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Estimating the Technical Efficiency of Maize Production In A Selected Area of Bangladesh

Mohammad Chhiddikur Rahman
Scientific Officer, Bangladesh Rice Research Institute, Gzipur, Bangladesh
Md. Abul Bashar
Student, Georg-August-Universitat Gottingen, Germany
Md. Faizul Kabir
Scientific Officer, Bangladesh Rice Research Institute, Gzipur, Bangladesh
Md. Imrul Kaysar
Scientific Officer, Bangladesh Agricultural Research Institute, Gzipur, Bangladesh
Kanij Fatema
Lecturer, Sylhet Agricultural University, Bangladesh

Abstract:
This study was conducted in a selected maize growing area of Bangladesh, during the period 2012-13 with a view to estimate the profitability and technical efficiency of maize growers. The study revealed that maize production was found profitable as benefit cost ratio (BCR) was 1.54 on full cost basis. The estimated result showed that the average level of technical efficiency of the sample maize farmers was very high (96.90%), implying that given the existing technology and level of inputs, the output can be increased by only 3.10%. Farmers' age, education and training received had significant positive effect on maize production. So, farmers' should be provided proper training on advanced farming and easy credit facilities to boost up maize production in Bangladesh.

Key words: *Technical efficiency, Profitability and Maize*

1. Introduction

The fertile soils and subtropical monsoonal climate make Bangladesh much suitable for maize cultivation, although maize is a new crop. Before independence in 1971, maize was rarely cultivated across Bangladesh except in a few tribal areas of the Southeastern Chittagong Hill Tracts (BBS, 2010). In 2009-10 cropping season, it was planted on about 147996.59 ha of land with national average yields of around 5.7 ton/ha producing well over a million tons of maize grain annually (BBS, 2010). Bangladesh is the 7th most populous country in the world with a total population of 153.6 million, population growth rate is 1.37 (BES, 2013) and its density of population is 1015 persons per Km^2 (BES, 2013). More than 70 percent of the country's population as well as 48.40 percent of its labour force are directly and indirectly being dependent on agriculture and contributing 19.95 percent to the GDP (BBS, 2010). In Bangladesh, total land area is the same in each year but the total cultivated area is decreasing year to year. Rice is the major cereal crop and is the staple food occupying 70.0 percent of the total cropped land (BER, 2010). The government policy is predominantly based upon a high yielding variety (HYV) rice and wheat (BBS, 2010). The country puts emphasis on replacing its traditional agricultural practices by applying modern inputs such as HYV seeds, fertilizer, irrigation, pesticides, power tiller, etc. (BARI, 2008). Bangladesh has a huge potentiality for increasing maize production. It has 14.09 million hectares of cultivated land and it is estimated that nearly 2.8 million hectares are suitable for maize cultivation but it covers only 1.5 million hectares (BBS, 2010). Local demand for maize stands at an estimated 12 million tons annually, and this demand is mostly from the poultry and fish sector. It is grown both in winter and summer seasons in Bangladesh. Maize farmers is always more profitable than many other crops and the enthusiastic farmers are getting a high yielding variety of maize seeds and latest scientific methods of cultivation for further success.

Bangladesh has a great opportunity to sustain such kind of flow in maize, if maize cultivation, processing and marketing are postulated in a scientific manner. But no in-depth study was conducted on productivity, efficiency, profitability in Bangladesh. A few efficiency studies regarding rice, wheat, potato, tomato, cauliflower, poultry and fish farming were observed in Bangladesh. That is why the

present study had been taken for measuring profitability and technical efficiency of maize production in Bangladesh. Therefore, this study is expected to generate valuable information which would be highly useful for the farmers, GOs, NGOs and policy makers to conduct a successful maize revolution in Bangladesh.

