efficiency in Bangladesh. The results showed that the probability to choose winter maize are influenced positively by gross return, subsistence pressure and soil suitability. The mean level of efficiency was found about to be 91% that is there is a scope to raise 9% of production with the existing level of technology.

Theoretical Framework: Measuring Technical Efficiency

The concept of efficiency is concerned with the relative performance of the processes used in transforming given inputs into outputs. Efficiency is an important aspect of productivity, when resources are scarce and opportunities for developing and adopting better technology are limited. Efficiency in production can be achieved either through maximizing output from given or fixed amount of resources or through minimizing use of resources for producing a given level of output. Farrel (1957) obtained economic efficiency as the product of two types of efficiencies- technical efficiency and allocative efficiency. Technical efficiency shows the ability of a firm to employ the best practice in production so that no more than the necessary amount of a given sets of inputs is used in producing the best level of output. Allocative efficiency refers to the optimal combination of the inputs to be used in right proportions so that output is produced at minimal cost.

Measurement of technical efficiency is a problem since long before and the measurements included methods like indexing or some other methods devoid of theoretical background. Farrell, (1957) introduced a technique of measuring technical efficiency with strong theoretical background. According to him technical efficiency can be measured using the production frontier. Technical efficiency can be output or input oriented. The ratio of technical efficiency ranges between 0 and 1, and the lower the ratio the lower the efficiency of the production process is. If a farm is able to continue its production on the production frontier, it is called an efficient farm. On the other hand, if the farm fails to continue its production on the production frontier, it is called an inefficient farm.

There are many approaches to estimate technical efficiency. According to Xu and Jeffrey (1998), empirical studies of production efficiency have employed a variety of modeling approaches. On the very broad basis, these techniques can be categorized into parametric approaches and non parametric mathematical programming approaches. Non parametric approaches are those approaches of measuring efficiency which do not make any *a priori* assumption on the data and do not impose functional form on the production function. A large number of empirical studies have applied this approach in the study of efficiency analysis worldwide (Chimai, 2011; Abu, 2011; Chiona, 2011). The non-parametric approach includes the Data Envelopment Analysis (DEA) method. DEA was firstly named by Charnes (1978) which had an input-oriented model with constant returns to scale. The method known as the basic DEA was an extension of Farrell's measure to multiple-input and multiple-output situations. The subsequent researchers such as (Banker et al, 1984) developed the variable returns to scale models and introduced the DEA literature. DEA is known as sensitive approach to outliers (Hasnain et al., 2015). One of the disadvantages lies in its deterministic nature where it fails to account for stochastic noise in data, which could be a potential bias to the estimated efficiency scores. On the other hand, the parametric approaches of efficiency analysis make *a priori* assumptions about the data and impose functional forms on the production function. Most of the recent studies such as (Hasnain et al., 2015; Rahman et al., 2013, Haider et al., 2011) are related to technical efficiency using parametric approach. Parametric approach takes into account the stochastic noises of the data where the data envelopment analysis assumes there is no stochastic noise in the data (Abedullah, 2007).

EMPIRICAL METHODOLOGY

Sampling and Data Collection

This paper is mainly based on primary data. To achieve the objectives of this study selections of the study area and the households are done with due care. For this study, *Thakurgaon* district is selected purposively as this district exposes high concentration of maize cultivation under both cropping patterns. The main source of income of 83.03% people of this district is agriculture and the rest 16.97% people depends on non-farm activities. Among the farmers 59% are involved with maize cultivation. In FY 2013-14, the total area used in maize production was 2600 hectares and the total production was 18,213 mt. Thus, selection of *Thakurgaon* district as the study area is worthwhile. After selecting the district, the sample households are drawn using multistage random sampling method. Thus, through the sampling process, one *upazila* from the district, three unions from the *upazila,* and six villages from three unions are selected. At the last stage, 20 maize farmers from each village are chosen as respondents comprising a total sample size of 120. The households, who are maize farmers, are interviewed using a structured questionnaire.

