Components of the wholesale bid-ask spread
and the structure of grain markets:
the case of rice in India

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Abstract

We investigate the market microstructure of the wholesale markets for rice in India. We propose a general method of splitting the wholesale bid-ask spread into its three constituent components: the order processing costs, the adverse information costs and the inventory holding costs. The bid-ask spread reflects the extent of information asymmetry and order imbalance in the market place. However, the dynamics of the bid-ask spread can only be understood in terms of the movement of its components; hence the importance of isolating these components. We use Zellner's seemingly unrelated regressions to split the bid-ask spread into the three components in the rice markets of 14 major centers in India. The results are then linked to the production and consumption patterns in the market areas covered by these centers. © 1999 Elsevier Science B.V. All rights reserved.

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1. Introduction

An important constituent of the volatility of retail prices in a vertical market, such as most agricultural markets in India is the movement in the wholesaler's

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[1]The wholesaler's margin is the BAS less his cost.

bid-ask spread (henceforth BAS)[1]. The BAS is defined as the difference between the wholesaler's selling price (the price at which the wholesaler sells to the retailer (ask price), and his purchase price (the price at which the wholesaler buys from the farmer (bid price)). Clearly the BAS and its dynamics will mediate between the wholesale and the retail price and affect both the level of the retail price as well as its volatility. However, the extant literature on the trans-

mission of price changes from one level of market to other(s) (e.g. Houck, 1977; Wolffram, 1971; Wohlgenant, 1985; Bailey and Brorsen, 1989; Taubadel, 1998) has ignored the role of the dynamics of the BAS[2].

In contrast, the market microstructure literature in financial economics (Roll, 1984; Stoll, 1989; George et al., 1991, (henceforth GKN) among others), has traditionally recognized the importance of the BAS in influencing movements of stock prices and considers it important to split up the spread into its three components: the order processing cost (opc); the inventory holding cost (ihc); and the adverse information cost (aic). The dynamics of prices in agricultural markets cannot be understood completely without analyzing the BAS. However, the dynamics of the BAS, itself, can be understood only in terms of the movement of its constituents. If these components can be isolated, then, the reasons for the movements of the BAS can be understood and used for advancing policy recommendations.

In this paper, we carry the basic insights of the microstructure literature in finance into the study of the components of the BAS in vertical agricultural markets. We propose an alternate and in our view, a more general method of splitting the spreads into its components.

The present paper differs from the existing literature on the microstructure of BAS behavior in several important aspects. First, this literature assumes that the spreads are time invariant, whereas this is actually an empirical proposition to be tested. In particular, this assumption seems unrealistic in the context of dynamic information acquisition and dissemination in grain markets. We allow for the possibility that these cost components change over time in response to information asymmetries occurring in the markets[3].

Second, a branch of the literature, for example, Afflect-Graves et al. (1994), and Stoll (1989), has examined variables that determine the variations of the spread in cross-section data (typically for stocks of various firms in the stock market). Since we are using aggregate prices for the same quality of rice in various centers, variety induced cross-sectional variations are, as such, absent. Our focus is, hence, on isolating those variables that explain the fluctuations over time of the BAS.

Third, the literature on the estimation of the spread components (Stoll, 1989; GKN, 1991) has relied on indirect procedures. These methods would not be helpful in showing the relationship between the underlying economic variables, such as value of the grain, traded volume and information shocks on BAS and its components. For example, it is not clear how an informational shock alters the adverse information cost component. Hence, existing methods are of limited predictive use when it comes to the components of the spreads, particularly in grain markets. In this paper, we explicitly identify the variables, which have an impact on the spread components and advance a new, and arguably a more suitable, method for splitting up the spread in the context of agricultural markets in 14 major rice trading centers/markets in India.

The plan of the paper is as follows. In the Section 2, we discuss the structure of rice markets in India. Section 3 details the data and the model used in the estimation and the results are discussed in Section 4. Section 5 concludes.

2. Structure of rice markets in India

Rice markets in India are vertical. Multiple layers of traders, each occupying a distinct position in the market hierarchy and performing a specific role, characterize such markets. In such markets, when demand or supply shocks travel from one level of the market to

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[2]This literature has, however, provided useful insights into the operation of vertical markets. For example, Bailey and Brorsen (1989), Taubadel (1998) have shown that the market structure of the trading system may lead to a difference in the speed with which traders react to shocks that raise prices as compared to those that lower them. Gardner (1975) shows that changes in demand or the rate of arrivals at the wholesale level can have differential impacts on prices at the wholesale level. Kinnucan and Forker (1987) point out that government intervention in the market place may lead to the emergence of menu costs which then leads wholesalers to interpret any price increase as a permanent feature. While all these results are important and interesting, a similar effort to model the BAS has been missing.

[3]In our specific case, since we allow week by week variations in the spread components we capture temporal movements in the BAS, including any seasonal behavior completely. We are grateful to an anonymous referee for drawing our attention to this.

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                    ┌─────────────────────────────────────┐
                    │              Farmer                 │
                    └─────────────────────────────────────┘
                            Government's interventions
                                      cause
                            uncertainties for the
                                 wholesalers

         ┌──────────────┐  Competition between wholesaler  ┌──────────────┐
         │  Wholesaler  │  and Government for grain        │  Government   │
         └──────────────┘                                  └──────────────┘

                         Imperfect knowledge of the
                         government's supplies to the PDS
                         can affect the order flow and
                         increase the information
                         asymmetry at the wholesale level

         ┌──────────────┐  "Competition" between PDS and the  ┌──────────┐
         │  Retailers   │  retailers                          │   PDS    │
         └──────────────┘                                     └──────────┘

                         Competition between PDS and
                         retailers is the source of
                         information asymmetry at the
                         wholesale level

                    ┌─────────────────────────────────────┐
                    │              Consumer               │
                    └─────────────────────────────────────┘
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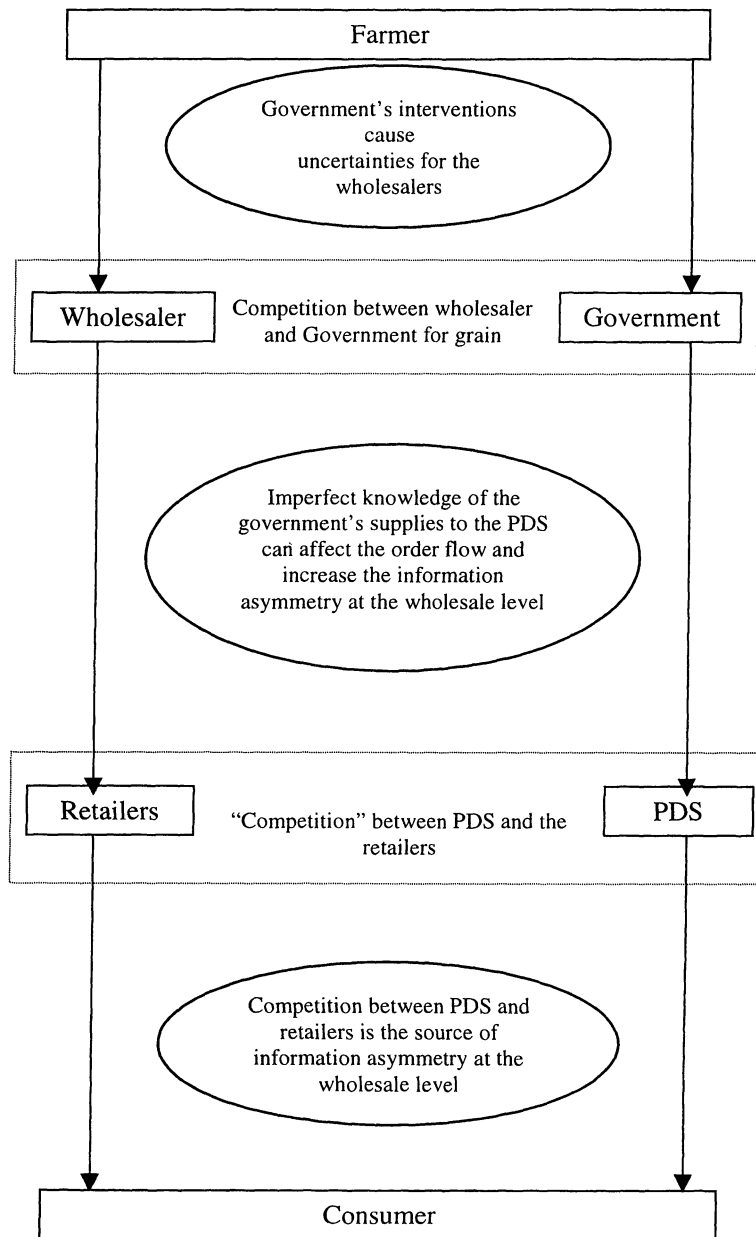
Fig. 1. Structure of rice markets in India.

