Testing Asymmetric Price Transmission in the Vertical Supply Chain in De-regulated Rice Markets in Bangladesh

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Abstract

Market liberalization at the domestic level and at the boarder level has been a dominant feature of market reforms in most developing countries including Bangladesh during the last two decades. A pre-requisite for producers and consumers to benefit from this new and changing market environment is the ability of market to function efficiently at their spatial or through the value chain dimensions which are very often constrained by different factors. The vertical integration of grain markets plays a crucial role in improving the welfare of the producers and the consumers. Therefore, the better the market integration, the lesser the intervention required by the government. There was a widely-held belief about the domestic markets in Bangladesh on possible manipulation in the agricultural markets as well as concerns about the sources of asymmetry. In the domestic markets, a price increase passes very quickly though the supply chain compared to a price decrease. As a result, perception by consumers and the government exists that at least the market is being manipulated, raising food prices unfairly, at the expenses of the poor households who are net buyers and for whom food is a major expenditure share (about 40-50 percent).

Examining, the market functioning at the vertical level in developing countries is of importance to evaluate how the private traders delivering to the market. That is why it is important to identify what kind of policy can be introduced and at what level of the marketing chain to correct the market inefficiency, if needed. The vertical price leadership at the wholesale level to the retail in the marketing literature is inferred but not empirically verified. Therefore, this paper is an attempt to fill up this gap. It first examines the price transmission between the wholesale and retail level of the rice market in Bangladesh in the regime of the changing market environment. Secondly, it examines whether the wholesale market dominates the retail one. Thirdly, it analyzes whether the price relationship is symmetric with respect to price increases and price decreases. The paper uses the average wholesale and retail price of rice for Bangladesh. The monthly price data used for this study are taken from FAO and different published series of Statistical Yearbook and the Economic Trend. The data period cover from February 2002 to June, 2007. From our unit root test, we find that the level data contain one unit root but are stationary at their first differences. Both Engel-Granger (1987) bi-variate and Johansen (1990) multivariate cointegration tests were applied to determine a linear combination which is stationary. Then the existence of long run causality was tested within the framework of Johansen cointegration by standard Wald test. To test the asymmetric transmission in the prices we used the asymmetric ECM-EG approach. The results show that the wholesale and retail prices are integrated, and in the line of the industrial organization theory, the wholesale price plays a leadership role to determine the retail prices. Results also confirm that the consumer and public concern about the asymmetric price transmission holds true.

Key words: vertical supply chain, asymmetry, rice markets, Bangladesh

1. Introduction

Market liberalization at the domestic level and at the boarder level has been a dominant feature of market reforms in most developing countries during the last two decades. Bangladesh has undertaken extensive market reforms, its main food grain rice by both reducing public intervention for procurement and distribution, and opening-up most of the private imports since 1992 (Ahmed, 1996). Rice accounts for a high caloric share in the diet of the Bangladeshi population. It is also the most important cereal crop produced and occupies a major share of the farmers' agricultural income and the employment. Therefore, a pre-requisite for producers and consumers to benefit from this new and changing market environment is the ability of market to function efficiently. But if the market at the spatial or through the value chain dimensions are constrained by factors such as imperfect market information, lack of credit availability to finance short run inventories, insufficient transportation, lack of management skills, market power etc. the inferred benefits from reforms will be jeopardized.

