TESTING AGRICULTURAL MARKET INTEGRATION: FURTHER CONCEPTUAL AND EMPIRICAL CONSIDERATIONS USING INDIAN WHOLESALE PRICES

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ABSTRACT

Spatial and intertemporal integration of food markets in developing countries are important for the price system to efficiently allocate resources and products across regions and time. India's liberalisation of food crop marketing in the early 1990's has renewed interest in evaluating the consequences for market integration. Not surprisingly, this interest is widespread because structural change and liberalisation have occurred in the agricultural sectors of many developing countries.

Given the importance of this topic there have been many international studies on agricultural market integration. The influential research in the 1990's criticised the early reliance on correlation analysis due to the prevalence of temporal trends in agricultural commodity prices. These studies commonly used Engle-Granger type cointegration techniques to overcome the statistical inference problems. The finding of cointegration was presented as evidence of market integration.

This paper provides a critique of the reliance of these studies on the analysis of pairwise price relationships using correlation and cointegration techniques. It is shown by a simple example using Indian wholesale wheat prices that analyses which ignore the effects of simultaneity are flawed and any conclusions about market integration based on this methodology, will be invalid. A conceptual framework is developed which formally models market price interdependencies in a simultaneous system of temporal price equations. Johansen's maximum likelihood procedure is used to estimate the minimum amount of information needed to identify the market system. This procedure derives significant long run cross-price, own-price, non-price and short run equilibrating price elasticity measures which are used to indicate the degree of market integration. Evidence is provided on market integration for Indian wheat, jower, paddy rice, groundnut, rapeseed and mustard seed. Comparisons are made before and after agricultural marketing liberalisation.

KEYWORDS: Market integration, system estimation, Johansen cointegration.

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1. *Introduction*

It is commonly believed that spatial and intertemporal integration of food markets in developing countries are preconditions for sustainable agricultural development. The more markets are integrated the greater is the likelihood the price system will more efficiently allocate resources and products across regions and time. This will allow the benefits of technical change and productivity improvements to alleviate poverty and help achieve food security. Since Lele's (1967) pioneering study of jower prices in Western India there has been renewed interest in market integration as a consequence of India's actions to liberalise food crop marketing in the early 1990's. The importance in determining the effectiveness of food markets to efficiently allocate agricultural produce under these new institutional arrangements is crucial to the development process. This interest has not been restricted to the Indian economy, since marketing liberalisation and structural change have occurred in the agricultural sectors of many developing countries.

Accordingly there have been a number of influential international studies in the late 1980's and the 1990's which attempt to measure agricultural market integration. The earlier research relied on correlation analysis, which was subsequently criticised by Harriss (1979) and others. This view argued that high correlations between agricultural prices might not reflect close behavioral relationships. Rather they may indicate spurious relationships caused by common temporal trends which are prevalent in agricultural time series. Ravallion (1986) modelled market prices as possibly non–stationary error correction type processes which were estimated using instrumental variables. Palaskas and Harris-White (1993) and Alexander and Wyeth (1994) estimated the error correction model using cointegration and Granger causality ordinary least squares (OLS) techniques.

Dercon (1995), Barrett (1996), Timmer (1996) and Baulch (1997a,b) have in turn criticised these studies for relying on market prices and cointegration techniques to explore the degree of market integration. Excluding other important information like transportation costs and trade flows means that finding cointegration does not necessarily mean that markets are integrated. For example, arbitrage will not occur where transport costs are high relative to price variations across markets. If these markets face common production shocks and prices have common time trends then the markets may be cointegrated although not necessarily integrated. Alternatively, integrated markets may not appear cointegrated due to the discontinuous nature of trade flows caused by seasonal and other effects. Indeed Barrett

(1996, p. 827) claims that ".. cointegration is neither necessary or sufficient for market integration".

This paper provides a critique of the empirical studies on market integration that are based on correlation and cointegration analyses.[1] It is argued here that these studies use inappropriate methods which neglect important simultaneity effects across product markets. The next section considers an example of Indian wheat markets to demonstrate the dangers of ignoring the possible multiple interdependencies between markets. A conceptual framework, which overcomes these problems by explicitly modelling price interdependencies across markets is developed in Section 3. The analysis is expanded in Section 4 to incorporate the complications caused by non-stationary market prices in the form of vector autoregression specifications. The model is then estimated in Section 5 using full information maximum likelihood techniques and wholesale prices for wheat. This procedure determines the rank of the price system and derives plausible cross-price elasticity measures, defined as the proportionate change in the equilibrium wholesale price in one market relative to a proportionate change in the equilibrium wholesale price in other markets. The robustness of these results are tested in terms of Granger block causality analysis. Section 6 reports the rank and elasticity estimates for jower, paddy rice, groundnut and rapeseed and mustard seed for the pre and post liberalisation periods in India. Summaries and conclusions are provided in Section 7.

