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PJBS

ISSN 1028-8880

Pakistan Journal of Biological Sciences

ANSInet

Asian Network for Scientific Information

308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

Pakistan Journal of Biological Sciences 5 (2): 225-229, 2002

Supply Response of Wheat in Bangladesh: an Application of Partial Adjustment Model

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Abstract: The present study was designed to determine the wheat supply response to selected factors and to analyze the short run and long run supply responses of wheat in Bangladesh. Time series data from 1972-73 to 1998-99 have been used in the analysis. Econometric and statistical techniques were used to estimate the supply response of wheat at the national level. The price responses of wheat supply under the partial adjustment (PA) model were 0.67 in the short run and in the long run this was 1.06 and was statistically significant. Similarly, the response of wheat supply to lagged irrigation was relatively higher, which was 1.11 in the short run and in the long run it was 1.76. Besides, this was highly significant at 1 per cent level. The adjustment coefficient was 0.63 in the wheat sector during the period. The results indicate that the implementation of a farm price support policy could be used to manipulate wheat supply in Bangladesh. If public expenditures were geared properly to build irrigation infrastructure, it would give positive impacts on wheat supply in the country. If the government would follow a price stabilization policy, it would reduce price risk and would produce a positive impact on wheat supply situation in Bangladesh.

Key words: Supply response, price and non price variables, partial adjustment model

Introduction

Wheat is the staple food for about one billion people in as many as 43 countries (BARI, 1986). Of all plant products, only wheat flour contains the particular kinds and combination of proteins to form light porous loaves of leavened bread. Wheat grains are used mainly for human consumption, livestock feed and for industrial purposes.

Compared to rice, wheat is relatively a new crop in Bangladesh. Its extensive cultivation started only after the late 70's. It is expected that the price response of wheat production (supply) is relatively higher than that of rice. It is also believed that the marketed surplus of wheat in Bangladesh is comparatively more than that of rice, since wheat is not a staple crop in Bangladesh. In Bangladesh, wheat is observed to be cultivated more in the areas of favourable environment where irrigation facilities and relatively better marketing infrastructures are available.

This study provides an idea to all those concerned with supply response of wheat, if, and to what extent, a given price policy will be effective in manipulating the wheat supply in Bangladesh. The study also analyzes other major factors responsible for influencing wheat supply in Bangladesh including their specific responses. Moreover, very few supply response studies have been conducted in Bangladesh for specific crops. Rahman (1986) estimated supply functions for both acreage and output for each crop. The 'model' supply functions yield good results in most cases and the estimated supply elasticities were comparable to those obtained for other developing countries. In the case of rape and mustard, the acreage response function utilized deflated price by one year lagged wholesale price index and one year lagged yield as the explanatory variables. The price elasticities of cash crops, e.g., jute, tobacco, cotton and sugarcane were relatively higher as one would expect. The price elasticity of boro rice which was not produced mainly for subsistence, was also high. The rapid expansion in production of wheat took place in response to the demand for food grain and under substantial government support. The influence of relative price on wheat supply might be therefore, not statistically significant. Alam (1992) studied the supply response of major crops for the period 1971-72 to 1987-88 and considered the relative product price changes and other influencing factors like rainfall, yield trends, price and yield risks for estimating the supply responses of all rice varieties and jute. He observed that the jute yield increase was not influenced by the preceding seasons prices but was conditioned by the availability of improved seed varieties and extension services. Jute areas were highly responsive to sowing period rainfall and jute/aus price ratio. Farmers were risk averse to jute price fluctuations. He also observed that rice areas were highly responsive to deflated product prices. Yunus (1993) estimated the supply response equations for a number of crops and 'crop groups' using the national level time series data for the period 1972-73 to 1988-89. The gross cropped area of food grain, rice and other crops/'crop groups' were used for estimating the acreage response functions. The short run and long run price elasticity for boro and wheat were 0.50, 0.61 and 2.86, 5.24 respectively. This suggests that boro and wheat was not cultivated to meet farmers' subsistence needs. The acreage responses of pulses, oilseeds and spices were very weak. Almost all of the cash crops, viz, jute, tobacco, cotton and sugarcane were relatively high responsive to price change as one would expect. In almost all of the cases, the yield elasticity estimates were several times higher than price elasticity estimates. This suggests that farmers responded much more strongly to yield augmenting (declining) technology than to price changes. The review of the studies reveal that there was no specific study on supply response of wheat in Bangladesh, only Rahman (1986) and Yunus (1993) estimated the wheat supply response along with other crops. Hence, the findings of the present study are expected to be useful to the wheat policy analysts of Bangladesh. The main objectives of the study are to determine the wheat supply response to selected factors and to analyze the short-run and long run supply response of wheat in Bangladesh.

