Bangladesh Development Studies
Vol. XXXIV, December 2011, No. 4

Estimates of Supply Response of Major Crops in Bangladesh

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The production of crops is an important economic activity for farmers, crop income, nutrition and economic transformation in developing countries. To facilitate better understanding of the synthetic parameters influencing supply response, this study uses annual data of Bangladesh covering 42 years to estimate a classic translog model providing area responses of rice, wheat, cotton, maize, sugarcane and rapeseed to changes in their gross product per hectare. The coefficients of each crop's equation in the system are estimated with the Full Information Maximum Likelihood method. The own and cross gross product elasticities for each crop are calculated showing important results. The crop area of the major crop (rice) is weakly gross product responsive as compared with the minor crops. Appropriate policy reforms could help the producers to respond more to price changes as well as to raise levels of average productivity.

I. INTRODUCTION

Bangladesh is primarily an agrarian economy. Agriculture is the single largest producing sector of economy since it comprises about 20 per cent of the country's GDP and employs around 50 per cent of the total labour force. The performance of this sector has an overwhelming impact on employment generation, poverty alleviation, and food security. According to most researchers farmers anticipate prices from their knowledge of current and past prices (Nerlove 1958). Most time-series studies are for particular crops and use acreage as a proxy for output because acreage is thought to be more subject to farmer's control than output because output is affected by other factors which have an impact on yields like climate, soil, water availability and technology, etc. Price elasticities of supply enter into a number of policy calculations, including support price and buffer stock operation (Gotsch and Falcon 1975, Pinckney 1989). A

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study of the price response incorporating the interdependence of different crops can improve the knowledge and therefore the reliability of supply parameters used in calculations. Krishna (1963) estimated short run and long run elasticities of supply (acreage) of agricultural commodities derived from time series data for Punjab region of Indo-Pakistan sub-continent.

Most research in economic literature on farmers land allocation decisions focuses on determinants such as portfolio selection, safety-first behaviour or learning, and uses market prices to value production (Feder 1980, Just and Zilberman 1983, Bellon and Taylor 1993, Brush, Just and Leathers 1992, Smale, Just and Leathers 1994). If, however, market prices fail to reflect the value of farmers' product, economic models may lead to wrong predictions and “surprising" farmers response to price signals. The inelastic supply response of maize farmers in rural Mexico despite of decreasing maize prices after NAFTA is an example (Nadal 2000). We consider this question with reference to the problem of farmers’ choice of land allocation. Farmers’ land allocation decisions have long been a subject of economic research, especially those related to high yielding crop varieties that have been studied in detail by the technology adoption literature following the Green Revolution (Feder 1980, Just and Zilberman 1983, Bellon and Taylor 1993, Brush *et al.* 1992, Smale, Just and Leathers 1994).

Bangladesh should have higher production per hectare and more cultivated land to meet the needs of its growing population. Even if a significant proportion of crop is consumed by farmer’s families, producers are also increasingly responding to market prices and, eventually, policy decisions such as support prices in their land allocation among crops. This paper is composed of two parts: Firstly, the methodology has been used to estimate the combined influence of prices and yields (gross product per hectare) on allocation of land among crops and to calculate matrices of own and cross price elasticities. This is an important challenge for econometric simulations as in present literature either there is no standard data available or not documented. These matrices are necessary to calculate new market equilibrium, in association with food and feed demand elasticities, to some exogenous factors such as national policy interventions, global price scenario, and population growth. Secondly, we present the own and cross gross product elasticities of each crop estimated from the coefficients of the translog functions.

II. METHODOLOGY

The choice of allocating system of production when we know the price received by farmers (P_i), the yield (Y_i) and the direct cost of production per hectare (C_i) i.e. when we know the value of gross product $V_i = Y_i * P_i$ *and* the gross margin $Mi = Y_i * P_i\text{-}C_i$, is conventionally written as a linear program:

$$Max \sum_i (S_i * M_i) \tag{1}$$

subject to:

$$\sum_i S_i = S_{total} \tag{2}$$

Different other constraints expressing agricultural parameters, availabilities in production factors (labour, machines, etc.) are also taken into account.