Stochastic Frontier Production Function

Empirical studies of production efficiency have been found to employ either non-parametric or parametric methods to measure technical efficiency. Non parametric approaches are those approaches of measuring efficiency which do not make any *a priori* assumption on the data and do not impose functional form on the production function. On the other hand, parametric approaches of efficiency analysis make *a priori* assumptions about the data and impose functional forms on the production function. Non-parametric technical efficiency models are often referred to as the Data Envelopment Analysis (DEA) which is sensitive approach to outliers and its deterministic nature often fails to account for uncertainties in data, which appears as a potential bias to the estimated efficiency scores (Hasnain ,2015). In Bangladesh, agricultural activities are always operated under uncertainly and the application of the DEA approach may not suite properly to achieve the study objectives. Thus, this study has employed the Stochastic Frontier production function approach in estimating the level of technical efficiency of maize production in the study area.

In the stochastic frontier approach, the technical relationship between inputs and outputs of a production process is described by a production function which establishes the maximum level of output attainable from a given vector of inputs. The Stochastic Production Frontier (SPF) was developed independently by Aigner et al. (1977) and Meeusen and Broeck (1977). Following Aigner et al. (1977) the frontier production function is estimated in an effort to bridge the gap between theory and empirical work. The stochastic frontier production function can be generally stated as follows:

$$Y_i = f(X_i, \beta)\exp\varepsilon_i \ldots \qquad (1)$$

Where, $i = 1, 2, \ldots$ n. Y_i is the output of the i^{th} farm, X_i is the input vector used by the i^{th} farm, β is the vector of unknown parameters to be estimated and ε_i is the stochastic disturbance term. The stochastic error term is composed of two factors v_i and u_i, so that $\varepsilon_i = v_i - u_i$, where, v_i is a two-sided error term representing the usual statistical noise found in any relationship such that $v_i \sim$ NID $(0, \sigma_v^2)$ and independent of the u_i. It is the inefficiency parameter which includes the variables outside the control of the farmer.

On the other hand, the term u_i is a one-sided ($u_i \geq 0$) efficiency component that captures the technical inefficiency of the i^{th} farmer defined as the ratio of total actual output to the potential output (Greene, 1990; Stevenson, 1980; Aigner et al., 1977; Meeusen et al., 1977). In this study, it is assumed that u_i follows a half normal distribution with N $(0, \sigma_u^2)$ as typically done in the applied stochastic frontier literature. The variance parameter of the model can be parameterized as follows:

$$\sigma_s^2 = \sigma_v^2 + \sigma_u^2 \quad \text{and} \quad \gamma = \frac{\sigma_u^2}{\sigma_s^2}$$

$$\text{Where, } 0 \leq \gamma \leq 1 \quad \ldots \quad (2)$$

That is, the parameter, γ, must lie between 0 and 1. It represents the level of technical inefficiency. γ =0 implies no technical inefficiency in the production process (Haider et al., 2011).

Now, the technical efficiency of the i^{th} farmer can be estimated as:

$$TE_i = \frac{Observed\ output}{Maximum\ potential\ output}$$

And, the mean technical efficiency can also be defined as:

$$Mean\ TE = E[\exp[-E\{u_i/(v_i - u_i)\}]]$$
$$= E[1 - E\{u_i/(v_i - u_i)\}]$$

Specification of Production Function and Inefficiency Effect Model

Under the Stochastic Frontier Approach researchers are found to use different methods to measure technical efficiency. Among them most of the studies used Cobb-Douglas or translog stochastic production frontier function. However, the transcendental or the translog stochastic production function has some advantages over the Cobb-Douglas production function. The translog stochastic production frontier is used by Kitilla and Alemu (2014), Hasnain et al. (2015) and many others. Following them, the functional form of the translog stochastic production function, for measuring technical efficiency of maize production, applied in this study is specified as:

$$\ln Y_i = \beta_0 + \sum_{j=1}^{5} \beta_j X_{ji} + 0.5 \sum_{j=1}^{5} \sum_{k=1}^{5} \beta_{jk} \ln X_{ji} \ln X_{ki} + v_i - u_i \quad ... \quad (3)$$

