REFEREED ARTICLE

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Exploring the potential and performance of maize production in Bangladesh

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ABSTRACT

Maize is gaining importance in recent years as a promising crop aimed at boosting agricultural growth in Bangladesh. The present study explores the potential of maize expansion by examining its profitability and economic efficiency using a survey data of 300 farmers from three regions. Maize ranks first in terms of yield (7.98 t/ha) and return (BCR=1.63) as compared with rice and wheat. The economic efficiency of maize production is also estimated at a high 87%, although a substantial 15% [(100-87)/87)] cost reduction is still possible while maintaining current output level by eliminating technical and allocative inefficiency. Education positively contributes towards increasing efficiency while large farmers are relatively inefficient. Geography does matter. Efficiency is lower in Bogra region as compared with Dinajpur and Kushtia. Policy implications include investment in education, setting up appropriate price policies to stabilise prices and facilitation of the input markets for timely delivery of required inputs.

KEYWORDS: Economic efficiency; profitability; stochastic cost frontier; maize; Bangladesh

1. Introduction

The Bangladesh economy is dominated by agriculture contributing 14.2% to the Gross Domestic Product (GDP). Of this, the crop sub-sector alone contributes 10.1% to the GDP (BBS, 2011a). Agriculture sector generates about 35.0% of the total foreign exchange earnings (Husain, *et al.*, 2001 and Islam, *et al.*, 2004) and is the main source of employment absorbing 45.6% of the labour force (BBS, 2011a). Land is the most important and scarce means of production resulting in intensive cropping on all available cultivable land. The cropping intensity in 2011 is estimated at a high 191% (BBS, 2011a). It has been increasingly realized that economic development in Bangladesh can not be achieved without making a real breakthrough in the agricultural sector (Baksh, 2003). Although rice is the main staple food grain, maize is gaining importance as a third crop after wheat covering 1.2% and 2.1% of the total and net cropped area in 2011, respectively (BBS, 2011a). The government is also keen to diversify its agriculture and had earmarked 8.9% of the total agricultural allocation (worth US$ 41.8 million[3]) during its Fifth Five Year Plan (1997–2002) (PC, 1998).

Maize in Bangladesh

Maize is one of the oldest crops in the world and is well known for its versatile nature with highest grain yield and multiple uses. In Bangladesh, maize cultivation started in the early 19th century (1809) in the districts of Rangpur and Dinajpur (Begum and Khatun, 2006). During 1962, the then governor of the erstwhile East Pakistan tried to re-introduce maize in those areas but did not succeed. However, the Bangladesh Agricultural Research Institute (BARI) has been conducting research on the varietal development of maize since 1960 with a thrust to develop composite varieties. So far, BARI has developed seven open pollinated and eleven hybrid varieties (Begum and Khatun, 2006; BARI, 2008). The yield potential of the released composite varieties are 5.5–7.0 t/ha and the hybrid varieties are 7.4–12.0 t/ha which are well above the world average of 3.19 t/ha (FAOSTAT, 2011).

Maize production and yield has experienced an explosive growth in Bangladesh in recent years. The cropped area of maize has increased from only 2,654 ha in 1972 to 165,510 ha in 2011; production from 2,249 t to 1,018,000 t; and yield from 0.85 t/ha to 6.15 t/ha during the same period. Maize has now positioned itself as the 1st among the cereals in terms of yield rate (6.15 t/ha) as compared to Boro rice (3.90 t/ha) and wheat (2.60 t/ha) (BBS, 2011a).

Maize possesses a wide genetic variability enabling it to grow successfully in any environment and in Bangladesh it is grown both in winter and summer time, although the former is the dominant pattern. Demand for maize is increasing worldwide and in Bangladesh and its production has crossed one million ton by 2011. A limited number of socio-economic investigations were made on maize cultivation in Bangladesh which revealed that maize is a profitable crop and stands well above from its competitive peers, e.g., rice (Hussain *et al*, 1995; Fokhrul and Haque, 1995)

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[3] In mid-December 2013, US$1 was approximately equivalent to £0.61 and €0.73 (www.xe.com).

and mustard (Haque, 1999) and has brought positive changes in different aspects of livelihood such as capital formation, food intake, income, household amenities, socio-economic conditions, etc (Islam, 2006).