2. A Critique of Market Integration Analyses

Earlier empirical studies of market integration relied on the calculation of pairwise correlation coefficients for observed market prices. By way of example, the correlation coefficients for the end of month wholesale wheat prices for nine important Indian markets are shown in Table 1.[2] Note that all measures for the period January, 1991 to June, 1998 are very high, within the range of 0.86 to 0.98, and with average 0.92. The simple and transparent measure of correlation is well known and forms the basis of much valued statistical analysis. However the criticism of this approach details the possibly misleading nature of these measures caused by spurious temporal relationships between the price variables. It is argued that it is important to distinguish the contribution of a common underlying time trend for the

[1] The focus of this paper is to provide a critique of market integration studies and to construct a conceptual model and apply empirical techniques which overcome the identified problems. Because if this focus the paper does not directly consider the broader and important issue of market efficiency.

[2] Microfit 4.0 was used for all the econometric estimations. *Vide* Pesaran and Pesaran (1997).

price series from joint behavioral characteristics of each of these price variables. If the correlation is principally due to the non-stationarity of the series then the incorrect conclusion that these variables are closely related in terms of the interactions of cause and effect will provide invalid policy advise.

To demonstrate the importance of the intertemporal behavior of prices, consider the simple first order autoregressive representation $p_t = r\, p_{t-1} + v_t,\ \ t = 2,3,..., n$ of the wholesale price series $\{p_t, t = 1,2,\ldots,n\}$ with customary assumptions $v_t \sim \mathrm{N}\left(0, s_e^2\right)$ and $-1 < r < 1$. This representation is common to the dynamic analysis of demand and supply and cobweb type specifications. The important restriction on r ensures stability of these classes of models. However if $r \geq 1$, the series in deemed non-stationary and the associated models become unstable. Moreover the presence of non-stationarity introduces problems of statistical inference. The ordinary least squares estimator, $\hat{r}$ has variance, $s_r^2 = \dfrac{s_e^2}{1-r}$ which is undefined for $r \geq 1$. The *t*-test cannot therefore be used to test for statistical significance of r, which importantly describes the dynamic evolution of the price variable, p_t. For these reasons the studies on market integration in the 1990's were critical of the reliance on correlation coefficients and used cointegration techniques to analyse non-stationary variables.

It is clear from inspection of Table 2 that the wholesale wheat prices are non-stationary, $p_t \sim I(1)$ according to the augmented Dickey-Fuller (ADF) test.[3] Whilst the Bahraich and Amritsar market prices are stationary, *I* (0), when the trend is included in the ADF regression, they become non-stationary without the trend. This implies that cointegration techniques should be used in place of simple correlation and linear regression analysis for these prices. To determine the effects of the non-stationary trend on the wholesale wheat prices, the trend values denoted $\{\tilde{p}_t; t = 1,2,\ldots,n\}$ were calculated from each original price series $\{p_t; t = 1,2,\ldots,n\}$ by optimising the Hodrick-Prescott (1980) criterion for suitably chosen smoothing parameter l :[4] $\min\limits_{\tilde{p}_1,\tilde{p}_2,\ldots,\tilde{p}_n} \left\{ \sum_{t=1}^{n} \left(p_t - \tilde{p}_t\right)^2 + l \sum_{t=2}^{n-1} \left(\Delta^2 \tilde{p}_{t+1}\right)^2 \right\}$

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3 If the absolute values of the test statistics are greater than the critical values then the null hypothesis of non-stationarity is rejected. The optimum order of the distributed lag (shown in parentheses) was selected according to the Schwarz Bayesian criterion (SBC).

4 The parameter l was set to 126,400 as advised by Peseran and Peseran (1997) for monthly observations. See also Harvey and Jaeger (1993).

Table 1

Correlation Coefficients

End of Month Wholesale Wheat Prices: Raw Data

January, 1991 to June, 1998

	Patna	Rajkot	Karnal	Indore	Hapur	Kanpur	Bahar-aich	Delhi	Amrit-sar
Patna	1.00	.91	.90	.91	.91	.91	.92	.93	.90
Rajkot		1.00	.90	.89	.88	.90	.89	.91	.88
Karnal			1.00	.90	.96	.91	.95	.98	.97
Indore				1.00	.87	.86	.86	.91	.90
Hapur					1.00	.97	.96	.97	.94
Kanpur						1.00	.98	.97	.93
Bahraich							1.00	.97	.94
Delhi								1.00	.97
Amritsar									1.00

Table 2

Augmented Dickey-Fuller Tests for Wholesale Wheat Price Non-Stationarity [1]

January, 1992 to June, 1998

	p_t - Price Level [2]	Δp_t - Price Difference [2]	Final Result
Patna	-1.884 *NT* (0)	**-5.850** *NT* (3)	I(1)
Rajkot	-2.450 *T* (1)	**-11.511** *NT* (0)	I(1)
Karnal	-2.815 *T* (1)	**-4.495** *NT* (6)	I(1)
Indore	-2.578 *T* (1)	**-12.986** *NT* (0)	I(1)
Hapur	-3.009 *T* (0)	**-8.793** *NT* (0)	I(1)
Kanpur	-3.373 *T* (1)	**-7.386** *NT* (0)	I(1)
Bahraich	**-3.761** *T* (1)		I(0) [3]
Delhi	-3.207 *T* (1)	**-7.596** *NT* (0)	I(1)
Amritsar	**-3.663** *T* (1)		I(0) [3]

Notes: [1] All wholesale prices are in Naperian logs.

[2] The test statistics in bold denote greater than the 5% critical values of -2.899 for no linear trend included (*NT*) in the ADF regression and -3.467 for linear trend included (*T*). The optimum order of the distributed lag in the ADF regression is shown in parentheses.

