Dynamics of Wholesale Bid-Ask Spreads in Vertical Markets

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Dynamics of Wholesale Bid-Ask Spreads in Vertical Markets[1]

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Abstract

This paper investigates the short run efficiency of wholesale markets within the context of vertical markets. We propose a partial adjustment model to examine the dynamics of the wholesale bid-ask spread and determine whether this has any impact on hoarding at the wholesale level. The dynamics of Bid-Ask spread is then endogenised in a general model of price transmission at the retail level to determine the impact of such dynamics on a) price transmission and b) the extent of hoarding. Finally we test this generalized model against the extant models of price transmission and show that the generalization is more appropriate.

JEL Classification: C32, D43, Q13, Q18.

Keywords: Bid-Ask spread, Vertical markets, Asymmetric price transmission, Partial adjustment

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I. Introduction

One of the primary concerns of the study of agricultural markets is the process of price transmission from one market to another. There have been several papers that have examined this issue in the context of market integration. Ravallion (1986), Dercon (1995), Goletti (1996), Jha et al (1997), Badiane and Shivley (1998), and, Alderman (1993). One of the implications of market integration is the ability of the integrated markets to react to innovations in other markets. That is, if markets are integrated, then, an innovation in one market will automatically be transmitted to other markets. However, market integration does not imply short run price efficiency. In fact, results based on market integration, hide two important facets of short run price dynamics viz., overshooting (mean reversion) of prices, and, asymmetry in the transmission of prices within the various markets.

When prices overshoot (mean-revert) their equilibrium values, we can conclude that, price formation is not necessarily based on rational expectations. Markets where spreads or prices continuously overshoot can be deemed inefficient. Overshooting (mean reversion) can be caused by short trading horizon of the traders. Such short horizons exist because of cropping cycles, government interventions, etc. This will lead to traders imputing potentially useless information into their price or spread calculations (Froot, Scharfstein, and Stein (1992)). Another cause for mean reversion is the herd behavior of traders. Herding is caused by certain types of institutional structures such as vertical markets, and, noisy markets (Black (1986)). Noisy markets make it difficult for traders to learn from their past trades or new noise traders might enter in the place of old ones.

In vertical markets, wholesalers have the ability to influence the process of price formation at the retail levels. However, the impact of any changes in either the wholesale selling price or spreads, is felt in an asymmetric manner at the retail level. That is, the reaction of retail prices or spreads depends on whether the changes in wholesale prices or spreads are positive or negative. Hence, the speed and magnitude of the reaction of retail spreads or prices can be asymmetric. If wholesale spreads periodically overshoot their equilibrium values then, in the context of vertical markets, this induces a strong element of uncertainty in the process of price formation at the retail level. This can lead to hoarding even at the retail level.

We propose, in this paper, first a partial adjustment model that tests the short run efficiency of wholesale markets[1]. We focus on the dynamics of the wholesale spreads to determine the informational efficiency of the wholesale markets. This is done for the following reason. Wholesale spreads, which represent the profit margin for the wholesalers, typically represent the inventory imbalances and the information asymmetries faced by them. The wholesalers through trading correct these imbalances and asymmetries. Government interventions cause misperceptions at the wholesale level regarding the extent of information asymmetries and order imbalances. We thus expect the spreads to be continuously rebounding (also referred to as overshooting or mean reversion). If spreads are overshooting the target values, given the structure of the rice markets, the retail prices will also be affected. Hence, it is important to understand the dynamics of the bid-ask spreads – specifically their mean reverting tendencies at the wholesale level to be able to formulate rational policies at the retail level. Secondly, the process of overshooting of wholesale spreads is endogenised in the model that estimates the magnitude of asymmetric price transmission in vertical markets. We wish to show that wholesale spread dynamics have an important role to play in the process of price transmission in vertical markets.

The rest of the paper is laid out in the following manner. Section II explains the model and the data that is used for estimation. In Section III we state the results of the estimation procedure, and, Section IV concludes.

II. Model and Data

There are several strands of literature that examine the mean-reverting tendencies of variables like exchange rate, interest rates, stock prices, and, commodity prices. One strand of literature use methods that crucially depend on the non-stationarity assumption of the variable in question. Representative work in this area includes those of Engsted and Tanggaard (1994), Hall, Anderson, and Granger (1992), and, Stock and Watson (1988). These papers examine the cointegration relationship between interest rates of different maturities. A second group of papers attempt to examine mean reversion in stock prices by using variance ratio tests. If stock prices are mean reverting, then, the ratio of long run volatility to short-run volatility is quite small. Poterba and Summers (1988), examine whether stock markets are efficient (i.e., absence of mean reversion) by testing whether volatility of prices rise in proportion to the length of the time series. A third group of papers use various types of linear models based on the methodology of Fama and French (1988) regress stock returns on a constant term plus past returns. In order for the market to be efficient, the coefficient on the lagged return must be zero or close to it. Finally, Lai et al (1996) propose a two sector model to examine the cause for overshooting commodity prices. This is based on an earlier paper by Frankel (1986) who uses the Dornbusch overshooting model to estimate the impact of shifts in monetary policy on commodity prices.

