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Supply response of wheat in Bangladesh: Cointegration and vector error correction analysis

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Numerous past studies on wheat cultivation in Bangladesh is criticized for using the weaker Nerlovian Partial Adjustment models and also for analytical interpretation through Ordinary Least Square (OLS) creating spurious results for time series data. This problem can be avoided if Econometric technique of co-integration is used. It is for this the present paper estimates the supply response of wheat in Bangladesh by using the modern technique of co-integration with Vector Error Correction Model (VECM). Our unit root analysis indicates that underlying data series were not stationary and are all integrated of order one, that is I(1). The Johansen multivariate co-integration approach indicates the presence of a co-integrating relationship in the supply response model. Wheat acreage is significantly influenced by price of wheat, and other competing crops such as *Boro* rice. The non-price factors weather has a highly positive effect on wheat area in the short-run. The wheat supply elasticity's are found to be inelastic both in the short-and long-run. The long-run and short run price elasticity's were 0.95 and 0.47, respectively.

Key words: Supply response, wheat, co-integration, vector error correction approach.

INTRODUCTION

Bangladesh has been striving for rapid development of its developing economy through improvement in the agriculture sector. Contribution of agriculture sector to the gross domestic product (GDP) is 23.50% (MoA, 2010). An upward trend is observed in food grain production, but it is loosing out in the race against growth of population and per capita availability of food remains almost unchanged. The present food grain production is not sufficient to meet domestic requirements. Among the major food crops, position of wheat is next to rice, but covers only 3.49 and 6.13% of the total cropped area and net sown area, respectively (BBS, 2008). Wheat area increased from 120 thousand hectares to 822 thousand hectares between 1972-1973 and 1998-1999 (BBS, 1982, 2004), while production increased from 90 thousand tonnes to 1908 thousand tonnes during the same period owing to using HYV and modern production. After 1998-1999, wheat area again is declining standing at 479 thousand hectares in 2005-06 (BBS, 2008). Wheat is grown in all over the Bangladesh except in the hilly areas but area, production and yield increases are not adequate to meet country's requirement. To explore the potentials and possibilities of area and production expansion of wheat, it is needed to examine the past performance.

Bangladesh has the capacity to increase wheat production to a substantial extent. At that situation continuous wheat import would not be acceptable or encouraged for meeting the food deficit. To solve the food problem and to check the drain of foreign currency for importing a huge quantity of wheat grain, more attention should be given to the intensive and extensive

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cultivation of wheat in the country.

Presently Bangladesh is marginally deficit in food grain, but it would be more acute in the coming years due to rapid population growth, lower per capita arable land, and less developed agricultural production system. Ground water level is declining gradually which disrupts climate due to excessive use irrigation water for *Boro* rice cultivation. Under these situations wheat could be able to play a vital role from the viewpoint of profitability, environment and nutrition. In this aspect government policy is the most important catalyst.

Agricultural pricing policy plays a key role in increasing both farm production and incomes and fundamental to an understanding of this price mechanism is supply response (Nerlove and Bachman, 1960). Agricultural supply response has remained a fundamental issue for sustainable economic development in Bangladesh. A significant and positive response from agricultural is justified as a means of improving the overall performance of the economy. Area allocation represents both production target and response to price. If future trend of market price is informed before production than the scarce resources can be allocated in a planned way.

Wheat is the important *Rabi* crop in Bangladesh, but its supplies in the country are quite lower to the potential. A great potential exist in increasing wheat supplies horizontally as well as vertically in the country. There had been only very few attempts to find and meet up the crying needs for its marketing system research. The supply of a farm product depends on both price and non-price factors. The study of area response coefficient can be an effective tool for area allocation decision through appropriate price policy. Ensuring a balance between the demand for and supply of food grains is one of the important tasks of the government or the planning authority in a developing economy. The production and the stable supply of agricultural commodities are always the major concerns of agricultural policy makers. Estimates supply of agricultural commodities is useful in designing appropriate policies for maintaining a stable supply of commodities over time. Therefore, the present study attempted to investigate such factors that might be playing a vital role in explaining the farmers' area allocation decision.