Given this backdrop, the objective of the present study is, therefore, to assess the potential of maize production as an alternative crop by specifically examining profitability, economic efficiency and its determinants at the farm-level in Bangladesh. This is because efficient use of scarce resources is an important indicator in determining potential to increase agricultural production. Although the rice-based Green Revolution technology in Bangladesh has paid off well, there is an urgent need to diversify agriculture in order to sustain its growth (Rahman, 2010). Furthermore, the focus of empirical studies of resource use efficiency in Bangladesh was on rice and wheat (e.g., Rahman, 2003; Coelli *et al*., 2002; Asadullah and Rahman, 2009; Rahman and Hasan, 2008). The importance of assessing economic efficiency of maize arises because although maize cultivation is highly profitable, it requires substantial upfront costs during the production process. Therefore, Bangladeshi farmers characterised with scarce land and credit constraints needs to focus on minimizing production cost while keeping up the high yield potential of the chosen crop in order to sustain their farming practices and benefit from the adoption of this new technology.

The paper is organized as follows. Section 2 describes the methodology and the data. Section 3 presents the results. The final section concludes and draws policy implications.

2. Methodology

Profitability or cost-benefit analysis

Profitability or cost-benefit analysis includes calculation of detailed costs of production and return from maize on a per hectare basis. The total cost (TC) is composed of total variable costs (TVC) and total fixed costs (TFC). TVC includes costs of human labour (both family supplied and hired labour, wherein the cost of family supplied labour is estimated by imputing market wage rate), mechanical power; seed, manure, chemical fertilizers; pesticides; and irrigation. TFC includes land rent (if owned land is used then the imputed value of market rate of land rent is applied) and interest on operating capital. The gross return (GR) is computed as total maize output multiplied by the market price of maize. Profits or gross margin (GM) is defined as GR–TVC, whereas the Net return (NR) is defined as GR–TC. Finally, the Benefit Cost Ratio (BCR) is computed as GR/TC.

Analytical framework: the stochastic cost frontier model

A limitation of profitability analysis presented above is that it does not tell us whether farmers are achieving the maximum potential yield and profit from their production process. However, an analysis of economic efficiency allows such information to be generated at the individual producer level which is important for farmers, policy makers and other stakeholders alike.

A cost function, which is a dual of the underlying production function, is defined as a function of input prices and output level. Specifying a cost function avoids the problem of endogeniety of variables used in modelling. This is because input prices are considered exogenous in nature and is not determined within the model. A conventional cost function assumes perfect efficiency in production which is not a valid assumption given widespread evidence of inefficiency in agricultural production process worldwide (e.g., Bravo-Ureta *et al*., 2007). However, specification of a stochastic cost frontier function allows us to identify the level of inefficiency (specifically economic inefficiency) in the production process at the individual producer level.

Economic efficiency, also known as cost efficiency, results from both technical efficiency and allocative efficiency. Technical efficiency refers to a producer's ability to obtain the highest possible output from a given quantity of inputs (Rahman, 2003). Allocative efficiency refers to a producer's ability to maximise profit given technical efficiency. A producer may be technically efficient but allocatively inefficient (Hazarika and Alwang, 2003). Therefore, economic/cost efficiency refers to a producer's ability to produce the maximum possible output from a given quantity of inputs at the lowest possible cost.

Consider the stochastic cost frontier function based on the composed error model (e.g. Aigner *et al*., 1977);

$$\ln C_i = \alpha_0 + \alpha \ln Q_i + \sum_{j=1}^{n} \beta \ln W_{ij} + \varepsilon_i \tag{1}$$

where C_i represents household *i*'s cost per ha maize production, Q_i denotes the maize output per ha; W_{ij} signifies the household-specific price of variable input *i*, and ε_i is a disturbance term consisting of two independent elements as follows:

$$\varepsilon_i = u_i + v_i \tag{2}$$

v_i, assumed to be independently and identically distributed as $N(0,\sigma_v^2)$, represents random variation in cost per acre due to extraneous factors such as the weather, crop diseases, and statistical noise. The term u_i is taken to represent cost inefficiency relative to the stochastic cost frontier, $\ln C_i = \alpha_0 + \alpha \ln Q_i + \sum_{j=1}^{n} \beta \ln W_{ij} + v_i$. It is, therefore, one-sided as opposed to being symmetrically distributed about the origin. In other words, u_i=0 if costs are, ceteris paribus, as low as can be, and u_i>0 if cost efficiency is imperfect. u_i is assumed to be identically and independently distributed as truncations at zero of the normal distribution $N(\mu,\sigma_u^2)$, The stochastic cost function (1), may be estimated by maximum-likelihood. Given the above distributional assumptions,