However, most of these preceding types of models are not useful for our purposes. Pretesting of the data shows that wholesale spreads are stationary. Hence cointegration models cannot be used for estimating mean-reversion. The variance-ratio tests have two flaws. First, the rate of convergence (mean-reversion) is never clear in these models. Hence, the half-life of an exogenous shock cannot be measured. Second, the results of these tests depend on the length of the time interval. This would then imply that mean-reversion could be absent if a longer time interval is chosen. The third class of models advanced by Fama and French (1988) are of the autoregressive form and, therefore, imply that current spreads are a function of past spreads alone. Linear models of this type at best partially represent the mean- reversion process.

We propose an alternative formulation here which seeks to address some of the salient weaknesses of the literature. This model is similar in some sense to that in Frankel (1986). However in that model we are still not able to derive the mean reversion rate. We recognize that the target or the expected value of BAS might be unobservable[2]. To treat it otherwise may lead to misspecification. We explicitly recognize this non-observability of the BAS and model the adjustments to it as a partial response, along the lines of the models discussed in Jorgenson (1986) and Marsh (1994). The partial adjustment model that is used here will help us derive the magnitude of overshooting (the reversion rate) and, the half-life of innovations. This model has several appealing features. First, the model is consistent with the idea of overshooting since, the change in spread is considered a function of excess spreads in the previous period. Second, the role of expectations is made explicit in explaining changes in spread. Expectations are formed by taking into account variables that capture both the information content and, the magnitude of order imbalance in the market place. Hence, this model also has the properties of adaptive expectations models. This implies that overshooting is now a function of both lagged spreads and, other variables that capture information asymmetries and, order imbalances[3]. The speed of adjustment therefore depends on the extent to which the expected (target) spread is different from the actual spread.

Consider the group of wholesale spreads of N centers spatially separated over the economic space of India, observed over a time period t, SP_{it}, where, i = 1,2... and t = 1,2... weeks. We posit that the desired spread is unobservable and the adjustment in the spread in the current time period take place as a partial adjustment t the gap between the desired and actual spread last period. Let ΔSP_{it} be the change in spread of center i at time t. Within the partial adjustment framework, this is then a function of excess spreads at time t-1.

That is,

$$\Delta SP_{it} = \alpha_i (SP^{*}_{it-1} - SP_{it-1}) \qquad \ldots(1)$$

Where, SP^{*}_{it-1} is the expected spread at time t-1. The desired spread is a function of the profit position of the wholesaler. We model this as a function of the retail price and the inventory level of the wholesalers.

$$SP^{*}_{it-1} = \beta_i(rtl_{it-1}, st_{it-1}) \qquad \ldots(2)$$

Where, rtl_{it-1} is the retail prices in center i at time t-1, and, st_{it-1} is the corresponding inventory level of the wholesaler. These represent, respectively, the information asymmetry and the order imbalance in the system. If the order imbalances persist i.e., if the wholesalers have more than optimal inventory for example, we would expect spreads to narrow. Any change in retail price however, represents potential shifts in retail demand. This is a source of information asymmetry at the wholesale level since the cause of the change in retail price is not known. Therefore we expect the lagged retail prices to have a positive impact on the spreads. Substituting in (1) and expanding, we have the following estimable equation,

$$\Delta SP_{it} = \alpha_i \beta_{i0} + \alpha_i \beta_{i1} rtl_{it-1} + \alpha_i \beta_{i2} st_{it-1} - \alpha_i SP_{it-1} \qquad \ldots(3)$$

Where α_i is the mean reversion rate of center i.

Equation (3) is to be estimated as a system[4] of non-linear equations with the non-linearity appearing in the parameters of the equations. Non-parametric tests indicate that the null hypothesis that the equation for any one center or group of centers can be estimated separately from the rest of the system is decisively rejected in all cases. Newton-Raphson methods are used for this purpose. In addition, we recognize that there may be serial correlation in the model. The estimation method used corrects for serial correlation.

Once equation (3) is estimated, the half-life of any innovation[5] can then be measured. The half-life measures the time taken for any deviation of the actual spread from its expected value, to be halved. A short half-life implies quick elimination of information asymmetries and order imbalances in the market place. A longer half-life implies that spreads have fairly longer cycles. Following Randolph (1991) the half-life is determined as follows:

$$h_{it} = \frac{\ln 2}{\alpha_i} \qquad ..(4)$$

We next propose a general model of price transmission in vertical markets. Here, we posit that, changes in retail spreads are, not only a function of the direction and magnitude of wholesale spread and farm prices, but also, is affected by the magnitude of overshooting of the wholesale spread.