Materials and Methods

The study was performed at the national level during the year 1972-73 to 1998-99 in Bangladesh. The major factors affecting the acreage decision of wheat in period ` t' are broadly grouped into two categories: prices and non-price variables. The possible price variables affecting the area allocation are: wheat price, competitive crops' price (oil seeds, pulses), input price (fertilizers, labour). Similarly, some non-price variables that likely to affect the wheat acreage allocation are weather conditions, irrigation infrastructure, technology, rice acreage in preceding season, risk variables (price and yield risk), and farmers' resources holding (Fig. 1).

Partial adjustment model is one of the simple dynamic models, which is based on the assumption of "static expectations". The model implies that the changes in current acreage is in proportion to the difference between the long run equilibrium acreage and actual acreage in the previous year.

$$A_t - A_{t-1} = K(A_t^* - A_{t-1}), \text{ where, } 0 \le K \le 1 \quad (1)$$

The equation (1) explicitly implies that the change in actual area is proportional to the difference between the desired and actual area. The partial adjustment is due to the presence of different factors such as technical, institutional rigidness, inertia, and cost of change (adjustment cost).

The long-run supply function may be written as:

$$A_t^* = f(P_t, Z_t)$$

In linear form, it can be written as:

$$A_t^* = a_o + a_l P_t + a_2 Z_t + e_t \quad (2)$$

From the equation (1) and (2) it can be derived that:

$$A_t = a_o K + a_l K P_t + a_2 K Z_t + (1-K) A_{t-1} + K e_t \quad (3)$$

From this equation (3), long and short run acreage responses can be estimated, where :

A_t^* = long run acreage equilibrium perceived by farmers at period t.

P_t = Nominal prices of wheat.

Z_t = Supply shifter; it is used as an explanatory variable affecting wheat acreage decision at period t.

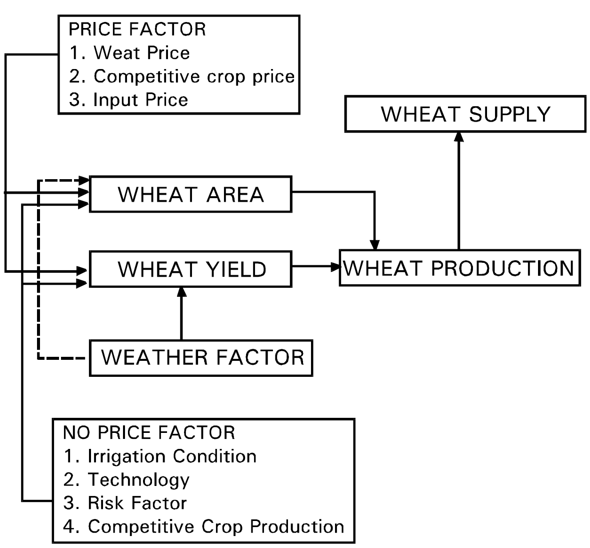

Fig. 1: Schematic representation of the determinants of wheat supply in Bangladesh

A_t = Actual observed wheat acreage at period t.

A_{t-1} = Wheat acreage at period t-1

K = Constant of proportionality, which is also called "coefficient of adjustment".

e_t = Random error term.

The wheat acreage function was specified as:

$$A_t = a_0 K + a_1 KP_{wt} + a_2 KP_{wt-1} + a_3 KI_t + a_4 KI_{t-1} + a_5 KP_{lt} + a_6 KP_{lt-1} + a_7 KP_{mt} + a_8 KP_{mt-1} + a_9 KP_{bt} + a_{10} KP_{bt-1} + a_{11} KP_{ft} + a_{12} KP_{ft-1} + a_{13} KSDP_t + (1-K)A_{t-1} + Ke_t \quad (4)$$

For simplicity, this equation could also be expressed as:

$$A_t = b_0 + b_1 P_{wt} + b_2 P_{wt-1} + b_3 I_t + b_4 I_{t-1} + b_5 P_{lt} + b_6 P_{lt-1} + b_7 P_{mt} + b_8 P_{mt-1} + b_9 P_{bt} + b_{10} P_{bt-1} + b_{11} P_{ft} + b_{12} P_{ft-1} + b_{13} SDP_t + (1-K)A_{t-1} + e_t \quad (5)$$

where,

A_t = Actual area of wheat planted in year t expressed in '000 ha

K = Coefficient of adjustment, $0 \le K \le 1$

P_{wt} = price of wheat in year t measured in Tk. /tonne

P_{wt-1} = Price of wheat in year t-1 measured in Tk./tonne

I_t = Irrigated area in year t in '000 ha.