[3] The price series in levels was found to be *I* (1) when the trend was excluded from the ADF regression.

Table 3

Correlation Coefficients

End of Month Wholesale Wheat Prices: Detrended

January, 1991 to June, 1998

	Patna	Rajkot	Karnal	Indore	Hapur	Kanpur	Bahar-aich	Delhi	Amrit-sar
Patna	1.00	.79	.74	.75	.77	.78	.80	.83	.75
Rajkot		1.00	.67	.67	.64	.73	.70	.71	.63
Karnal			1.00	.65	.90	.90	.91	.94	.90
Indore				1.00	.59	.60	.62	.67	.65
Hapur					1.00	.93	.90	.91	.83
Kanpur						1.00	.95	.93	.83
Bahraich							1.00	.94	.86
Delhi								1.00	.90
Amritsar									1.00

Table 4

Correlation Coefficients

End of Month Wholesale Wheat Prices: Partial Effects

January, 1991 to June, 1998

	Patna	Rajkot	Karnal	Indore	Hapur	Kanpur	Bahar-aich	Delhi	Amrit-sar
Patna	1.00	.38	-.21	.33	.16	.00	.20	.23	-.09
Rajkot		1.00	.00	.25	-.22	.27	-.07	.00	-.03
Karnal			1.00	.16	.23	.02	.03	.39	.35
Indore				1.00	-.04	-.08	-.17	.10	.18
Hapur					1.00	.46	-.05	.16	.02
Kanpur						1.00	.56	.12	-.14
Bahraich							1.00	.21	.11
Delhi								1.00	.31
Amritsar									1.00

The correlation coefficients for the de-trended series are shown in Table 3. Note the reduction in many of the values, with the average falling from 0.92 to 0.79 and the range increasing from 0.86-0.98 to 0.59-0.95. The Rajkot and Indore market prices appear most affected by trending prices whilst the Karnal, Delhi and Amritsar prices, with important exceptions, are least affected.

It is clear that the very high correlations reported in Table 1 are dependent to varying degrees on the temporal effects, although these effects are not as large as some would expect. Nevertheless, the use of estimation procedures which explicitly allow for non-stationarity in the wholesale prices are appropriate. Examples of the studies which use cointegration analysis include Baffes (1991), Goodwin and Schroeder (1991), Palaskas and Harris-White (1993), Alexander and Wyeth (1994), Dercon (1995), Goletti, Ahmed and Farid (1995), Schroeder (1997), Ismet, Barkley and llewelyn (1998), Zanias (1993, 1999) and Centeno and Mello (1999).

However, this paper argues that these studies ignore the simultaneous interdependencies across markets. The cointegration techniques used in these studies all have the common characteristic of pairwise price analyses. This paper argues that this approach is flawed and contradicts the notion of testing market integration. The finding of pairwise relationships is only one simple aspect of market integration. Indeed it is possible that whilst markets may not exhibit high pairwise relationships the interdependencies may accumulate in complicated ways over a range of markets. Alternatively, observed correlations between two price variables may be due to the effects of prices in other markets.

Removing the simultaneous effects from each wholesale price variable and calculating the new correlation coefficients can easily test whether these effects are important. This was done by regressing each price variable against all other prices (excluding the price which was to be included in the pairwise correlation). The predicted values for each price, $\hat{p}_t$, was then removed from the original price variable and the correlation coefficients recalculated. These values are shown in Table 4 and the differences are striking when compared to the correlations for the detrended prices in Tables 1 and 3. These results have a number of important implications. The first is that only seven of these 36 measures are now greater than 0.30. They are Kanpur with Bahraich (0.56) and Hapur (0.46), Karnal with Delhi (0.39) and Amritsar (0.35), Delhi with Amritsar (0.31), and Patna with Rajkot (0.38) and Indore (0.33). Second, the new range of -0.21 to 0.56 is double the previous range of 0.59-0.95, indicating a much larger variation in pairwise relationships. Third, there are small negative correlations indicating inverse relationships between market prices for Patna and Karnal (-0.21), Rajkot and Hapur (-0.22), Indore and Bahraich (-0.17) and Kanpur and Amritsar (-0.14). Negative relationships are possible, for example, a shift of productive or marketing resources from one market to another could cause an inverse relationship between the costs and prices in these two markets.[5] Finally, the majority of measures are not different from zero with the average value of the correlation coefficients falling from 0.79 to 0.11. The conclusion to be drawn from this simple demonstration is that simultaneous inter-market effects are very important. The analytic methods based on pairwise analysis of market prices do not identify these significant effects. In one sense the correlation and Engle-Granger type cointegration analyses may double count the interdependencies, which inflates the pairwise measures used causing a bias towards finding in favour of market integration. An alternative interpretation is that these studies, which do not find significant pairwise relationships, may in fact be missing more complicated simultaneous market integration effects.