In the classical theory of production for each of the i crops (i= 1 to N[1]), the total revenue *(R)* and production function can be written as:

$$R = \sum_i x_i * p_i \tag{3}$$

and

$$x_i = f(p_i) \tag{4}$$

The optimal x_i (noted x_i*) is given by the Shepard lemma:

$$x_i^* = dR/dp_i \tag{5}$$

Here we are more focused on relation of revenue per hectare of specific agricultural products with allocation of area to different agricultural commodities. We know that total revenue is a function of price, area and yield.

$$R = f(P_i, S_i, Y_i) \tag{6}$$

where

R is the total revenue of the N crops planted by the farmer

P_i is the price of crop i

S_i is the area of crop i

Y_i is the yield of crop i

To limit the number of parameters to estimate, we assume that the farmer is taking his allocation decision not on the basis of anticipated prices and of anticipated yields, but on the basis of the anticipated gross product per hectare of each product (V^a)[2] that is defined by:

$$V^a{}_i = P^a{}_{i*} Y^a{}_i \tag{7}$$

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[1] N= 6.

[2] In fact, the farmer allocation is also dependent on the input prices (fertilizer, seeds, irrigation water, cost of labour etc.), but we have no information on the evolution of these cost by crop for Bangladesh. So we consider only output prices in estimation, even if in a complementary study we introduce price of urea in Bangladesh in the translog model.

With introduction of anticipated gross product the total revenue of the farmer can be written as:

$$R^a = g\ (Si, V^a i) = \sum_i (Si * V^a{}_i) \quad (8)$$

The translog production function was introduced by Christensen, Jorgenson and Lau (1971), and was a logical choice given the difficulties posed by other functional forms. It is simply a second order Taylor's series expansion of ln(R) in ln (xi), whereas the Cobb-Douglas is a first order expansion. The revenue function as a Taylor's series can be written as:

$$Ln\ (R^a) = \beta_o + \sum_i \beta_i\, ln\ (V^a{}_i) + \sum_{ij} \beta_{ij}\, ln\ (V^a{}_i) * ln\ (V^a{}_J) \quad (9)$$

j (j = 1 to N) represents numbers of crops. Some mathematical relations are to be satisfied by the coefficients β_i and β_{ij} to express:

(a) the equality of the two partial derivatives of $ln(R)$ in function of $ln(Vi)$ and $ln(V_J)$ which implies:

$$\beta_{ij} = \beta_{ji} \quad (10)$$

(b) the constant return of total revenue $g(Si, k*Vi) = k*g(Si, Vi)$ implies:

$$\sum_i \beta_i = 1 \quad (11)$$

$$\sum_i \beta_{ij} = \sum_j \beta_{ij} = 0 \quad (12)$$

For anticipated prices and yield, we consider that the farmer uses a moving average of the preceding year's data.

For yield, the equation is:

$$Y^a{}_i(t) = 1/N1 * \sum_d Y_{i\ (t-d)} \text{ for } d=1 \text{ to } N1 \quad (13)$$

For price, the equation is:

$$P^a{}_i\ (t) = 1/\ (N2+1) * \sum_d P_{i\ (t-d)} \quad \text{for } d=0 \text{ to } N2 \quad (14)$$

The difference between the two equations is due to the fact that price concerns calendar year's average since the farmers have information about the price concerning the year of plantation and harvest. But for yields, they have to rely only on preceding years. One empirical advantage of using "smoothed" data for prices and yields is to limit the impact on estimated parameters of the uncertainty on the "true" values. The values of $N1$ and $N2$ (the same for all products) have been chosen for each country in a manner to get the best estimations on the basis of the adjusted R^2 and the sign of own gross product elasticities.[3] The counterpart is that the estimated coefficients of equations (and the elasticities) are smaller (in absolute value) than those which would have been calculated with "true" annual values.

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[3] For Bangladesh N1=2 and N2=1.