The liberalization of the rice markets in Bangladesh has significantly changed the structure of the markets. In the post-liberalization period, the activities of the private traders have increased and have contributed for the country's overall food security especially after a devastating flood in 1998 (Dorosh, 2001, Carl Ninno, 2003). Subsequently, the Bangladesh government's roles in rice procurement and distribution decreased at their minimum level. Thus, there is an emerging market structure which is dominated by the private traders. Even though Bangladesh is one of the world's major rice importers, about 80-85 percent of its total domestic food requirement comes from the domestic production which has benefitted from the domestic market reforms. Market liberalization has increased the rice productivity and therefore it has decreased real producer and consumer prices (Irina Klytchnikova, 2006). Furthermore, boarder policy has contributed to the domestic price stabilization and national food security (Dorosh, 2001). So far, there is no study which has examined the market efficiency capturing the potential asymmetry either at the spatial level or through the value chain. Examining the market efficiency in the regime of market liberalization is mainly limited to the spatial level, i. e., testing the law of one price (Dawson, 2002), and to estimating the structural determinants of market integration (Golletti, 1995). Therefore, there is a dearth of information on the nature of the price relationships in the vertical level under the new market structure. The vertical integration of grain markets plays a crucial role in improving the food security and the welfare of the poor consumers. The degree and the nature of integration also determine the level of intervention required by the government to correct the inefficiencies in the market, if required. Therefore, better the market integration, lesser the intervention required by the government. The food grain (mainly rice) marketing chains are long in developing countries because of many small scale intermediaries which make the producer prices to be lower and consumer prices to be higher, therefore resulting in the higher price spread. This was true in the case of commercial rice marketing in Bangladesh. There was a widely-held belief about the domestic markets that possible manipulation in the agricultural markets as well as concerns about the sources of asymmetry. In the domestic markets, a price increase passes very quickly though the supply chain compared to a price decrease. As a result, perception by consumers and the government exists that at least the market is being manipulated and raising food prices unfairly, at the expenses of the poor households who are net buyers and for whom food is a major expenditure share (about 40-50 percent).

In the industrial organization literatures retail prices are often assumed to be determined by the conditions of the wholesale market (Tirole, 1988). In the mark-up model, prices are determined by the upstream of the supply chain to the downstream, although, there are some criticisms on it. Examining the market functioning at the vertical level in developing countries is of importance to evaluate how the private traders and the markets are delivering for the producers and the consumers' welfare. It is also important to identify what kind of policy can be introduced, if needed at all and at what level of the marketing chain to correct the market inefficiency, if any. The vertical price leadership at the wholesale level to the retail in the marketing literature is inferred in one hand but also in the other hand in the development economics literatures, there are suspicious that in the developing country, the retail price might dominate the wholesale prices but none of these are empirically verified and conclusive in any cases. On the contrary, there are many empirical studies on spatial price integration of agricultural commodities in the developing countries (Ravallioan, 1986; Baulche, 1997; Kuiper, *et al.*, 1999; Abdulai, 2000).

Therefore, this paper is an attempt to fill up this gap. The paper address the research questions: Is there a relationship between wholesale and retail prices in rice supply chain in the regime of new market environment in Bangladesh or is price formation independent each other? Is the wholesale market dominates the retail one or the vice-versa? Is the price relationship linear or non-linear? In other words, whether price relationship in the supply chain is symmetric with respect to price increases and price decrease? The next section describes the data used in the analysis followed by the econometric methodology and results in section 3. The last section concludes.

2. Data

The paper uses the monthly average wholesale and retail price of rice for Bangladesh. The wholesale price data used for this study are taken from Global Information on Early Warning System, FAO. The monthly retail prices are taken from different published issues of Statistical Yearbooks and the Economic Trends published from Bangladesh Bureau of Statistics (BBS), Bangladesh and the Bangladesh Bank (BB) respectively. The data period covers from February 2002 to June, 2007. The data period was selected on the basis of availability of a continuous time series data for the entire set of the price variables considered. The data period considered here seem consistent for such exercise as there were not any abnormalities in the prices.