I_{t-1} = Irrigated area in year t-1 in '000 ha

P_{lt} = Price of lentil in year t and measured in Tk./tonne

P_{lt-1} = Price of lentil in year t-1 and measured in Tk./tonne

P_{mt} = Price of mustard in year t and measured in Tk./tonne

P_{mt-1} = Price of mustard in year t-1 and measured in Tk./tonne

P_{bt} = Price of boro rice in year t and measured in Tk./tonne

P_{bt-1} = Price of boro rice in year t-1 and measured in Tk./tonne

P_{ft} = Price of fertilizer in year t and measured in Tk./tonne

P_{ft-1} = Price of fertilizer in year t-1 and measured in Tk./tonne

SDP_t = Standard deviation of wheat prices during the preceding three-years

e_t = Random error term.

Sources of Data and Types of Data Collected: The data utilized in the present study were obtained form various publications of the Bangladesh Bureau of Statistics (BBS). Prices data for wheat, its competitive crops and fertilizers were not available prior to independence. Therefore, the study period was decided to be the Bangladesh years from 1972-73 to 1998-99 (27 years) for the latest data as available.

The time series data on harvest price of wheat, lentil, mustard, boro rice, irrigated area and irrigated boro rice area in Bangladesh were obtained from various issues of BBS (1979).

Fertilizer prices for the period of 1974-75 to 1990-91 were collected from BBS 1979, 1982, 1990 and 1996, prices for the period of 1991-92 to 1992-93 were collected from Monthly Statistical Bulletin Bangladesh (1998) and prices for the period of 1994-95 to 1998-99 were collected from the Bulletin Published by International Fertilizer Development Center (IFDC), Consultant to the Ministry of Agriculture, 1996 and 2000. Data on wheat area and production were obtained from FAO Yearbook (1999).

Missing data on some variables e.g. Consumer Price Index (CPI) for some years for the study period 1972-73 to 1998-99 were generated through extrapolation and intrapolation techniques.

Estimation procedure: In estimating the acreage model, the ordinary least square (OLS) estimation procedure was adopted using TSP, a computer software. Also appropriate t-test and D-W statistics were applied in testing the statistical significance of the estimated parameters.

Specification of variables: In this study such variables were included in the final estimated national level supply model which are acceptable due to economic logic. These variables were as follows:

a. Selection of price: Harvest prices of wheat, boro rice, lentil and mustard have been taken into consideration for the reason that wholesale and retail price may not reflect what the farmers actually receive, because they are usually set at a considerably higher level than what the farmers get. Assuming that the margin between farm gate prices and harvest prices over the year was constant, then the harvest prices could be used as a proxy for farm-gate price (Upadhyaya, 1982).

In this paper the nominal harvest prices of agricultural products instead of real harvest prices were used. Because the two prices gave almost the same result. So, due to time saving and easy calculation nominal prices were used. In this study, the average nominal prices of urea, triple supper phosphate (TSP) and murate of potash (MP) were taken as the fertilizer price.

b. Wheat area (A_t): It is the actual area of wheat planted in period (year) ` t' measured in '000 hectares.

c. Prices of competitive crops (P_{lt}, P_{mt} and P_{bt}) : Wheat is grown during the winter season (November-April) in Bangladesh. The competitive crops of wheat during the winter season are mainly lentil, mustard and boro rice. The prices of lentil (P_{lt}), mustard (P_{mt}) and boro rice (P_{bt}) in a particular year were taken as prices of competitive crops.

d. Input price (P_{ft}): Among the inputs used in wheat production, labour, fertilizer, seed, and irrigation water are the major input items. However, in Bangladesh time-series data on agricultural wage rate at the national level were not available. Hence, wage rate variable could not be included in the analysis. Similarly, the time-series prices of wheat seeds and irrigation water were not available in Bangladesh. In addition, the specification of seed price was quite complicated since wheat price were already specified separately as an explanatory variable in the model. Thus only the price of fertilizers was included in estimating the national level supply response function.

e. Irrigation variable (I_{t-1}): Irrigation has a significant impact on wheat production. Wheat is specifically grown in areas where adequate irrigation facilities are available. It is hypothesized that the improvement of irrigation facility may increase the wheat acreage.