There are very few studies in Bangladesh which estimate supply response using historical data. These include the Matin and Alam (2004) for wheat, Sabur (1984) for potato, Huq et al. (2007) for potato, Rahman (1986) for crops, Alam (1991) for major crops, Yunus (1993) for crops, Jabber et al. (1997) for rice. All previous studies on agricultural supply response in Bangladesh use time series data and classical regression analysis; most use Nerlove's (1958) restrictive adaptive expectations/ partial adjustment model(s). These studies can be criticized on the grounds that they applied Nerlovian Partial Adjustment models, which are considered weak. The common weaknesses of past studies are that the Nerlovian Partial Adjustment models do not give an adequate distinction between short- and long-run elasticity's (McKay et al., 1999; Townsend, 1997). They used time series data, which may be non-stationary and poses the danger of spurious regression (Granger and Newbold, 1974; Nelson and Plosser, 1982; Townsend, 1997). The assumption that production adjusts to a fixed target of supply, towards which actual supply adjusts, is considered unrealistic under dynamic conditions (Nerlove, 1979). There is empirical evidence that the dynamics of supply can be better described by Error-Correction Models (ECM) than Partial Adjustment Models (McKay et al., 1999; Hallam and Zanoli, 1993). Present study investigate supply response using co-integration and vector error correction approach, which is widely acclaimed to be more suitable for time-series modeling than previous studies for Bangladesh. Particularly, it estimates short and long-run elasticity's of price changes on wheat.

METHODOLOGY

Sources of data

Time series data during the post independence of the country for the period 1972-1973 to 2005-2006 (BBS, 1982, 1998, 2004, 2005, 2008) were used for this study. Data on area, production and price of wheat, boro paddy, potato, mustard were collected from "The Yearbook of Agricultural Statistics" published by the Bangladesh Bureau of Statistics (BBS), Ministry of Planning, and Government of the People's Republic of Bangladesh.

The variable chosen includes natural logarithm of wheat area (A), natural logarithm of deflated wheat price (WP,), natural logarithm of deflated *Boro* paddy price taken as competitive crop (BP). and proxy variable for weather (WE). The impact of weather on wheat yield variability is measured with a Stalling index (Stalling, 1960). To obtain expected yield, yield is regressed on time. The ratio of the actual to the predicted yield is defined as weather variable. The direct effects of weather such as rainfall and temperature may captured by this index in supply response model. Data on infrastructural developments, expenditure on agricultural research and extension, applications of modern techniques like fertilizers and improved rice varieties etc, are hardly available particularly in developing countries like Bangladesh. Therefore, these variables cannot be easily represented in the wheat supply response equations directly and individually. An attempt is made to capture their effects collectively by introducing time-trend dummy variable.

Nominal harvest price was deflated with the Laspeyres price index (using base year weights). The Laspeyres price index was constructed for boro paddy, chick pea, mung bean, lentil, potato and mustard harvest price as they are competing crops of wheat. The Laspeyres price index can be written in terms of a mathematical formula as follows (Koop, 2009):

$$LPI_t = \frac{\sum_{i=1}^{n} P_{it} Q_{i,baseyear}}{\sum_{i=1}^{n} P_{i,baseyear} Q_{i,baseyear}} \times 100$$

In this study, the area planted is used in lieu of planned output, which may be justified by the fact that the farmers have greater control over the area than on the production or output. In this case, we assume that other inputs are varied in proportion to land and that constant returns to scale prevail. Harvest price of wheat is taken in this model because most of the farmers in Bangladesh dispose off their products just after the harvest.

Analytical framework

The methodology used was the method of co-integration and its implied vector error correction approach (VEC), extensively used in supply response studies. The VEC model is considered appropriate for non-stationary time series with a common long-term trend. This implies that although the variables may exhibit a dynamic of their own in the short term, they tend to move together in the long run. The application of VEC models has been relevant in supply respose, market leadership and integration studies (Nkang et al., 2007; Huq and Arshad, 2010, Engler and Nahuelhual, 2006; Vickner and Davis, 2000; Thompon et al., 2002; Sephton, 2003). The empirical application of the VEC approach follow three steps: (i) unit root tests to identifying the order of integration of the variables; (ii) cointegration test to identify the existence of relationship using Johansen maximum likelihood approach for multivariate cointegration; and (iii) estimation of the VEC to obtain the short-run and long-run coefficients.

Unit roots tests

To ascertain the order of integration, a unit roots analysis was undertaken for each of the chosen time series variables. Order of integration for all the variables must be known prior to cointegration analysis, at least to ensure that variable is not integrated of order greater than one (Abbott et al., 2000). In order to identify the order of integration of each single time series, we performed an augmented Dickey - Fuller (ADF) unit root test (Dickey and Fuller, 1981; Said and Dickey, 1984), both with or without deterministic trend using Standard Version of Eviews-6 Econometric Software. The test formula for the ADF is shown in Equation 1.

$$\Delta Y_t = \alpha + \rho Y_{t-1} + \sum_{t-1}^{j} \gamma \Delta Y_{t-1} + \mu_t \qquad (1)$$

Where: Y is the series to be tested; ρ is the test coefficient; and j is the lag length chosen for ADF such that μ_t is empirical white noise. Here the significance of p is tested against null, based on t-statistics obtained from the OLS estimates of Equation 1. Thus if the null hypothesis of non-stationary cannot be rejected, the variables are differenced until they become stationary, that is until the existence of a unit root is rejected, before proceeding to test for co-integration.