The literature on asymmetric price transmission (non-reversibility) in vertical markets is extensive. Houck (1977) and earlier Wolffram (1971) have suggested an approach based on segmenting the explanatory variables involved, into positive and negative changes. These are linear models that help us understand whether for example, a positive or negative net relation exists between changes in the retail prices and, changes in the wholesale spreads and farm prices. Gardner (1975) and Heien (1980) offer equilibrium models for explaining differential impacts of changes in supply and demand on wholesale and retail prices that cause asymmetric price transmission. Wohlgenant (1985) offers an explanation based on the inventory control behavior using the rational expectation framework to examine the relationship between retail and wholesale prices. This is perhaps the first model that explains the role of inventories in the relationship between wholesale and retail spreads. Finally, Taubadel (1998) has proposed a model that is consistent with cointegration between prices at various levels in the market hierarchy.

While all the preceding models offer interesting insights into the price transmission process in vertical markets, there still is an important lacuna. For instance, none of these papers examine the role of profit seeking by the wholesalers in the process of price transmission. Changes in retail spreads are not only a function of the direction of changes in wholesale spread, and the farm price, but also, a function of the degree of stability of the changes in the wholesale spreads. If the changes in the wholesale spread are stable, i.e., if there is no overshooting then, it implies no order imbalance or information asymmetry at the wholesale level. This issue is especially important in the light of causal relationships that exist between wholesale spreads and retail spreads. If there exists bi-directional causality, then, there can be feedback effects that will influence the degree of asymmetric price adjustments at the retail level. Another problem with these papers is that, the various markets in a given economy are treated as distinct entities. It is possible that both wholesale and retail markets across space could be informationally linked. This will affect price transmission within any vertical market.

We therefore propose a general method of estimating price transmission in vertical markets by endogenising the tendency of the wholesale spreads to overshoot. This is done by introducing a partial adjustment component (along the lines of Marsh (1994)) into the model for estimating the process of price transmission. Wholesalers are constantly engaged in dynamic information acquisition. In a perfect foresight world, this will not have any impact on the process of price transmission in vertical markets. However information asymmetry is endemic to vertical markets. In this context dynamic information acquisition will induce instabilities into the system. This process is therefore endogenised in the model of price transmission as in Chavas and Holt (1993).

Let R_{it} be the retail spread in market i at time t, and, W_{it} and F_{it}, the corresponding wholesale spread and farm prices. The target spread at the wholesale level which is unobservable, is SP^*_{it}. We segment the variables W_{it} and F_{it}, in the manner prescribed in Houck (1977) into positive and negative changes. Hence;

$W^{+}_{it} = W_{it} - W_{it-1}$ if $W_{it} > W_{it-1}$, and = 0 otherwise ...(a)

$W^{-}_{it} = W_{it} - W_{it-1}$ if $W_{it} < W_{it-1}$ and = 0 otherwise ...(b)

$F^{+}_{it} = F_{it} - F_{it-1}$ if $F_{it} > F_{it-1}$ and = 0 otherwise ...(c)

$F^{-}_{it} = F_{it} - F_{it-1}$ if $F_{it} < F_{it-1}$ and = 0 otherwise ...(d)

Using this, we can write the model of price transmission in each market as:

$$\Delta R_{it} = \alpha_{i0} + \alpha_{i1}\Delta W^{+}_{it} + \alpha_{i2}\Delta W^{-}_{it} + \alpha_{i3}\Delta F^{+}_{it} + \alpha_{i4}\Delta F^{-}_{it} + \beta_i (SP^*_{it} - SP_{it-1}) + \varepsilon_{it} \quad \text{...(5)}$$

Where β_i measures the rate of overshooting of the wholesale spread in market i. The term (SP^*_{it} - SP_{it-1}), captures the deviation of the wholesale spread from its target value. The target SP^*_{it} spread is a function of inventory level (measuring the order imbalance in the system), and, the lagged retail selling price. We can therefore write the target spread as follows

$$SP^*_{it} = \gamma_i (st_{it-1}, rtl_{it-1}) \quad \text{...(6)}$$

Where, st_{it-1} is the wholesale inventory (stocks) at time t-1, and, rtl_{it-1} is the retail selling price at time t-1. Substituting equation (6) in equation (5) and expanding, we have

$$\Delta R_{it} = \alpha_{i0} + \alpha_{i1}\Delta W_{it}^{'} + \alpha_{i2}\Delta W_{it}^{''} + \alpha_{i3}\Delta F_{it}^{'} + \alpha_{i4}\Delta F_{it}^{''}$$

$$+ \beta_i \gamma_{i1} st_{it-1} + \beta_i \gamma_{i2} rtl_{it-1} - \beta_i SP_{it-1} + \varepsilon_{it} \qquad \ldots(7)$$