Lagged irrigated area was selected as an appropriate explanatory variable in wheat acreage function. In Bangladesh wheat was usually planted during the winter season (from November to April). This showed that the farmers' decision on how much wheat should be planted in November in year t was influenced by the irrigated area in the previous year (t-1), rather than in year t. Therefore, a one year lag in irrigated area was more realistic than without lag, as specified in the study mainly due to country specific conditions (factors).

f. Risk factors (R): Among different risk factors, the fluctuation in prices and yield are the major ones. The national wheat yield level had almost stagnated in Bangladesh. Therefore, in this study, only the price risk or the standard deviation of prices of wheat for the preceding three years (SDP_t) was used as a risk variable (explanatory variable) in the acreage response model. This may be a sufficient way to incorporate risk particularly in the annual time series (aggregate) model (Sidhu and Sidhu, 1988).

Results and Discussion

Under the partial adjustment hypothesis, three different supply models of wheat in Bangladesh were estimated (Table I). In equation 1, six out of fifteen explanatory variables had insignificant effects on wheat supply at the 5 per cent probability level. This equation (model) was not appropriate because of multicollinearity problems. When the partial correlation matrix of these explanatory variables was checked, it was found that boro rice price had a high correlation coefficient with other explanatory variables such as lagged wheat area and irrigated area. Among the three variables, boro rice price had a relatively weak economic theory apriori and justification for inclusion in the wheat supply model. Thus, this model was rerun excluding boro rice price to obtain better estimates (Equation 2).

In equation 2, four out of the thirteen explanatory variables were statistically insignificant at 5 per cent probability level. Equation 2 was not seriously affected by the problem of multicollinearity. All the parameters had the expected signs.

To further improve the model, equation 3 was estimated without fertilizer price and irrigated area which was insignificant in equation 2. All the parameters except lentil price and mustard price were highly significant in equation 3. Since, the sign and the magnitude of the coefficients were consistent with economic theory apriori and wheat price and lagged wheat price became significant at 1 per cent probability level, equation 3 was selected as the most appropriate national wheat supply model under the partial adjustment hypothesis. The adjusted R^2 was also very high (R^2 = 0.98) indicating that the equation 3 had a good fit and 98 per cent of the variation in wheat supply were explained by the explanatory variables included in the model. The Durbin Watson Statistics was 2.77. From the Durbin Watson table we found that for 24 observations and eleven explanatory variables (excluding the intercept), d_L = 0.758 and d_u = 2.355 at the 5 percent level. Therefore, as a rule of thumb, since the estimated value 2.77 was greater than 2.355, we accepted the null hypothesis that there was no evidence of positive first order serial correlation in the equation.

The price elasticity of the wheat acreage function was 0.67 (Table I, equation 3), which was inelastic. This means that for every one per cent increase in wheat price, wheat area at the aggregate or national level could increase only by 0.67 per cent (significant at 1 per cent level). The regression coefficient for lagged wheat price was 0.74 which was significant at 1 per cent level. This revealed that 1 per cent increase in lagged wheat price, keeping other variables constant, would increase the wheat acreage by 0.74 per cent. From the results, it could be inferred that in Bangladesh, wheat supply was positively

Table 1: Double-log wheat supply (area) response function, Bangladesh

Items	Equation 1	Equation 2	Equation 3
Constant term	11.493 (2.99)***	11.34(3.74)***	6.04(3.37)***
Wheat price	0.54 (2.56)***	0.57(2.83)***	0.67(2.63)***
Lagged wheat price (1 year lag)	0.67 (3.03)***	0.66(3.33)***	0.74(3.78)***
Irrigated area	-0.13 (-0.19)NS	-0.19(-0.25)NS	-
Lagged irrigated area (1 year lag)	1.66 (2.59)***	1.75(3.39)***	1.11(3.17)***
Lentil price	-6.8(-0.28)NS	-0.81(-0.71)NS	-0.17(-0.32)NS
Lagged lentil price (1 year lag)	0.26(1.19)NS	0.24(1.23)NS	0.54(2.52)***
Mustard price	-0.81(-0.71)NS	-0.85(-0.84)NS	-0.88(-0.85)NS
Lagged mustard price (1 year lag)	0.28(2.05)**	0.29(2.59)***	0.23(2.40)***
Boro rice price	0.51(1.91)*	-	-
Lagged boro price (1 year lag)	0.77(3.10)***	0.79(3.43)***	0.87(3.49)***
Fertilizer price	0.45(1.10)NS	0.44(1.20)NS	-
Lagged boro price (1 year lag)	0.43(1.26)NS	0.46(1.69)*	0.42(0.07)**
Standard deviation of wheat price (3 years)	-0.19(-2.12)**	-0.18(-1.72)*	-0.13(-1.68)*
Lagged wheat area (1 year lag)	1.01(5.03)***	1.00(5.95)***	0.37(2.98)***
Adjusted R square	0.97	0.98	0.98
Durbin Watson status	2.85	2.70	2.77

