Competitiveness, profitability, input demand and output supply of maize production in Bangladesh

Article

Published Version

Rahman, S. ORCID: https://orcid.org/0000-0002-0391-6191, Kazal, M. M. H., Begum, I. A. and Alam, M. J. (2016) Competitiveness, profitability, input demand and output supply of maize production in Bangladesh. Agriculture, 6 (2). 21. ISSN 2077-0472 doi: https://doi.org/10.3390/agriculture6020021 Available at https://centaur.reading.ac.uk/105879/

To link to this article DOI: http://dx.doi.org/10.3390/agriculture6020021

Publisher: MDPI Publishing

agriculture

MDPI

Article

Competitiveness, Profitability, Input Demand and Output Supply of Maize Production in Bangladesh

Sanzidur Rahman [1,*], Mohammad Mizanul Haque Kazal [2,†], Ismat Ara Begum [3,†] and Mohammad Jahangir Alam [4,†]

1 School of Geography, Earth and Environmental Sciences, University of Plymouth, Plymouth PL4 8AA, UK
2 Department of Development and Poverty Studies, Sher-e-Bangla Agricultural University, Dhaka 1207, Bangladesh; mhkazal@gmail.com
3 Department of Agricultural Economics, Bangladesh Agricultural University, Mymensingh 2202, Bangladesh; ishameen@yahoo.com
4 Department of Agribusiness and Marketing, Bangladesh Agricultural University, Mymensingh 2202, Bangladesh; alambau2003@yahoo.com
* Correspondence: srahman@plymouth.ac.uk; Tel.: +44-1752-585911; Fax: +44-1752-584710
† These authors contributed equally to this work.

Academic Editor: Les Copeland
Received: 4 December 2015; Accepted: 16 May 2016; Published: 23 May 2016

Abstract: The study assesses international competitiveness, profitability, output supply and input demand of maize production using a farm survey data of 165 farmers from two major maize growing areas (*i.e.*, Dinajpur and Lalmonirhat districts) of northwestern Bangladesh. Results revealed that maize production is globally competitive and, therefore, can successfully substitute its import. Maize production is also profitable at the farm level (Benefit Cost Ratio = 1.21) with no adverse influence of farm size on yield and profitability. Maize farmers are also responsive to changes in market prices of inputs and outputs. A 1% increase in maize price will increase output supply by 0.4%. The most dominant driver of maize supply and other input demands is land. A 1% increase in available land will increase maize supply by a substantial 3.9%. In addition, landless laborers will benefit through an increase in hired labor demand when land area increases. Policy implications include investments in R&D, tenurial reform to consolidate land holding and smooth functioning of the hired labor market in order to increase maize production and profitability in Bangladesh.

Keywords: competitiveness; Policy Analysis Matrix (PAM) analysis; profitability; output supply; input demand; translog profit function; maize; Bangladesh

1. Introduction

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. Although the expansion of maize was not successful in Bangladesh during the 1960s due to the thrust of the government to promote a rice based Green Revolution technology, the production and yield of maize has experienced an explosive growth in recent years [1]. For example, the total cropped area of maize has increased from only 2654 ha in 1972 to 165,510 ha in 2012; production from 2249 t to 1,298,000 t; and yield from 0.85 t/ha to 6.59 t/ha during the same period [1,2]. In fact, maize is ranked 1st among the cereals in terms of yield rate (6.59 t/ha) as compared to Boro (dry winter) rice (3.90 t/ha) and wheat (2.78 t/ha) [2]. This is because the Bangladesh Agricultural Research Institute (BARI) has developed seven open pollinated and 11 hybrid varieties [3,4] whose yield potentials are 5.5–7.0 t/ha and 7.4–12.0 t/ha, respectively, which are well above the world average of 3.19 t/ha [5]. Maize possesses a wide genetic variability, enabling it to grow successfully in any environment, and in Bangladesh, it is grown in winter and summer seasons, although the former is the dominant pattern [1]. The sowing time of the winter maize is mid-October to December and reaping time is April to May.

A limited number of socio-economic investigations were conducted on maize cultivation in Bangladesh, which revealed that it is a more profitable crop than rice [6,7] and mustard [8]. Rahman and Rahman (2014) [1] and Rahman *et al.* (2012) [9] noted that maize production is not only profitable but the technical and economic efficiency of the maize farmers is much higher than those of rice and wheat farmers. Although Rahman *et al.* (2012) [9] noted that the gross return is the main driver of choosing winter maize production in Bangladesh, it is not known whether maize production is internationally competitive or not. This is because conventionally maize was imported to Bangladesh, which drains valuable foreign currency reserves to pay for import. Therefore, if maize is globally competitive, then an increase in the production of maize can successfully substitute its import and save foreign currency. Further the nature of responsiveness of the maize farmers to changes in input and output prices is not known. This information is important because Bangladeshi farmers not only need to be more efficient in their production activities, but also to be responsive to market indicators, so that the scarce resources are utilized efficiently to increase productivity as well as profitability in order to ensure supply to the urban market [10] and increase farmers' welfare. Furthermore, the government of Bangladesh is seeking to diversify its agricultural sector to other cereals than rice (*i.e.*, wheat and maize) as well as non-cereals (e.g., potatoes, vegetables, and spices, *etc.*). In fact, the Fifth Five Year Plan (1997–2002) emphasized set specific objectives to attain self-sufficiency in food-grain production and increased production of other nutritional crops and earmarked 8.9% of the total agricultural allocation to promote crop diversification [11]. Subsequently, the Poverty Reduction Strategy Paper (2005) [12] and the Sixth Five Year Plan (2011–2015) [13] also emphasized crop diversification [12,13].

Given this background, the present study specifically addresses this critical research gap and systematically examines performance of the maize sector using an in-depth farm survey data of 165 maize growers from two major growing regions in northwestern Bangladesh (*i.e.*, Dinajpur and Lalmonirhat districts). Specifically, the study aims to: (i) assess global competitiveness of the maize sector; (ii) assess financial profitability of producing maize at the farm level; and (iii) estimate input demand and output supply elasticities of maize production at the farm level. The present study is aimed at providing a holistic picture of the maize sector in order to judge its potential as a driver of agricultural growth in Bangladesh. For example, if maize production proves to be globally competitive, then its expansion can successfully substitute its import. In addition, information on the farm level profitability and responsiveness of the farmers to changes in prices of maize and associated inputs will enable formulation of policies appropriate for promoting maize sector. The paper is organized as follows. Section 2 presents the analytical frameworks, the study area and the data. Section 3 presents the results. Section 4 provides conclusions and draws policy implications.