3. Analytical framework and results

The paper follows different steps sequentially to answer the research questions addressed in the introduction section. Since the data are monthly basis, it may contain seasonality effect. Therefore we deseasonalised monthly data with orthogonalised (centered) seasonal dummy to remove seasonality. The first step of testing cointegration is to testing all the time series variables for their stationarity. Therefore, augmented Dickey-Fuller (ADF) and the Philip Perron (PP) test were performed to test whether the data are difference stationary or trend stationary and to determine the number of the unit roots at the level data. The ADF tests use the following equation.

$$\Delta Y_{t=}c + \rho Y_{t-1} + \beta t + \sum_{j=1}^{k} d_j \Delta Y_{t-j} + \varepsilon_t \qquad (1)$$

Where Y_t is the respective price series and Δ is first difference (Y_t-Y_{t-1}) operator and ε_t denotes white noise error term. Equation (1) tests the null of a unit root ($\rho = 0$) against a stationary alternative ($\rho < 0$). We also test the presence of a unit root using Philip and Perron (1988) in the following specification.

$$X_t = c + \beta\left\{t - \frac{T}{2}\right\} + \rho X_{t-1} + v_t \qquad (2)$$

Where X_t is respective time series, {t -$\frac{T}{2}$), is the time trend and T is the sample size, v_t is the usual white noise error term. This procedure, in fact, uses a non-parametric adjustment to the Dickey–Fuller test statistics and allows for dependence and heterogeneity in the error tem. Equation (2) also tests the null of a unit root ($\rho = 0$) against a stationary alternative ($\rho < 0$).

Table 1: Unit root test results

Prices Series (Tests)	Deseasonalised level		First Differences ($\tau - stat_w$)		Order of Integration I(d)	
	$\tau - stat_c$	$\tau - stat_{c,t}$				
Wholesale						
Augmented Dickey Fuller	-0.200	-2.492	-8.234**		I(1)	
Philip Perron	0.350	-2.527	-8.250**		I(1)	
Retail						
Augmented Dickey Fuller	-0.179	-2.507	-8.899**		I(1)	
Philip Perron	-0.186	-2.402	-8.852**		I(1)	
Critical values	τ_c		$\tau_{c,t}$		τ_w	
Level of Significance	5 %	10 %	5 %	10 %	5 %	10 %
Augmented Dickey Fuller	-2.907	-2.591	-3.482	-3.169	-1.946	-1.613
Philip Perron	-2.907	-2.591	-3.482	-3.169	-1.946	-1.613

Notes: Lag length for Augmented Dickey-Fuller (ADF) test is decided based on Schwarz info criteria (SBC) and maximum bandwidth for Philip Perron (PP) test is decided based on Newey-West (1994); ** indicates that unit root in the first differences are rejected at 5 percent level; τ-$stat_c$, τ-$stat_{c,t}$ and τ-$stat_w$ indicates *tau*-statistics of random walk with drift, random walk with drift and slope, pure random walk respectively

The augmented Dickey-Fuller and Philip Perron unit root test on each of the variables are reported in the Table 1. The results of all the tests indicate that all price series are non-stationary at their level but stationary at their first difference. Note that the ADF and PP tests were done both only with drift and drift plus trend models. In time series econometrics, it is said that prices are integrated of order one denoted by presenting $P_t \sim I(1)$ and prices of integrated of order zero denoted by $\Delta P_t \sim I(0)$. Here the order of the integration is one. Therefore, the results allow to proceed for cointegration tests for the testing the long run equilibrium relationship.

Cointegration tests using maximum likelihood estimation

Once we found the price series (wholesale and retail prices) are non-stationary we apply Johansen and Juselius (1990 and 1992) maximum likelihood estimation technique, begins with a vector autoregressive (VAR) model in which a vector of price (*P x 1*) at time t are related to the vector of past prices. According to Granger representation theorem, the vector P_t has a vector autoregressive error correction representation in the following specification:

$$\Delta P_t = \Pi P_{t-1} + \sum_{i=1}^{k-1} \Gamma_i \Delta P_{t-i} + \Phi D_t + \omega_t \quad (3)$$

$$\text{Where } \Pi = \sum_{i=1}^{p} A_i - I \text{ and } \Gamma_i = -\sum_{j=i+1}^{p} A_j$$