We also note that,

$$R_{it} = R_{i0} + \sum_{t=1}^{n} \Delta R_{it} \qquad \ldots(8)$$

Where, R_{i0} is the initial value of the retail spread in market i at any point in the time interval. We can write (8) as follows

$$R_{it} - R_{i0} = \sum_{t=1}^{n} \Delta R_{it} \qquad \ldots(9)$$

Which is the sum of the period to period changes in retail spreads. Recognizing this for the other segmented variables in (a) to (c), we can rewrite equation (7) as follows

$$R_{it} - \Delta R_{i0} = \alpha_{i0} + \alpha_{i1}\Sigma\Delta W_{it}^{'} + \alpha_{i2}\Sigma\Delta W_{it}^{''} + \alpha_{i3}\Sigma\Delta F_{it}^{'} + \alpha_{i4}\Sigma\Delta F_{it}^{''}$$

$$+ \beta_i \gamma_{i1} st_{it-1} + \beta_i \gamma_{i2} rtl_{it-1} - \beta_i SP_{it-1} + \varepsilon_{it} \qquad \ldots(10)$$

Equation (10) is now estimated as a nonlinear system of equations for i = 1…n markets in any given economy

The magnitude of the impact of the rate of mean reversion of wholesale spread, on the retail markets is measured by

$$W_{imp} = \frac{\ln 2}{\beta_i} \qquad \ldots(11)$$

Where W_{imp} is the "impact factor" of the half-life of the innovation affecting the wholesale markets. Hence, wholesale markets that are noisy can cause short-term impacts on the retail markets. It is also possible for wholesale markets where mean reversion is absent, to have an impact on the movement of the retail spreads. This reflects the direction of causality in the vertical markets.

We estimate equation (3) and (10) using Indian data on rice for 14 centers that are spatially separated. The Indian rice markets fall into the category of vertical markets (figure (1)) where the middlemen are the wholesalers who purchase grain from the farmer and sell to the retailers. We use weekly data for the period 1990-1994, on wholesale spreads, wholesale selling prices, farm prices, retail spreads and, wholesale inventories, to estimate our model. The next section describes the results of this estimation procedure.

III. Results

The results of the estimation of equation (3) are shown in table 1. The half-life of the innovation is indicated by figure (2). Significant mean reversion takes place in 10 out of the 14 centers. We do not find any market where the spreads tend to move away from equilibrium values rapidly. However, there are 3 markets viz., Ahmedabad, Cuttack and Madurai where, the movement away from the target value is slow. The center where the slowest mean reversion takes place is Lucknow where, it is roughly 39 weeks. We find that the retail prices have a significant positive impact on changes in wholesale spreads in some markets where mean reversion is observed. This is consistent with our maintained hypothesis that any increase in the information asymmetry will lead to an increase in the wholesale spread. The impact of the inventory position with the wholesaler on changes in bid-ask spread is negative in a few centers. This is logical given that the wholesaler will reduce the spread in order to counter order imbalance. However, in a few centers, both retail prices and inventory levels exert positive pressure on spreads.

These results indicate that there is a fair amount of noise in the market place. However, the markets are able to adjust to new information within a short time. The half-life of innovation ranges between 39 weeks in the case of Lucknow, to roughly 3 weeks in the case of Bhuvaneshwar. We posit that the extent of noise in the market is due to the vertical nature of markets where, the various layers create increasing degrees of information asymmetry to the wholesalers. Hence, there is a general degree of instability of spread adjustments at the wholesale level.

One of the more important results of this paper is that we can infer hoarding on the part of the wholesaler by observing the signs on the variables st and rtl. If the signs are positive then, the wholesaler is likely to engage in hoarding. Ordinarily if there is an inventory build up, then, the spreads must narrow. That is, the sign on st must be negative. Also, the response of an increase in retail price is to widen the spread because this is perceived as an increase in demand at the retail level. However if the wholesaler expects the increased demand to persist then, the inventories can have a positive impact on spreads. That is, wholesalers widen the spread to control inventory in anticipation of further increases in retail prices. We notice that this happens in 6 centers viz., Bangalore, Chandigarh, Kanpur, Lucknow, Ludhiana and Shimla, where spreads are overshooting and, in 4 others viz., Ahmedabad, Cuttack, Madurai, and Vijayawada where, the spreads are deviating slowly from the target values. We can perhaps conclude from this evidence that the wholesale markets are not efficient in the short run.

What role does overshooting play in the lower levels of the market hierarchy? The results of the estimation of the generalized model are shown in table (2). First, we detect significant degrees of asymmetric price transmission. The coefficients α_1, α_2, α_3 and α_4 are negative and unequal. This suggests that a negative net relationship between the movements of the retail spreads, wholesale selling price and farm price. A test for asymmetric price transmission is to test the hypothesis whether $\alpha_1 = \alpha_2 = \alpha_3 = \alpha_4$. This is rejected at the 5% level. Second, overshooting tends to widen the retail spreads for the most part. The impact factor, of the wholesale spread is consistently positive and exists even in those centers where, there is no mean reversion of wholesale spreads. We find that innovations at the wholesale level create incentives for retailers to hoard. This is evident from the sign on the variable st. If this is positive the order imbalances widen spreads. This indicates hoarding. This result is applicable to 6 centers viz., Ahmedabad, Bangalore, Cuttack, Kanpur, Madurai and Vijayawada. It is interesting to note that 4 of these centers viz., Ahmedabad, Bangalore, Cuttack and Kanpur are major industrial towns with a large consuming population.