another, information asymmetries and order imbalances are created due to various frictions (for example, differences in information on the availability of grain across buyers and sellers) existing at different levels. This causes the BAS to fluctuate continually. Another feature of these markets (in India) is their dual nature.

As shown in Fig. 1, there are two parallel hierarchies. The link between the farmer and the consumer through the government is the controlled hierarchy of trade while the one that has the wholesalers playing the role of the intermediary is the free market hierarchy. Controlled markets have been introduced for two

reasons: (i) welfare purposes such as providing rice at subsidized rates; and (ii) controlling the volatilities that naturally arise out of vertical markets.

In the controlled hierarchy, the government procures rice from the farmers at various times during the year. There are two types of procurement, namely (a) procurement for enhancing the buffer stocks with the government and (b) procurement of the 'surplus' grain with the farmers. These forms of procurement are effected at the procurement and the support prices, respectively. Both these prices are announced just after the start of sowing, namely in May and in August/September for the two growing seasons. The procurement price is set at a slightly lower level than the support price and the government makes mandatory the procurement of a part of the rice output at the former price. Procurement is done through the various state food corporations (SFC) at various times in a year. On the other hand, the support price acts as a guarantee to the farmer in the form of an outlet for the produce if the market price falls below this price. However, there is no guarantee that the government will intervene whenever the market price falls below the support price. Intervention at the support price is conditioned by the government's perception of the surplus levels with the farmers, its own buffer stock positions and retail price movements. The procured grain is then issued to the various 'fair price shops' of the public distribution system (PDS), at the issue price, which is lower than the purchase price from the farmers. These shops form the controlled retail market for rice.

The dynamics of the free market are different from those of the controlled market. The wholesalers purchase rice from the farmers at the harvest price (bid price) and process this in mills either controlled by these wholesalers or operating independently. The processed grain is sold to the retailers at the wholesale selling price (ask price).

The wholesale market for rice resembles a call auction market where there is a temporal aggregation of both sell and buy orders which, themselves, come in at various prices with the final settlement being made at the best sell and buy price. Hence, such markets are characterized by continuous order imbalances that are cleared periodically. The Indian rice markets at the wholesale level, however, resemble the call auction market at the clearing stage only. In any given week,

the offers to sell from the farmers come at a single price (this is caused by the government's attempt to control prices at this level) whereas bids to buy come at different prices depending upon the nature of the buyers. We can therefore expect a fair degree of week to week fluctuation in the wholesale ask price while the bid price is slow to adjust. The wholesale buying price and the consequent selling price to the other constituents of the hierarchy depends to a large extent, on the nature of uncertainties prevailing in the market hierarchy.

Broadly speaking, these uncertainties take three forms: (a) uncertainties caused by government interventions through procurement/support prices; (b) uncertainties caused in the transition of grain from the Government to the PDS; and (c) uncertainties caused by the competition between the retailers and the PDS. We now discuss briefly the expected impact of these uncertainties on the movement of spreads.

2.1. Uncertainties due to government intervention through procurement/support prices

The government procures grain from the farmers after the announcement of the appropriate procurement/support prices. These prices are upward revisions of the past procurement and support prices. The wholesalers' bid prices are equal to or greater than these prices. The announcement of procurement/support prices by the government causes the true value of rice as perceived by the wholesaler's to change. For the wholesalers the true price is the midpoint of the BAS. With every revision, the mid-point shifts. Such a revision is inevitable since the wholesaler has to increase the bid price and make appropriate adjustments to the ask price in order to efficiently compete in the market. The BAS is, thus, revised upwards. This is shown in Fig. 2 where the spread has adjusted upwards in order to 'compensate' for the upward movement of the support prices.

Another cause for constant pressure on the spreads is the fact that quantity and frequency of procurement are unknown. If the frequency of intervention and the magnitude of procurement are unknown then there is an increase in the information asymmetry at the wholesale level. This will make the wholesalers change the bid prices continuously in order to be able
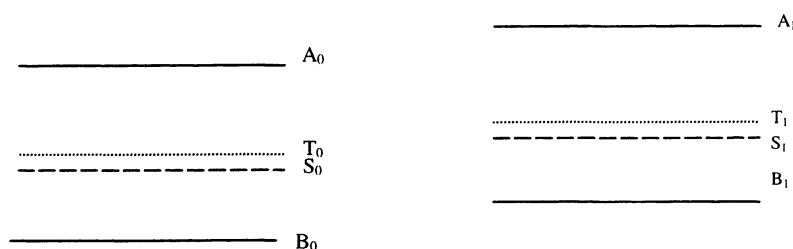
Fig. 2. The true price (T_0) has to be equal to or greater than the support price (S_0).

to effectively procure from the farmer and, thus, result in a revision of the midpoint of the BAS.

2.2. Uncertainties caused by the amount of stocks with the Government

This takes place due to imperfect knowledge at the wholesale level, regarding the stock position with the various SFC. Since these government controlled SFC supply the PDS, knowledge of the stock levels with the SFC will influence the inventory levels and the procurement activities of the wholesalers. If the wholesale markets are situated primarily in consumption zones with low local production, then the wholesalers have to incur high procurement and storage costs. To the extent that these stock levels are not known, we will observe volatility of spreads, *ceteris paribus*, whenever there is an increase in the uncertainty at the wholesale level.

2.3. Uncertainties arising from competition between retailers and the PDS

During any given week, the quality of rice available from the PDS shops could be coarse, fine or superfine. The price charged will vary accordingly. However, both consumers and retailers are imperfectly informed about the quality of and hence, of the price of rice. Since, on average (for an average quality of rice) the PDS price dominates the retail price, given the uncertainty regarding the quality, the retail spreads fluctuate widely. In the context of vertical markets, there will be a feedback effect on the wholesale spread. If the retail spreads narrow or widen then, the wholesale spreads will also have to adjust accordingly to reflect this. Another factor that affects the wholesale spread is the stock levels with the PDS. An imperfect knowledge of

this will affect the retail spread, which in turn will influence the wholesale spread.

These three types of uncertainties influence not only the structure but also the volatility of the BAS. The BAS may, for instance, overshoot their equilibrium values. The process of returning to equilibrium might be spread over several weeks.

The movements in the BAS, induced by the aforementioned uncertainties will be reflected in a movement in the components of the BAS. If, for example, an increase in retail demand increases the true price of the commodity, these components may change in such a manner that the net BAS movements around the true price are symmetric. This is shown in Fig. 2. If the change in retail demand is predicted 'accurately' by the wholesalers, then the magnitude of the information asymmetry is unaffected and so too is the order imbalance. Hence, none of the cost components is affected. There is also no reason for the spreads to change further (Fig. 3) when spread from time t_1 = spread at time t_0). However, this is not the only case possible. Spread adjustments can depend on the inventory position of the wholesaler and the expected information asymmetries in the system.