2. Methodology

We apply a range of analytical tools to address the three objectives. These include: (a) construction of a Policy Analysis Matrix (PAM) and computation of some selected ratio indicators to measure global competitiveness of the maize sector; (b) Cost-Benefit Analysis (CBA) to determine financial profitability of maize production at the farm level; and (c) translog profit function to estimate input demand, output supply and fixed factor elasticities of maize production at the farm level. The details are as follows.

2.1. Analysis of Competitiveness of Maize

PAM framework, which was utilized to analyze competitiveness and economic efficiency of maize production, uses two enterprise budgets, one valued at market prices and the other valued at social prices (Table 1). PAM framework is particularly useful in identifying appropriate direction of change in policy [14] and is commonly used (e.g., Rashid *et al.*, 2009 [15]; Khan, 2001 [16]).

Table 1. Framework of Policy Analysis Matrix (PAM).

Items	Revenue	Costs		Profit
		Tradable Inputs	Domestic Factors	
Private prices	A	B	C	D
Social prices	E	F	G	H
Divergences	I	J	K	L

Source: Adapted from Monke and Pearson (1989) [17].

Private profit (D) = A − (B + C); Social profit (H) = E − (F + G); Output transfer (I) = A − E; Input transfer (J) = B − F; Factor transfer (K) = C − G; Net transfer (L) = D − H or (L) = I − J − K, where $A = P_{id} \times Q_i$; $B = P_{jd} \times Q_j$; $C = P_{nd} \times Q_n$; $E = P_{ib} \times Q_i$; $F = P_{jb} \times Q_j$; $G = P_{ns} \times Q_n$; P_{id} = domestic price of output i; P_{jd} = domestic price of tradable input j; P_{ib} = international price of output i; P_{jb} = international price of tradable input j; P_{nd} = market price of non-tradable input n; P_{ns} = shadow price of non-tradable input n; Q_i = quantity of output; Q_j = quantity of tradable input; Q_n = quantity of non-tradable input.

The indicators in the first row of Table 1 provide a measure of private profitability (D), or competitiveness, and are defined as the difference between observed revenue (A) and costs (B + C). Private profitability demonstrates competitiveness of the system, given current technologies, prices of inputs and outputs, policy interventions and market failures. The second row of the matrix calculates measure of social profitability (H) defined as the difference between social revenue (E) and costs (F + G). Social profitability measures economic efficiency/comparative advantage of the system. To estimate social prices, the inputs used were divided into two categories: (a) tradable intermediate inputs; and (b) non-tradable intermediate inputs. The tradable intermediate inputs were different types of fertilizers and irrigation equipment. We have used import parity price by converting FOB price to CIF at the Chittagong port by adding freight cost to FOB prices of fertilizers. Since detailed cost of production of irrigation equipment is not available, it was not considered. For the non-tradable intermediate inputs, such as agricultural labor, machinery, seed, organic manure, insecticides, cultivated land, irrigation fees and interest on operating capital, we have applied domestic costs adjusted with specific conversion factors (SCF) for each input (for details of full social costs and SCF, see Kazal *et al.*, 2013 [18]; Shahabuddin and Dorosh, 2002 [19]). The opportunity cost of operating capital was calculated at 10% interest rate for the duration of maize production period.

2.2. Ratio Indicators of Competitiveness

The PAM framework can also be used to calculate important indicators for policy analysis. Popular measures of global competitiveness are: the Nominal Protection Coefficient (NPC) and Effective Protection Coefficient (EPC). We apply NPC on output (NPCO) and input (NPCI) as well as EPC to determine competitiveness of maize. These are defined as follows:

(a) Nominal Protection Coefficient on Output (NPCO): This ratio shows the extent to which domestic prices for output differ from international reference prices. NPCO > 1 means that domestic farm gate price is greater than the world price of output and is uncompetitive (Reddy and Bantilan, 2012). On the contrary, if NPCO < 1, the production system is competitive. NPCO is expressed as:

$$\text{NPCO} = (P_{id} \times Q_i)/(P_{ib} \times Q_i) \quad (1)$$

(b) Nominal Protection Coefficient on Input (NPCI): This ratio shows how much domestic prices for tradable inputs differ from their social prices. If NPCI >1, the domestic input cost is greater than the comparable world prices and the system is taxed by policy. If NPCI < 1, the system is subsidized by policy. NPCI is defined as follows:

$$\text{NPCI} = (P_{jd} \times Q_j)/(P_{jb} \times Q_j) \quad (2)$$

(c) Effective Protection Coefficient (EPC): EPC is the ratio of value added in private prices (A–B) to value added in social prices (E–F). An EPC > 1 suggests that government policy protects the producers, while EPC < 1 indicates that producers are unprotected through policy interventions. EPC is expressed as:

$$\text{EPC} = \{(P_{id} \times Q_i) - (P_{jd} \times Q_j)\}/\{(P_{ib} \times Q_i) - (P_{jb} \times Q_j)\} \tag{3}$$

(d) Domestic Resource Cost (DRC): The DRC was brought into common use by Bruno (1972) [20] specifically for the purpose of measuring comparative advantage. According to Bruno (1972) [20] and Krueger (1966, 1972) [21,22], the economic efficiency in domestic resource use of a commodity system can be assessed by using this ratio. Since minimizing DRC is equivalent to maximizing social profit, if DRC < 1, then the system uses domestic resources efficiently and thus has a comparative advantage. If DRC > 1, then the system shows inefficiency in domestic resource use and has a comparative disadvantage. The method of calculating DRC ratio in the PAM framework is given as:

$$\text{DRC} = (\text{G})/(\text{E} - \text{F}) = (P_{ns} \times Q_n)/\{(P_{ib} \times Q_i) - (P_{jb} \times Q_j)\} \tag{4}$$

2.3. Profitability Analysis of Maize

Profitability or Cost-Benefit Analysis (CBA) includes calculation of detailed financial costs of production and returns from maize on a per hectare basis. The total cost (TC) is composed of total variable costs (TVC) and total fixed costs (TFC) (Rahman and Rahman, 2014). TVC includes costs of human labor (both family supplied and hired labor, wherein the cost of family supplied labor was estimated by imputing market wage rate), mechanical power; seed, manure, chemical fertilizers; pesticides; and irrigation. TFC includes land rent (if owned land was used, then the imputed value of market rate of land rent was applied) and interest on operating capital. The gross return (GR) was computed as total maize output multiplied by the market price of maize. Profits or gross margin (GM) was computed as GR–TVC, whereas the Net Return (NR) was computed as GR–TC. Finally, the Benefit Cost Ratio (BCR) was computed as GR/TC [1].