***,** and * mean significant at 1, 2 and 5%probability level, respectively. NS = Not significant at 5% probability level.
Figures in parentheses are t values

Table 2: Short run and long run wheat supply responses to selected variable, Bangladesh

Items	Short run response	Long run response
Wheat price	0.67(2.63)***	1.06
Lagged wheat price (1 year lag)	0.74(3.78)***	1.17
Lagged wheat area (1 year lag)	1.11(3.17)***	1.76
Lagged lentil price (1 year lag)	0.54(2.52)***	0.86
Lagged mustard price (1 year lag)	0.23(2.40)***	0.37
Lagged boro rice price (1 year lag)	0.87(3.49)***	1.38
Lagged fertilizer price (1 year lag)	0.42(0.07)*	0.67
Standard deviation of wheat price of past 3 years	-0.13(-1.68)*	-0.21
Lagged wheat are (1 year lag)	0.37(2.98)***	-

***,**,* Mean significant at 1, 2 and 5% probability level, respectively.
Note:
1. The above short-run responses were derived from the equation no. 3 of Table 1.
2. Figures in parentheses are t values

influenced by market signals (price), and hence, small incremental changes in wheat prices had significant impacts on the national wheat supply level. The impact of lagged irrigated area on wheat supply was highly significant (at 1 per cent level) and elastic (1.11). This means that per cent increase in lagged irrigated area would increase the wheat area by 1.11 per cent, keeping other variables constant. Wheat is usually grown in areas where assured irrigation facilities are available. The relatively higher responses of irrigation variable is consistent with farmers observed behaviour in the real world.

The coefficient of lentil price was -0.71 which revealed that every 1 per cent increase in lentil price would decrease the wheat area by 0.71 per cent and the coefficient of mustard price was -0.88. However, these coefficients were insignificant, which help to infer that though wheat, mustard and lentil were planted in almost the same time and in similar type of land, farmers wheat acreage allocation was in fact, independent of lentil and mustard prices. The rapid expansion in production of wheat took place in response to the demand for food grains and under substantial government support, the influence of relative price on wheat supply might be, therefore, not statistically significant.

The coefficients of lagged prices of lentil, mustard and boro rice were 0.54, 0.23 and 0.87, respectively, (significant at 1 per cent level) indicating that every 1 per cent increase in lagged prices of lentil, mustard and boro rice would increase the wheat area by 0.54, 0.23 and 0.87 per cent, respectively. Fluctuation in the price of agricultural crops usually maintain a cycle. If the price is higher in the current year, it is expected that it will be lower in the next year. That is why the farmers could give their attention to alternative crops. For this reason there might be a positive relationship between the lagged crop prices and the wheat area.

The response of boro rice price to wheat acreage was significant at 5 per cent probability level. The model was seriously affected by multicollinearity problem when boro rice price was added as an explanatory variable. Thus, the interaction of boro rice price and wheat areas at the national level could not be analyzed confidently.

The coefficient of fertilizer prices was insignificant at 5 per cent probability level which was dropped in equation 3. There was usually, scarcity of chemical fertilizers in Bangladesh specially during the wheat sowing time. Farmers' long queue at fertilizer's agencies was the usual scene during the wheat planting time in Bangladesh. Therefore, the result also helps us to conclude that in Bangladesh, unavailability of chemical fertilizer was the problem but not its price.

The coefficient of lagged fertilizer price was 0.42 which was significant at 2 per cent probability level. This indicated that every 1 per cent increase in lagged fertilizer price would increase the wheat area by 0.42 per cent. The positive relationship between the lagged fertilizer price and wheat area might be due to higher marginal productivity of wheat than the marginal cost of fertilizers. As a result farmers would increase wheat area in spite of increased lagged fertilizer price.