The market microstructure literature (for example, Stoll, 1989) posits two broad types of spread changes in response to inventory imbalance, information asymmetry, or both:

(i) *When inventory level is of concern.* This is caused either by the uncertainties that exist at the level of the farmer or the government or the retailers, or by the uncertainties arising simultaneously from all three sources (Fig. 1). Since the wholesaler competes with the government for rice from the farmers the magnitude of procurement by the government will cause inventory imbalances. Another source of inventory imbalance is the uneven releases of rice from the
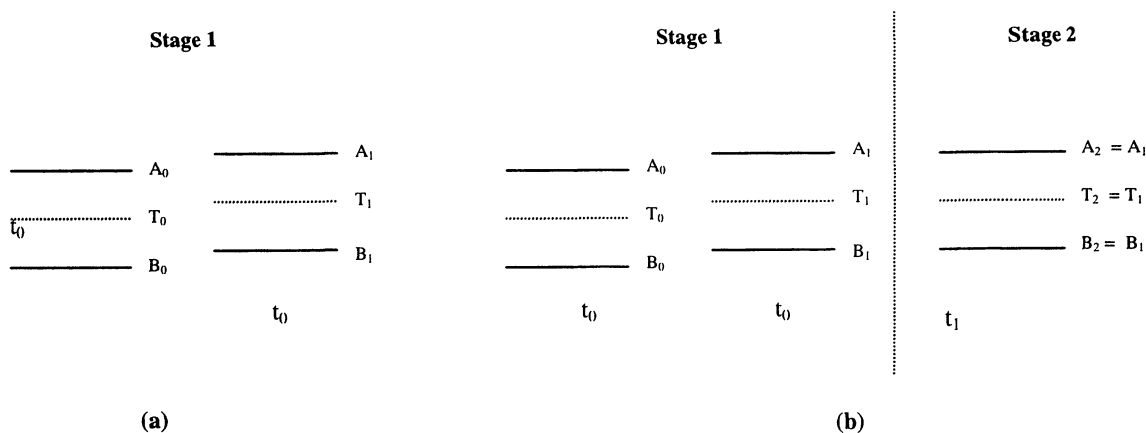
Fig. 3. The change in spread when the inventory levels is of no concern.

government to the PDS. This will affect retail demand, which will, in turn, influence the quantum of sales by the wholesalers to the retailers. A third source of inventory imbalance is the demand fluctuation caused by the influence of the PDS on the retailers. The result of such inventory imbalance is a change in the inventory holding costs. This brings about changes in spreads of different magnitudes depending on whether there is excess inventory or the wholesalers are left with less than optimal inventory.

In the first case, if the retail demand changes (let us say it increases), then, given excess inventory at the wholesale level the spread will narrow. The narrowing of the spread is accomplished either by lowering the

ask price or lowering the bid price or both (between t_0 and t_1). This is shown in Fig. 4(a) and (b). With excess inventory the elasticity of supply of the wholesalers increases. We also note from these figures that the adjustment of the bid and ask prices between time t_0 and t_1 is not symmetric. This is because the farmers' elasticity of supply is low during the harvest season since the government is procuring. Hence, the wholesalers will not lower the bid price to control inventory when the availability of grain is plentiful or, at any point at which it is known that the government will procure. During the 'off-season' or those periods when government intervention is absent, the wholesaler can reduce supply from the farmers sharply by lowering
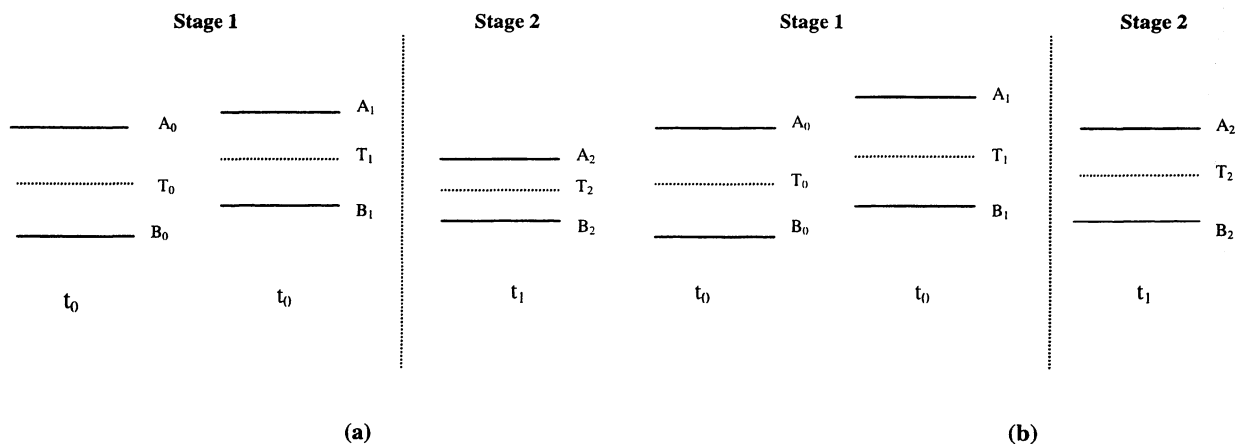

Fig. 4. Change in spread when there is excess inventory (a) During procurement (harvest) season (b) During off-season.
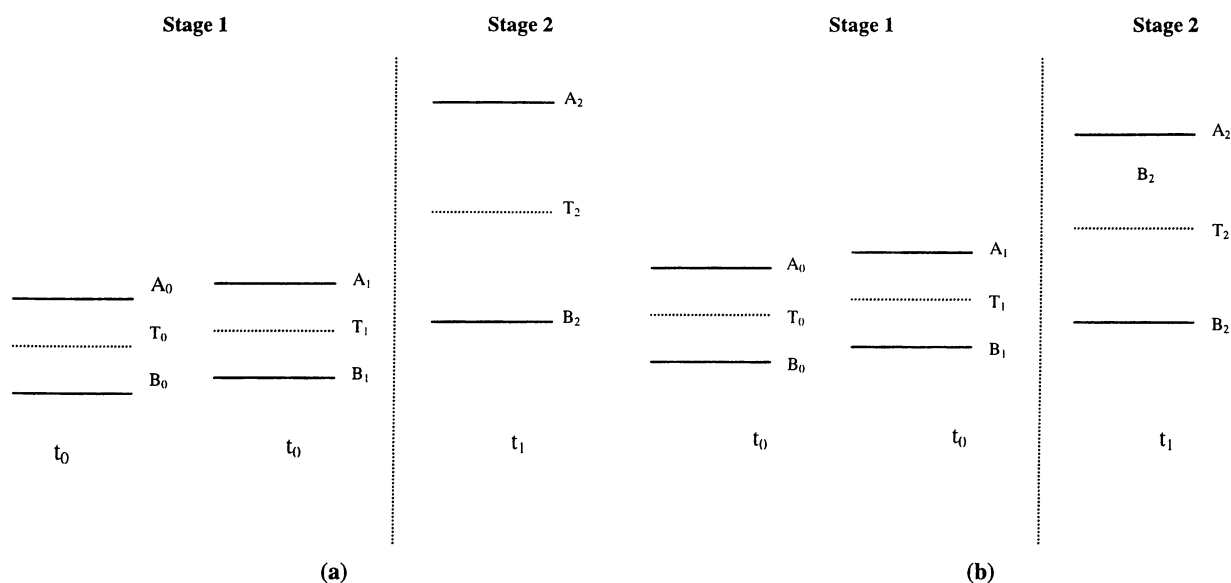
Fig. 5. Change in spread when there is less than optimal inventory (a) During regular season (b) During off-season.

the bid-price marginally. The retail demand is however inelastic since, the only source of supply for the retailer is the wholesale market. Given this asymmetry at the farmer and the retail levels, the wholesaler is able to reduce inventory imbalances by narrowing the spread.