$$E(u_i|\varepsilon_i) = \frac{\sigma\lambda}{(1+\lambda^2)}\left[\frac{\phi(\mu_i^*)}{1-\Phi(\mu_i^*)} - \mu_i^*\right] \tag{3}$$

where ϕ and Φ denote, respectively, the standard normal p.d.f. and the standard normal c.d.f., $\lambda = \sigma_u + \sigma_v$, $\sigma = \sqrt{\sigma_u^2 + \sigma_v^2}$, and $\mu_i^* = (\varepsilon_i\lambda/\sigma) + (\mu/\sigma\lambda)$ (Hazarika and Alwang, 2003). Replacing ε_i in the above expression by the regression residual and the other parameters by their ML estimates yields an estimate, u_i, of farm-specific cost inefficiency (Jondrow *et al.*, 1982).

Next, in determining the predictors of cost inefficiency, we use the single stage approach proposed by Battese and Coelli (1995) wherein the cost inefficiency parameter (u_i) is specified as a linear function of farm-specific managerial and household characteristics subject to statistical error, such that:

$$u_i = \sum_{k}^{m} \delta Z_i + \zeta_i \geq 0, \tag{4}$$

where, Z_i are the farm-specific managerial and household characteristics and the error ζ_i is distributed as $\zeta_i \sim N(0,\sigma_\zeta^2)$. Since $u_i \geq 0, \zeta_i \geq -\delta Z_i$, so that the distribution of ζ_i is truncated from below at the variable truncation point, $-\delta Z_i$ (Rahman and Hasan, 2008).

Study areas and the sample farmers

Maize is cultivated almost all over the country, though the intensity of planted area and land suitability are not equal in all regions. Therefore, we computed a maize area index for each greater district.[4] The maize area index for the *j*th district is expressed as:

$$MAI_j = (Area_j/GCA_j) * 100, \tag{5}$$

where MAI is the maize area index, $Area$ is the maize area and GCA is the gross cropped area. Based on this index, maize growing regions were classified into three levels of intensity: high intensity ($\text{MAI} \geq 1.00$), medium intensity ($1.00 < \text{MAI} \geq 0.50$), and low intensity areas ($\text{MAI} < 0.50$).

A multistage sampling procedure was adopted to select the sample farmers. First, three areas were selected according to the rank of MAI as well as percent of total winter maize area. The selected regions are Kushtia, Bogra and Dinajpur which covered 59% of total maize area of the country. In the second stage, one new district was chosen from each aforesaid selected greater district according to higher percent of maize area and ease of communication. Then, one upazila (sub district) from each new district and one union from each upazila were selected purposively. Finally, three villages (one from each union) were selected randomly for collection of primary data. In the third stage, a number of steps were followed to select the households to ensure a high level of representation. At first, a list of all maize growing farmers was collected from the Department of Agricultural Extension (DAE). Then, these farm holdings were stratified into three standard farm-size categories commonly adopted in Bangladesh (e.g., Rahman and Hasan, 2008). Then, a total of 300 maize producing households were selected following a standard stratified random sampling procedure. Structured questionnaire was administered for data collection which was pre-tested prior to finalization. Data on production technologies of maize, inputs, outputs and prices were recorded seasonally by three visits covering the crop season. First visit was done just after sowing of seeds, second visit following completion of all intercultural operations and the last one after harvesting and threshing of the crop. Data also includes socio-economic profile of the sampled farmers. The survey covered winter maize growing period from November 2006 to April 2007.

The empirical model

An extended general form of the Cobb-Douglas stochastic cost frontier function is used.[5] This was done in order to include variables representing environmental production conditions within which the farmers operate (e.g., Sherlund *et al.*, 2002; Rahman and Hasan, 2008). Hence, the model is written as:

$$\ln C_i^* = \alpha_0 + \alpha \ln Q_i + \sum_{j=2}^{14} \beta \ln W_{ij}^* + \sum_{l=1}^{2} \omega E_{il} + \sum_{d}^{5} \tau D_{id} + u_i + v_i \tag{6}$$

and

$$u_i = \delta_0 + \sum_{k=1}^{10} \delta Z_{ik} + \zeta_i \tag{7}$$

where C^*_i is the total cost of maize cultivation normalized by one of the input prices[6] (Muriate of Potash price), W^*_{ij} is *j*th normalized price of the *j*th input for the *i*th farmer; D_{id} is the *d*th dummy variable used to account for zero values of input use and have the value of 1 if the *j*th input used is positive and zero otherwise[7]; E_{il} is the *l*th dummy variable representing environmental production conditions, v_i is the two sided random error, u_i is the one sided half-normal error, *ln* natural logarithm, Z_{ik} is the *k*th variable representing managerial and socio-economic characteristics of the farm to explain cost inefficiency, ζ_i is the truncated random variable; α_0, α, β, ω, τ, δ_0, and δ are the parameters to be estimated.