The transposition of Sheppard lemma gives:

$$S_i{*} = dR^a/dV^a{}_i \quad (15)$$

We can write

$$S_i{*} = R^a{*}(dR^a/R^a) / (V^a i{*}(dV^a{}_i/V^a i)) = (R^a/V^a{}_i) * (dR^a/R^a)/ (dV^a{}_i/V^a{}_i) \quad (16)$$

That is equivalent to:

$$S_i{*}\ V^a{}_i/R^a = (dR^a/R^a)/ (dV^a{}_i/V^a{}_i) = dln(R^a)/dln(V^a{}_i) \quad (17)$$

where

$S_i{*}\ V^a{}_i/R^a = r_i$ is the anticipated share of the crop i in the total anticipated revenue.

In the particular case where we utilize a translog function for total revenue.

$$ln\ (R) = \beta_0 + \sum\beta_i ln\ (V_i) + \sum\beta_{ij} ln\ (V_i){*}ln\ (V_j) \quad (18)$$

We have:

$$r_i = dln\ (R)/ dln\ (V_i) = \beta_i + \sum\beta_{ij}\ ln\ (V_i)\ ln\ (V_j) \quad (19)$$

for estimation purpose when we have chosen a functional form for the revenue function. We can use equations of the revenue shares to estimate the coefficients of the revenue function and the value of the different gross product area elasticities for each crop. Since by definition $\sum r_i = 1$, we have to estimate only N-*1* equations, the coefficients of the last one being calculated from those of the other equations. The system has been estimated with the free software GRETL and the method FIML (Full Information Maximum Likelihood) which is equivalent to the iterative SUR method (Seemingly Unrelated Regression) and gives results which are independent of the equations not included in the system.

In the case of translog, it can be demonstrated that the expressions of surface gross product elasticities can be calculated from the parameters of the system of equations (β_{ij}) and the part of each crop in the total revenue (r_i) and are obtained by:

$$E_{ii} = dln(Si)/dln(Vi) = (\beta_{ii} + r_i r_i - r_i) / r_i \quad (20)$$

$$E_{ij} = dln(Si)/dln(Vj) = (\beta_{ij} + r_j r_i) / r_i \quad (21)$$

where E_{ii} is own gross product elasticity of crop i surface to its gross product and E_{ij} is cross elasticity of crop i surface to gross revenue per hectare of crop j. To be consistent with economic theory, all the own elasticities must be positive, i.e. if all other revenues are constant, the area of a crop increases when its gross product increases.

III. INTERPRETATION OF REGRESSION RESULTS

Table I shows the estimated equations of the translog system for Bangladesh. The R^2 values are mostly high, more than 0.75 except maize (0.50). The explanatory power becomes lower when different relations between parameters of different equations are taken into account. The significance of different parameters for different crops at the probability levels of 1%, 5% and 10% are also indicated in Table I. For the coefficients of own gross product value in the equation of each crop, the sign is always positive (in accordance with theory) and the value is generally significant at 5% probability level. Many coefficients corresponding to cross effects are also significant.

The Durbin-Watson statistics often indicate some autocorrelation between the residuals of each equation. This fact has not been addressed here, as according to our opinion, the data are not that reliable to justify this correction (for example, by introducing the lagged value of r_i).

The elasticities indicated in Table II express the variation of surface area of each crop due to change in the gross product per hectare. Conforming to what was expected, the signs of own elasticities are always positive for Bangladesh for six crops (wheat, maize, cotton, sugarcane, rice and rapeseed), considered in the exercise.

The elasticities indicated in Table II have not been calculated for specific years but as mean values for the period, 1966-2008. The values of r_i and r_j appearing in equations (21) and (22) have been replaced by their mean value of the period. Concerning the own revenue elasticities of crop areas, the values are higher for maize (7.62), wheat (2.66) and sugarcane (2.40) while these are lower for cotton (1.36), rapeseed (0.40) and especially for rice (0.012).