In order to illustrate these effects consider the four markets Amritsar, Delhi, Karnal and Hapur. Figure 1 summarises the relationships between these market prices with the three pairwise correlations calculated from the 'raw data' (Table 1)/ 'detrended data' (Table 3) and on the next line, 'partial data' with the simultaneous effects removed (Table 4). The measured correlation between the Amritsar and Hapur raw data prices of 0.94 conceals a non-existent direct relationship of 0.02 between these prices. The simultaneity occurs between Amritsar and Karnal and between Karnal and Hapur. This indirect relationship, whilst different in details, also occurs between Hapur and Amritsar via the Delhi market. Both of these indirect effects reinforce the apparent direct correlation and cointegration between the Amritsar and Hapur markets whilst the partial correlation is only 0.02. This result is very different to the direct relationship between the Delhi and Karnal markets, where the partial correlation effect is relatively high at 0.39. Clearly the finding of significant (or insignificant) cointegrating relationships between pairs of price does not indicate whether markets are integrated or not. The studies by Baffes (1991), Goodwin and Schroeder (1991), Palaskas and Harris-White (1993), Alexander and Wyeth (1994), Dercon (1995), Goletti, Ahmed and Farid (1995), Schroeder (1997), Ismet, Barkley and llewelyn (1998), Zanias (1993, 1999) and Centeno and Mello (1999) use flawed methodology. By ignoring important simultaneous effects their conclusions relating to market integration based on this analysis will be invalid.

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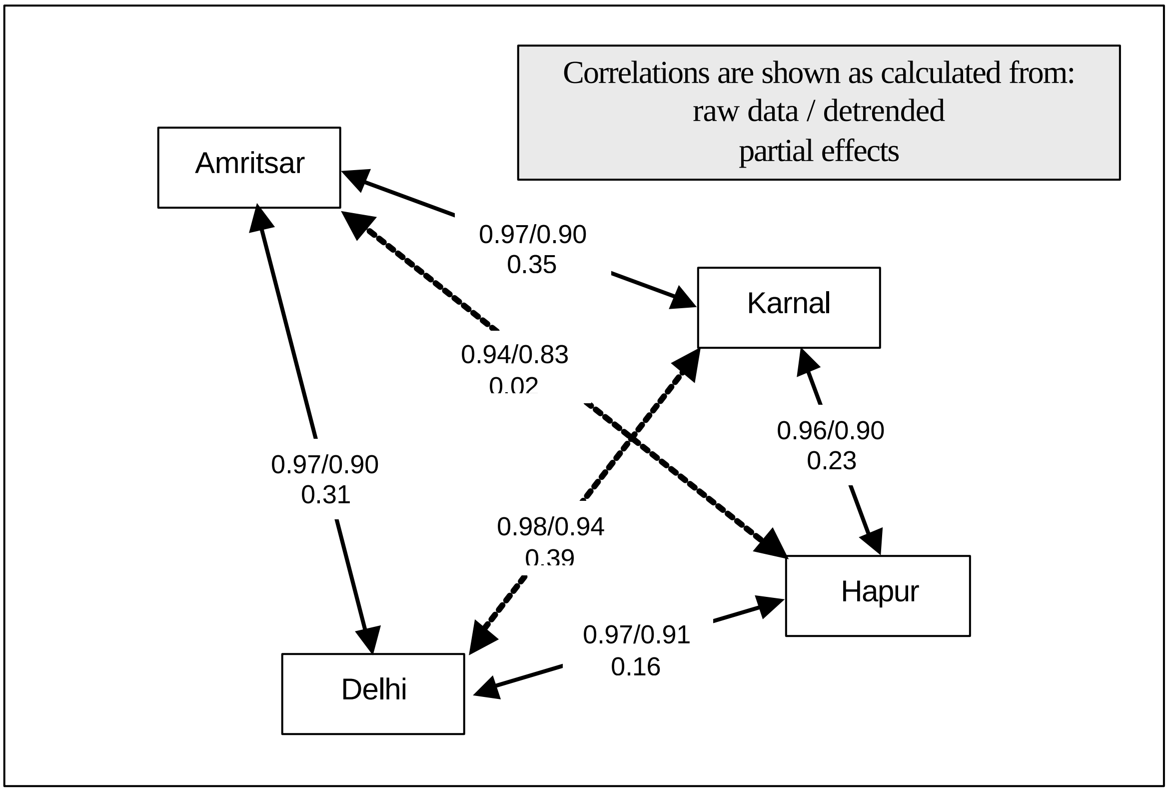
[5] There are another five correlations, which although negative, are in the range of -0.03 to -0.90. The possibility of inverse relationships is discussed in more detail in Section 5 of this paper.

Figure 1

Selected Correlation Coefficients

End of Month Wholesale Wheat Prices

January, 1991 to June, 1998



In light of the many insignificant partial correlations shown in Table 4, the question becomes how many significant relationships (if any) exist within the system of prices? Remembering that the example in Figure 1 only considers a maximum of two links at a time the question is non-trivial for the large subsets of the system of markets. Another way of viewing this is to consider how many combinations of prices describe, or more correctly, identify the significant multi-dimensional spatial price relationships. For the small subset of four markets considered in Figure 1, two pairs of prices describe the links between Amritsar and Hapur via Delhi and/or Karnal. Equivalently, an alternative combination of two price pairs link Delhi with Karnal via Amritsar and/or Hapur. The complexity increases nonlinearly as the spatial dimension increases and so it becomes necessary to formulate the problem of identification of the vector of prices more formally. This is done in the next section by developing a system of simultaneous equations which also overcomes the objections of Ravallion (1986) and Baulch (1997a).