One unique feature of maize cultivation in Bangladesh is the use of a wide range of inorganic fertilizers, organic fertilizer and other modern inputs. As a result, a total of 14 input prices (W), two environmental production condition variables (E), and five dummy variables (D) to account for zero use of inputs are used in the cost frontier model, and 10 variables representing managerial and socio-economic characteristics of the farmer along with two regional dummy variables (Z) are included in the inefficiency effects model as predictors of cost inefficiency. Table 1 presents the definitions, units of measurement, and summary statistics for all the variables.

Limitation of the parametric approach used

One limitation of adopting a stochastic cost frontier approach is that it requires assumptions regarding

[4] Although there are 64 districts in Bangladesh, most secondary data are still reported at the level of these 21 former greater districts.

[5] We did not use the translog model because of the limited sample size and the large number of explanatory indicators (22 in the cost frontier model). Moreover, Kopp and Smith (1980) suggest that the choice of functional form has a limited effect on efficiency. Consequently, the Cobb-Douglas specification is widely used in production or cost frontier studies (e.g., Hazarika and Alwang, 2003; Rahman and Hasan, 2008; Asadullah and Rahman, 2009; Alene, 2007).

[6] The Muriate of Potash price (Taka/kg) was used for normalization of total cost and all other input prices. The homogeneity condition is imposed by this normalization.

[7] In this study, inputs that contain zero values for some observations are specified as *ln* {*max* (X_j, 1 – D_j)} following Battese and Coelli (1995).

Table 1: Definition, measurement and summary statistics of variables

Variables	Measure	Mean	Standard deviation
Dependent variable			
Cost of maize production	Taka per ha	44411.22	3,722.71
Output			
Maize output	Kg per ha	7897.97	561.34
Input prices			
Muriate of Potash price[a]	Taka per kg	14.24	0.81
Urea price	Taka per kg	6.11	0.42
Zinc sulphate price	Taka per kg	61.09	13.30
Gypsum price	Taka per kg	4.12	0.52
Borax price	Taka per kg	50.78	12.53
Triple Super Phosphate price	Taka per kg	16.27	2.48
Mixed fertilizer price	Taka per kg	13.13	0.49
Manure price	Taka per kg	0.39	0.05
Pesticide price	Taka per ha	651.00	328.81
Labour wage	Taka per person-day	76.10	6.78
Mechanical power price	Taka per ha	4146.16	676.47
Seed price	Taka per kg	159.83	27.31
Irrigation price	Taka per ha	3210.22	852.42
Land rent	Taka per ha	11516.64	1,672.30
Cow dung users	Dummy (1=Yes, 0=No)	0.51	--
Pesticide users	Dummy (1=Yes, 0=No)	0.52	--
Gypsum users	Dummy (1=Yes, 0=No)	0.60	--
Borax users	Dummy (1=Yes, 0=No)	0.53	--
Mixed fertilizer users	Dummy (1=Yes, 0=No)	0.26	--
Environmental factors			
Land suitability	Dummy (1=Medium high land or High land – suitable, 0 otherwise)	0.99	--
Soil type	Dummy (1=loamy, sandy loam or clay loam, 0 otherwise)	0.65	--
Regional dummies			
Dinajpur region	Dummy (1=Yes, 0=No)	0.33	--
Bogra region	Dummy (1=Yes, 0=No)	0.33	--
Managerial variables			
Area under maize	ha	0.79	0.80
Age of the farmer	Years	40.94	11.06
Education of the farmer	Completed years of schooling	5.44	4.35
Experience in growing maize	Years	6.47	5.45
Family size	Persons per household	5.43	2.28
Sowing date	Dummy (1=if sown during optimum time, 0 otherwise)	0.56	--
Variety	Dummy (1=if 900M variety is used, 0 otherwise)	0.51	--
Link with extension services	Dummy (1=if had extension contact or received training on maize production, 0 otherwise)	0.48	--
Total number of observations		300	