If the wholesaler has less than optimal inventory levels during the off-seasons then widening the spread rectifies this. This is shown in Fig. 5. Here, the ask price has increased from A_1 to A_2 in response to an increase in demand accompanied by inventory imbalance. Wholesalers faced with a relatively elastic supply from the farmer, hike the bid price marginally. The increase in the ask price is usually greater than the corresponding increase in the bid price. This is due to the retailers' tendency to hold on to inventories that are in excess of the optimal quantities as they foresee temporary stockouts at the wholesale level. We therefore once again observe asymmetric adjustments in ask and bid prices.

(ii) *Change in retail demand accompanied by a change in the information asymmetry.* Information asymmetry is created whenever we have changes in the uncertainties associated with procurement prices, timing of procurement, stock availabilities at the PDS, etc. In addition there may be other generic uncertain-

ties, such as production fluctuations, changes in the consumption pattern at the retail level, monsoon forecasts, revisions to these forecasts, etc. Imperfect knowledge about any of these creates information asymmetry at the wholesale level. This would influence the adverse information cost component and cause the spread to fluctuate.

The dynamics of spread adjustment in this case is similar to that shown in Fig. 4(a) and (b) and in Fig. 5. Information asymmetry will cause true price revision which, in turn, will affect inventory levels with the wholesalers. In terms of the dynamics shown in Fig. 4(a) and (b) and Fig. 5, the second round impact of information asymmetry (that is between t_0 and t_1), is similar to that caused by inventory imbalance. This implies that there is a common set of factors affecting more than one BAS component. Information asymmetry can cause all the three components of spread to fluctuate. Another source of information asymmetry is unanticipated information shock. These shocks revise the true price of the wholesaler, following which the spreads adjust in the same manner as when reacting to an inventory imbalance. Examples of such shocks are unannounced transport strikes, natural disasters, policy shifts on the part of the government in relation to local procurement, etc.

This discussion warrants the following four conclusions:

1. Uncertainties at the various levels of the trading hierarchy cause order imbalances and information asymmetries.
2. Changes in these uncertainties need not have any impact on information asymmetry. This implies that the adverse information cost component may not be affected and the spreads may change mainly due to fluctuation in the inventory and the order processing costs.
3. If these uncertainties create information asymmetries, then, we may expect all three components of the spread to change.
4. The market could effectively ignore new information and cause the spreads to remain constant over short intervals.

Given our understanding of the cause and the structure of spread fluctuations, we are now able to identify broad variables that could be used to estimate the spread components. These are:

1. the true price perceptions of the wholesalers and the retailers;
2. volume;
3. stocks; and
4. the overall change in spreads.

We now use these to model the BAS components.

3. Data and the model

The extent and frequency of rice crop varies across India. In the northwestern states, only one crop is grown while in the Gangetic plains at least two crops are grown. Up to two crops are grown in the northeastern areas of the country, such as Bihar and coastal Orissa. In the south, there are regions where three crops are grown and the acreage is very high. For instance, in the coastal and delta districts of Andhra Pradesh three crops are grown. This is also the case in the Thanjavur district of Tamil Nadu. Additionally, the magnitude of local rice consumption varies widely across the country. We have chosen 14 centers to reflect the diversity of production and consumption patterns in India. Table 1 shows the centers, and the

average output per crop in the district surrounding these centers. Weekly data on wholesale selling price (ask price) harvest price (the bid price), volumes and retail prices for the years 1990 to 1992 are used. The Ministry of Civil Supplies, Government of India, provided the data. All data referred to are for fair average quality (FAQ) of rice.

We propose a general model for decomposing spreads into the three components[4]. Our model is different from that used in the extant literature such as in Stoll (1989) and GKN (1991) for the following reasons. (i) The agricultural markets in India are not explicitly auction markets. The market microstructure literature on spreads assumes the existence of an auction market where the auctioneer (the market maker) makes quotes. Given that the grain markets function alongside a controlled market, the question of a market maker for a grain does not arise. There usually is a prevailing price at which the wholesaler buys from the farmer. The price is the 'realized' price. Therefore, in this sense, there is no difference between quoted and realized spreads. This also enables us to get around the need for using transaction prices. We are then able to obviate the need to use covariance measures for deriving the spread components. (ii) The Stoll (1989) model is also rendered inappropriate for

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[4]Empirical financial economists have extensively studied spreads and spread components. Methods used to estimate spreads and its components are to a large extent indirect ones. For instance, GKN (1991) make a distinction between quoted spreads and estimated spreads. The estimated spreads are derived using either the covariance of the transaction price changes or, covariance of the difference between transaction returns and bid-price changes. These are then regressed on the quoted spreads to infer spread components. Coefficient of the quoted spread in the regression is the order processing cost. Since GKN (1991) assign little importance to inventory holding cost, the remainder is naturally the order processing cost. Stoll (1989) also estimates spread components using covariance measures. Two measures of covariance are identified, namely the covariance of transaction prices, and the covariance of quoted prices. These two measures depend to a large extent on (i) the probability of price reversal (i.e., the probability that the next trade would take place at the bid or ask given that the current trade is at ask or bid) and (ii) the magnitude of the price reversal. Stoll claims that these two factors explain to a large extent the order processing and the inventory cost components of spread. There is also an assumption made by Stoll about the symmetric nature of price reversals and the spread being constant over time (for instance, the probability of a price reversal hovers ca. 50%).

Table 1
Cropping pattern of rice in India

Center	State	District	No. of Crops	Average output over the crop cycle (tonnes)
Ahmedabad	Gujarat	Ahmedabad	1	54 666
Amritsar	Punjab	Amritsar	1	700 000
Bhubaneshwar	Orissa	Puri	2	470 496
Bangalore	Karnataka	Bangalore	2	280 000
Chandigarh	Punjab/Haryana	Chandigarh	No local production	—
Cuttack	Orissa	Cuttack	2	672 400
Kanpur	Uttar Pradesh	Kanpur	2	140 913
Lucknow	Uttar Pradesh	Lucknow	2	62 700
Ludhiana	Punjab	Ludiana	1	713 000
Patna	Bihar	Patna	2	157 286
Shimla	Himachal Pradesh	Shimla	1	5200
Vijayawada	Andhra Pradesh	Krishna	3	1 164 360

our purposes given the asymmetric nature of price reversals. Price reversals in the rice markets depend on the price elasticity of supply of the farmer, and the demand elasticity of the retail markets. These elasticities are time variant. Hence, the spread adjustments can be expected to be asymmetric.

The methodology of estimation used in this paper has two objectives. On the one hand, it captures the simultaneity in the determination of the components of the spread. Whether spread components can be separately estimated is treated (appropriately) as a hypothesis to be tested rather than as a maintained hypothesis (as in the case of the extant literature). A natural candidate for decomposition of spread into its components while, at the same time, ensuring simultaneity of determination of these components is Zellner's seemingly unrelated regression techniques. One of the problems with both Stoll (1989) model and the GKN (1991) model is that, the various components are independently determined, each through an OLS regression. This is incorrect given the fact that the three components are, in practice, simultaneously determined. In any case, estimation of the latter model would permit us to test whether the OLS specification is valid. In our model, a set of similar variables along with certain unique ones affect the three different spread components. Hence, it is only natural that the efficient estimation would anticipate that the error terms from the three regressions might be related and, hence, prescribe generalized least squares (GLS) estimation. Second, the search technique used in the decomposition of the spread has a well-defined objec-

tive: to maximize the likelihood value of the estimated model. This, then, provides good statistical foundations for the method used.