2.4. The Profit Function Approach

A profit function approach was used to examine impacts of prices and fixed factors on farmers' resource allocation decisions. This is because profit function has a duality relationship with the underlying production function. An advantage of a profit function model is that it is specified as a function of prices and fixed factors, which are exogenous in nature and, therefore, are free from possible endogeneity problem associated with a production function model [9]. The basic assumption is that farm management decisions can be described as static profit maximization problem. Specifically, the farm household is assumed to maximize 'restricted' profits from growing specific crops, defined as the gross value of output less variable costs, subject to a given technology and given fixed factor endowments [23].

We used a flexible functional form, the translog function that approximates most of the underlying true technology. The general form of the translog profit function, dropping the *i*th subscript for the farm, is defined as [24,25]:

$$\begin{aligned}\ln\pi' = {} & \alpha_0 + \sum_{j=1}^{4} \alpha_j \ln P\prime_j + \tfrac{1}{2}\sum_{j=1}^{4}\sum_{k=1}^{4} \gamma_{jk} \ln P\prime_j \ln P\prime_k + \sum_{j=1}^{4}\sum_{l=1}^{5} \delta_{jl} \ln P\prime_j \ln Z_l + \sum_{l=1}^{5} \beta_l \ln Z_l \\ & + \tfrac{1}{2}\sum_{l=1}^{5}\sum_{t=1}^{5} \theta_{lt} \ln Z_l \ln Z_t + v,\end{aligned} \tag{5}$$

where:

π' = restricted profit (total revenue less total cost of variable inputs) normalized by price of output (P_y),
P'_j = price of the jth input (P_j) normalized by the output price (P_y),
j = 1, fertilizer price,
= 2, labor wage,
= 3, animal power price,
= 4, seed price,
Z_l = quantity of fixed input, l,
l = 1, area under specific crops,
= 2, experience,
= 3, irrigation cost,
= 4, education,
= 5, land fragmentation,
v = random error,
ln = natural logarithm, and α_0, α_j, γ_{jk}, β_l, δ_{jl}, and θ_{lt}, are the parameters to be estimated.

The corresponding share equations are expressed as (Farooq *et al.*, 2001):

$$S_j = \frac{P_j X_j}{\pi} = -\frac{\partial \ln \pi'}{\partial \ln P\prime_j} = -\alpha_j - \sum_{k=1}^{4} \gamma_{jk} \ln P\prime_k - \sum_{l=1}^{5} \theta_{jl} \ln Z_l \, , \tag{6}$$

$$S_y = \frac{P_y X_y}{\pi} = 1 + \frac{\partial \ln \pi'}{\partial \ln P_y} = 1 - \sum_{j=1}^{4} \alpha_j - \sum_{j=1}^{4} \sum_{k=1}^{4} \gamma_{jk} \ln P\prime_j - \sum_{j=1}^{4} \sum_{l=1}^{5} \theta_{jt} \ln Z_l , \tag{7}$$

where S_j is the share of jth input, S_y is the share of output, X_j denotes the quantity of input j and Y is the level of output. Since the input and output shares form a singular system of equations (by definition $S_y - \Sigma S_j = 1$), one of the share equations, the output share, is dropped and the profit function and variable input share equations are estimated jointly using SURE procedure. The joint estimation of the profit function together with factor demand equations ensures consistent parameter estimates [24].

2.5. Variable Input Demand and Output Supply Elasticities

The own price elasticity of demand for variable input j (η_{jj}) was computed as [24]:

$$\eta_{jj} = -S_j - \frac{\gamma_{jj}}{S_j} - 1 \tag{8}$$

where S_j is the jth share equation, at the sample mean.

For the cross-price elasticity of demand for jth variable input with respect to the price of kth variable input (η_{jk}) was computed as [24]:

$$\eta_{jk} = -S_k - \frac{\gamma_{jk}}{S_j} for\, j \neq k \tag{9}$$

The elasticity of demand for variable input with respect to output price, P_y (η_{jy}) was computed as [25]:

$$\eta_{jy} = S_y + \sum_{j=1}^{4} \frac{\gamma_{jk}}{S_j} \tag{10}$$

where S_y is the output share at the sample mean.

The elasticity of demand for variable input with respect to the lth fixed factor, (η_{jl}) was computed as [25]:

$$\eta_{jl} = \beta_l + \delta_{jl}\ln P_j' + \sum_{l=1}^{5} \theta_{jl}\ln Z_l - \frac{\delta_{jl}}{S_j} \quad (11)$$

The elasticity of output supply with respect to price of jth variable input (ε_{yj}) was computed as [25]:

$$\varepsilon_{yj} = -S_j - \frac{\sum_{j=1}^{4} \gamma_{jk}}{S_y} \quad (12)$$

The elasticity of output supply with respect to its own price (ε_{yy}) was computed as [25]:

$$\varepsilon_{yy} = \sum_{j=1}^{4} S_j + \frac{\sum_{j=1}^{4} \gamma_{jk}}{S_y} \quad (13)$$

Finally the output supply with respect to lth fixed factor (ε_{yl}) was computed as [25]:

$$\varepsilon_{yl} = \left(\beta_l + \sum_{j=1}^{4} \delta_{jk}\ln P_j' + \sum_{l=1}^{5} \theta_{lt}\ln Z_l \right) + \frac{\sum_{j=1}^{4} \delta_{jl}}{S_y} \quad (14)$$