Note: Muriate of Potash price is used to normalize total cost and all other input prices for the regression analysis.
Exchange rate of USD 1.00=Taka 68.80 in 2006-07 (BB, 2010).
Source: Field survey 2007.

specification of the production technology and behaviour of the market and the producer. We have specified an extended Cobb-Douglas cost function to represent the true underlying technology which does not allow any interaction amongst input variables and assumes market to be perfectly competitive and impose cost minimizing behaviour on the part of the producer. Since maize is produced mainly for sale, these assumptions seem quite logical. In fact, market for agricultural products (e.g., maize) closely approximate perfectly competitive market since buyers and sellers cannot dictate price and the products are homogenous in nature. Therefore, we are quite confident that our approach portrays real situation quite closely and is a valid approach.

3. Results

Profitability of maize

Profitability of maize cultivation by regions is presented in Table 2. The highest cost component is human labour followed by chemical fertilizers and mechanical power services. Land rent, which is a fixed cost element, is also very high and represents a real burden particularly for tenants and landless farmers. It is clear from Table 2 that although there are significant regional variations in all elements of costs and returns, the Benefit-Cost Ratio (BCR) is very high estimated at 1.63. The comparable estimates of BCR for wheat is 1.40 (Hasan, 2006) and Boro rice (dry winter season) is 1.14 (Baksh, 2003)

Table 2: Cost, return and profitability of maize production

Items	Taka per hectare				F-test for regional differences[a]
	Bogra	Kushtia	Dinajpur	All regions	
Human Labour	12342	11661	9590	11198	117.84***
Mechanical power	4678	4257	3503	4146	160.13***
Seed	3119	3323	3551	3331	14.78***
Manure	1079	809	2939	1609	79.95***
Chemical fertilizers	9327	9363	7281	8657	53.54***
Pesticides	814	270	90	391	114.22***
Irrigation	3032	3772	2825	3210	40.29***
Interest on operating capital	372	375	310	352	12.55***
Land rent	11205	10718	12627	11517	41.09***
Total variable cost (TVC)	34391	33455	29780	32542	56.66***
Total cost (TC)	45968	44548	42717	44411	20.37***
Gross Return (GR)	74145	80177	62766	72363	215.17***
Gross Margin (GM=GR-TVC)	39754	46722	32986	39821	127.94***
Net return (NR=GR-TC)	28177	35629	20050	27952	132.77***
Benefit-Cost Ratio (BCR=GR/TC)	1.61	1.80	1.47	1.63	103.33***

Note: [a]=One-way ANOVA using the Generalised Linear Model (GLM).
***significant at 1 percent level ($p<0.01$).
Source: Field survey 2007.

thereby, establishing that maize stands high in terms of returns amongst major cereals in Bangladesh. Also, maize ranks first in terms of yield estimated at 7.97 t/ha (Table 1) as compared to wheat at 2.40 t/ha (Hasan, 2006) and Boro rice at 5.05 t/ha (Baksh, 2003).

Determinants of maize production cost

Parameter estimates of the stochastic cost frontier along with inefficiency effect model are reported in Table 3 using the Maximum Likelihood Estimation (MLE) procedure in STATA Version 8 (STATA Corp, 2003). First we checked the sign of the third moment and the skewness of the Ordinary Least Squares (OLS) residuals of the data in order to justify the use of the stochastic frontier framework (and hence the MLE procedure).[8] The computed value of Coelli's (1995) standard normal skewness statistic (M3T) based on the third moment of the OLS residuals is 1.77 ($p<0.10$) H_0: M3T=0. In other words, the null hypothesis of no inefficiency component is rejected and, therefore, the use of the stochastic frontier framework is justified. The significant value of the coefficient on γ reported in Table 3 also strongly suggests presence of cost inefficiency.