One of the innovations in this paper is the introduction of the partial adjustment term in the process of price adjustment at the retail level. It is imperative that we check whether this generalization is valid. To this end we compute the following non-parametric statistic:

$$\lambda = 2(l(\rho^u) - l(\rho^r))$$

Where $l(\rho^u)$ represents the value of the log of the likelihood function with unrestricted values of the vector of parameters ρ and $l(\rho^r)$ represents the log of the likelihood function with r restrictions. (In our case the restrictions are that all parameters associated with the partial adjustment term are zero). The statistic λ is distributed as a χ^2 with r degrees of freedom (see Davidson and MacKinnon (1993)) under the null hypothesis that the restrictions hold. In the present case the value of λ (with 42 degrees of freedom) is 222.914 which is much higher than the critical value of chi-squared with 42 degrees of freedom at even the one per cent level. These restrictions are, hence, strongly rejected, indicating that the more general model of price adjustment presented in this paper is more suitable. Results for the restricted model are reported in Table 3. Even though we continue to detect asymmetry in price transmission, we fail to reject the hypothesis of equality of the coefficients α_1,α_2, α_3 and α_4 at the 5% level of significance for all centers. For some centers we can reject this at 10%. This reinforces our claim that endogenising the instability at the wholesale level into the model of price adjustment at the retail level significantly influences asymmetric price transmission.

IV. Conclusions

The paper used a non-linear model with partial adjustment to examine the dynamics of BAS in the wholesale markets for rice in India. It is found that there are significant levels of short run inefficiencies in the markets. The paper also proposes a generalized model of examining the dynamics of retail spreads when, the overshooting behavior of wholesalers is endogenised. The results indicate that significant possibilities for hoarding exist at the retail level. A test of the functional form indicates that the general model is indeed more appropriate for examining the various types of price dynamics at the retail level.

Notes

1. Wholesale markets are efficient if the following features are satisfied

a) The first feature is that the expected real spread returns should be constant and equal to the real interest rate. This is especially important, since, wholesalers often borrow from the banks for purchasing grains. If the real interest rate is constant over a period of time, the spreads will grow over this time period along a straight line with a slope equal to the interest rate.

b) If the wholesale markets are efficient then spreads should reflect the true nature of supply and demand conditions in the market. That is, spreads will change, if and only if, wholesalers get new information about expected changes in the supply and demand.

c) Finally, in an efficient market, if there is a sudden change in spreads, the wholesalers should not believe that these abnormal values would continue to persist in the future. In other words, if spreads rise more than expected, wholesalers should not expect these spreads to continue to grow at this abnormal rate just because they did so in the past.

2. The stipulation that the target spread is unobservable is common in the market microstructure literature in finance. See George, Kaul and Nimalendran (1993).

3. Order imbalances (inventory imbalance) occur, when the wholesaler moves away from his optimal inventory position. Since the wholesalers in India are operating in a Fooling environment, they will not be able to perfectly forecast the changes in supply and demand. This implies that the order imbalance will persist and change over time.

4. This is done for the following reasons. First as shown in table (1), the across the center correlations are fairly high. Hence, this technique will capture the contemporaneous cross-center correlations. Secondly, given that markets can be integrated, it is only logical that we estimate mean-reversion in this manner. Integrated markets transmit changes in the information quickly across the economic space.

5. Innovation is defined as an information shock that causes information asymmetries. This will have a bearing on the future prices, and the traded volumes. We might expect the current spreads to adjust in order to reflect these informational asymmetries. In the world of rational expectations, the change in the current spread will equal the expected change and, more importantly, the time taken for any spread adjustment is nearly zero. We however assume that the wholesalers have imperfect information regarding future prices and volumes causing spread adjustments to be sluggish. Government announcements regarding procurement/support prices, sudden strikes, information regarding monsoons, etc., constitute innovation, since these will affect the true price perceptions of the wholesalers.