The VEC cointegration approach

Once the order of integration of time series data was determined the co-integration was used by using Johansen's approach (1988) which provides likelihood ratio tests for the presence of number of cointegrating vectors among the series and produces long-run elasticities. It is hypothesized that wheat area and real wheat price are jointly determined (that is endogenous to the system) while the other variables (as expected) is exogenous to the system. The Johansen maximum likelihood approach for multivariate cointegration is based on the following VAR model:

$$Z_t = A_t Z_{t-1} + \ldots + A_k Z_{t-k} + u_t \qquad (2)$$

where Z_t = (n ×1) vector of I(1) variable (containing both endogenous and exogenous variables), A_t is an (n ×1) matrices of parameters, and μ_t is an (n ×1) vector of white noise errors. Equation 1 can be estimated by OLS because each variable in Z_t regressed on the lagged values of its own and other variables in the model.

As Z_t is assumed to be non-stationary, therefore, to estimate the hypotheses of integration and cointegration in Equation (1) we changed it into first-difference or vector error correction form:

$$\Delta Z_t = \Gamma_1 \Delta Z_{t-1} + A_2 \Delta Z_{t-2} + \ldots + \Gamma_{k-1} \Delta Z_{t-k+1} + \Gamma\pi Z_{t-k} + \mu_t \qquad (3)$$

where $\Gamma_1 = I - A_1 - A_2, \ldots - Ai$, (i = 1, …, k-1), and $\pi = -(I - A_1 - A_{2, \ldots,} - A_{k)}$

This specification provides information regarding short-and long-run adjustments to changes in Zt through the estimates of Γ_i and π respectively. The term πZ_{t-k} gives information about the long-run equilibrium relationship between the variables in Z_t. The information about the number of cointegrating relationship between the variables in Z_t is given by the rank of the matrix π. If the rank of π matrix r is 0< r <.n, there are r linear combination of variables in Z_t that are stationary. Here the π matrix can be decomposed into two matrices α and β such that π = α β, where α is error correction term, which measures the speed of adjustment in ΔZ_t , while β contains r distinct cointegrating vectors, showing cointegrating relationship between the non-stationary variables. A large value of α means that the system will respond to a deviation from long-run equilibrium very quickly (that is, with a rapid adjustment) and *vice versa.* Johansen procedure provides two likelihood ratio tests, the trace test and the maximum eigenvalue test. The trace test tests the null hypothesis of r cointegrating relations against the alternative of greater than r cointegrating relations, where r is the number of endogenous variables. The maximum eigenvalue tests the null hypothesis of r cointegrating vectors against the alternative of r+1 cointegrating vectors.

Given the above vector error correction model in Equation 1, the long-run co-integrating equation for wheat can be written as:

$$LnAt = \phi_0 + \phi_1 LnP_t + e_t \qquad (4)$$

Where, ϕ_0 is a constant intercept term; ϕ_1 is the long-run static coefficients; and e_t is the random term with the usual stochastic assumptions.

The study adopts the Johansen Maximum Likelihood procedure of cointegration. In this method, a preliminary analysis is carried out first to assess the order of integration of the data series through the use of unit root tests after which we test for the existence of cointegrating (long-run *equilibrium)* relationships among the data series. If a valid co integrating relationship is found, then we estimate a vector error correction model, since cointegration is a pre-condition for the estimation of an error correction model (Mohammad et al., 2007, Nkang et al., 2007; Huq and Arshad, 2010)

RESULTS

Tests for order of integration

It is important to check the time-series properties of the data as we are using time-series data. Augmented Dickey-Fuller (ADF) tests which are discussed in the Methodology, used for testing unit roots. Result of all the individual series (in logarithms) used in the estimations is

Table 1. Results of augmented dickey fuller (ADF) unit root tests.

Variable level	ADF static	Critical value	Variable first difference	ADF static	Critical value
WA	1.343258	-1.951332	WA	-3.286337	-1.951332
WP	0.558380	-1.952910	WP	-4.869765	-1.952910
BP	-0.330029	-1.952473	BP	-6.674263	-1.952473
WE	0.192287	-1.951332	WE	-3.161875	-1.951332

Critical value of ADF tests are based on Mac Kinnon (1996) one-sided p-values at 5% level. Lag length selection was automatic based on Eviews' Schwarz Information Criteria.