2.6. Data and the Study Area

The data to analyze competitiveness, profitability, output supply and input demand of maize production at the farm level were obtained from a recently completed NFPCSP-FAO project. The data were collected during February–May 2012 through an extensive farm survey in 17 districts (or 20 sub-districts) of Bangladesh. A multistage stratified random sampling technique was employed. At the first stage, districts where the specified crops are dominant were selected, which included maize as one of the crops. At the second stage, sub-districts (upazilla) were selected according to highest concentration of these specified crops in terms of area cultivated based on the information from the district offices of the Directorate of Agricultural Extension (DAE). At the third stage, unions were selected using the same criteria at the union/block level, which were obtained from the upazilla (subdistrict) offices of the DAE. Finally, the farmers were selected at random from the villages with the same criteria classified into three standard farm size categories. These are: marginal farms (farm size 50–100 decimals), small farms (101–250 decimals), and medium/large farms (> 251 decimals). Specifically, information on winter maize production was collected from two districts where winter maize production is dominant. These are Dinajpur and Lalmonirhat districts in northwestern region. A total of 165 High-Yielding Varieties (HYV) of maize-producing households (61 marginal farms, 64 small farms and 40 medium/large farms) were interviewed. The questionnaire used was pre-tested in Tangail district prior to finalization. The survey was carried out by trained enumerators who were graduate students of the Sher-e-Bangla Agricultural University, Dhaka and Bangladesh Agricultural University, Mymensingh.

3. Results and Discussion

3.1. Competitiveness of Maize

A country should specialize in producing commodities in which they are competitive in the global market [26]. Conventionally, maize was imported to Bangladesh as the sector was not successful in the past. Table 2 presents the results of the competitiveness analysis of maize. Maize production generates a substantial profit at social prices because of the low level tradable input use (for details of the background calculations, please see Kazal *et al.*, 2013 [18]). Analysis of NPCO, NPCI and EPC showed that maize producers are competitive (NPCO < 1 and EPC < 1) although the inputs were subsidized by government policy (NPCI < 1) (Section 3.3). The DRC value for maize was found to be less than one (0.54), indicating that Bangladesh has comparative advantage in producing maize for import substitution. This is plausibly attributed to the higher yield of hybrid maize, which results in lower cost of production per unit of land. Moreover, higher demand for maize in the poultry and fisheries industries has led to efficient production of maize. The results are similar to those noted by Rashid *et al.* (2009) [15] for maize in Bangladesh.

Table 2. Competitiveness of maize.

Items	Values
Revenue at social prices (BDT)	22,529.90
Tradable inputs at social prices (BDT)	2827.96
Domestic factors at social prices (BDT)	10,721.99
Profits at social prices (BDT)	8979.96
Nominal Protection Coefficient on Output (NPCO)	0.71
Nominal Protection Coefficient on Input (NPCI)	0.51
Effective Protection Coefficient (EPC)	0.73
Domestic Resource Cost (DRC)	0.54

Exchange rate: USD 1.00 = BDT 81.86 in 2012 [27].

3.2. Sensitivity Analysis

Since PAM is a static analysis, it is important to conduct some sensitivity check by varying selected key outcome indicators (*i.e.*, international price of the output) in order to determine the robustness of the findings given the nature of volatility in the international market for agricultural produce including maize. This is because the results of comparative advantage (both economic return and DRC) could vary if the parameter values used in the PAM are changed and sensitivity analysis can provide some indication of the magnitude of these effects. For example, the maize price has been falling since September 2012 in the international market due to a range of factors including policy changes in major maize producing regions [28]. It should be noted that in addition to animal feed and biofuel production, a substantial amount of maize produced in USA and Argentina is used for human consumption [29] whereas maize in Bangladesh is mainly used for animal feed (particularly poultry production) and the main import is from neighbouring India. The Sixth Five Year Plan (2011–2015) [13] noted that the demand for maize as a feed ingredient is increasing rapidly in the country due to the establishment of new poultry, dairy and fish farms. For example, poultry farms with an average capacity of 5000 birds or less use imported maize to fulfil as much as one-quarter of their requirements, and the commercial feed suppliers use imported maize to fulfil two-thirds of their grain requirements [30].

We have simulated the effects of the changes in maize price on the economic return and DRC and the results are presented in Table 3. The output price change has been simulated through the change in international reference price. We have simulated the change in output price with 20% increase and 20% decrease from the base international price of maize. The economic return per ton was first calculated by subtracting the costs for tradable inputs (fertilizers) and domestic factors (labor, manure, irrigation, land, *etc.*) from the revenue in social prices per ton (Table 1), which was computed as BDT 8979.96 per ton. Then, per hectare economic return was obtained by multiplying the economic return per ton with average yield per ha estimated at 6.2277 t/ha, *i.e.*, BDT 8979.96 × 6.2277 t = BDT 55,924.20 per ha (Table 2). The results of the exercise show that economic return and DRC are highly sensitive to changes in maize price. When the international price of maize was increased by 20%, the corresponding economic return and DRC calculations show that the country has comparative advantage for import substitution, as expected. Interestingly, when the international price of maize was decreased by 20%, the resulting calculation of the economic return and DRC shows that the country still has comparative advantage for maize import substitution. The corresponding DRC values are 0.46 for a 20% increase in international price of maize and 0.67 for a 20% decrease in the international price of maize, compared with 0.54 in the base year (Table 2). The DRC values of 0.46 and 0.67 indicate that the costs of domestic resources used in the production of maize per hectare are far less than the cost of its import, which implies that Bangladesh can produce maize domestically for import substitution. However, a drastic change in the international price of maize and other tradable inputs could alter the results either way.

Table 3. Effect of changes in output prices on economic returns and DRC.

Effect on Economic Returns (Tk/ha)			**Effect on DRC**		
Base Case	Changes in output price (Tk/ton)		Base case	Changes in output price	
	−20%	20%		−20%	20%
Net economic return (BDT/ha)	Changed economic return (BDT/ha)		Base DRC	Changed DRC	
55,924.20	32,732.98	79,115.41	0.54	0.67	0.46

Exchange rate: USD 1.00 = BDT 81.86 in 2012 [27].

3.3. Financial Profitability of Maize

Maize production is profitable based on net return and undiscounted BCR in the northwestern region (Table 4). The net return and BCR for the marginal farms were the highest followed by medium/large farms and small farms. The net returns per hectare were BDT 19,633.17, BDT 14,699.51 and BDT 17,687.20 for marginal, small and medium/large farms respectively. However, the differences were not statistically significant, implying that farm size has no influence on yield and profitability of maize. The overall BCR result of 1.21 is lower than the BCR of 1.63 for HYV winter maize reported by Rahman and Rahman (2014) [1] for Bangladesh.