2. Methodology

The aim of the present study is to determine the technical efficiency of maize production. The Northwestern districts are considered as the granary of Bangladesh and produce surplus maize. For the present study, Natore district was purposively selected as it represents the vast area in the northwest region of Bangladesh. Natore is one of the largest maize producing area. By following the logic of concentration of maize production three villages of Gurudaspur Upazila under Natore district namely Dadua, Noyabazar, Hasmari were purposively selected to interview the maize growing farmers. For the selection of sample farmers, a list of the maize growers in the selected Upazila was prepared with the help of extension officials. A total of 60 maize growing farmers were selected randomly from the list for data collection. Thus sample composed of 60 maize growers taking 20 farmers each from Dadua, Noyabazar and Hasmari villages.

The Cobb-Douglas stochastic frontier production function was used to analyze productivity and resource use efficiency of Maize production. The functional (double-log) form of stochastic frontier is as follows

$$lnY = \beta_0 + \beta_1 lnX_1 + \beta_2 lnX_2 + \beta_3 lnX_3 + \beta_4 lnX_4 + \beta_5 lnX_5 + \beta_6 lnX_6 + \beta_7 lnX_7 + V_i - U_i \ldots\ldots (2)$$

Where, ln = Natural logarithm, Y = Observed farm output (kg/ha), X_1 = Human labor (man-days/ha), X_2 = Seed (kg/ha), X_3 = Urea (Kg/ha), X_4 = TSP (kg/ha), X_5 = MoP (Kg/ha), X_6 = Gypsum (kg/ha), X_7 = Insecticide/pesticide (kg/ha).

The technical inefficiency effects U_i in eq (7) are defined as

$$U_i = \delta_0 + \delta_1 Z_1 + \delta_2 Z_2 + \delta_3 Z_3 + \delta_4 Z_4 + \delta_5 Z_5 + W_i \ldots\ldots (3)$$

Where, Z_1 = Age of farmer (year), Z_2 = Education of farmer (year of schooling), Z_3 =Farm size (number of person in a farm household), Z_4 = Family size (total cultivable land of farmer in decimal), Z_5 = Credit (Dummy: '1' if taken; '0' otherwise).

V is two sided uniform random variable beyond the control of farmer having $N(0, \sigma_v^2)$ distribution, U is one sided technical inefficiency effect under the control of farmer having a positive half normal distribution ($U \sim |N(0, \sigma_u^2)|$) and W_i is two sided uniform random variable. The models will be estimated simultaneously using frontier package 4.1.

The β and δ coefficients are unknown parameters to be estimated together with the variance parameters which are expressed in terms of

$\sigma^2 = \sigma_u^2 + \sigma_v^2$ And $\gamma = \sigma_u^2 / \sigma^2$

Where, γ parameter has the value between zero and one.

The technical efficiency of the ith farmer can be shown to be equal to

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

$$= \exp(-u_i)$$

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

$$= 1 - E\{u_i / (v_i - u_i)\}, \text{ ignoring high order of exponential series}$$

The mean technical efficiency can be defined by

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

3. Socioeconomic Characteristics

Size and Composition of Families

Age, sex, family size and dependency ratio of the respondents have been shown in Table 1. A family in the present study was defined as a group of individuals living together, taking meals unitedly and living under the control of one head. Using such a definition, the average size of family was found to be 8.31 persons. The family size was observed to be higher for the medium farm (11.00) followed by small (8.33) and large (6.33) in the study area. The dependency ratio in general was found to be 3.69 persons. The dependency ratio was found to be the lowest in case of large farms (2.34) during the study.

***Dependency ratio** = $\frac{\text{Total members of the family}}{\text{Total earning members}}$

Members' ages from 15 to 60 years were dominant in case of both male and female which showed more active family members in the study area. The average number of earning person was found to be 2.25. It was the highest for the large farms and lowest for small ones.