3. A Formal Model of Price Interdependencies

Consider the system of n demand equations. The demand for the i^{th} commodity (i = 1, 2, …, n) denoted q_i^d, is specified to be a function of its own price, p_i, the prices of all other commodities, p_j (j = 1, 2, …, i-1, i+1,…, n) and income, x_i. All other effects on the demand for good i are included in each demand equation in the form of a vector z_i :

$$\begin{aligned} q_1^d &= \pi_{10} + \pi_{11} p_1 + \pi_{12} p_2 + \dots\dots\dots + \pi_{1n} p_n + \gamma_1 x_1 + \delta_1 z_1 \\ q_2^d &= \pi_{20} + \pi_{21} p_1 + \pi_{22} p_2 + \dots\dots\dots + \pi_{2n} p_n + \gamma_2 x_2 + \delta_2 z_2 \\ &\vdots \qquad\qquad \vdots \qquad\qquad \vdots \\ q_n^d &= \pi_{n0} + \pi_{n1} p_1 + \pi_{n2} p_2 + \dots\dots\dots + \pi_{nn} p_n + \gamma_n x_n + \delta_n z_n \end{aligned} \tag{1}$$

Assume that the demand for each commodity is inversely related to its own price and positively related to the prices of other commodities, which are assumed to be gross substitutes. That is:

$$\pi_{ii} = \partial q_i^d / \partial p_i < 0 \quad \text{and} \quad \pi_{ij} = \partial q_i^d / \partial p_j < 0 \ , \ \ \forall \ i \neq j \ . \tag{2}$$

The commodities are also assumed to be normal, giving positive income effects, whilst the effects of all other factors, z, are allowed to be ambiguous:

$$\gamma_i = \partial q_i^d / \partial x_i \geq 0 \quad \text{and} \quad \delta_i = \partial q_i^d / \partial z_i \lessgtr 0 \ . \tag{3}$$

Now consider possible interdependencies between these equations. For example, let total income affect the demand for each commodity, so that the income variable in each demand equation, x_i is replaced by $x = \sum_{i=1}^{n} x_i$. If it is also assumed that total production supplied to these markets comprises total income for the economy, then the identity, $q^s \equiv x$, also holds. In equilibrium we have for each market, $q_i^d = q_i^s$, so that:

$$\sum_{i=1}^{n} \frac{\partial q_i^d}{\partial x} = 1 \quad \text{and} \quad \sum_{i=1}^{n} \frac{\partial q_i^d}{\partial p_j} = 0 \ , \ \ \forall j = 0, 1, \dots. n. \tag{4}$$

The equalities in (4) can be simply expressed as the adding up requirements:

$$\sum_{i=1}^{n} \pi_{ij} = \sum_{i=1}^{n} \delta_i = 0 \ , \ \ \forall j = 0, 1, \dots. n \quad \text{and} \quad \sum_{i=1}^{n} \gamma_i = 1 \tag{5}$$

which are the direct results of:

$$q_i^d = q_i^s = x = \sum_{i=1}^{n} x_i \;. \tag{6}$$

The important consequences of these assumptions shown in relationships (4), (5) and (6) are that the n equations in (1) form a linearly dependent set. Accordingly, any arbitrarily chosen equation in this example can be determined from the remaining n-1 equations in (1) and the constraining identity (6).

The importance of this demonstration lies in the possible interdependencies across these equations. If some of these markets are integrated then each will form a linear combination of the other markets. Prices for each of these commodities do not need to be the same, only some constant multiple of the other prices. This structure therefore realistically allows for price differentials across markets, which may be due to different production environments, varying qualities of the same commodities or different transportation and other marketing costs. Now consider the subset of the vector of prices in the commodity demand equations (1) in more detail:[6]

$$\begin{array}{c} \{ p_{10} + p_{11} p_1 + p_{12} p_2 + \dots\dots\dots + p_{1n} p_{n1} \} \\ \{ p_{20} + p_{21} p_1 + p_{22} p_2 + \dots\dots\dots + p_{2n} p_n \} \\ . \\ . \\ \{ p_{n0} + p_{n1} p_1 + p_{n2} p_2 + \dots\dots\dots + p_{nn} p_n \} \end{array} \tag{7}$$

The minimum number of equations, necessary to fully describe the system, will indicate the extent of market interdependencies. Putting the system of prices shown in (7) into matrix form gives:

$$\Pi^1 \underline{p}^1 = \begin{bmatrix} p_{10} & p_{11} & \cdot & \cdot & p_{1n} \\ p_{20} & p_{21} & \cdot & \cdot & p_{2n} \\ . & . & & & . \\ . & . & & & . \\ p_{n0} & p_{n1} & \cdot & \cdot & p_{nn} \end{bmatrix} \begin{bmatrix} 1 \\ p_1 \\ \\ \\ p_n \end{bmatrix} \tag{8}$$

$$= \begin{bmatrix} p_{10} \\ p_{20} \\ . \\ . \\ p_{n0} \end{bmatrix} + \begin{bmatrix} p_{11} & p_{21} & \cdot & \cdot & p_{n1} \\ p_{21} & p_{22} & \cdot & \cdot & p_{n2} \\ . & . & & & . \\ . & . & & & . \\ p_{n1} & p_{n2} & \cdot & \cdot & p_{nn} \end{bmatrix} \begin{bmatrix} p_1 \\ p_2 \\ . \\ . \\ p_n \end{bmatrix}$$