Table 4. Financial profitability of HYV winter Maize according to farm size in northwestern region.

Region and Farm Type	**Yield (t/ha)**	**Sale Price (BDT/ton)**	**Gross Return (BDT/ha)**	**Variable Cost (BDT/ha)**	**Total Cost (BDT/ha)**	**Gross Margin (BDT/ha)**	**Net Return (BDT/ha)**	**Undiscounted BCR**
All	6.23	15,793.18	101,772.66	51,105.68	84,393.72	50,672.89	17,378.94	1.21
Marginal	6.18	16,248.16	103,399.44	51,487.78	83,746.27	51,911.66	19,653.17	1.23
Small	6.33	15,340.91	100,900.94	52,299.88	86,201.43	48,601.06	14,699.51	1.17
Medium & Large	6.18	15,778.07	101,035.32	49,529.37	83,348.12	51,505.95	17,687.20	1.21
χ^2	0.01						1.38	

3.4. Output Supply, Input Demand and Fixed Factor Elasticities of Maize Production

Table 5 presents the estimates of the profit function estimated jointly with four input demand equations for maize. Among the regularity properties of the profit function specified in Equation (5), homogeneity was automatically imposed because the normalized specification was used [23]. The monotonicity property of a translog profit function model holds if the estimated output share is positive (Wall and Fisher, 1987 cited in Farooq *et al.*, 2001 [25]), which was found in our case. The symmetry property was tested by imposing cross-equation restrictions of equality on the corresponding parameters between the profit function and the four factor demand equations, which were estimated jointly using the SURE procedure. The test failed to reject the restrictions, thereby confirming that the symmetry property also holds and the sample farms do maximize profit with respect to normalized prices of the variable inputs [24]. The convexity property was checked by examining the bordered Hessian matrix evaluated at the sample means. The convexity property of a profit function holds if the bordered Hessian matrix is positive semidefinite. This is checked by examining the signs of the principal minors of the bordered Hessian matrix, which should alternate in sign starting with a negative sign. The check showed that the required condition holds at the sample mean.

Table 5. Restricted parameter estimates of the translog profit functions along with input share equations of maize.

Variables	Parameters	Estimates	*t*-ratio
Profit function			
Constant	α_0	2.3048	0.26
$\ln P'_F$	α_F	0.7553	0.79
$\ln P'_W$	α_W	−0.5176	−0.27
$\ln P'_M$	α_M	−0.5454	−0.95
$\ln P'_P$	α_P	0.4875	0.99
½$\ln P'_F \times \ln P'_F$	γ_{FF}	−0.2841 ***	−3.12
½$\ln P'_W \times \ln P'_W$	γ_{WW}	−0.6463 *	−1.70
½$\ln P'_M \times \ln P'_M$	γ_{MM}	−0.1199 ***	−2.96
½$\ln P'_P \times \ln P'_P$	γ_{PP}	−0.0650 **	−2.29
$\ln P'_F \times \ln P'_W$	γ_{FW}	−0.3088 **	−2.05
$\ln P'_F \times \ln P'_M$	γ_{FM}	0.0579	1.25
$\ln P'_F \times \ln P'_P$	γ_{FP}	−0.0467	−1.00
$\ln P'_W \times \ln P'_M$	γ_{WM}	−0.2542 ***	−2.60
$\ln P'_W \times \ln P'_P$	γ_{WP}	−0.0872	−1.10
$\ln P'_M \times \ln P'_P$	γ_{MP}	0.0026	0.10
$\ln P'_F \times \ln Z_L$	δ_{FL}	−0.0344	−0.35
$\ln P'_F \times \ln Z_G$	δ_{FG}	−0.1150	−0.55
$\ln P'_F \times \ln Z_I$	δ_{FI}	0.0371	1.02
$\ln P'_F \times \ln Z_S$	δ_{FS}	−0.0042	−0.11
$\ln P'_F \times \ln Z_E$	δ_{FE}	0.2358 *	1.88
$\ln P'_W \times \ln Z_L$	δ_{WL}	0.1331	0.72
$\ln P'_W \times \ln Z_G$	δ_{WG}	0.1715	0.44
$\ln P'_W \times \ln Z_I$	δ_{WI}	0.1092	1.52
$\ln P'_W \times \ln Z_S$	δ_{WS}	−0.1040	−1.48
$\ln P'_W \times \ln Z_E$	δ_{WE}	0.0753	0.31
$\ln P'_M \times \ln Z_L$	δ_{ML}	0.0238	0.38
$\ln P'_M \times \ln Z_G$	δ_{MG}	0.1925	1.52
$\ln P'_M \times \ln Z_I$	δ_{MI}	0.0406 *	1.64
$\ln P'_M \times \ln Z_S$	δ_{MS}	−0.0090	−0.36
$\ln P'_M \times \ln Z_E$	δ_{ME}	−0.0070	−0.08
$\ln P'_P \times \ln Z_L$	δ_{PL}	−0.0113	−0.23
$\ln P'_P \times \ln Z_G$	δ_{PG}	−0.0906	−0.86
$\ln P'_P \times \ln Z_I$	δ_{PI}	0.0130	0.70
$\ln P'_P \times \ln Z_S$	δ_{PS}	0.0014	0.07
$\ln P'_P \times \ln Z_E$	δ_{PE}	0.1101 *	1.71
$\ln Z_L$	β_L	3.6239 **	2.03
$\ln Z_G$	β_G	−0.1458	−0.04
$\ln Z_I$	β_I	−1.3794 *	−1.79
$\ln Z_S$	β_S	0.1652	0.26
$\ln Z_E$	β_E	−1.0948	−0.47
½$\ln Z_L \times \ln Z_L$	θ_{LL}	0.3815 *	1.70
½$\ln Z_G \times \ln Z_G$	θ_{GG}	−0.1469	−0.16
½$\ln Z_I \times \ln Z_I$	θ_{II}	0.0080	0.25
½$\ln Z_S \times \ln Z_S$	θ_{SS}	−0.0575	−0.57
½$\ln Z_E \times \ln Z_E$	θ_{EE}	0.8585 **	1.95
$\ln Z_L \times \ln Z_G$	θ_{LG}	−0.6925 *	−1.79
$\ln Z_L \times \ln Z_I$	θ_{LI}	−0.2256 **	−2.46
$\ln Z_L \times \ln Z_S$	θ_{LS}	−0.1515 *	−1.88
$\ln Z_L \times \ln Z_E$	θ_{LE}	−0.1894	−0.82
$\ln Z_G \times \ln Z_I$	θ_{GI}	0.4897 **	2.33
$\ln Z_G \times \ln Z_S$	θ_{GS}	0.0708	0.57
$\ln Z_G \times \ln Z_E$	θ_{GE}	0.0981	0.22