The system of equations to be estimated is provisionally written as:

$$aic = \alpha_0 + \alpha_1 mpd\_rtl + \alpha_2 mpd\_sp + \alpha_3 rtl + \alpha_4 dd\_sp + \varepsilon_1 \tag{1}$$

$$ihc = \beta_0 + \beta_1 mpd\_rtl + \beta_2 mpd\_sp + \beta_3 sd\_st + \varepsilon_2 \tag{2}$$

$$opc = \gamma_0 + \gamma_1 mpd\_rtl + \gamma_2 mpd\_sp + \gamma_3 dd\_vol + \varepsilon_3 \tag{3}$$

where aic is the adverse information cost, ihc the inventory holding cost and opc the order processing cost. mpd_sp the change in the midpoint of the BAS, mpd_rtl the change in the midpoint of the retail spread, rtl is the 'normative' retail price, dd_sp the change in BAS, sd_st the change in stocks, dd_vol is the change in wholesale volume, ε_1, ε_2, ε_3 are error terms.

The midpoint of the wholesale spread is the wholesale price that would prevail in the absence of any of the cost components[5]. A change in this will imply a change in true price perception, which is usually caused, by changes in the rate of arrival of grains in

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[5] The true price of rice as perceived by the wholesaler is measured by mpd_sp. A change in this will capture the effect of government policy such as revisions to the procurement/support price (which revises the effective bid price of the wholesaler) because this mid-point will shift when either end of the spread shifts.

the market, possible changes in the demand from other wholesalers, etc. Revision in the support prices announced by the government will change the true price perceptions of the wholesaler.

The midpoint of the retail spread measures the likely true price of grain at the retail level. Changes in the midpoint of the retail spread will have a feedback effect on the wholesale spread. The midpoint will change if there is an increase in the information asymmetry at the retail level which can be caused by retailer's expectations of unavailability of grain at the wholesale level and changes in retail demand.

The retail selling price reflects whatever mark ups the retailer adds to his buying price. These mark ups reflect the cost components of the retail spread. To detect information asymmetry at the retail level, the wholesaler can first estimate the normative retail price and compare it with actual retail price. The normative retail price reflects that price which ought to prevail under ideal typical market conditions. Any change in this reflects the presence of information asymmetry. The normative retail price is measured by rtl. This is computed as follows:

Let,

$$mp1\_sp = mp\_sp + (w\_sp) \qquad (4)$$

$$mp1\_rtl = mp\_rtl + (rtl\_sp) \qquad (5)$$

where mp_sp and mp_rtl are the midpoints of the wholesale and the retail spreads, respectively. The variables w_sp and rtl_sp represent the BAS and retail spread, respectively. Given mp1_sp and mp1_rtl, we determine the normative retail price rtl.

$$rtl = \frac{(mp1\_sp + mp1\_rtl)}{2} \qquad (6)$$

Any change in rtl reflects information asymmetries in the retail markets.

Information asymmetry is also caused by information shocks in the market place. These are exogenous events that occur randomly. In dual markets, the external noise in the trading process is very high. Evidence of the continuous nature of this external noise is found in the week to week changes in both retail and wholesale spreads. This implies that information asymmetries are never fully corrected. Hence, there is a fair degree of noise trading on the part of the wholesalers and retailers. We measure the magnitude

of these information shocks by using the change in the wholesale spreads as a proxy. This is given by dd_sp. Information asymmetry can affect order imbalance in the wholesale markets. The order imbalance is measured is by both changes in stocks (s_st) and volumes (dd_vol).

We tested each of these variables including spread for unit roots. The BAS was found to be stationary in the presence of a time trend. This implies that in the system of Eqs. (1)–(3), we should use trend as an independent variable. The following system of equation is to be estimated using SUR:

$$aic = \alpha_0 + \alpha_1 trend + \alpha_2 mpd\_sp + \alpha_3 mpd\_rtl$$
$$+ \alpha_4 rtl + \alpha_5 dd\_sp + \alpha_6 \varepsilon_1 \qquad (7)$$

$$ihc = \beta_0 + \beta_1 trend + \beta_2 mpd\_sp$$
$$+ \beta_3 mpd\_rtl + \beta_4 sd\_st + \beta_5 \varepsilon_2 \qquad (8)$$

$$opc = \gamma_0 + \gamma_1 trend + \gamma_2 mpd\_sp$$
$$+ \gamma_3 mpd\_rtl + \gamma_4 dd\_vol + \gamma_5 \varepsilon_3 \qquad (9)$$

where the constant term in each equation represents the time invariant part of the respective cost components. The remainder captures the dynamics of the grain markets and represents the time variant part of the spread components. In order to estimate Eqs. (7)–(9), we require the initial values of the left-hand side and the estimates of the various parameters.

Our strategy for estimation is as follows: First, the following regression is estimated for each center in order to determine the initial estimates of the parameters.

$$spread = \delta_0 + \delta_1 trend + \delta_2 mpd\_sp + \delta_3 mpd\_rtl$$
$$+ \delta_4 rtl + \delta_5 dd\_sp + \delta_6 sd\_st + \delta_7 dd\_vol$$
$$+ error \qquad (10)$$

where spread is the BAS of the given center. In the second step, the initial forms of (Eqs. (7)–(9)) are set up as follows.

$$aic = \delta_1 trend + \delta_2 mpd\_sp + \delta_3 mpd\_rtl$$
$$+ \delta_4 rtl + \delta_5 dd\_sp \qquad (11)$$

$$ihc = \delta_1 trend + \delta_2 mpd\_sp + \delta_3 mpd\_rtl + \delta_4 sd\_st \qquad (12)$$

$$opc = \delta_1 trend + \delta_2 mpd\_sp + \delta_3 mpd\_rtl + \delta_4 dd\_vol \qquad (13)$$

Table 2
Correlation between WPI and spreads

	Ahd	Amr	Bhu	Bng	Chd	Cut	Kar	Knp	Luc	Lud	Mad	Pat	Sim	Vij
WPI	0.13	0.04	0.10	0.08	0.01	0.13	0.05	0.08	0.11	0.20	0.03	0.01	0.06	0.04

The error term in Eq. (10) is divided into three equal parts and added to Eqs. (11)–(13). Let the resultant values of the left-hand side in these equations be aic′, ihc′ and opc′. These now represent the pure time-variant initial values of the spread components. To capture the full initial values of the spread components we apportion the constant term δ_0 as follows, to the three components.

$$\alpha_0 = \left(\frac{|aic'|}{|aic' + ihc' + opc'|} \right) \delta_0 \qquad (14)$$

$$\beta_0 = \left(\frac{|ihc'|}{|aic' + ihc' + opc'|} \right) \delta_0 \qquad (15)$$

$$\gamma_0 = \left(\frac{|opc'|}{|aic' + ihc' + opc'|} \right) \delta_0 \qquad (16)$$

where α_0, β_0 and γ_0 are the shares of the constant term δ_0 being apportioned to the three time variant cost components aic′, ihc′ and opc′. We are now in a position to estimate the (Eqs. (7)–(9)) as a system.

The three-equation system can now be written as:

$$y_m = X_m \beta_m + \varepsilon_m \qquad (17)$$

$m = 1, 2, 3$.

The error term for the system is written as:

$$\varepsilon = [\varepsilon_1', \varepsilon_2', \varepsilon_3']$$

Hence,

$$V = E[\varepsilon_i \varepsilon_j'] = \sigma_{ij} I, \ i, j = 1, 2, 3$$

is the covariance matrix of the error terms. Clearly,

$$V = \sum \otimes I, \text{ with } \sum = [\sigma_{ij}]$$

Hence, the generalized least-squares estimator can be written as:

$$\bar{\beta} = [X'V^{-1}X]^{-1}X'V^{-1}y$$
$$= \left[X' \left(\sum{}^{-1} \otimes I \right) X \right]^{-1} X' \left(\sum{}^{-1} \otimes I \right) y \qquad (18)$$

This estimator is consistent, unbiased and efficient in contrast to the OLS estimator of GKN (1991) which is only consistent. Whether $\sum$ is diagonal can be tested using a variety of tests including the Breusch–Pagan test (Greene, 1993).