P_t is a (*P x 1*) dimension vector corresponding to the number of price series in which all the prices are $\sim I(1)$, the Π, Γ_i and Φ are parameter matrices with (*P x P*) to be estimated, D_t is a vector with deterministic elements (constant, trend and dummy) and ω_t is a (*P x 1*) random error follows as usual Gaussian white noise process with zero mean and constant variances. From the equation (3), there can never be any relationship between a variable with a stochastic trend, $I(1)$ and a variable without a stochastic trend, $I(0)$. Therefore from the equation (3), three cases are permissible. So, if $\Delta P_t \sim I(0)$, then Π will be a zero matrix except when a linear combination of the variables in P_t is stationary. So the specific interest of testing is, the rank of matrix (Π) which contains long run information (also the loading factors) about the variables. First case, If rank (Π) = P, then Π is invertible and all the variables in levels are stationary meaning that no co-integration exists, Second, if rank (Π) = 0, i. e., Π is a null matrix meaning that all the elements in the adjustment matrix has value zero, therefore, none of the linear combinations are stationary, and can be estimated the unrestricted VAR to identify the short run-dynamics. Third, according to the Granger representation theorem that when 0< rank (Π=r) < P, there are r cointegrating vectors or r stationary linear combinations of the variables. For example if rank (Π = r) = 1, there is single cointegrating vector or one linear combination which is stationary such that the coefficient matrix Π can be decomposed into $\Pi = \alpha\acute{\beta}$ where α is the speed of the adjustment vector (loading factor) and β is the long run equilibrium (cointegrating) vector. In this case P_t is $I(1)$ but the combination $\acute{\beta} P_{t-1}$ is $I(0)$. So, the Johansen method is to estimate the Π matrix from an unrestricted VAR and to test whether we can reject the restrictions implied by the reduced rank of Π. There are two methods of testing for reduced rank (Π), the trace test and maximum eigen value which are as follows:

$$\lambda_{trace} = -T \sum_{i=r+1}^{n} \ln(1 - \hat{\lambda}^2{}_i) \quad (4)$$

$$\lambda_{max}(r, r+1) = -Tln(1 - \lambda_{r+1}) \quad (5)$$

Where, λ_i is the estimated values of the ordered eigen values obtained from the estimated matrix and T is the number of usable observations after the lag adjustment. The trace statistics tests the null hypothesis that the number of distinct cointegrating vectors (r) is less than or equal to r against a general alternative. Another statistics called maximal Eigen value tests the null that the number of cointegrating vectors is r against the alternative of r +1 cointegrating vectors.

The trace test (λ_{trace}) and maximum eigenvalue (λ_{max}) results from equation (4) and (5) are presented in Table 2. Many studies showed that the rejection of the null hypothesis of no integration by using only trace test is sufficient to identify the cointegration rank (Dawson and Dey, 2002; Mohanty *et al.,* 1996; Taylor *et al.,* 1996). From the test results in Table 2, it is seen that in the vertical level of rice supply chain contain one cointegrating vector. That means this cointegrating rank gives the number of stationary linear combinations of the price series. So it is consistent with the identification of one linear combination of prices (as it is a bi-variate case) that exhibits stability over the time. The leg length was determined using AIC and SIC but as the inclusion of the deterministic terms (constant and trend) in the cointegration space is sensitive to the identification of cointegration rank, therefore according to Harris and Sollis (2003) we estimated three realistic models which are denoted by model 2, model 3 and model 4 implicit in equation (3). Model 2 restricts all the deterministic components to a constant in the cointegration space, model 3 allows linear trends in the level of the variables and in model 4, the linear trend is allowed in the cointegration space. From the three different estimated models; we find there is no evidence of cointegration in the case of model 2 and model 4. There is one cointegration relation identified in the model 3. Both the trace and maximum eigenvalue tests rejected the null of no cointegration at 5 percent significant level. The specification tests shows there are no problem of the autocorrelation, heterosacdasticty and non-normality.