Where, Y_i is the output of the i^{th} farm, and Xj is the vector of inputs. The inputs which serves as explanatory variables are- farm size, amount of seed, fertilizer cost, ploughing cost, irrigation frequency, and labour man days. The β's are the parameters to be estimated. According the theory of production, being inputs of production, all the explanatory variables are expected to have positive effect on the level of production. These variables are considered as explanatory variables in the studies carried out by Kitila and Alemu (2014), Ohajianya, et al., (2010), Naqvi et al., (2013), Geta et al., (2013) and Hasan, (2008).

In the Stochastic Frontier production function, the error term, u_i, is a distributional parameter and serves as a technical inefficiency indicator. Therefore, to determine the factors of technical inefficiency of the farm the underneath inefficiency effect model is used following Battese and Coelli (1995) and Hasnain et al. (2015).

$$u_i = \delta_0 + \sum_{j=1}^{9} \delta_j K_{ji} + w_i \quad ... \quad (4)$$

Where, u_i is the inefficiency of the i^{th} farm. δ_j's (j = 1, 2, ……., 9) are the parameters to be estimated. K_j is the vector of inefficiency factors serving as the explanatory variables in the model. In the studies of technical inefficiency model different variables are used to determine the inefficiency factors. In general- farm size, family size, age of the household head, experience of the household head, level of education of the household head, access to credit, gender of the household head, level of specialization in maize cultivation, off- farm income, level of fragmentation, training etc. are used by Tefaye and Bashir, (2014), Geta et al., (2013), Moniruzzaman et al. (2009), Rahman et al. (2013), Ogunniyi and Ajao (2011) as the determinant variable in the technical inefficiency model. The variables are found to portray impacts from both dimensions- positive and negative, on technical inefficiency of maize production.

RESULTS AND DISCUSSION

Results of Technical Efficiency of Maize Production

There are two main seasons of maize production in the study area, and in this paper, technical efficiency is estimated for *Rabi* and *Kharif* seasons' maize production and comparisons are made between the two cropping seasons. The level of technical efficiency is measured using the empirical framework of the stochastic frontier approach. The following table summarizes the results of the level of technical efficiency of the two types of maize production in the study area.

Table 1: Level of Technical Efficiency for Maize Producers

Efficiency	*Rabi* Season		*Kharif* Season	
Level	No. of farmers	Percentage	No. of farmers	Percentage
(60-70)%	8	6.67	12	10
(70-80)%	15	12.50	15	12.50
(80-90)%	67	55.83	23	19.17
Above 90%	30	25	70	58.33
Total	120	100	120	100
Mean TE	87.5%		92%	
Minimum TE	67.5%		68.5%	
Maximum TE	95.5%		98.5%	

Source: Authors' calculation.

From the above table it is observed that, there is significant variation in the level of technical efficiencies between the two types of maize seasons. In *Rabi* season the maximum and minimum technical efficiency for maize producers are found as 95.5% and 67.5%, respectively, with mean value of 87.5%. Again, the maximum and minimum technical efficiency for the maize producers in *Kharif* season are found as 98.5% and 68.5%, respectively, with mean value of 92%. It is also observed from Table 1 that in case of *Kharif* more than half (58.33%) of the respondents operate with technical efficiency level above 90%. In contrary, almost 56% maize producers in *Rabi* season lie between the technical efficiency level of above 80%. However, in both cases it is possible to increase the production of maize through increasing the efficiency using available resources.

Results of Translog production function

In the tranlog stochastic frontier function production five inputs are used, and the impacts of these inputs in log level, log squared and log interaction forms on maize production under *Rabi* and *Kharif* seasons are estimated separately. The obtained results are combined in Table 2 for making comparison between the results of two cropping patterns.