Age group (years)	Farm size			
	Small (No.)	Medium (No.)	Large (No.)	All farms (No.)
	Male			
Below 15	20	25	9	54
15-60	110	60	45	215
60 above	13	5	2	20
A. Total	**143**	**90**	**56**	**289**
	Female			
Below 15	36	22	6	64
15-60	60	40	25	125
60 above	5	12	4	21
B. Total	**101**	**74**	**35**	**210**
Total family members (A+B)	**244**	**164**	**92**	**499**
Average family size	8.33	11	6.33	8.31
Average earning members	1.95	2.25	2.70	2.25
Dependency Ratio*	4.27	4.88	2.34	3.69

Table 1: Composition of Family According To Farm Size
Sources: Field Survey, 2013. Figures within Parentheses Indicate Percentages

3.1. Average Size of Land Holding of the Respondent Households

In the present study, land ownership was classified into seven categories i.e., cultivated own land, land rented in, land rented out, land mortgaged in, land mortgaged out, pond and homestead area. Average farm size of small, medium and large farms was 77.62, 256.86 and 434.53 decimals respectively with overall average being 256.33 decimal (Table 2). Average farm size was calculated as:
Average farm size = Own land in cultivation + Rented in land + Mortgaged in land - Rented out land - Mortgaged out land.

Land type	Small (decimal)	Medium (decimal)	Large (decimal)	All (decimal)
Homestead area	7.40(8.29)	13.53(4.97)	13.53(3.00)	11.48(4.25)
Pond	0.33(.36)	–	–	0.11(.04)
Own land in cultivation	70.33(78.80)	220.00(80.96)	390(86.66)	226.66(83.95)
Rented in	8.63(9.66)	36.20(13.32)	44.53(9.89)	29.78(11.00)
Rented out	1.67(1.87)	0.67(.24)	0.67(.14)	1(.37)
Mortgaged in	0.33(.36)	1.33(.48)	0.67(.14)	.77(.228)
Fallow Land	0.33(.36)	–	–	0.11(.04)

	Small (decimal)	Medium (decimal)	Large (decimal)	All (decimal)
Other	0.23(.25)	_	_	0.07(.02)
Total land	89.25(100)	271.73(100)	450(100)	269.98(100)
Average farm size	77.62	256.86	434.53	256.33

Table 2: Average Land Holding of Farm Families
Sources: Field Survey, 2013. Figures within parentheses indicate percentages

3.2. Average Annual Income of the Respondent Households

Income is the most important indicator of the socio-economic status of the people living on rural areas of Bangladesh. Average annual income of a family in the present study has been estimated by adding up the earnings of all active members of the family from all income generating activities during the year under investigation. Table 3 shows the distribution of annual income of farmers in relation to different farm size groups in the study area.

Table 3 shows that the overall average annual income for all farms was Tk. 77251.54. About 41.00 percent of all income was earned from non-farm sources. Maize farming contributes 30.00 percent to the annual income and other farming operations contributed 29.00 percent. Small farmers also had more income from Maize es having relatively more acreage in Maize cultivation during the year. Considering only the income accrued from agriculture, it is very much clear that income from Maize cultivation shared maximum irrespective of farm size categories in the study area.

Farm size	Average annual income			
	Maize production (Tk)	Farm income (Tk)	Non-farm income (Tk)	Total (Tk)
Small	17493.33(30.00)	11200.00(19.00)	29800.00(51.00)	58493.00(100)
Medium	26357.33(31.00)	27200.00(32.00)	30333.33(37.00)	83890.00(100)
Large	25837.33(29.00)	29866.67(33.00)	33666.67(38.00)	89371.00(100)
All	23229.33(30.00)	22755.55(29.00)	31266.66(41.00)	77251.54(100)

Table 3 Average Annual Household Income of the Respondents
Source: Field Survey, 2013. Figures within parentheses indicate percentages.

3.3. Average Annual Expenditure of the Respondent

Total expenditure of maize production credit beneficiaries was estimated using three main categories, i.e. farm expenditure, expenditure on food item and expenditure on non-food item. Expenditure on food items indicates the expenditure for food item likes rice, wheat, vegetable, etc. and non-food item indicates expenditure on housing, clothing, medical services etc.