The system is estimated with the observed magnitudes on the right-hand side as the exogenous variables. We repeat this procedure by giving different values to the left-hand side (with the sum still adding up to the actual spread) till the log of the likelihood function of the system is maximized. Those left-hand side values for which the log of the likelihood function is maximized represents the optimal division of the bid-ask spread into the various components. These estimates are not biased in any manner and reflect the underlying market structure and any changes in it.

4. Interpreting the results

The first point to be noted here is that the spreads show a tendency to accumulate over time. A natural question might be to ask whether the spread movements are influenced by the changes in the WPI.[6] However, we find that the correlation between WPI and the spreads is insignificant in all the centers. The correlation between WPI and the spreads is reported in Table 2.

The results of the estimation using SUR are shown in Table 3. For all the centers, the Breusch–Pagan test strongly rejects the null hypothesis that the off diagonal elements of the variance covariance matrix of the error terms in (Eqs. (7)–(9)) are zero. This vindicates our contention that the spread should be estimated as a system and not separately by OLS. The correlation between the proportion of trade with other centers and the cost components are reported in Table 4. The maximum values of the log of the likelihood function along with the R^2 values are reported in Table 5. These are high (as are individual equation R^2s) which suggests that the parameter estimates are robust. We

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[6]We are grateful to an anonymous referee for suggesting this line for enquiry.

Table 3
Results of seemingly unrelated regression of (Eqs. (7)–(9))

Centre	Dependent variable															
	aic						ihc					opc				
	Explanatory variables															
	const	trend	mp_rtl	mp_sp	rtl	d_sp	const	trend	mp_rtl	mp_sp	s_st	const	trend	mp_rtl	mp_sp	d_vol
Ahd	0.0168	0.0046	0.3075	0.2442	0.2594	0.02455	0.3036	0.0062	0.4308	−0.03260	0.000005	0.3037	0.0062	−0.04309	0.00326	0.00004
	(0.17)	(3.01)	(3.37)	(8.01)	(121)	(79.17)	(2.33)	(3.08)	(3.61)	(−8.15)	(298)	(2.33)	(3.08)	(−3.61)	(8.15)	(2.18)
Amr	0.2809	0.0050	0.0213	0.2933	0.2640	0.02543	0.6489	0.0068	0.0339	−0.03976	0.000005	0.6491	0.0068	0.00337	0.00398	0.00002
	(2.19)	(3.455)	(0.11)	(8.72)	(57.8)	(38.63)	(3.80)	(3.44)	(0.12)	(−8.78)	(387)	(3.80)	(3.44)	(0.13)	(8.78)	(2.52)
Bhu	0.0742	0.0031	0.1682	0.2693	0.2621	0.02296	0.6282	0.0042	0.2453	−0.03518	0.000005	0.4689	0.0042	0.02464	0.00349	0.0026
	(0.558)	(2.380)	(1.724)	(7.621)	(76.4)	(50.52)	(3.79)	(2.574)	(1.999)	(−7.919)	(259.9)	(2.83)	(2.55)	(2.01)	(7.875)	(2.44)
Bng	0.3408	0.0089	0.2036	0.3652	−0.2608	0.02330	0.7832	0.0119	0.2775	−0.04725	0.000004	0.7833	0.0119	0.02776	0.00473	0.00005
	(4.664)	(8.87)	(1.936)	(16.45)	(−95.8)	(67.05)	(8.163)	(8.986)	(1.999)	(−16.13)	(304.7)	(8.16)	(8.986)	(2.00)	(16.13)	(4.089)
Chd	0.5313	0.0057	0.2599	0.4086	−0.2531	0.02256	1.387	0.0094	0.3419	−0.05986	0.000004	1.389	0.0094	−0.03434	0.00599	0.0003
	(1.954)	(2.64)	(3.846)	(5.572)	(−35.1)	(33.23)	(3.534)	(3.01)	(3.493)	(−5.645)	(448.3)	(3.54)	(3.01)	(−3.511)	(5.653)	(2.877)
Cut	0.0217	0.0044	0.3318	0.2511	0.2532	0.02428	0.3407	0.0058	0.3938	−0.03317	0.000004	0.3320	0.0057	−0.04029	0.00329	0.0006
	(0.197)	(3.22)	(5.85)	(7.49)	(54.96)	(52.845)	(2.407)	(3.336)	(5.422)	(−7.723)	(218.5)	(2.33)	(3.242)	(−5.508)	(7.609)	(3.261)
Knp	0.1430	0.0039	0.3036	0.1973	0.2759	0.02421	0.0831	0.0045	0.3687	0.2621	0.000004	0.0826	0.0045	0.03692	0.00262	0.000001
	(1.597)	(1.932)	(3.396)	(7.423)	(45.31)	(37.70)	(0.708)	(1.665)	(3.141)	(7.540)	(182.43)	(0.704)	(1.664)	(3.147)	(7.539)	(3.002)
Kar	0.5434	0.0006	0.2933	0.1596	0.2753	0.01378	0.1204	0.0014	0.1208	0.1303	0.000002	0.2712	0.0014	0.01158	0.00128	0.00001
	(3.217)	(1.295)	(4.321)	(1.718)	(6.946)	(2.331)	(4.111)	(2.956)	(1.981)	(1.33)	(1.50)	(9.193)	(2.934)	(1.885)	(1.298)	(1.759)
Luc	0.2146	0.0027	0.2901	0.1983	0.2608	0.02332	0.1055	0.0037	0.3943	0.2651	0.000005	0.1061	0.0038	0.03947	0.00265	0.00024
	(2.287)	(1.59)	(3.94)	(6.815)	(58.304)	(46.67)	(0.859)	(1.702)	(4.08)	(6.964)	(141.60)	(0.863)	(1.706)	(4.09)	(6.966)	(2.699)
Lud	0.3007	0.00032	0.2715	0.1673	0.2921	0.01974	0.7944	0.00069	0.3610	0.2359	0.000005	0.750	0.0007	0.03619	0.00236	0.0002
	(3.93)	(0.262)	(2.729)	(9.662)	(55.84)	(40.02)	(0.792)	(0.437)	(2.847)	(11.10)	(289.48)	(0.792)	(0.435)	(2.854)	(11.10)	(1.937)
Mad	0.2750	0.00075	0.1582	0.3135	0.2609	0.02306	0.7503	0.0012	0.2345	0.4149	0.000005	0.7504	0.0012	0.02345	0.00415	0.00002
	(2.763)	(1.477)	(2.249)	(12.30)	(102.77)	(88.74)	(5.45)	(1.769)	(2.393)	(11.68)	(430.26)	(5.454)	(1.769)	(2.394)	(11.68)	(2.674)
Pat	0.1757	0.0057	0.3746	0.3196	0.2519	0.02355	0.6593	0.0079	0.5245	0.4259	0.00004	0.6594	0.0079	0.05245	0.00426	0.00002
	(1.69)	(4.84)	(3.967)	(10.33)	(56.1)	(0.35)	(4.86)	(5.15)	(4.24)	(10.51)	(307.3)	(4.86)	(5.15)	(4.24)	(10.51)	(2.29)
Shm	0.3484	0.00022	0.2375	0.1398	0.2545	0.02465	0.0931	0.0003	0.3296	0.1931	0.000004	0.0936	0.00029	0.03299	0.00193	0.00016
	(2.09)	(0.191)	(5.36)	(3.22)	(114.70)	(102.96)	(0.417)	(0.196)	(5.558)	(3.327)	(284.8)	(0.419)	(0.194)	(5.56)	(3.326)	(1.981)
Vij	0.1442	0.0102	0.1704	0.312	0.2605	0.02365	0.4913	0.0127	0.1890	0.3945	0.000005	0.4916	0.0127	0.01889	0.00395	0.00068
	(2.168)	(7.33)	(2.138)	(14.99)	(75.717)	(64.88)	(5.918)	(7.26)	(1.876)	(14.95)	(300.08)	(5.936)	(7.279)	(1.881)	(14.99)	(2.058)