Table 2: Results of Translog Production Function for *Rabi* and *Kharif* Season Maize Farms

Variables	*Rabi* Season		*Kharif* Season	
	Coefficient	*t* value	Coefficient	*t* value
Constant	6.3	5.23*	3.08	1.23
ln farm size	-0.64	-2.15**	4.77	3.25*
ln seed	0.42	1.60	4.55	0.37
ln fertilizer	0.37	3.69*	-2.08	-0.86
ln irrigation	0.73	4.67*	-6.15	-1.73***
ln labour	-0.15	-1.31	8.96	1.40
$(\ln \text{farm size})^2$	1.61	1.34	0.01	0.21
$(\ln \text{seed})^2$	1.37	1.38	3.95	0.96
$(\ln \text{fertilizer})^2$	-1.31	-1.96***	0.39	0.83
$(\ln \text{irrigation})^2$	-3.03	-3.40*	-0.24	-0.57
$(\ln \text{labour})^2$	-4.14	-4.80*	-1.31	-1.55
ln farm size* ln seed	0.35	2.56**	-0.31	-1.04
ln farm size* ln fertilizer	0.86	2.13**	-0.48	-2.93*
ln farm size* ln irrigation	-0.67	-1.90***	-0.03	-0.23
ln farm size* ln labour	0.34	2.10**	-0.07	-0.55
ln seed* ln fertilizer	-0.59	-2.45**	-0.59	-0.43
ln seed* ln irrigation	0.25	1.60	-1.49	-1.84***
ln seed* ln labour	0.47	0.78	0.33	0.27
ln fertilizer* ln irrigation	0.51	3.15*	0.78	1.79***
ln fertilizer *ln labour	0.49	1.67	-0.75	-1.08
ln irrigation* ln labour	0.98	2.34**	0.38	0.72
Sigma square	0.61	1.95***	0.01	3.43*
Gamma	0.79	1.86***	0.67	4.76*
Log-likelihood function	38.89		17.80	
Log-likelihood ratio	145.51		4.54	

Source: Authors' own calculation. Note: *, ** and *** indicate 1%, 5% and 10% level of significance, respectively.

From the above table, it is observed that fertilizer and irrigation are found positively significant whereas the farm size is found negatively significant in case of *Rabi* season maize production in the study area. The estimated coefficients of translog production function indicate that 1 percentage increase in fertilizer cost and irrigation frequency may increase the *Rabi* season maize production by 0.37 and 0.73 percent, respectively. On the other hand, 1 percent increase in farm size may decrease the *Rabi* season maize production by 0.64 percent.

In case of square variables, it is observed that the coefficients of fertilizer square, irrigation square and labor square are significant. The negative coefficients of these square terms imply that the increase of these variables may increase the production of *Rabi* season maize at a decreasing rate. Moreover, the interaction variables show that farm size*seed, farm size*fertilizer, farm size*labour, fertilizer*irrigation, and irrigation*labor have positive effects on *Rabi* season maize production. On the other hand, farm size*irrigation and seed*fertilizer are found as negatively related to the *Rabi* season maize production in the study area.

The value of gamma (γ) is found as 0.79, which is significant. This means inefficiency remains in *Rabi* maize production in the study area. The significant value of σ^2 suggests that the technical inefficiency effect is an important component in the total variability of the yield of *Rabi* season maize.

From Table 2 it is also observed that farm size and irrigation have significant effect on *Kharif* season maize production in the study area. Farm size shows positive effect and irrigation shows negative effect. The estimated coefficient of farm size indicates that 1 percent increase in farm size may increase the *Kharif* season maize production by 4.77 percent. In contrast, 1 percent increase in irrigation may decrease the maize production by 6.15 percent. In addition, the interaction between farm size and fertilizer, seed and irrigation, fertilizer and irrigation also show significant effect on maize production. The first two interactions show negative effect and the last one interaction shows positive effect to the technical efficiency. The value of the gamma parameter (γ) is found as 0.67, meaning that inefficiency remains in *Kharif* season maize production in the study area. Moreover, the estimated parameter value of σ^2 is 0.01 and also significant at 1% level.