Table 4 indicates that farm expenses were Tk. 6426.67, Tk. 7400.00 and Tk. 15200.00 for small, medium and large farms respectively. It also indicates that the average overall expenses of all farms were Tk. 299480. Farm and food expenditure accounted for 11.00 and 32.00 percent respectively while that of non-food items shared only 57.00 percent. The table also provides support that small farm spends more on food. In this study, small farmers have been found to have spent 37.00 percent on food items.

Farm Size	Average annual expenditure			
	Farm expenses (Tk.)	Expenditure on food item (Tk.)	Expenditure on Non-food item (Tk.)	Total (Tk.)
Small	6426.67 (8.00)	30933.33 (37.00)	45906.67 (55.00)	83267 (100.00)
Medium	7400.00 (8.00)	32200.00 (33.00)	56773.33 (59.00)	96373 (100.000
Large	15200.00 (13.00)	34200.00 (29.00)	70440.00 (59.00)	119840 (100.00)
All	29026.67 (11.00)	97333.33 (32.00)	173120.00 (57.00)	299480 (100)

Table 4: Average Annual Expenditure of the Respondent
Source: Field Survey 2013. Figures within parentheses indicate percentages

4. Cost and Return of Maize Production

In the study area, rate of human labor, on an average was Tk. 200 per man-day. The total average costs of labor were Tk. 13500, 25000, 27500 and 22000 for the small, medium large and all farms, respectively. Per hectare power tiller cost was Tk. 2870, 2600 and 3300, for small, medium and large farms respectively. Power tiller cost was high in large farm and low in medium farm. The seed cost per hectare was found to be the highest for large farms of Tk. 5450 followed by small farms (Tk. 4650) and medium farms (5000) in the study villages. The average cost of seed for all categories of farms was Tk. 5033. Farmers used four types of fertilizer namely urea, triple super phosphate (TSP), muriate of potash (MP) and gypsum for Maize cultivation. Fertilizer cost was determined by the actual market prices paid by the farmers. Thus the respective total average cost of fertilizer per hectare was stood at Tk. 6000, 6500, 6550, and 6350. In the study area fertilizer cost per hectare was the highest in large farm, followed by medium farms and small farms. Cost of weeding per hectare was Tk. 2000, Tk. 2100 and Tk. 2200 for small, medium and large farmers, respectively. The average cost of cow dung for all categories of farms appeared to be Tk. 2100. Cow dung cost per hectare was Tk. 1800, Tk. 1850 and Tk.1900 for small, medium and large farms. The average cost of cow dung for all categories of farms appeared to be Tk. 1850. Different kinds of insecticides were used for Maize production, namely Sundronil, Indrofil, Comigrin, Tiodit, etc. The price of the insecticides largely varied from brand to brand. The actual cost of insecticide was used. The total average costs of insecticides per acre were Tk. 450, Tk. 600 and Tk. 570 for small, medium and large farms, respectively. So, the highest insecticide cost was borne by small farm followed by large and medium farm in the study area. Farmers in all the villages used irrigation water in the Maize fields during cultivation period. It may be noted here that maximum of the selected farmers had to buy water from the owners of shallow tube-wells (STWs) and a few of them had their own STWs. Irrigation cost was found to be the highest in large farm (Tk. 3800) and it was almost the same for small and medium farm. The average cost of irrigation for all categories was Tk. 3600. Land use cost was estimated for the cropping period covering around 6 months in the study area. It was the highest in large farms (Tk. 8700) than that of the medium farms (Tk. 8200) and small farms (Tk. 7600). The average cost of land use for all categories of sample farmers amounted to be Tk. 8167. IOC per hectare was estimated at Tk. 650, 730 and 910 for small, medium and large farms respectively. The average IOC for all categories of farmers was Tk. 763. The average total cost of Maize cultivation was estimated at Tk. 42820 for small farm, Tk. 56280 for medium farm, Tk. 60880 for large farm. So, medium farm incurred the highest cost followed by the small and large farms. Per hectare total cost for all categories of farms was Tk. 53327.