Cost per ha of maize production significantly increases with maize output as expected ($p<0.01$). Most of the signs on the coefficients of input prices are positive consistent with theory. The two negative signs on the coefficients of gypsum and land rent variables are not significantly different from zero and may not be the true relationship. Since Cobb-Douglas model is used, the coefficients on the variables can be directly read as cost elasticities. The coefficient on the output variable is 0.41, indicating that a one percent increase in output level will increase cost by 0.41%. Cost per ha of maize production significantly increases with the use of labour, mechanical power, seed, irrigation, pesticides, Triple Super Phosphate (TSP), Zinc sulphate, and manure. The elasticity values of mechanical power and labour are the highest estimated at 0.17 and 0.16 indicating that a one percent rise in the prices of these inputs will increase the cost of producing maize by 0.17% and 0.16%, respectively. Similarly, a one percent rise in the cost of TSP and zinc sulphate fertilizers will increase maize production cost by 0.12% and 0.09%, respectively. Movement in other fertilizer prices (e.g., urea, borax, mixed fertilizers and gypsum) do not seem to have a statistically significant influence on the production cost of maize.

It is surprising to see lack of the influence of environmental variables. One reason may be that 99% and 65% of the farmers are cultivating maize on the most suitable land (in terms of elevation) and soil type, respectively (Table 1). Controlling for the non-use of some inputs are justified as indicated by the significant coefficients on the dummy variables ($p<0.01$ to $p<0.10$). Also the formal joint test of hypothesis of no effect of controlling dummies were strongly rejected at 1 percent level ($\chi^2_{(5,\ 0.99)}=166.17$, $p<0.01$).

Economic inefficiency in maize production and its determinants

The economic/cost efficiency of maize cultivation is estimated at 87% implying that 15% [(100-87)/87] of cost reduction is still possible while maintaining current level of output by removing technical and allocative efficiency (Table 4). Our estimate is at the higher end of the range seen in the literature (e.g., Alene, 2007; Hazarika and Alwang, 2003; Rahman and Hasan, 2008; Coelli *et al.*, 2002; Bravo-Ureta *et al.*, 2007) implying that maize also performs relatively better than rice and wheat, particularly in Bangladesh (e.g., Rahman and Hasan, 2008; Coelli *et al.*, 2002). The cost efficiency ranges between 67% to 99% percent and three-quarter of

[8] In the stochastic frontier framework, the third moment is also the third sample moment of the u_i. Therefore, if it is negative, it implies that the OLS residuals are negatively skewed and technical inefficiency is present.

Table 3: Joint parameter estimates of the stochastic cost frontier with inefficiency effects model

Variables	Parameter	Coefficient	t-ratio
Stochastic cost frontier model			
Constant	α_0	4.5847***	16.35
Maize output level	α_1	0.4164***	7.51
Normalized input prices			
Urea price	β_2	0.0065	0.45
Gypsum price	β_3	-0.0517	-1.42
Borax price	β_4	0.0550	1.44
Triple Super Phosphate price	β_5	0.1220***	3.87
Zinc sulphate price	β_6	0.0927***	3.63
Mixed fertilizer price	β_7	0.1084	1.47
Manure price	β_8	0.0831***	3.01
Pesticide price	β_9	0.0666***	9.75
Labour wage	β_{10}	0.1617***	3.99
Mechanical power price	β_{11}	0.1676***	5.60
Seed price	β_{12}	0.0933***	4.55
Irrigation price	β_{13}	0.1146***	10.01
Land rent	β_{14}	-0.03374	-1.49
Cow dung users	τ_1	0.0599***	6.79
Pesticide users	τ_2	0.0502***	6.64
Gypsum users	τ_3	0.0401***	3.73
Borax users	τ_4	0.0016	0.13
Mixed fertilizer users	τ_5	-0.0331*	-1.78
Environmental factors			
Land suitability	ω_1	-0.0110	-0.96
Soil type	ω_2	0.0015	0.19
Variance Parameters			
$\sigma^2=\sigma_u^2+\sigma_v^2$	σ^2	0.0042***	11.27
$\gamma=\sigma_u^2/(\sigma_u^2+\sigma_v^2)$	γ	0.99***	121.00
Log likelihood		433.524	
Wald χ^2 (21 df)	χ^2	7480.58***	
Inefficiency effects function			
Constant	δ_0	0.1146***	4.40
Maize area	δ_1	0.0115*	1.81
Age of the farmer	δ_2	-0.0002	-0.60
Education of the farmer	δ_3	-0.0018*	-1.66
Experience in growing maize	δ_4	-0.0006	-0.28
Family size	δ_5	-0.0025	-1.22
Sowing date	δ_6	-0.0095	-1.02
Variety	δ_7	0.0087	0.93
Link with extension services	δ_8	0.0024	0.20
Dinajpur region	δ_9	0.0113	0.70
Bogra region	δ_{10}	0.1496***	4.72
Total number of observations		300	

Note: *** significant at 1 percent level ($p<0.01$).
**significant at 5 percent level ($p<0.05$).
*significant at 10 percent level ($p<0.10$).

the farmers were operating at an efficiency range above 80% which is very encouraging.