As we found the technical efficiency of *Kharif* season maize is higher than *Rabi* season maize and scope of increasing production efficiency of maize in case of *Rabi* season is higher than K*harif* season. It is observed from Table 2 that farmers of *Rabi* season can increase their production by increasing fertilizer cost and irrigation frequency. Whereas, *Kharif* season maize farmers can increase their production by increasing farm size only.

DETERMINANTS OF TECHNICAL INEFFICIENCY IN MAIZE PRODUCTION

In this section the result of the inefficiency effect model of maize production is explained. The inefficiency factors are mainly the socio-economic, farm level, farmer specific features of the farm households. These features include age, marital status, education, household size, experience of the respondents, own land holding, access to credit, total income, extension service, etc. The results of the inefficiency effect models for *Rabi* and *Kharif* season maize production are summarized in Table 3.

Table 3: Determinants of Technical Inefficiency of *Rabi* and *Kharif* Season Maize Production

Variable	*Rabi* season maize		*Kharif* season maize	
	Coefficient	t-ratio	Coefficient	t-ratio
Constant	-0.1052	-0.1048	0.0448	0.137
Age	-0.54	-0.55	-0.63	-2.01**
Marital status	0.19	0.19	0.60	1.56
Education	-0.37	-3.70*	-0.50	-1.83***
Household size	-1.12	-1.90***	-0.84	-2.15**
Experience	0.40	1.09	-0.14	-2.27**

Own land holding	-1.91	-3.69*	0.75	2.19**
Access to credit	-0.59	-4.28*	0.08	0.86
Total income	-0.83	-2.82*	-0.10	-1.90***
Extension service	0.21	0.21	0.19	0.97

Source: Authors' calculation. Note: *, ** and *** indicate 1%, 5% and 10% level of significance, respectively.

The estimated result of the inefficiency effect model for the *Rabi* season maize shows that education, household size, own land holding, access to credit and total income of the respondents are significantly and negatively related to the inefficiency of *Rabi* season maize production. That is, inefficiency in maize production can be decreased in the study area by increasing the levels of these variables. However, age, marital status, experience and extension services are found insignificant in the inefficiency effect model for *Rabi* maize production.

In case of *Kharif* season maize production age, education, household size, experience, own land holding, and total income of the respondents are significantly related to the inefficiency of maize production. Among these variables age, education, household size, experience and total income are negatively related to inefficiency in maize production. That is, as the values of these variables increase the extent of inefficiency may decrease and thus, efficiency may increase. Contrary to the case of *Rabi* season, own land holding has positive effect on inefficiency of *Kharif* maize production. That is if amount of own land holding increases then the inefficiency of production increases. The other variables such as marital status, access to credit and extension services are insignificant in the inefficiency effect model for *Kharif* maize production.

CONCLUSIONS AND POLICY IMPLICATIONS

Maize is an emerging and important food crop in Bangladesh for ensuring food security and sustainable agriculture. However, in spite of its importance there still exists inefficiency in maize production. From this study it is found that maize production in *Thakuegaon* is not technically efficient, and 12.5% and 8% production may be increased in *Rabi* and *Kharif* seasons, respectively, with the present level of technology. It is also found that technical efficiency of *Rabi* season maize production is lower than *Kharif* season maize production. While *Rabi* season maize production can be increased with the increased use of fertilizer and irrigation frequency, the *Kharif* season maize farmers can increase their production by increasing farm size. It is also found from the inefficiency effect model that education, household size, own land holding, access to credit and total income have negative relationship with technical inefficiency in case of *Rabi* season maize production. On the other hand, age, education, household size, experience and total income have negative effect while own land holding has positive effect on inefficiency in *Kharif* season maize production. The findings of this study have important policy implications towards increasing the technical efficiency of maize production in the study area. The findings suggest that policy towards enhancing proper use of fertilizer and irrigation would help to increase maize production. Furthermore, technical efficiency can be increased by improving the education level of the farmers and increasing their access to credit facilities. Therefore, government and non-government organizations may come forward with some intervention activities so that productivity of the farmers and their technical efficiency would increase and contribute to change in their livelihoods.

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