Table 2. Results of multivariate cointegration tests.

Null hypothesis	Eigen values	Trace statistic	Critical value (0.05)	Prob.	Null hypothesis	Max-Eigen statistic	Critical value (0.05)	Prob.
r = 0*	0.655383	66.27794	47.85613	0.0004	r = 0*	34.09028	27.58434	0.0063
r = 1*	0.501076	32.48766	29.79707	0.0239	r = 1*	22.24960	21.13162	0.0347
r = 2	0.218558	10.23806	15.49471	0.2629	r = 2	.891674	14.26460	0.3898
r = 3	0.070701	2.346386	3.841466	0.1256	r = 3	.346386	.841466	0.1256

*Rejection of the hypothesis at the 0.05 level.

given in Table 1. ADF statistics for log-level series of WA (area under wheat) was 1.343258, WP (price of wheat) was 0.558380, BP (price of *Boro* rice) was -0.330029 and WE (weather) was 0.192287, which were smaller in absolute term than their respective critical value. It indicates that they were non-stationary. Consequently we applied the ADF test on the log of the differenced series, to make them stationary. ADF statistics for first difference series of WA (area under wheat) was -3.286337, WP (price of wheat) was -4.869765, BP (price of *Boro* rice) was -6.674263 and WE (weather) was -3.161875, which were more negative than their respective critical value. First difference series are stationary and these variables were subjected to cointegration analysis.

Testing for cointegration

Following the Johansen's Maximum Likelihood cointegration test relations in a Vector Auto Regression (VAR) model, cointegration was estimated. The Johansen cointegration tests are based on the Maximum Eigenvalue of the stochastic matrix as well as the Likelihood Ratio test which is in turn based on the Trace of the stochastic matrix. Table 2 presents the trace and maximum eign value test statistics of the Johansen's Maximum Likelihood cointegration test. For the null hypothesis of r = 1, the calculated trace statistics was 32.48766 which was larger than its critical value 29.79707 and calculated maximum eigenvalue was 22.24960 which was larger than its critical value 21.13162 at 5% level of significance. Both the tests confirm that there are at least two cointegrating vectors at the 95% significance level.

Estimation of vector error correction model

After the long run relation is confirmed, an ECM is developed. We estimate the ECMs for each cointegrating vector for which general-to-specific modeling procedure of Hendry and Ericsson (1991) was applied in selecting the preferred ECM. This method first estimates the ECM with different lag lengths for the difference terms and then, simplifies the representation by eliminating the lags with insignificant parameters. Our cointegration coefficients normalised on wheat supply are presented as long-run estimates in Table 3.

Table 3 shows the results of the VECM estimates for supply response of wheat to changes in real prices. Both the short and long run estimates as well as diagnostics are presented. All the estimated coefficients have the expected signs. The magnitude of the coefficient of determination, (R^2), and the F statistics show the equation's goodness of fit and significance of estimated relationships. Based on the value of adjusted R^2, the explanatory variables explained almost 78% of the variation in the dependent variable. Moreover, the signs of the coefficients meet *a priori* expectations. These together imply that wheat supply response in Bangladesh largely depended on real wheat price during the period under study.

Wheat area is influenced by real price changes. An increase in wheat price positively affects the wheat area. In the short-run, the relevant real wheat price elasticity is 0.466107 and it is significant at the 1% level while in the

Table 3. Long-run and short-run VECM estimates.

Regressor	Long-run estimates	
WA(-1)	1.000000	
WP(-1)	0.948812 (5.01382)	
@Trend(1)	-0.051893 (-28.1314)	
Constant	-6.380438	
	Short-run estimates	
Error correction	**∆WA**	**∆WP**
Coint Eq.1 (ECM(-1))	-0.815542 (-13.6716)	0.289186 (2.13999)
∆WA(-1)	-0.016656 (-0.22069)	0.011516 (0.06736)
∆WA(-2)	-0.100809 (-1.30747)	0.477479 (2.73369)
∆WP(-1)	0.466107 (6.17650)	-1.123699 (-6.57308)
∆WP(-2)	0.248835 (4.27377)	-0.739195 (-5.60428)
Constant	-3.991556(-12.4975)	1.299362 (1.79586)
BP	-0.228926 (-1.36320)	0.212331 (0.55814)
WE	4.200572 (13.0437)	-1.512247 (-2.07289)
R-squared	0.918864	0.720723
Adj. R-squared	0.894170	0.635725
S.E. equation	0.050077	0.113442
F-static	37.21047	8.479344
Log likelihood	53.45977	28.10998
Akike AIC	-2.932889	-1.297418
Schwarz SC	-2.562827	-0.927357

long-run, the real wheat price elasticity is 0.948812 which is equally significant at the 1% significance level.