TABLE I
ESTIMATED REGRESSION RESULTS FOR SELECTED CROPS IN BANGLADESH

	Wheat (A)	Rice (A)	Rapeseed (A)	Cotton (A)	Maize (A)	Sugarcane (A)
constant	3.2%***	95.3%***	2.6%***	0.2%***	-0.18%	3.0%***
V(wheat)	3.9%***	-3.6%***	0.6%***	0.09%**	-0.7%***	0.36%
V(rice)	-3.6%***	8.3%***	-1.7%***	-0.3%***	0.9%***	-2.9%***
V(rapeseed)	0.7%***	-1.7%	1.7%***	-0.032%	-0.32***	-0.3%***
V(cotton)	.091%**	-0.3%***	-0.03%	0.2%***	0.01%	-3.3%***
V(maize)	-0.7%***	0.9%***	-0.3%***	-0.01%	0.3%***	-0.2%***
V(sugarcan)	0.40%**	-3.7%	-0.31%**	0.00%	-0.22%**	0.8%***
dum_71_74	0.30%	0.11%	-0.16	-0.03%	-0.16	0.22%
Trend	.07%***	-0.1%***	0.00	0.00%	0.02***	0.06%**
R^2	0.85	0.82	0.75	0.87	0.50	0.93
R^2 adj	0.81	0.77	0.69	0.84	0.37	0.89

Source: Authors' calculations.
Note: (A) = surface area and V = gross product per hectare

Rice being the staple food occupies a central position in the agricultural farming system in Bangladesh. Own gross product elasticity for rice has the lowest value (0.012). It means that 10% increase in gross product per hectare of rice can increase its area by 0.12%. The elasticity coefficient, though small, however, does underline the role of gross product per hectare in influencing the area planted to rice crop. One of the main reasons for having low value of elasticity coefficient may be attributed to the fact that a very large area is already devoted to rice cultivation and its dominance in the cropping pattern, not leaving much scope for further expansion of rice area.

Wheat is the second largest crop in terms of surface area among six crops considered here. The elasticity of wheat is 2.66 which is much higher compared to rice. It means that there is ample scope of its area expansion. The elasticity of maize is the highest (7.62), representing the largest influence of gross product per hectare on its area. One of the main reasons is the high price of maize or development of good market structure for it. Elasticity of cotton (1.36) and sugarcane (2.40) also indicates that areas cultivated for these two crops have been increasing due to increase in gross product per hectare.

TABLE II

MATRIX OF ESTIMATED GROSS PRODUCT ELASTICITIES OF SELECTED FOR BANGLADESH

	Wheat (A)	Rice (A)	Rapeseed (A)	Cotton (A)	Maize (A)	Sugarcane (A)
Wheat (V)	2.66	-2.12	2.2	0.30	-2.24	-0.78
Rice (V)	-0.075	0.012	-0.02	-0.01	0.12	-0.02
Rapeseed (V)	4.20	-1.10	0.40	-0.18	-1.87	-1.46
Cotton (V)	5.80	-6.52	-1.77	1.36	0.72	0.45
Maize (V)	-36.0	55.5	-16.0	0.62	7.62	-10.7
Sugarcane(V)	-0.66	-0.58	-0.64	0.02	-0.55	2.4

Source: Authors' calculations.
Note: (A) = surface area and (V) = gross product per hectare.

It is also interesting to analyse the crops in terms of substitutes and complements on the basis of the signs of the estimated cross elasticities. When the sign is positive, this indicates that an increase in the gross revenue of a crop simultaneously increases the area of the other crops (they are said to be "complementary crops"). When cross elasticity is negative, the two crops are said to be substitutes. The values of gross product elasticities are much influenced by the importance of each crop area (a "minor" crop having tendency to have higher revenue elasticity compared to a "major" crop) and the matrix of these own and cross elasticities is not symmetric. Table III shows that for rice which is a major crop, it appears that this crop is a significant complement for maize and substitute for wheat, rapseed, cotton and sugarcane. The main reason behind this may be its importance as a staple food covering large cultivated area and land suitability. Wheat, which is also an important crop, is a substitute for maize and sugar cane.