Table 5. *Cont.*

Variables	Parameters	Estimates	*t*-ratio
$\ln Z_I \times \ln Z_S$	θ_{IS}	0.0904 **	2.00
$\ln Z_I \times \ln Z_E$	θ_{IE}	0.1217	1.42
$\ln Z_S \times \ln Z_E$	θ_{SE}	−0.0004	0.00
Fertilizer share equation			
Constant	α_F	0.7553	0.79
$\ln P'_F$	γ_{FF}	−0.2841 ***	−3.12
$\ln P'_W$	γ_{FW}	−0.3088 **	−2.05
$\ln P'_M$	γ_{FM}	0.0579	1.25
$\ln P'_P$	γ_{FP}	−0.0467	−1.00
$\ln Z_L$	δ_{FL}	−0.0344	−0.35
$\ln Z_G$	δ_{FG}	−0.1150	−0.55
$\ln Z_I$	δ_{FI}	0.0371	1.02
$\ln Z_S$	δ_{FS}	−0.0042	−0.11
$\ln Z_E$	δ_{FE}	0.2358 *	1.88
Labor share equation			
Constant	α_W	−0.5176	−0.27
$\ln P'_F$	γ_{FW}	−0.3088 **	−2.05
$\ln P'_W$	γ_{WW}	−0.6463 *	−1.70
$\ln P'_M$	γ_{WM}	−0.2542 ***	−2.60
$\ln P'_P$	γ_{WP}	−0.0872	−1.10
$\ln Z_L$	δ_{WL}	0.1331	0.72
$\ln Z_G$	δ_{WG}	0.1715	0.44
$\ln Z_I$	δ_{WI}	0.1092	1.52
$\ln Z_S$	δ_{WS}	−0.1040	−1.48
$\ln Z_E$	δ_{WE}	0.0753	0.31
Machine share equation			
Constant	α_M	−0.5454	−0.95
$\ln P'_F$	γ_{FM}	0.0579	1.25
$\ln P'_W$	γ_{WM}	−0.2542 ***	−2.60
$\ln P'_M$	γ_{MM}	−0.1199 ***	−2.96
$\ln P'_P$	γ_{MP}	0.0026	0.10
$\ln Z_L$	δ_{ML}	0.0238	0.38
$\ln Z_G$	δ_{MG}	0.1925	1.52
$\ln Z_I$	δ_{MI}	0.0406 *	1.64
$\ln Z_S$	δ_{MS}	−0.0090	−0.36
$\ln Z_E$	δ_{ME}	−0.0070	−0.08
Seed share equation			
Constant	α_P	0.4875	0.99
$\ln P'_F$	γ_{FP}	−0.0467	−1.00
$\ln P'_W$	γ_{WP}	−0.0872	−1.10
$\ln P'_M$	γ_{MP}	0.0026	0.10
$\ln P'_P$	γ_{PP}	−0.0650 **	−2.29
$\ln Z_L$	δ_{PL}	−0.0113	−0.23
$\ln Z_G$	δ_{PG}	−0.0906	−0.86
$\ln Z_I$	δ_{PI}	0.0130	0.70
$\ln Z_S$	δ_{PS}	0.0014	0.07
$\ln Z_E$	δ_{PE}	0.1101 *	1.71
R–squared		0.74	
F–stat		16.82 ***	
Observations		165	

*** Significant at 1% level ($p < 0.01$); ** Significant at 5% level ($p < 0.05$); * Significant at 10% level ($p < 0.10$); F = fertilizer price, W = labor wage, M = machine price, P = seed price, L = land cultivated, G = experience, I = irrigation, S = education, and E = land fragmentation.

The value of the adjusted R^2 for the profit function (from OLS) indicated good fit for the model. Further, a large number of coefficients on the variables are significantly different from zero at the 10% level at least in the model. Significance of the coefficients in some of the interaction terms indicates non-linearity in the production structure, which justifies use of a translog function instead of a more restrictive Cobb-Douglas function.

The parameter estimates of the profit function model were used to estimate the elasticities with respect to variable input demand, output supply and fixed factors using Equations (8) through Equations (14) (Table 6). All own price elasticities have negative signs consistent with theory, but all of them are in the inelastic range except labor, which is highly elastic. Results of the cross-price elasticities of demand are mixed with some being complements and some being substitutes.

Table 6. Estimated elasticities of the translog profit function of maize.

Parameters	Output Price	Fertilizer Price	Labor Wage	Machine Price	Seed Price	Land	Experience	Irrigation	Education	Land Fragmentation
Output supply	0.4001 ***	−0.0295	−0.0247	0.0273	0.0322	3.8790 **	−0.0045	−1.1680	−0.3650	1.3514
	(2.63)	(−1.13)	(−1.10)	(−0.34)	(−0.13)	(2.24)	(0.00)	(−1.45)	(−0.52)	(0.52)
Fertilizer demand	0.1810	−0.2958 ***	0.4371	−0.3403	0.0180	4.0596 **	0.4913	−1.2011	−0.0780	−1.4819
	(1.41)	(−2.64)	(−0.04)	(−2.10)	(−0.48)	(2.24)	(0.13)	(−1.50)	(−0.13)	(−0.61)
Labor demand	7.1893	−1.4913	−4.1243	−1.0926	−0.4810	4.4387 **	0.7242	−0.6539	−0.4867	−0.3443
	(1.42)	(−0.06)	(−2.07) **	(0.96)	(−0.58)	(2.07)	(−0.05)	(−1.50)	(0.10)	(−0.32)
Machine demand	−0.6491	−0.8645 *	1.6981	−0.0096	−0.1748	3.7124 *	−1.7255	−1.4472	−0.0087	−0.5637
	(0.99)	(−1.93)	(0.54)	(−2.43) **	(−0.99)	(1.94)	(−0.27)	(−1.52)	(−0.06)	(−0.23)
Seed demand	−2.2636	0.2628	0.4149	−0.1632	−0.3357 ***	4.0773 **	1.2120	−1.2300	−0.1103	−2.0106
	(0.22)	(−0.42)	(−0.49)	(−0.95)	(−4.26)	(2.19)	(0.20)	(−1.43)	(−0.16)	(−0.62)

*** Significant at 1% level ($p < 0.01$); ** Significant at 5% level ($p < 0.05$); * Significant at 10% level ($p < 0.10$).