Table 2: Johansen cointegration test results

Cointegration rank (r)	**Model 2**		**Model 3**		**Model 4**	
	Test statistics (λ_{trace}), (λ_{max})	Critical values ($\lambda_{0.95}$)	Test statistics (λ_{trace}), (λ_{max})	Critical values ($\lambda_{0.95}$)	Test statistics (λ_{trace}), (λ_{max})	Critical values ($\lambda_{0.95}$)
Trace statistics (λ_{trace})						
$H_0: r = 0 \;\; vs\, H_1: r \geq 1$	19.802	20.262	15.133**	15.095	21.844	25.872
$H_0: r \leq 1 \;\; vs\, H_1: r \geq 2$	4.354	9.165	0.002	3.841	6.225	12.518
Maximum eigenvalue statistics (λ_{max})						
$H_0: r = 0 \;\; vs\, H_1: r = 1$	15.449	15.892	15.131**	14.265	15.619	19.387
$H_0: r \leq 1 \;\; vs\, H_1: r = 2$	4.354	9.165	0.002	3.841	6.225	12.518

Notes: Figures in the parentheses are the 95% critical values of the respective test statistics, ** indicates the hypotheses are rejected at the 5% level

Testing Causality in the VECM framework

So far, there were only an attempt (Jayanta Das *et. al.,* 1997) to measure the relationship and the causality between the wholesale and retail price of rice for major two cities (Dhaka and Chittagong) in Bangladesh. The authors used conventional Granger Causality using F-test for the causality without testing the long-run equilibrium relationship. If the variables are co-integrated in the long run, the conventional Engle-Granger causality is not a valid test. For testing the asymmetry in the same study, the authors used only one dummy variable to capture the increases and decreases of the exogenous prices (wholesale in that case). But the present study is an attempt to use the state of the art methodology for testing first the log-run relationship and then the direction of the causality followed by the asymmetry test.

Once it is found that there is a long run-relationship between the prices, but there is still a problem of identification the direction of causality. Therefore, the existence of cointegration in the bi-variate relationship implies Granger causality which under certain restrictions can be tested within the framework of Johansen cointegration by standard Wald test (Masconi and Giannini 1992; Dolado and Lutkephol, 1996). If α matrix in the cointegration matrix (Π) has a complete column of zeros, no casual relationship exist, because there is no cointegrating vector appear in that particular block. For pair-wise causal relationship, it can be written in the following two equations

$$\Delta PW_{t=}\mu_1 + \sum_{t=1}^{k1} \beta_{pw} PW_{t-i} + \sum_{t=1}^{k2} \beta_{pr} PR_{t-i} - \alpha_{11} Z_{1,t-1} + \varepsilon_{t,1} \qquad (4)$$

$$\Delta PR_{t=}\mu_2 + \sum_{t=1}^{k1} \beta_{pw} PW_{t-i} + \sum_{t=1}^{k2} \beta_{pr} PR_{t-i} - \alpha_{21} Z_{2,t-1} + \varepsilon_{t,2} \qquad (5)$$

In the equations (4 and 5), there are three possible cases of testing causality if the variables are co-integrated in the long run:

a) $\alpha_{11} \neq 0$, $\alpha_{21} \neq 0$, which implies bi-directional causality meaning that there exist a feed-back long run relationship between two variables and no individual price play leadership role

b) $\alpha_{11} = 0$, $\alpha_{21} \neq 0$, implies uni-directional causality and wholesale price granger causes to the retail price, retail price is weakly exogenous in this block

c) $\alpha_{21} = 0$, $\alpha_{11} \neq 0$, implies uni-directional causality and retail price granger causes to the wholesale prices, wholesale price is weakly exogenous in this block

There can never be both $\alpha_{11} = 0$, $\alpha_{21} = 0$ as our previous result shows that there is a long run equilibrium relationship between the price series. The tests results clearly failed to accept the reject case (a) and case (b) but accept the case (b). So in the bi-variate price relationship, the wholesale price is weakly exogenous.