The predictors of economic inefficiency are presented at the lower panel of Table 3. The joint test of hypothesis of no inefficiency effects was strongly rejected at 1 percent level ($\chi^2_{(10,\ 0.99)}=35.93$, $p<0.01$). Education of the farmers significantly improves efficiency while large farmers are relatively cost inefficient which are consistent with the existing literature (e.g., Alene, 2007; Asadullah and Rahman, 2009). Use of optimal variety (i.e., 900M) or sowing during optimum date has no significant influence on cost inefficiency. However, geography does matter. Farmers in Bogra region are relatively inefficient as compared to their Dinajpur and Kushtia peers. The reason may be due to differences in micro-climate, soil type, other regional factors as well as production practices of the farmers. For example, farmers from Bogra used lowest doses of chemical fertilizers (except urea) as compared with farmers from Dinajpur and Kushtia. Similarly, the use rate of organic manure by farmers in Bogra is about a quarter of the amount applied by farmers in Dinajpur and Kushtia.

4. Conclusions and policy implications

The present study assessed the potential for maize expansion by examining profitability and economic efficiency of maize producers in Bangladesh using an extended Cobb-Douglas stochastic cost frontier model. Our results demonstrate that yield and profitability of maize is higher than rice and wheat. The cost of maize production increases significantly with increase in input prices and output level. The level of economic efficiency is also relatively high at 87% although scope still exists to reduce cost by 15% by eliminating technical and allocative

Table 4: Cost efficiency distribution

Items	Percentage of farmers
Efficiency levels	
up to 60%	0.00
61–70%	1.70
71–80%	20.30
81–90%	44.00
91% and above	34.00
Mean efficiency by farm size	
Large farms	0.85
Medium farms	0.87
Small farms	0.87
Mean efficiency by region	
Kushtia	0.91
Dinajpur	0.90
Bogra	0.79
Overall	
Mean efficiency score	0.87
Standard deviation	0.07
Minimum	0.67
Maximum	0.99

inefficiency while maintaining current production level. Education has a significant influence on reducing inefficiency while large operation size increases this.

The policy implications are clear. Facilitation of the input markets by setting appropriate price policies would significantly reduce cost of production and raise profitability of the farmers. High price of good quality seed and TSP fertilizers and low price of maize were ranked as the 1st, 4th and 6th major constraints by these maize growers. Wide variation in input prices presented in Table 1 further proves that farmers indeed face highly variable farm-specific input prices. The reasons may be due to market imperfections and/or lack of infrastructure for timely delivery of inputs resulting in highly variable input prices. The Directorate of Marketing (DAM) and Bangladesh Agricultural Development Corporation (BADC) of the Ministry of Agriculture have an important role to play in this regard. DAM can play a role in stabilising prices while BADC can expand/improve on its traditional role of supplying inputs to farmers at the right time and in right quantities, which in turn will support price stability.

Investment in education targeted at farmers will significantly improve economic efficiency. Literacy rate in Bangladesh is on the rise, estimated at 57.7% in 2010 (defined as population aged 7 years and over who can read and write) (BBS, 2011b) which is partly due to government sponsored adult literacy program since the early 1980s, strengthening of state run universal primary education as well as several thousand fixed term primary schools run by BRAC (a leading NGO) and other NGOs. The average level of education of farmers in our sample is just above the primary level qualification (Table 1). Asadullah and Rahman (2009) noted that the impact of education on efficiency kicks in when farmers' education level lies between primary and secondary level education. Therefore, the Ministry of Education has an important role to play in creating opportunities for secondary level education which will enable farmers to gain more out of their production processes. Also with easy access of cell phone technology throughout Bangladesh, the adult literacy program can be further strengthened and disseminated to farmers effectively. For example, the existing tenant farmer scheme of BRAC provides an institutional set up which can make this feasible along with NGO run learning centres in rural communities.

The geographical variation in production performance of farmers may be due to a number of factors such as micro-climate, soil types, high input costs and/or differences in production practices which needs further investigation. Nevertheless, maize has strong potential and should be promoted. A boost in maize production could significantly curb dependence on rice as the main staple in Bangladeshi diet, which is a goal worth pursuing.

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