On the whole, changes in market price of inputs and output significantly influence farmers' resource use and productivity (maize supply) as expected. The output supply response to output price change is positive consistent with theory. The elasticity value of 0.40 indicates that a 1% increase in maize price will increase output supply by 0.4%. The output supply response is higher than for HYV rice estimated at 0.27 [23] but much lower than HYV wheat estimated at 0.95 [9] in Bangladesh. Demand for fertilizer and labor will increase in response to an increase in output price consistent with expectation. This rise in labor demand in response to maize price increase will lead to a redistribution of gains accrued from modern agriculture to landless laborers via wages, an argument in favor of widespread diffusion of modern agricultural technology in the first place [31]. In fact, labor input alone accounted for 24.4% of the total input costs or 40.3% of total variable costs in maize production. However, demand for machine and seed will not increase with an increase in maize price. The main reason may be due to the fact that seeds must be applied at a more or less fixed rate in order to ensure optimum yield and therefore, increase in output price is not going to increase seed use rate substantially as overuse of seed will not increase yield but may increase weeding costs.

The responsiveness of labor demand to wage increase is substantial. This is expected because labor is the main variable input in maize production as mentioned above. Therefore, the farmers' response to an increase in wage is quite high, estimated at −4.12, implying that a 1% increase in labor wage will reduce labor demand by 4.12%. Elastic response of labor demand to an increase in wage was also reported for HYV wheat in Bangladesh estimated at −1.11 [9]. The own price elasticity of other inputs is quite low and similar to those reported for HYV rice [23] and HYV wheat [9].

Among the conventional fixed factors, the role of land area in influencing productivity and resource use remains dominant. This is expected in a land-scarce country like Bangladesh where the average farm size is only 0.37 ha [32]. Therefore, an increase in the availability of land dramatically increases the supply of maize and will result in a consequent increase in the use of variable inputs. The elasticity value of 3.88 for the land variable indicates that a one percent increase in land area under maize will increase output supply by a substantial 3.88 percent. Similarly, an increase in land area under maize will increase demand for all inputs substantially, consistent with expectation. Once again, landless laborers will gain access to the profit generated by maize production via higher demand for hired labor owing to an increase in maize area. However, these elasticity values are substantially higher than those reported for HYV rice [23] and HYV wheat [9].

4. Conclusions and Policy Implications

The principal aim of this study was to assess competitiveness of maize production, financial profitability at the farm level and responsiveness of the maize farmers to input and output price changes in order to judge the potential of the maize sector as a driver of agricultural growth in Bangladesh. Results revealed that maize production is competitive in Bangladesh and can be a good substitute for maize import even when international price of maize varies slightly. Maize is also profitable at the farm level (BCR = 1.21) with no adverse influence of farm size on yield as well as profitability. Farmers are responsive to changes in market prices of maize and inputs although the level of responsiveness is low. However, an increase in the land available for maize will have a dramatic increase in maize supply and corresponding demand for other inputs.

The following policy implications can be derived from the results of this study. First, investment in R&D could further enhance productivity of maize, which would not only increase profitability at the farm level but will also successfully substitute maize imports. The Bangladesh Agricultural Research Institute should be supported with investments to develop open-pollinated and hybrid varieties, which are suitable for the summer season as well. Second, measures should be implemented to improve land available for maize production at the farm level. The average farm size in Bangladesh is declining over time due to population pressure on a closing land frontier. Although conventional land reform policies to redistribute land is not feasible in the Bangladesh context [33], tenurial policies aimed at improving land rental market in order to allow landless and marginal farmers to acquire land, will significantly improve maize supply. This is particularly important since there is no adverse effect of farm size on maize profitability. Third, the smooth operation of the hired labor market should be improved, which in turn will enable the landless laborers to reap the benefits of increased maize production through wages. This is because labor is the major variable input in the maize production process.

Effective implementation of these policy measures, although formidable, will boost maize production, which in turn will substitute its import demand, curb consumption demand for rice as the main staple in the Bangladeshi diet and increase farmers' welfare through higher profits, which are goals worth pursuing.

Acknowledgments: The database required for this project was created with funding support from National Food Policy Capacity Strengthening Program, FAO-Bangladesh Research Grant, Phase II (2011). Some of the materials presented in this paper are available in the report "Financial and economic profitability of selected agricultural crops in Bangladesh" NFPCSP-FAO Research Grant Report #05/11, Dhaka Bangladesh, July 2013. The authors gratefully acknowledge critical comments made by two anonymous referees, which have substantially improved the paper. All caveats remain with the authors.

Author Contributions: The first author (Co-I of the main project) conducted the profit function analysis and wrote the paper. The second author (PI of the main project) was in-charge of the field survey and data management and conducted the farm level profitability analysis. The third and fourth authors (Co-Is of the main project) jointly conducted the PAM analysis.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Rahman, S.; Rahman, M.S. Exploring the potential and performance of maize production in Bangladesh. *Int. J. Agric. Manag.* **2014**, *3*, 99–106.
2. Bangladesh Bureau of Statistics. *Yearbook of Agricultural Statistics of Bangladesh 2012*; Bangladesh Bureau of Statistics: Dhaka, Bangladesh, 2012.