$$\therefore \Pi^1 \underline{p}^1 = \Pi^0 + \Pi \underline{p} \tag{9}$$

6 The constant terms, p_{i0}, $i = 1, 2, \dots, n$, may be considered to include all other relevant factors.

This shows that the rank, $r > 0$ of the $n \times n$ coefficient matrix Π, will indicate the number of independent price equations. If the rank of the matrix Π is unity then only one equation is required to describe the full system of price equations, which implies the markets prices are fully interrelated. On the other hand, if Π is found to have full rank, n, then all of the n equations are required to describe the system so that there needs to be an equation to explain each endogenous price. For all other possible values, $1 \leq r < n$, the rank will indicate the extent of the interdependencies between market prices. For example, integrated markets segmented into two disjoint regions will have a rank of two.

Returning to the wheat example, the end of month wholesale prices for each of the nine markets are graphed in Figure 2 for the period January, 1991 to June, 1998. Whilst it is difficult to disentangle individual market price behavior, it can be seen that there are possibly two identifiable groups. The Patna, Rajkot and Indore market prices are characteristically higher than the remaining market prices and casual observation indicates that possibly two price vectors are sufficient to describe the nine markets. However closer examination of the first group of prices in Figure 3 shows that there are important divergences in price movements. From mid 1991 to mid 1992, the Patna price is consistently above the Rajkot and Indore market prices, which move closely together. There are changing patterns between these prices until mid 1995, after which the three prices come together until early 1997. After this, the close relationships break down with the Indore price moving away and above the Patna and Rajkot prices. It is possible that two (or more) prices are required to explain these markets.

Figure 4 details the remaining six markets whose price behavior appear more consistent across markets, although it is possible that the Hapur, Kanpur, Bahraich and Delhi markets could be separated into another sub-group. It appears there needs to be two prices to describe this group, giving a total of at least four price vectors needed to explain the price behavior of the nine markets. The rank, r, of the system would therefore be expected to be in the order of four (or more).