Globally, there are different relationships between crops which are generally taken into account : cotton-wheat (C), cotton-rice (S), cotton-rapeseed (S), cotton-maize (C), cotton-sugarcane (C), rapeseed-rice (S), rapeseed-wheat (C), rapeseed-cotton (S), rapeseed-maize (S), rapeseed-sugarcane (C), maize-wheat (S), maize-rice (C), maize-rapeseed (S), maize-cotton (C), maize-sugarcane (S), sugarcane-wheat (S), sugarcane-rice (S), sugarcane-rapeseed (S), sugarcane-maize (S), where (C) represents compliments and (S) represents substitutes.

In fact, three types of crops have been analysed: food crops, cash crops and feed crops. In Bangladesh, rice and wheat are used as staple food so they are less competitive to each other but in our results there is a negative relationship between gross product per hectare of wheat and surface area of rice while there is no relationship between gross product revenue of rice and surface area of wheat. It may be due to dominance of rice in terms of area; also rice receives price support by the government. Cash crops (such as cotton and sugarcane) are more responsive to gross product per hectare. Feed crops like maize is generally considered as the most responsive crop to gross product per hectare and this may be due to boom in animal, especially poultry production. As mentioned earlier, the figures presented are highly dependent on the quality of data used in the estimations (mainly concerning prices received by farmers indicated by FAO, but also in some cases concerning areas which have been adjusted with national data whenever possible[4]).

TABLE III
SUBSTITUTE AND COMPLEMENTARY CROPS IN BANGLADESH

	Wheat	Rice	Rapeseed	Cotton	Maize	Sugarcane
Wheat	-	S	C	C	S	S
Rice	I	-	I	I	C	I
Rapeseed	C	S	-	S	S	S
Cotton	C	S	S	-	C	C
Maize	S	C	S	C	-	S
Sugarcane	S	S	S	I	S	-

Source: Authors' Calculations from Table II.
Notes: C= complement, S=substitute, I = independent.

IV. CONCLUDING REMARKS

The paper develops a model to estimate the gross product per hectare elasticities of different crops and empirically applies the model to estimate own

[4]In cases when these adjustments were not possible, we had to introduce dummy variables in the translog system of equations.

and cross gross product per hectare elasticity of major and minor crops which cover more than 80 per cent of the total cropped area in Bangladesh. The data used in this study are collected from FAO database.

Based on parameter estimation of a translog model for six crops in Bangladesh, short run own and cross elasticities for these crops were calculated. According to our empirical exercise, it appears that farmers are more or less responsive to gross product per hectare, but contrary to the situation in many developed countries where the response is quick, in Bangladesh farmers are influenced by the average product of last years' yields and prices (considered as anticipated gross product). The parameters of the different share equations have statistical significance when some dummy variables are introduced to take into account some apparent discontinuities in data (mainly prices).

Globally, own gross product elasticity for major crop (rice) is weaker as compared to other crops. On this basis it is possible to distinguish the influence of a crop on another in three possible ways: competitive, complementary and unrelated. The classification of crops is compared for Bangladesh, but some unexplained differences can be observed. In fact it is important to emphasise that some data used in estimations could be biased, and, from a methodological point of view, due to lack of data we could only incorporate output prices and yields in our estimation. But it is well known that the prices and availabilities of some inputs (irrigation, fertilizer, machine, labour, etc.) are also important in farmer's allocation decisions.

Therefore, a careful analysis of gross product per hectare (and when possible of gross profit) change for any crop is necessary because this not only affects the production (acreage) of that particular crop but also changes the composition of other crops. This indicates that there is a need to develop a systematic and comprehensive approach on which agro-policy reflecting government priorities for certain crops should be based. In Bangladesh, low magnitude of elasticity for rice reflects lack of improved production technology, access to credit, marketing system, weak research-extension linkages, and support price for feed crops excluding wheat. The analysis could be extended in different directions. Firstly, the cost of production and non-price factors should be included and data should be disaggregated for different crop zones to obtain better values of elasticity, by a panel data approach; for each zone that may be different according to climatic, agronomic and social parameters. Secondly, it should be analysed whether the anticipated gross product is the effective parameter taken into account by farmers or if the prices and yields have different roles. Finally, these matrices of gross product supply elasticities can be used along with matrices of food and feed price elasticities of demand to analyse their implications for producers and consumers welfare and also for appropriate formulation of public policies.

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