3. Begum, M.; Khatun, F. *Present Status and Future Prospect of Hybrid Maize in Bangladesh. Training on Hybrid Maize Seed Production Technology 20–21 September 2006 Training Manual*; Development of Hybrid Maize Research Project (GOB) Plant Breeding Division Bangladesh Agricultural Research Institute: Gazipur, Bangladesh, 2006.
4. Bangladesh Agricultural Research Institute. *Udvabita Krishiprojukti 2006–2007*; Bangladesh Agricultural Research Institute: Gazipur, Bangladesh, 2008.
5. FAO. *FAOSTAT. 2011*; Food and Agricultural Organization of the United Nations: Rome, Italy, 2011.
6. Hussain, M.S.; Islam, M.N.; Anwar, M.M. *Comparative Study on Hybrid and Composite Variety of Maize in Selected Areas of Bangladesh. Annual Report*; Agricultural Economics Division, BARI: Gazipur, Bangladesh, 1995; pp. 44–52.
7. Fokhrul, M.; Haque, M.F. *Integrating Maize into Existing Cropping System. Opportunities and Constraints in Existing Agro-Economic Niches*; On Farm Research Division Bangladesh Agricultural Research Institute: Gazipur, Bangladesh, 1995.
8. Haque, N. An Economic Study of Maize and its Competitive Crops: A Study in Sherpur Thana of Bogra District. Master's Thesis, Bangladesh Agricultural University, Mymensingh, Bangladesh, 1999.
9. Rahman, S.; Rahman, M.S.; Rahman, M.H. Joint determination of the choice of growing season and economic efficiency of maize in Bangladesh. *J. Asia Pac. Econ.* **2012**, *17*, 138–150. [CrossRef]
10. Rahman, S. Profit efficiency among Bangladeshi rice farmers. *Food Policy* **2003**, *28*, 487–503. [CrossRef]
11. PC. *The Fifth Five Year Plan (1997–2002)*; Ministry of Planning Government of Bangladesh: Dhaka, Bangladesh, 1998.
12. IMF. *Bangladesh Poverty Reduction Strategy Paper. IMF Country Report No. 05/410*; International Monetary Fund: Washington, DC, USA, 2005.
13. PC. *The Sixth Five Year Plan (2011–2015)*; Ministry of Planning Government of Bangladesh: Dhaka, Bangladesh, 2011.
14. Gonzales, L.A.; Kasryno, F.; Perez, N.D.; Rosegrant, M.W. *Economic Incentives and Comparative Advantage in Indonesian Food Crop Production Research Report 93*; International Food Policy Research Institute: Washington, DC, USA, 1993.
15. Rashid, M.A.; Hassan, M.K.; Harun-ur-Rashid, A.K.M. *Domestic and International Competitiveness of Production of Selected Crops in Bangladesh*; National Food Policy Capacity Strengthening Programme: Dhaka, Bangladesh, 2009.
16. Khan, N.P. Comparative advantage of wheat production in Pakistan and its policy implications. *Pak. J. Agric. Econ.* **2001**, *43*, 193–196.
17. Monke, E.A.; Pearson, S.R. *The Policy Analysis Matrix for Agricultural Development*; Cornell University Press: Ithaca, New York, NY, USA, 1989.
18. Kazal, M.M.H.; Rahman, S.; Alam, M.J.; Hossain, S.T. *Financial and Economic Profitability of Selected Agricultural Crops in Bangladesh*; National Food Policy Capacity Strengthening Programme: Dhaka, Bangladesh, 2013.
19. Shahabuddin, Q.; Dorosh, P. *Comparative Advantage in Bangladesh Crop Production, MSSD Discussion Paper No. 47*; International Food Policy Research Institute: Washington, DC, USA, 2002.
20. Bruno, M. Domestic resource costs and effective protection: Clarification and synthesis. *J. Polit. Econ.* **1972**, *80*, 16–33. [CrossRef]
21. Krueger, A.O. Some economic costs of exchange control: The Turkish Case. *J. Polit. Econ.* **1966**, *74*, 466–480. [CrossRef]
22. Krueger, A.O. Evaluating restrictionist trade regimes: Theory and measurements. *J. Polit. Econ.* **1972**, *80*, 40–62. [CrossRef]
23. Rahman, S.; Parkinson, R.J. Soil fertility and productivity relationships in rice production system, Bangladesh. *Agric. Syst.* **2007**, *92*, 318–333. [CrossRef]
24. Sidhu, S.S.; Baanante, C.A. Estimating farm-level input demand and wheat supply in the Indian Punjab using a translog profit function. *Am. J. Agric. Econ.* **1981**, *63*, 237–246. [CrossRef]
25. Farooq, U.; Young, T.; Russell, N.; Iqbal, M. The supply response of Basmati rice growers in Punjab, Pakistan: price and non-price determinants. *J. Int. Dev.* **2001**, *13*, 227–237. [CrossRef]
26. Reddy, A.A.; Bantilan, M.C.S. Competitiveness and technical efficiency: Determinants in the groundnut oil sector in India. *Food Policy* **2012**, *37*, 255–263. [CrossRef]
27. Bangladesh Bank. *Economic Trends*; Bangladesh Bank: Dhaka, Bangladesh, 2013.
28. FAO. *FAOSTAT. 2016*; Food and Agricultural Organization of the United Nations: Rome, Italy, 2016.

29. Ranum, P.; Pena-Rosas, J.P.; Garcia-Casal, M.N. Global maize production, utilization, and consumption. *Ann. N. Y. Acad. Sci.* **2014**, *1312*, 105–112. [CrossRef] [PubMed]
30. SFYP. *The Sixth FiveYear Plan (2011–2015): Accelerating Growth and Reducing Poverty, Part 2, Sectoral Strategies, Programs and Policies*; Planning Commission, Ministry of Planning Government of Bangladesh: Dhaka, Bangladesh, 2011.
31. Rahman, S.; Hasan, M.K. Environmental constraints and profitability relationships in agriculture: A case study of wheat farming in Bangladesh. *J. Asia Pac. Econ.* **2011**, *16*, 630–643. [CrossRef]
32. Bangladesh Bureau of Statistics. *Census of Agriculture 2008. National Series, Volume 1*; Bangladesh Bureau of Statistics: Dhaka, Bangladesh, 2010.
33. Rahman, S.; Rahman, M.M. Impact of land fragmentation and resource ownership on productivity and efficiency: The case of rice producers in Bangladesh. *Land Use Policy* **2008**, *26*, 95–103. [CrossRef]