Figure 2
End of Month Wholesale Wheat Prices

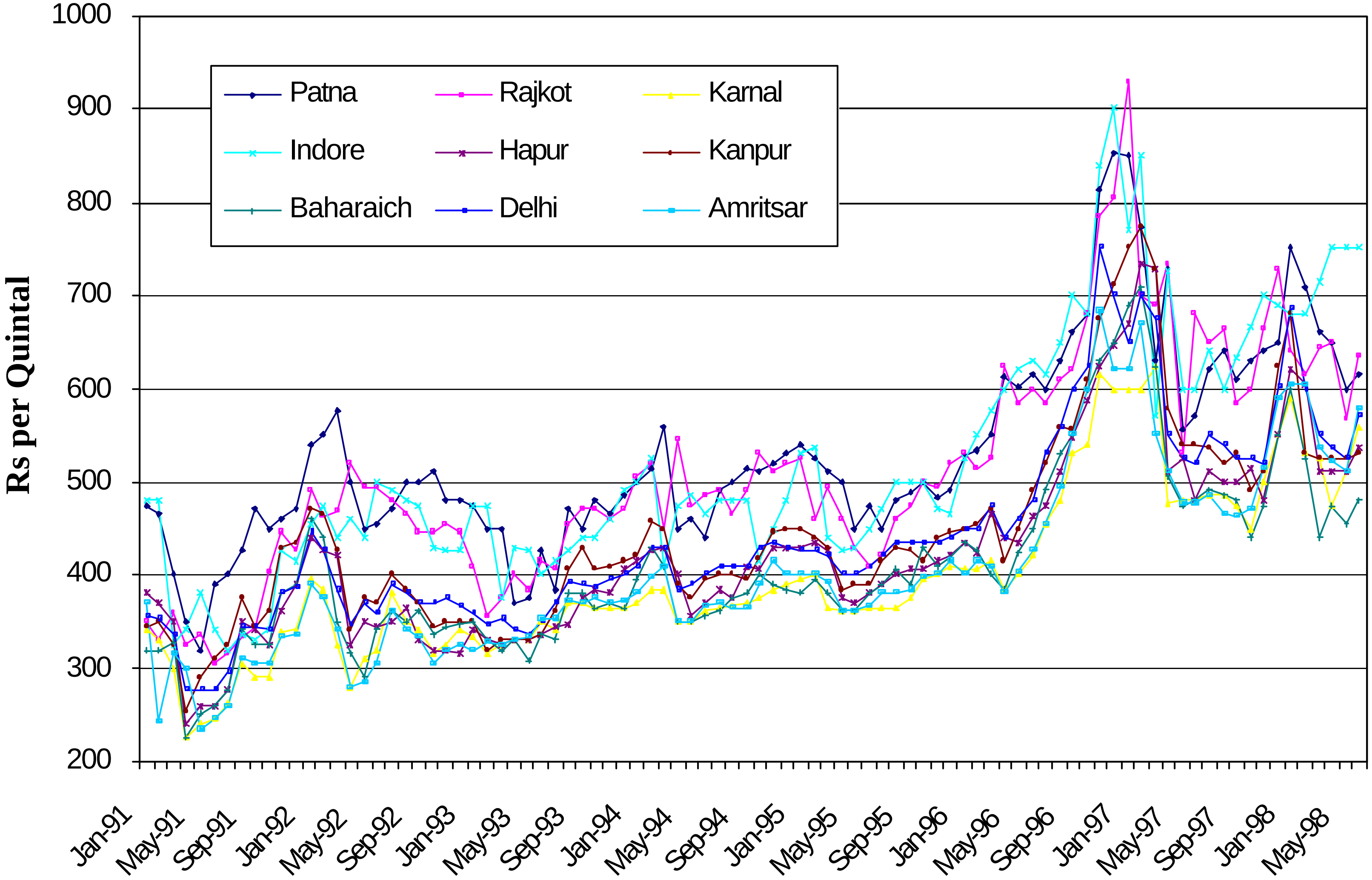


Figure 3
End of Month Wholesale Wheat Prices

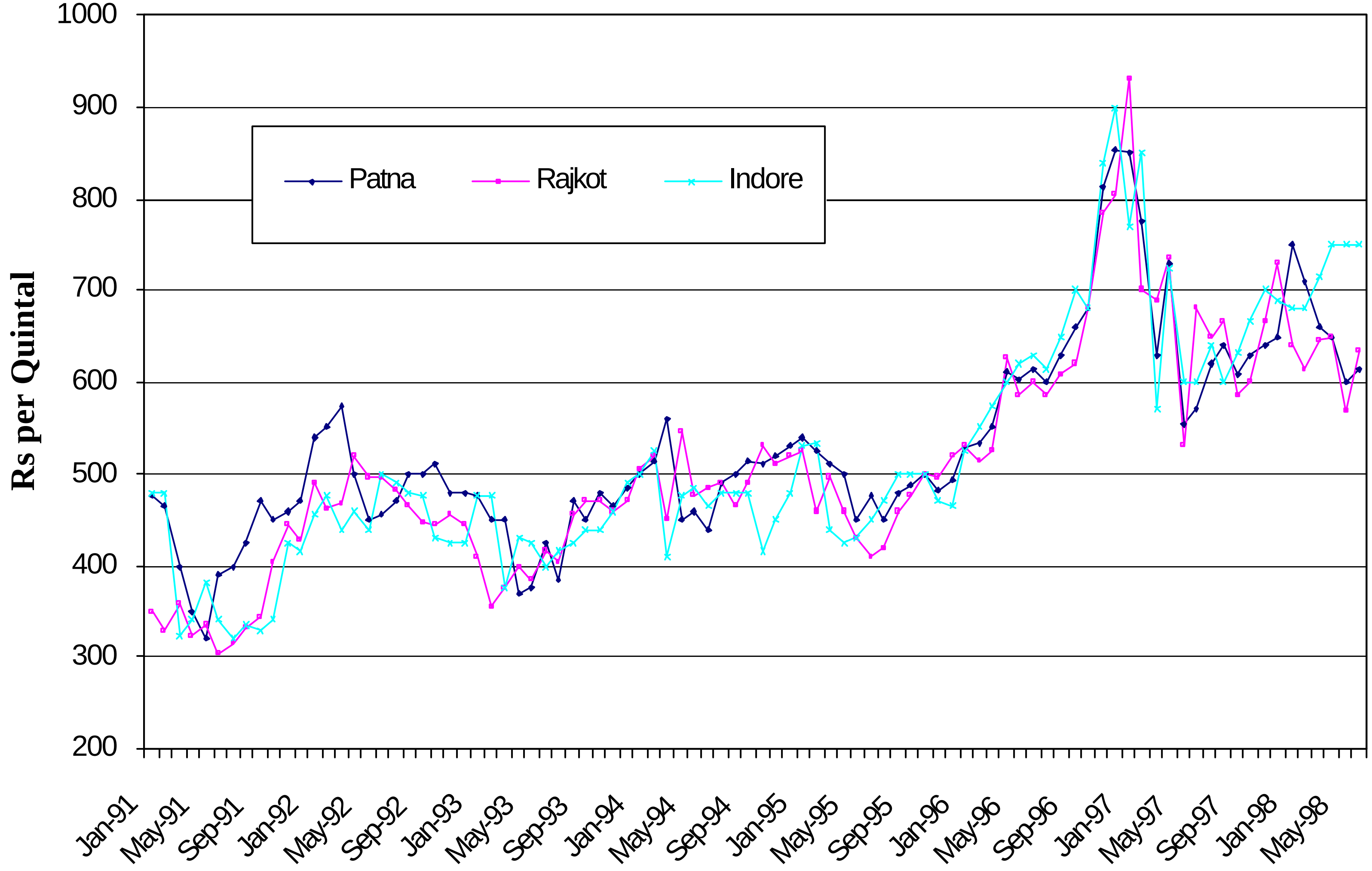
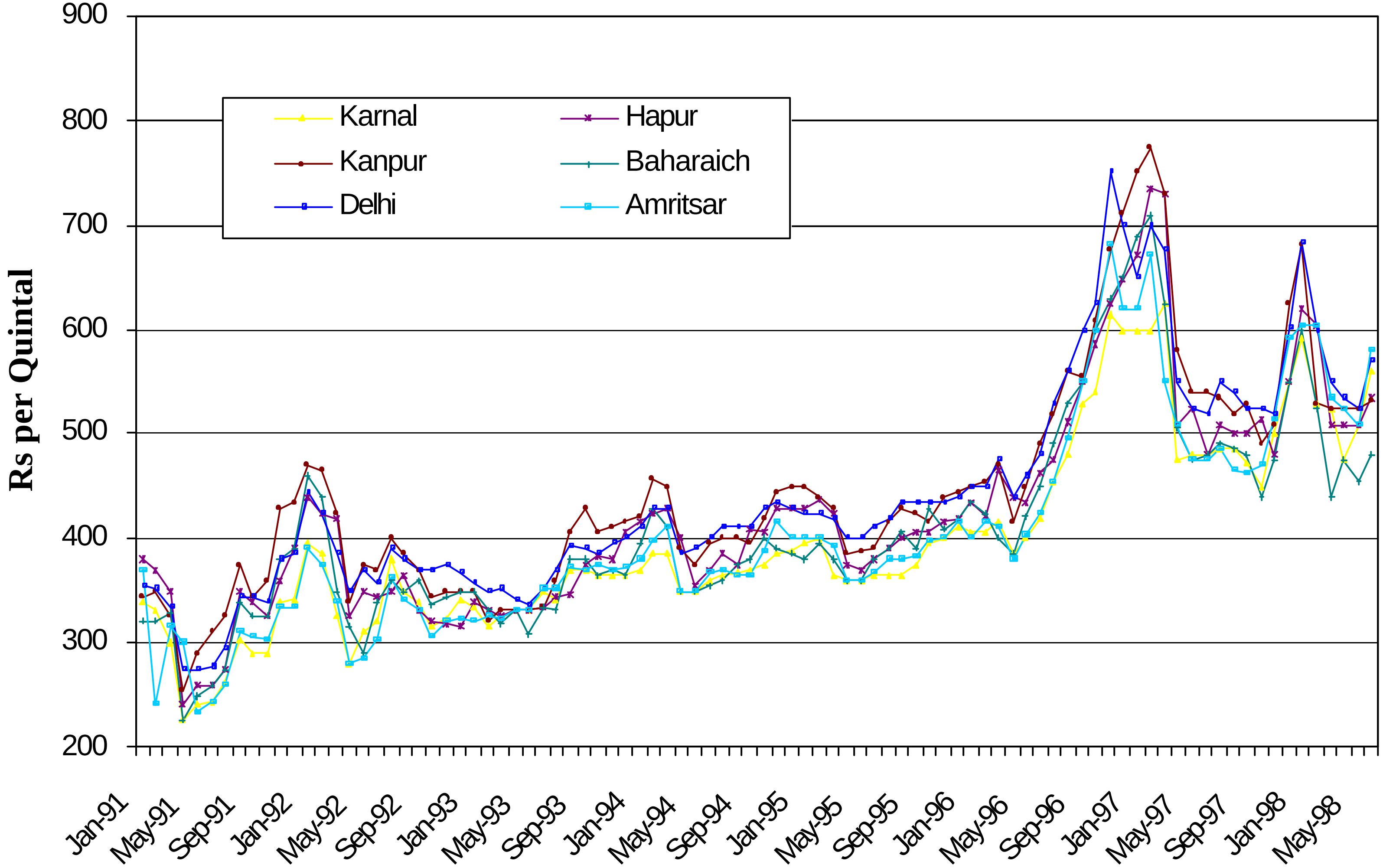