Table 4
Correlation between proportion of distant trade and cost component

Centers	Cost components		
	aic	ihc	opc
Ahmedabad	0.54	0.47	0.02
Amritsar	0.63	0.22	0.09
Bhubaneshwar	0.35	0.57	0.14
Bangalore	0.28	0.67	0.08
Chandigarh	0.69	0.26	0.06
Cuttack	0.22	0.65	0.12
Karnal	0.64	0.33	0.18
Kanpur	0.30	0.58	0.11
Lucknow	0.22	0.62	0.04
Ludhiana	0.56	0.30	0.07
Madras	0.54	0.46	0.12
Patna	0.57	0.50	0.03
Simla	0.66	0.12	0.17
Vijaywada	0.52	0.47	0.09

Table 5
Values of the log of the likelihood function

| Center	Log of the likelihood function	System R^2
Ahmedabad	679.163	0.9539
Amritsar	622.967	0.8982
Bhubaneshwar	408.682	0.9112
Bangalore	712.154	0.9854
Chandigarh	451.230	0.8336
Cuttack	436.703	0.9768
Kanpur	502.386	0.9461
Karnal	493.231	0.6230
Lucknow	497.836	0.9475
Ludhiana	536.904	0.9360
Madurai	760.540	0.9460
Patna	727.825	0.9787
Shimla	620.820	0.9603
Vijaywada	510.520	0.9782
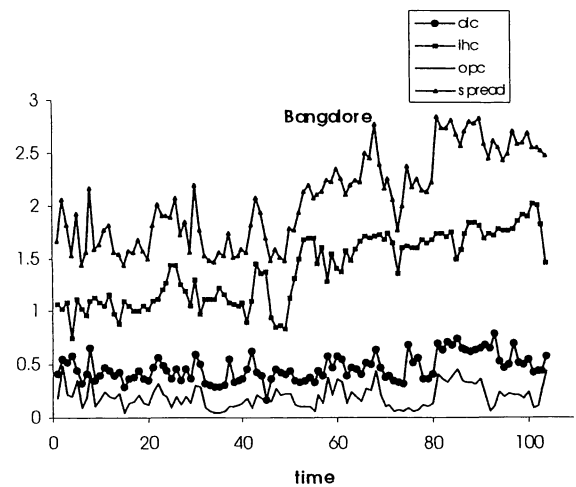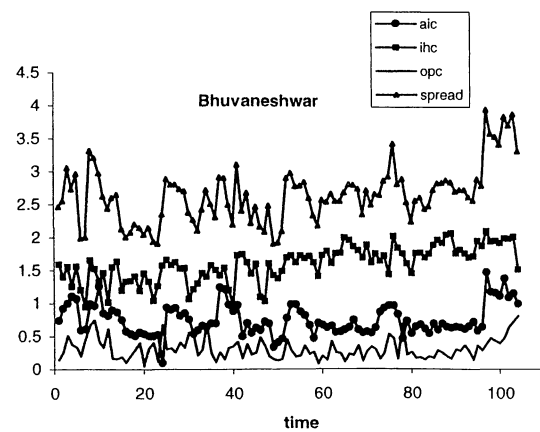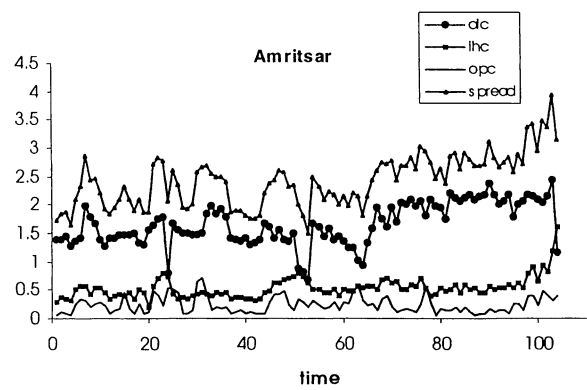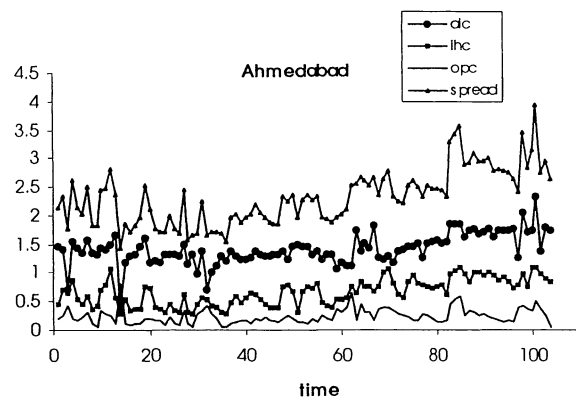
Fig. 6. Spread and its components.
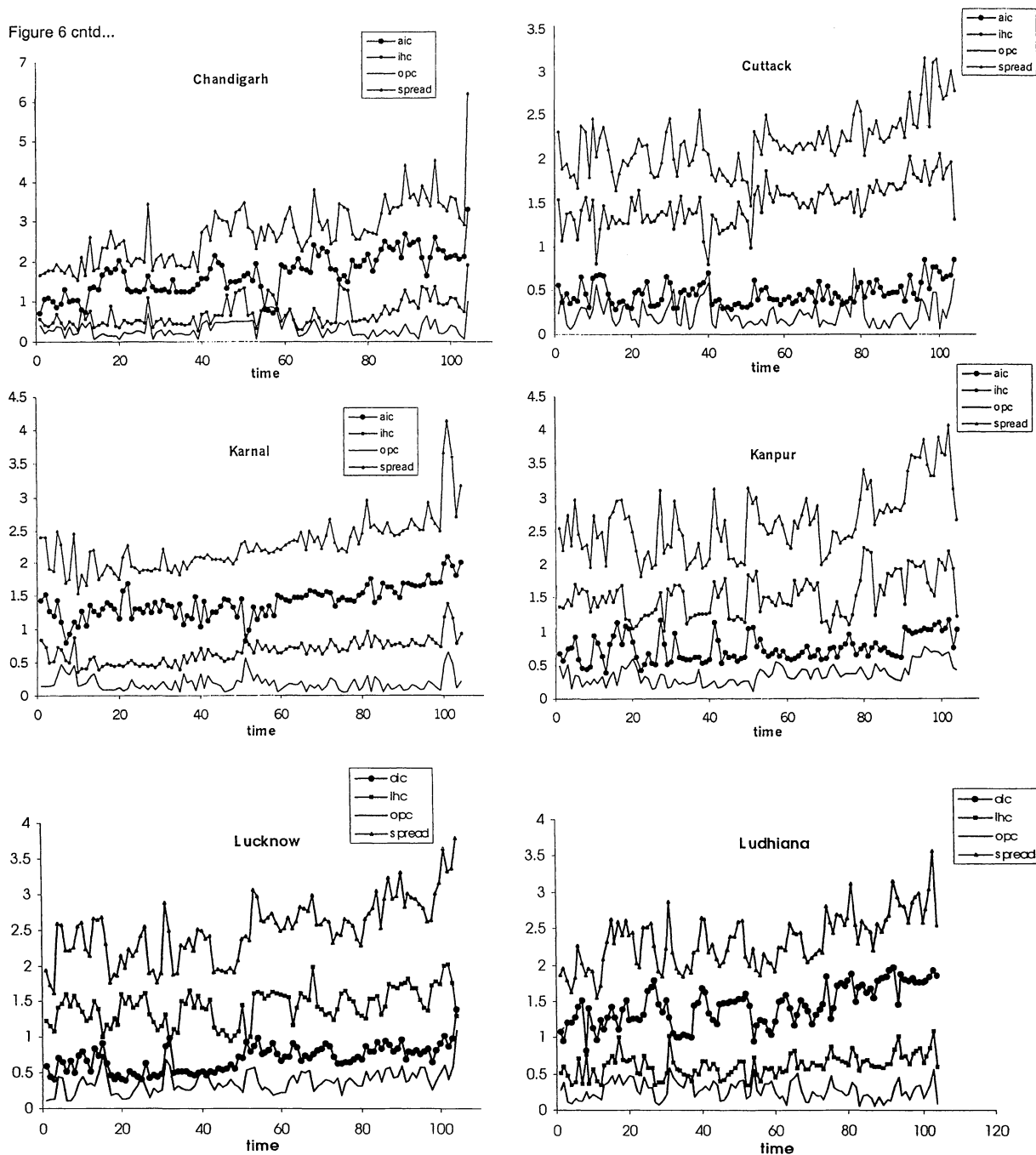
Figure 6 cntd...