Table 1

Results of the Estimation of the Non-Linear System of Equations[3]

Center	Explanatory variables			
	Alpha	constant	rtl	st
Ahmedabad	-.0024 (-1.4940)	-129.72 (-5.5796)	25.561 (4.6021)	.013 (1.0499)
Amritsar	.1793 (2.6201)	2.9458 (1.4923)	.802 (1.9851)	-.105 (-12.9243)
Bhubaneshwar	.2345 (2.0644)	4.6421 (1.5694)	1.4461 (2.6091)	-.0619 (-22.09)
Bangalore	.0743 (11.79)	181.17 (6.0531)	39.209 (5.2261)	.024 (3.98)
Chandigarh	.1564 (3.3501)	7.4859 (2.8574)	1.071 (1.9812)	.0004 (2.271)
Cuttack	-.0024 (-5.2309)	-178.62 (-4.1393)	35.018 (3.7648)	.049 (4 9774)
Karnal	.1522 (3.6674)	1.0117 (.62398)	.734 (1.9524)	-.016 (-6.9421)
Kanpur	.1931 (3.1252)	2.3639 (1.5956)	.539 (1.9977)	.0261 (2.932)
Lucknow	.018 (12.9953)	164.11 (4.6464)	30.833 (4.7372)	.0085 (2.2992)
Ludhiana	.0852 (1.9709)	5.8926 (1.3382)	1.8311 (1.9755)	.0574 (3.4621)
Madurai	-.0032 (-1.7143)	-163.61 (-6.8943)	30.710 (7.6543)	.0368 (2.7421)
Patna	.2707 (5.2143)	2.0177 (2.8433)	.2701 (1.9846)	-.0634 (-3.2744)
Shimla	.5969 (8.0208)	1.2592 (3.1622)	.034 (1.8362)	.0906 (5.2126)
Vijayawada	-.00009 (-.9750)	-112.06 (-3.7162)	43.158 (2.725)	.024 (1.976)

[3] Log of likelihood function: -539.4435, figures in parentheses indicate t-values.

Table 2

Nonlinear model of price transmission with endogenous overshooting[4]

Centre	Independent Variables							
	constant	$\Sigma\Delta X'$	$\Sigma\Delta X''$	$\Sigma\Delta Z'$	$\Sigma\Delta Z''$	beta	rtl	st
Ahmedabad	1.040 (2.3972)	-.041 (-2.9577)	-.047 (-2.4533)	-.246 (-2.3431)	-.517 (-1.9837)	.059 (3.1421)	.050 (2.50)	1.970 (7.2388)
Amritsar	1.987 (5.4537)	-.1708 (-9.2331)	-.726 (-6.003)	-.789 (-8.4628)	-1.447 (-10.423)	.084 (9.5705)	8.220 (8.0604)	-.019 (-5.0311)
Bhubhaneshwar	1.040 (2 37)	-.054 (-3.58)	-.0003 (-1.985)	-.191 (-2.01)	-.313 (-1.85)	.072 (4.97)	3.961 (3.22)	-.923 (-22.948)
Bangalore	.455 (2.36)	-.274 (-2.98)	-.011 (-1.31)	-.028 (-1.95)	-.886 (-5.44)	.051 (4.16)	4.206 (4.22)	.068 (3.58)
Chandigargh	1.174 (1.63)	-.221 (-1.78)	-.081 (-2.91)	-.573 (-3.41)	-.764 (-2.81)	.128 (8.74)	1.651 (1.423)	-.0005 (-4.9962)
Cuttack	.870 (2.93)	-.533 (-6.92)	-.0007 (-7.93)	-.108 (-5.48)	-1.417 (-7.41)	.178 (9.82)	3.382 (3.91)	1.151 (6.22)
Karnal	1.262 (2 32)	-.099 (-5.48)	-.991 (-1.29)	-.111 (-8.61)	-1.198 (-5.62)	.130 (7.21)	.538 (2.499)	-.325 (-15.478)
Kanpur	.581 (1.91)	-.026 (-2.99)	-.081 (-4.21)	-.0002 (-2.43)	-.603 (-3.24)	.048 (2.57)	4.714 (6.32)	.082 (5.83)
Lucknow	.612 (1.50)	-.160 (-7.32)	-.00007 (-2.49)	-.051 (-2.63)	-.396 (-1.44)	.0897 (6.85)	2.157 (2.48)	-.013 (-5.43)
Ludhiana	1.583 (4.22)	-.052 (-3.62)	-.012 (-1.97)	-.050 (-2.71)	-.400 (-2.53)	.064 (5.65)	1.747 (2.12)	-.467 (-7.09)
Madurai	1.780 (2.14)	-.064 (-5.22)	-.00016 (-5.38)	-1.045 (-5.10)	-.763 (-3.36)	.060 (5.33)	1.745 (2.67)	.236 (38.67)
Patna	.573 (1.69)	-.033 (-2.44)	-.012 (-1.97)	-.042 (-2.13)	-.595 (-2.44)	.052 (6.23)	10.476 (11.04)	-.044 (-2.41)
Shimla	1.144 (1.97)	-.049 (-3.45)	-.012 (-1.87)	-.254 (-1.82)	-1.375 (-6.35)	.075 (5.42)	3.000 (3.44)	-.015 (-1.44)
Vijayawada	.474 (1.86)	-.066 (-5.28)	-.021 (-3.36)	-.029 (-1.45)	-.436 (-1.98)	.088 (4.73)	2.632 (2.95)	.189 (9.59)

[4] Log of likelihood function: -555.3591, figures in parentheses indicate t-values.