Table 3: Restrictions on the VECM for testing causality between the retail & the wholesale prices

Rank (Π)	Trace test	Max. eigenvalue	Exogeneity test		Causality direction
			Retail price $H_0: \alpha_{11} = 0$ vs $H_1: \alpha_{11} \neq 0$	Wholesale price $H_0: \alpha_{21} = 0$ vs $H_1: \alpha_{21} \neq 0$	
H_0: $r = 0$ vs $H_1: r \geq 1$	15.133** [0.05]	15.131** [0.036]	4.698** [0.030]	2.283 [0.131]	Uni-directional (wholesale prices cause retail prices)
H_0: $r \leq 1$ vs $H_1: r \geq 2$	0.002 [0.961)	0.002 [0.961]			

* and ** indicates the significant level at 5 per cent and 10 percent respectively; the significant level are in the parentheses

Testing Asymmetry

Houck (1977) developed a test for asymmetry in the price transmission based on the splitting of price variables into increasing or decreasing cases. Other studies, notably Boyd and Brorsen (1988); Kinnucan and Forker (1987); Baily and Brorsen (1989); Zhang, Fletcher, and Carley (1995); Mohanty, Peterson and Kruse (1195); Willet, Hansmire and Bernard (1997), Peltzman (2000); and Bart Minten (2000) Aguiar (2002) followed the suit. All of these studies differ from each other in technical point of views but focused the testing of asymmetry in the agricultural and food markets in the developed countries. With few exceptions, all the previous researches, at least in the agricultural economics literature have not considered the inherent time series properties of the data i. e., non-stationarity and the long run equilibrium relationship. The asymmetric error correction model approach was motivated first by the fact that all the aforementioned approach in the Houck specification was not consistent with the cointegration between the retail and the farm price series (Von Cramon-Taubadel (1998) and von Cramon-Taubadel and Loy (1999)). They first recognized the inconsistencies by investigating asymmetric price behavior of producer and consumer prices of the pork market in Germany. They concluded the classical Houck approach is fundamentally incorrect with cointegration between two price series. Two recent articles by Meyer and Von Cramon-Taubadel (2004) and Giliola Frey (2007) provided a comprehensive discussion of the possible causes and types of the asymmetric price transmission along with a brief review of the empirical works done during last couple of decades. The authors concluded that the existing literature is far from being conclusive and it has largely been method driven with little attention devoted to the theoretical underpinnings and the plausible interpretation of the results. Therefore much interesting theoretical and empirical works remains to be done. All the literatures discussed above are based on the asymmetry in agricultural markets in developed countries but there are not many such studies in the context of the developing countries. There are few studies who dealt the asymmetry problem in the agricultural markets in developing countries notably Abdulai (2000), Michele and Johann (2006), Van Campenhout (2007) and found the existence of asymmetry in the developing countries agricultural and food commodities markets.

To test the asymmetric transmission in the prices we used the asymmetric ECM-EG modeling approach. In this stage, based on our results of cointegration and causality we proceed for focusing the asymmetric error correction representation, in the form of an asymmetric error correction model. When the two variables are co-integrated the estimates in the Engle-Granger (1987) two steps methodology are super consistent, that is why we decided to estimate the asymmetry using this methodology. From our earlier results, we use wholesale price of rice as exogenous for estimating the static OLS, so that

$$RP_t = \gamma_0 + \gamma_1 WP_t + \psi t + \varepsilon_t \qquad (6)$$

In where the RP is the retail price, WP is the wholesale prices, t is the time trend and ε is the usual error term. The short term dynamic price adjustment based on error correction model is

$$\varDelta RP_t = \mu_1 + \sum_{i=1}^{k1} \beta_{rp} \varDelta RP_{t-i} + \sum_{i=0}^{k2} \beta_{wp} \varDelta WP_{t-i} - \alpha \hat{\varepsilon}_{t-1} + \epsilon_t \qquad (7)$$