The risk caused by price fluctuations had a negative value of 0.13, consistent with economic theory apriori (significant at 5 per cent probability level). One per cent increase in price risk would decrease wheat area by 0.13 per cent, keeping other variables constant. This indicated the presence of a risk aversion behaviour among Bangladesh wheat producers even at the aggregate level. This could be concluded that price stability was important factor that influenced the area under wheat.

The coefficient of lagged wheat area was 0.37 (significant at 1 per cent probability level). This indicated that current wheat area was significantly dependent on lagged wheat area. A 1 per cent increase in lagged wheat area would increase the current wheat area by 0.37 per cent, keeping other variables constant. The adjustment coefficient (K = 1-0.37 = 0.63), which inferred that 63 per cent of adjustment in wheat area caused by fluctuations of exogenous variables took place within a year.

Adjustment coefficient: From Table I, the adjustment coefficient ` K' which was equal to 0.63 (1-0.37 = 0.63), during the period of 1972-73 to 1998-99 in the wheat sector in Bangladesh was estimated using the parameter obtained in equation 3 under the PA model. K = 0.63, means that the Bangladeshi wheat growers could adjust only 63 per cent of the changes caused by fluctuations of exogenous variables (supply shifters) within a production period of one year. The remaining adjustment shock would be made (realized) in subsequent years.

Short run and long run supply response: The long run supply responses for each variable was simply derived by dividing each corresponding short run response with the coefficient of adjustment obtained from the model (K = 0.63). The estimates of the selected variables of the model are presented in Table 2. The long run wheat supply response was the highest for lagged irrigated area (1.76). So, the long run wheat supply response to lagged irrigated area was greater than unity, or within the elastic range.

Long run wheat supply response to lagged boro rice price was 1.38. This was also within the elastic range.

Wheat was price responsive. The short run and long run price elasticity for wheat and lagged wheat were 0.67, 0.74 and 1.06, 1.17, respectively. This suggests that wheat was not cultivated to meet farmers subsistence needs. Nerlove (1958) mentioned that the full impact of the distributed lag is called the long run response. Long run is the sufficient time when full adjustment is possible. And full adjustment is possible when the supply is elastic. That is why long run wheat supply response to its current price and lagged price were greater than unity, or within the elastic range. The results of the study were, therefore, consistent with the Nerlove theory. Elastic supply means wheat has many alternative crops.

In the present study, following were the possible reasons for short run price inelasticity of wheat supply in Bangladesh:

Wheat requires frequent, but well managed irrigation. Irrigation was one of the limiting factors in Bangladesh agriculture, especially in winter. Farmers preferred to grow wheat in areas where reliable irrigation facility was available, since the application of irrigation water was very critical for the crop. In a situation where irrigation facilities were limiting, it was normal for the price response of wheat to remain at an inelastic range.

During the wheat growing season, the distribution and availability of the right types of chemical fertilizers were always a problem in Bangladesh. Bangladesh had to import all the required chemical fertilizers. Its delivery and distribution were handled by one of government agencies. Generally, the delivery of fertilizers to different sales center at the district level was delayed. Similarly, the availability of imported seeds at affordable prices was another problem faced by Bangladeshi wheat growers. These constraints had helped to dampen the price elasticity of wheat supply in Bangladesh in the short run.

Harvesting and threshing of rice grains coincided with the land preparation time for wheat cultivation. Average farmers always faced constraints in doing all the activities within a limited time frame. Plowing of land was mostly done by using a country plow, a single pointed harrow which was not so efficient. Plowing then became one of the major constraints faced by Bangladeshi farmers. In sum, the higher requirement of turnaround time between rice and wheat and the scarcity of farm resources had contributed to the reduction of price response of wheat supply in Bangladesh in the short run.

Based on economic theory and the statistical significance of the estimates obtained from the supply model, it could be inferred that the partial adjustment model performed better using Bangladesh data series. More precisely, equation 3 did fairly well in explaining the supply behaviour of Bangladeshi wheat farmers. It is, therefore, recommended that in analyzing any farm policy in the Bangladesh context, the partial adjustment model can be used. The results indicate that the implementation of a farm price support policy can be used to manipulate wheat supply in Bangladesh. If public expenditures are geared properly to build irrigation infrastructure in the country, it will give positive impacts on wheat supply in the country, *Ceterus paribus*. If the government follow a price stabilization policy, it will produce a positive impact on the wheat supply situation in Bangladesh. The statistically insignificant coefficient of competitive crop prices of wheat in the national model indicates that the government can formulate a policy to increase wheat acreage without having much adverse effects on other winter crops grown in the country, *Ceterus paribus*.

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