Table 3

Nonlinear model with the restriction that the partial adjustment part is inoperative[5]

Centre	Independent Variables				
	constant	ΣΔX'	ΣΔX"	ΣΔZ'	ΣΔZ"
Ahmedabad	-.087 (-1.8321)	-1.0125 (-4.3085)	-1.0728 (-4.2578)	-1.3935 (-2.1376)	-1.3679 (-3.3053)
Amritsar	-.0247 (-.9041)	-.4151 (-3.3376)	-.4092 (-1.6277)	-.2113 (-.8179)	-.0315 (-.1216)
Bhubhaneshwar	.0130 (.4451)	-.1422 (-1.3633)	-.1702 (-2.8161)	-.5497 (-1.277)	-.5246 (-1.0831)
Bangalore	.0308 (1.0422)	-.5311 (-1.8509)	-.4759 (-2.281)	-.0171 (-.0459)	-.0025 (-.00048)
Chandigargh	-.0798 (-2.5016)	-1.1091 (-5.1608)	-1.1539 (-4.7457)	-.9627 (-3.1626)	-.9482 (-3.4622)
Cuttack	-.0752 (-1.7811)	-.7911 (-2.0698)	-.7578 (-2.2903)	-.8171 (-2.3120)	-.9533 (-2.2676)
Karnal	-.0306 (-.8397)	-.1584 (-.5742)	-1.4580 (-.1615)	-1.893 (-4.9899)	-.0331 (-.0826)
Kanpur	.0022 (.0531)	-.7588 (-4.4952)	-.7963 (-6.7449)	-.9243 (-3.9409)	-.8954 (-4.0711)
Lucknow	-.0523 (-1.6260)	-1.0533 (-7.2407)	-1.1041 (-.1184)	-.8803 (-3.6762)	-.8501 (-3.090)
Ludhiana	-.0026 (.0982)	-.5936 (-2.7868)	-.5674 (-3.8453)	-.6036 (-3.0134)	-.5990 (-2.3025)
Madurai	-.1021 (-2.5822)	-1.3975 (-7.6266)	-1.4304 (-6.1820)	-1.1806 (-3.9073)	-1.1693 (-4.1551)
Patna	-.0363 (-1.1451)	-1.1005 (-6.3516)	-1.0065 (-6.4999)	-1.4474 (-4.9546)	-1.4586 (-4.4279)
Shimla	-.0412 (-1.1467)	-1.0634 (-7.0636)	-.9850 (-7.4888)	-1.1243 (-6.4496)	-1.2129 (-5.8385)
Vijayawada	-.0202 (-.6779)	-.6253 (-3.1240)	-.6466 (-4.062)	-1.1947 (-3.697)	-1.2304 (-3.3729)

[5] Log of likelihood function: -443.9024, figures in parentheses indicate t-values.

Table 4

Relationship between Convergence Rate and Half Life of Innovations

Center	Convergence rate of wholesale spreads	Half life of innovations at the wholesale level in weeks	Impact factor of shocks at the wholesale level
Ahmedabad	no mean reversion	-	11.748
Amritsar	0.179	3.866	8.252
Bhubaneshwar	0.235	2.956	9.627
Bangalore	0.074	9.329	13.591
Chandigarh	0.156	4.432	5.415
Cuttack	no mean reversion	-	3.894
Karnal	0.152	4.554	5.332
Kanpur	0.193	3.590	14.441
Lucknow	0.018	38.508	7.727
Ludhiana	0.085	8.136	10.830
Madurai	no mean reversion	-	11.552
Patna	0.271	2.561	13.330
Shimla	0.597	1.161	9.242
Vijayawada	no mean reversion	-	7.877