The average unit price of Maize per kg considered in the present study was Tk. 12. Total return per hectare was the highest in large farms of Tk. 90000 followed by the medium farms (Tk. 85000) and small farms (Tk. 70000). Per acre total return for all categories of farms was estimated at Tk. 81667. The net returns for small, medium and large Maize farms were appeared to be Tk. 27180, Tk. 28720 and Tk. 29120, respectively (Table 5). So, net return is the highest in large farm which is followed by medium and small farms. It indicates that net return was positively related with farm size in the study area. The overall benefit-cost ratio of Maize farming came out to be 1.54 indicating that a one Taka investment resulted in a net benefit of Tk. 0.54.

Particulars	Small Farmers (Tk./ha)	Medium Farmers (Tk./ha)	Large Farmers (Tk./ha)	All Farmers (Tk./ha)
Variable cost				
Power tiller cost	2870	2600	3300	2923
Labor cost	13500	25000	27500	22000
Seed cost	4650	5000	5450	5033
Fertilizer cost	6000	6500	6550	6350
Weeding	2000	2100	2200	2100
Cow-dung	1800	1850	1900	1850
Insecticides	450	600	570	540
Irrigation charge	3300	3700	3800	3600
Total variable cost	**34570**	**47350**	**51270**	**44397**
Fixed cost				
Interest on operating capital	650	730	910	763
Land use cost	7600	8200	8700	8167
Total fixed cost	**8250**	**8930**	**9610**	**8930**
Total cost	**42820**	**56280**	**60880**	**53327**
Total Return	**70000**	**85000**	**90000**	**81667**
Net Return	**27180**	**28720**	**29120**	**28340**
BCR (Undiscounted)	**1.63**	**1.51**	**1.47**	**1.54**

Table 5: Cost and Return of Maize Production by Farm Category (Per Hectare)
Source: Field Survey, 2013

5. Estimates of Stochastic Frontier Production Function for Maize Production

The estimate of the stochastic frontier shows the best practice i.e. efficient use of available technology. The estimated is shown in Table 6. The estimated value of the coefficient of urea was positive (0.449) and significant for maize production at 5 percent level. This means, on an average the maize production will be increased if the farmers used more urea in their field. The estimated value of the coefficient of pesticide was also positive (0.318) and significant at 1 percent level, which means if the farmer increased pesticides use at 1 percent, the production of maize might increased by 0.318 percent. So, the farmers of the study area may increase the application of urea and pesticides to boost up maize production with the existing technology. The coefficients of MoP and gypsum were positive (0.046 and 0.192, respectively), but had no significant effect on maize production.

The coefficient of human labor was negative (-0.042) and significant at 10 percent level which reveals that if the application of labor increased by 1 percent, the production of maize might be decreased by 0.042 percent. The coefficient of seed was also negative (-0.168) and significant at 10 percent level. So, the farmers should reduce the application of human labor and seed for efficient maize production. Dominance of inefficiency effect over random error can easily be visualized from the significant values of gamma (γ) (0.884), in Table 6. The γ parameter associated with the variances in the stochastic frontier is significant for maize production. It indicates that there were inefficiency effects in maize production and the random component of the inefficiency effects made a significant contribution to the analysis of agricultural production. The estimates of $\sigma 2$ (the ratio of the variance of farm specific technical efficiency to the total variance of output) were 0.841and significant at 10% level. These suggest that the technical inefficiency effects were a momentous component to the total variability of the yield of maize crops. The sign of the 'δ' parameters in the inefficiency effect model were expected to be negative. The negative signs of the coefficients imply their inverse effect on technical inefficiency and direct effects on technical efficiency. The effect on technical efficiency of some socio-economic and demographic variables which were included in technical inefficiency model was interpreted below:

- **Age**
  The coefficient of age was positive and significant at 5 percent level. It implies that the technical efficiency decreases as the age of farmers' increase. The older farmers were relatively inefficient than that of younger's. In our sample young farmers are more educated than older and this result reflects in next paragraph.
- **Education**
  The sign of the coefficient of education was negative (-0.005) and significant at 1 percent level. It means that technical inefficiency decreases with increase in education level. So, the higher educated farmers were technically more efficient in maize production.
- **Farm size**
  The coefficient of farm size in the inefficiency effect model was positive but not significant. Although it indicated the negative relationship with farming efficiency, farm size had no significant impact on farming efficiency.
- **Family size**
  The coefficient of farm family size was negative and insignificant. It indicates positive relationship with farming efficiency of maize production but no significant impact on it.
- **Credit**
  The coefficient of credit was negative and significant 1 percent level. This indicates that farmer who has received credit can reduce technical inefficiency compared to non receiver.

Variable	Parameters	coefficient	Standard error	t-ratio
Constant	β_0	6.450***	0.756	8.527
Labor	β_1	-0.042*	0.067	-1.610
Seed	β_2	-0.168*	0.156	-1.734
Urea	β_3	0.449**	0.201	2.233
TSP	β_4	-0.099	0.262	-0.376
MoP	β_5	0.046	0.275	0.166
Gypsum	β_6	0.192	0.146	1.311
Insecticides/pesticides	β_7	0.318***	0.103	3.091
Technical inefficiency model				
Constant	δ_0	-0.568*	0.325	-1.749
Age	δ_1	0.014**	0.005	2.855
Education	δ_2	-0.005***	0.008	-6.190
Farm size	δ_3	0.002	0.005	0.286
Family size	δ_4	-0.057	0.069	-0.829
Credit (dummy: 1, if taken; 0, otherwise)	δ_5	-0.252***	0.081	3.090
Log likelihood value		62.680		
Mean technical efficiency		0.969		
Variance parameter				
Sigma-squared	σ^2	0.841*	0.062	1.841
Gamma	γ	0.884***	0.417	4.512

Table 6: Maximum likelihood estimates of the parameters of
C-D stochastic frontier production function and technical inefficiency effect model for maize
****, ** and * indicate significant at 1%, 5% and 10% level, respectively*

The frequency distribution of the technical efficiency estimates of the farmers obtained from C-D stochastic frontiers for maize production was shown in Table 7.
It is observed from the Table 7 that technical efficiency varied from 73.3 to 99.5 percent for maize growers. The mean technical efficiency of maize farming was 96.9 percent in the study area.

It is evident that technical efficiency of maize growers was distributed over a range from 70 to100 and maximum farmers (93.33 percent) belonged to technical efficiency range 91 to 100.

Efficiency level (%)	No. of farmers
70-80	2 (3.33%)
81-90	2 (3.33%)
91-100	56 (93.33%)
No. of farms	60
Minimum efficiency	73.3
Maximum efficiency	99.5
Standard deviation	4.7
Mean efficiency	96.9

Table 7: Frequency distribution of technical efficiency estimates from C-D stochastic frontier production function
Source: Author's estimation

6. Conclusion

The objectives of this study were to examine the resource profitability and technical efficiency of maize farming in a selected area of Bangladesh. The estimated result showed the net return from maize production on an average was Tk. 28340. The benefit cost ratio (BCR) was 1.54 which indicating that one Taka investment resulted in a net benefit of Tk. 0.54 from maize production. The coefficients of labor, seed, urea and insecticides had significant effect on maize production. The average technical efficiency of maize production was 96.90%. This implies that the farmers were more efficient in maize production and the output per farm can be increased, on an average, only 3% without incurring additional production cost. The coefficients of age, education and credit had significant positive effect on efficiency of maize production. If the efficient management of the existing resources can be ensured and modern variety of seed and technology is available to the farmers, yield and production can be increased which may help to increase their income and ensure food security.

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