From the equation (7), $\beta_{rp}$and β_{wp} measures the short run impact of changes in retail prices and the domestic prices respectively but α measure the speed of the adjustment to the long run equilibrium, $\hat{\varepsilon}_{t-1}$ is the estimated lag residuals from the long run cointegration equation in equation (6). As we expect that the adjustment towards long run-equilibrium and adjustment of wholesale prices increases and price decreases towards retail price, that is why, the equation (7) can be re-parameterization into equation (8) by splitting the wholesale price increase and price decreases and also the adjustment towards long run equilibrium when the error correction term is positive and negative values. The asymmetric price adjustment of equation (8) is as follows

The ECM-EG asymmetric model has the following form

$$\Delta RP_t = \sum_{i=1}^{k1} \beta_{rp}^{-} RP_{t-i}^{-} + \sum_{i=0}^{k2} \beta_{wp}^{-} WP_{t-i}^{-} + \alpha_{11}^{-} Z_{1,t-1} + \sum_{i=1}^{k3} \beta_{rp}^{-} RP_{t-i}^{+} + \sum_{i=0}^{k4} \beta_{wp}^{+} \Delta PW_{t-i}^{+} + \alpha_{11}^{+} Z_{1,t-1} + \varepsilon_t \qquad (8)$$

From the equation (8), the existence of asymmetry, will be tested by the implementation of the Wald χ^2-test for the hypothesis that $\alpha_{11}^{+} = \alpha_{11}^{-}$ as well as the asymmetry in $\beta_{wp}^{+} = \beta_{wp}^{-}$ with different lag periods. In addition we also tests the hypothesis of $\beta_{rp(t-1)}^{+} = \beta_{rp(t-1)}^{-}$. If any of the hypotheses are rejected then the asymmetric error correction model is superior. We also estimated the symmetric error correction model to verify our results that both the series are cointegrated.

Table 4: Results of the symmetric and asymmetric price transmission

Regressors	Symmetric ECM-EG model		Asymmetric ECM-EG	
	Co-efficients	t-statistics	Co-efficients	t-statistics
Intercept	-0.247*	-2.598	-0.243*	-2.482
ΔWP_t	0.269**	2.822	-	-
ΔWP_{t-1}	0.253*	2.260	-	-
ΔRP_{t-1}	-0.286*	-2.512	-	-
$\Delta RP^{+}{}_{t-1}$	-	-	-0.308*	-2.051
$\Delta RP^{-}{}_{t-1}$	-	-	-0.336	-1.398
ΔWP^{+}	-	-	0.474**	3.129
ΔWP^{-}	-	-	-0.082	-0.506
$\Delta WP^{+}{}_{t-1}$	-	-	0.352*	2.11
$\Delta WP^{+}{}_{t-1}$	-	-	0.162	0.942
$\Delta WP^{+}{}_{t-2}$	-	-	0.424**	2.889
$\Delta WP^{+}{}_{t-2}$	-	-	-0.102	-0.569
α_1^{+}	-	-	-0.009	-0.060
α_1^{-}	-	-	-0.566**	-2.786
α	-0.247**	-2.597		
R^2	0.38		0.56	
Ramsey RESET test	3.16 [~F (1, 57)]		3.417 [~F (1, 50)]	
LM autocorrelation test	1.76 [~F (2, 56)]		0.485 [~F (2, 49)]	
Normality test (JB)	2.77 [0.25]		1.26	
ARCH test	0.813 [~F (1, 60)]		0.761 [~F (1, 59)]	
CUSUM test	Lies within the 5% level of significance		Lies within the 5% level of significance	