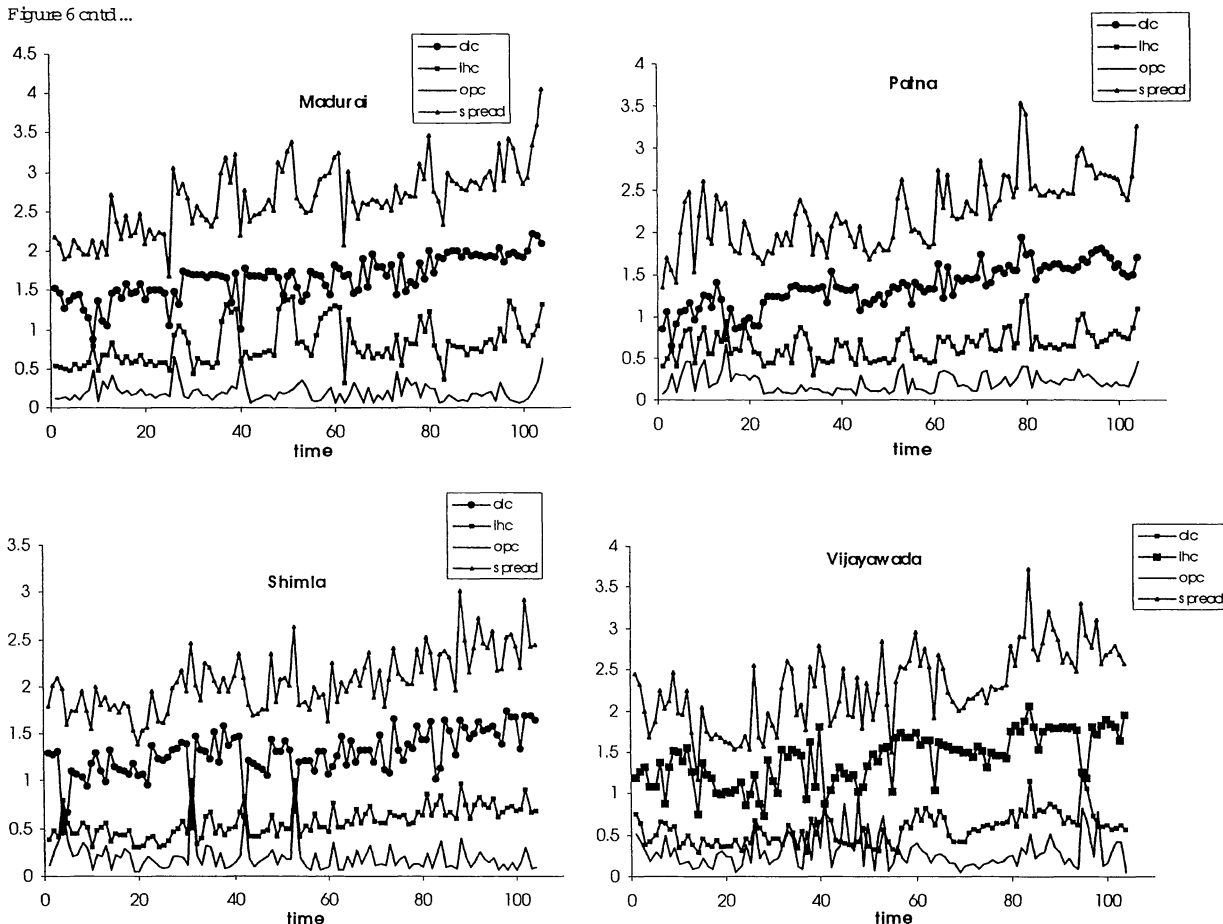

Fig. 6. (*Continued*)

Figure 6 cntd...

Fig. 6. (Continued)

note that in those centers where local consumption is low (Amritsar, Ludhiana) and in those centers where procurement for the purposes of local trade is expensive (Shimla, Ahmedabad), the correlation between adverse information and the proportion of trade with the other centers is high. We also find that in these centers, the dominant cost components are the adverse information and the inventory holding costs. These centers have to deal with spatial fluctuations in demand and supply.

We summarize these results broadly as follows:

1. There is significant week to week variation in both the spreads and its components. This is evident from Fig. 6. Time varying cost components

indicate the extent of noise trading, that is prevalent in the markets. Noise trading is endemic to vertical agricultural markets. The Indian grain markets are vertical markets. Information asymmetries at various levels of trading do not remain insulated from one another.

2. Reinforcing our observation that there could be noisy trading, is the presence of a significant and positive constant term (Table 3) for all of the cost components. This implies that the wholesalers expect week to week changes in information asymmetry and order imbalances. To prevent losses from such asymmetry and imbalances, the wholesalers fix a minimum for each of the cost components of the spreads.

3. Even though there is a week to week fluctuation of each of the spread components, we do not detect any well-defined cycles in many centers. Exceptions are Amritsar, Bhuvaneshwar and Ludhiana. In the Amritsar–Ludhiana corridor where these cycles seem to coincide broadly with the procurement cycles of the government, while in Bhuvaneshwar, it seems to coincide with that of the tourist traffic.
4. In all the centers, the order imbalances and information asymmetries (measured by mp_sp and mp_rtl, rtl) have a positive impact on both adverse information and the inventory holding costs. This is consistent with our earlier maintained hypothesis on the impact of order imbalances and information asymmetries on movements of spreads and spread components (as outlined in Section 2). The impact of these variables on the order processing costs seems to be much more negligible.

On the basis of the results, the following general conclusions about individual centers can be made.

(a) If procurement is expensive (because of low local production and high costs of obtaining from elsewhere) then the adverse information cost can be expected to be high. An example of such a center is Madurai.

(b) The inventory holding cost is expected to be high if local consumption is high and local production is low, but procurement is easy. An example is Bangalore.

(c) Even if local consumption exhibits seasonality, with easy procurement and moderate local production, only the inventory holding cost will be high. Examples are Bhuvaneshwar and Cuttack.

(d) When seasonal demand fluctuations are not high, high local consumption in the presence of low local production can be compensated by procurement. If procurement is easy/inexpensive then the inventory holding cost is substantial. Examples include Kanpur and Lucknow.

(e) If the outward flow of grain dominates the traded volume, then demand uncertainties influence the BAS components and the adverse information cost will dominate.

In these centers local consumption is low with very high local production. Examples are Amritsar and Ludhiana.

5. Conclusions

We have suggested a simple model of determining spread components. We find that the results, thus, generated are consistently robust and support to a large extent the theory of spread formation in the market microstructure literature. Our model unlike the standard ones suits the study of agricultural markets that constantly undergo change. Several interesting results emerge from our paper, namely

1. There is a significant time variation in the spread components. This arises out of the inherent information asymmetry that never seems to be entirely purged from these markets.
2. All the components of spread show a tendency to 'accumulate', that is the spread components mirror the changing structure of the grain markets.
3. Government intervention and the presence of a parallel controlled market create information asymmetries that are strong. This is perhaps the reason why spreads themselves are constantly adjusting upward (though periodically showing mean-reverting tendencies)

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