The coefficient of weather variable is 4.200572 and it is highly significant. The negative coefficient (-0.228926) of the *Boro* rice price (competitive crop), significant at 10% level.

The error correction coefficient (-0.815542), which measures the speed of adjustment towards long-run equilibrium carries the expected negative sign and it is highly significant at the 1% level.

DISCUSSION

The results unit root test indicates that we cannot reject the null hypothesis of a unit root at 5 per cent level in all the series. It indicates that they were not stationary (that is contained a unit root), as they are all integrated of order one, that is, I(1). The calculated ADF test statistics in first difference series are higher in absolute terms than the critical values, thus we reject the null hypothesis of the presence of unit root and these variables were subjected to cointegration analysis.

In cointegration test, both trace and maximum eigen value confirm that there are at least two cointegrating vectors at the 95% significance level. Cointegrating results indicate that a strong long-run equilibrium relationship exists among the variables, because it is known that the more stable the specified relationship is, the greater the number of cointegrated vectors (Berg and Jayanetti, 1993).

Clearly, both coefficients are inelastic and suggest that a one hundred per cent increase in real wheat price results in an increase by 47% in the following year while the same percentage increase would raise the supply of wheat by 95% in the long-run. The wheat area is inelastic with response to wheat price. Low short and long-run elasticities of supply indicate that wheat growers do not make considerable area adjustments in response to expected prices. By using Nerlovian "Area (Partial) Adjustment Model", Matin and Alam (2004) obtained 0.57 as short-run elasticity and 2.29 long-run elasticity with respect to price for the period 1982/83 to1998/99. The short- run and long run price elasticities of wheat was 0.61 and 5.24 respectively for the country as whole (Yunus, 1993) for the period from 1972/73 to1988/89.

Previous studies do not consider the unit root problem (that is, a nonstationarity situation) of time series data. If unit root problem exists in the time series data than it resulted spurious result. Present study considered this problem and obtained result is more realistic.

Weather variable turned out to be important non price variable explaining the wheat area in the short run. It indicate that favourable weather have a highly significant positive effect on wheat supply. The negative coefficient of competitive crop *Boro* rice price indicates that it have a negative influence of wheat supply, which is expected.

The error correction coefficient indicates a feedback of about 82% of the previous year's disequilibrium from the long-run elasticity of wheat price. This implies that the speed with which wheat price adjust from short-run disequilibrium to changes in wheat supply in order to attain long-run equilibrium is 82% within one year. This further confirms once again, the existence of the cointegration relationship in the models.

Conclusion

Present paper estimates the long-run relationship between wheat area, price incentives and non-price factors in Bangladesh by Using Johansen's Cointegration approach. Generally, the results conform to a priori expectations. Farmers' response to producer prices is statistically significant and positive.

Two basic results turned out from the analysis - firstly, the estimated supply elasticities came out to be less than one, but they appeared to be high enough to imply that further agricultural reforms are required. Secondly, weather appeared to be important non-price variables explaining wheat area, which shows crop production in Bangladesh are still largely influenced by weather variability. Our result indicates that *Boro* crops compete with wheat crop.

Supply elasticity in consideration to price is significantly positive, in case of wheat, for which price policies will be effective in obtaining the desired level of output. Producers react to the prices at the time of harvest it is for which any policy intervention with regard to price must be made at that time. As the impact of price on production is higher in the long run compare to that of the short run, the government should focus on the factors that affect the long run price instability. Government should focus on the policies that ensure the profitable price to the producers in the long run. It also important to noted that, price alone has limited influence on farmers' resource allocation decisions, external factors, such as government agricultural and trade policies as well as weather conditions is critical for output supply.

Weather remains one of the most important uncontrollable variables involved in agricultural production systems; the estimated result shows that weather plays a critical role in wheat production in Bangladesh. Wheat yield are mainly affected by temperature condition and fogy weather throughout the production period in winter.

Increasing the area under wheat cultivation can be done by removing the hurdles, like quality seed, fertilizer, institutional credit, fuel/oil for irrigation, machine tillage etc. Primitive technology is being used for wheat cultivation for which budgetary allocation should be made for research and development.

The study therefore recommended that an improve policy package that encompasses price and non price incentive as well as transmission mechanism is needed for obtaining a better response from wheat farmers.

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