Cointegration equation in the first stage of ECM-EG

$$RP_t = 4.759 + 0.704WP_t + 0.056t$$

(4.455) (7.859) (6.812)

Test for cointegration	$H_0: \alpha=0$ vs $H_1: \alpha \neq 0$ (No cointegration)	$\chi^2(1)$ =6.747** (0.009)
Test for cointegration	$H_0: \alpha_{11}^{+} = \alpha_{11}^{-} = 0$ (No cointegration)	$\chi^2(1)$=9.317** (0.009)
Wald Test for Symmetry		
Hypothesis 1:	$H_0: \alpha_{11}^{+} = \alpha_{11}^{-}\ vs\ H_1: \alpha_{11}^{+} \neq \alpha_{11}^{-}$	$\chi^2(1)$= 3.676* (0.05)
Hypothesis 2:	$H_0: \beta_{wp}^{+} = \beta_{wp}^{-}\ vs\ H_1: \beta_{wp}^{+} \neq \beta_{wp}^{-}$	$\chi^2(1)$=4.530* (0.03)
Hypothesis 3:	$H_0: \beta_{wp(t-1)}^{+} = \beta_{wp(t-1)}^{-}\ vs\ H_1: \beta_{wp(t-1)}^{+} \neq \beta_{wp(t-1)}^{-}$	$\chi^2(1)$=0.514 (0.473)
Hypothesis 4:	$H_0: \beta_{wp(t-2)}^{+} = \beta_{wp(t-2)}^{-}\ vs\ H_1: \beta_{wp(t-2)}^{+} \neq \beta_{wp(t-2)}^{-}$	$\chi^2(1)$=4.162* (0.041)
Hypothesis 4:	$H_0: \beta_{rp(t-1)}^{+} = \beta_{rp(t-1)}^{-}\ vs\ H_1: \beta_{rp(t-1)}^{+} \neq \beta_{rp(t-1)}^{-}$	$\chi^2(1)$=0.009 (0.935)

* indicates the hypothesis are rejected at the 5 percent level of significance, the probability level are in the parentheses

Table (4) shows the results of the both models. The hypothesis of no cointegration is rejected in the symmetric error correction model. The sign and the magnitude of the error correction tem provide the expected results. Our specific interest of testing the asymmetry, therefore we tested different hypotheses which are given in the Table 4 and denoted from hypothesis 1 to hypothesis 4. We failed to reject the null of symmetric adjustment towards its long run equilibrium. We also failed to reject the null of the adjustment of wholesale prices increase and price decrease towards the retail prices. So the estimated model support on asymmetric price transmission for rice in Bangladesh.

4. Conclusion

The paper focuses on time series estimation to test the price transmission and the asymmetry in the vertical level of the rice supply chain in Bangladesh. The objective of this paper is to estimate the link between different levels of supply chain for commodity rice which is subject to the different level of controversy in the policy level. The result shows that the wholesale and retail prices are integrated in the long run, and in the line of the industrial organization theory and the mark-up model in the pricing analysis, the wholesale price (as upstream) plays a leadership role to determine the retail price (at downstream). Results also confirm that the consumer and public concern about the asymmetric price transmission that wholesaler pass on increases in wholesale prices to consumers as quickly as wholesale price decreases holds true. Note that our analysis is not confirming the sources where the asymmetry comes from. There can be considerable interest to find out the causes of the asymmetry and there are much remains that to be done in the future research in this aspect. Therefore, the policy maker should be very cautious to formulate any decision on the existing private traders dominated markets efficiency which supposed to be much welfare enhancing for the poor consumers who mostly depends on the markets for rice.

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Table A1: Descriptive statistics of monthly wholesale and retail prices of rice

Markets	N	Mean (Taka/kg)	Standard Deviation	Minimum	Maximum	Co-efficient of Variation (CV)
Wholesale price	65	14.60	1.74	12.09	18.86	0.120
Retail price	65	16.89	2.30	13.75	21.50	0.136