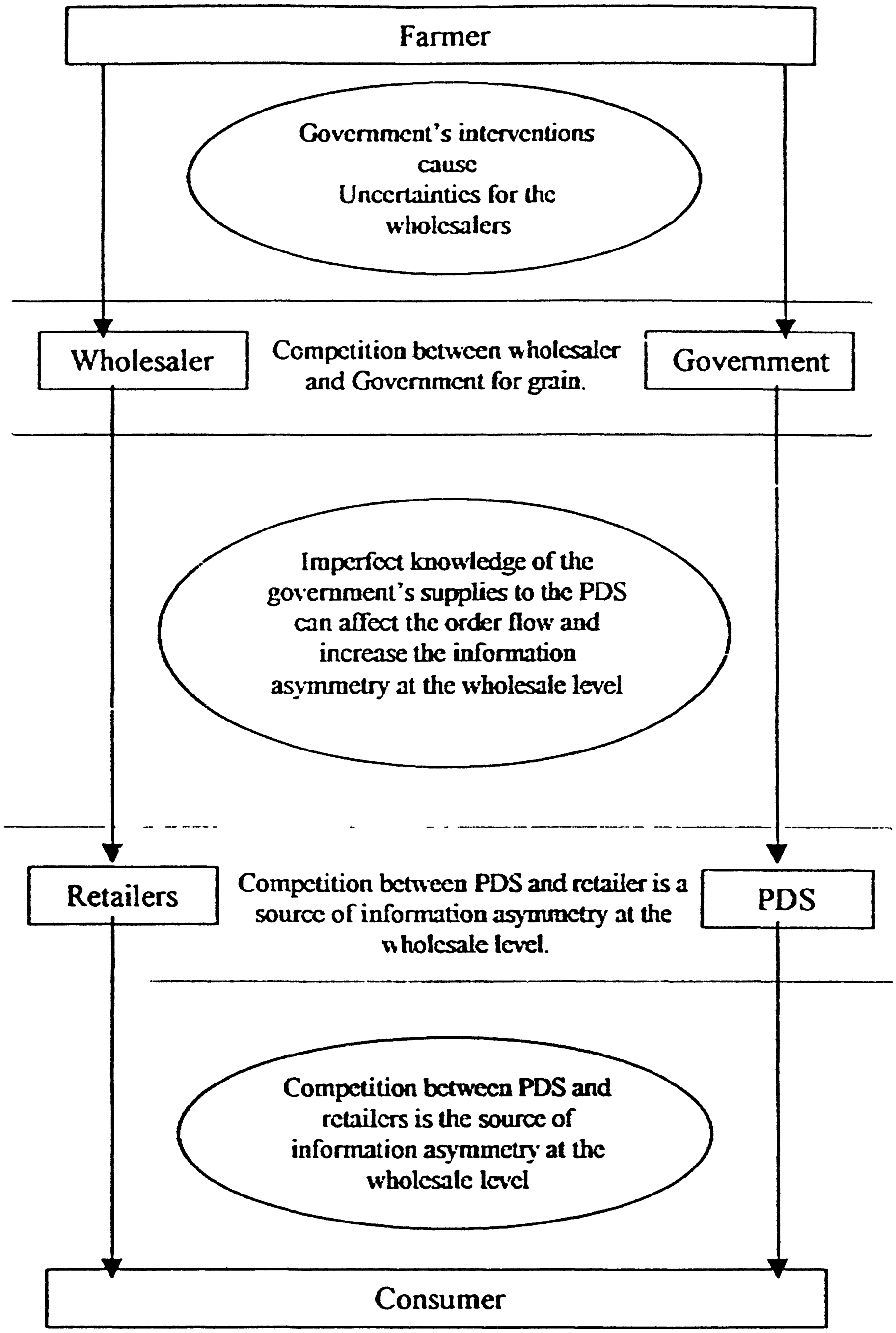

Figure 1

Structure of Rice Markets in India

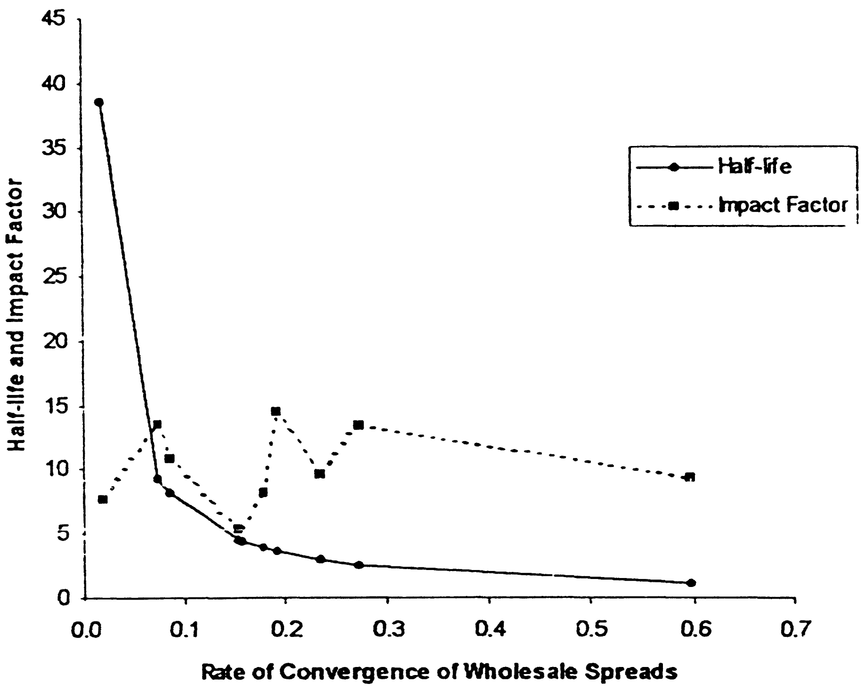

Figure 2

Rate of Convergence of Wholesale Spreads and its Impact on Retail Spreads

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