Figure 4
End of Month Wholesale Wheat Prices



The reduced rank system, $\underline{b} \subset \Pi$ has dimension $r \times n$, for $r < n$, and can be formally represented as:

$$\underline{b}\,\underline{p} = \begin{bmatrix} b_{11} & b_{21} & . & . & b_{n1} \\ b_{21} & b_{22} & . & . & b_{n2} \\ . & . & & & . \\ . & . & & & . \\ b_{r1} & b_{r2} & . & . & b_{rn} \end{bmatrix} \begin{bmatrix} p_1 \\ p_2 \\ . \\ . \\ p_n \end{bmatrix} \qquad (10)$$

The number of reduced rank vectors required to span the Π space is therefore *r*, shown as the number of rows in $\underline{b}$. The estimation of the $\underline{b}$ matrix will also provide important detail about how prices are related across markets. This will require efficient and consistent estimation in a simultaneous setting, which explicitly includes cross market covariances. Full information maximum likelihood is therefore appropriate. It would be very useful if the procedure also provided standard errors estimates for these coefficients.

The final important complication that needs to be addressed is the possible presence of common temporal affects on prices across markets. It is necessary to determine whether observed relationships represent statistically significant behavioral interdependencies between the prices or spurious relationships due to non-stationary time series. These aspects will be considered in more detail in the next section.

4. Modelling Non-Stationary Prices

The estimation procedure needs to obtain estimates of the rank, *r*, of the coefficient matrix Π and to efficiently and consistently estimate the $b_{ij} \in \underline{b}$ coefficients of the reduced matrix.[7] This procedure needs to take into account both the simultaneity and possible non-stationary characteristics of the market prices. Unfortunately, the presence of intertemporal non-stationary effects complicates the system specification and estimation. An appropriate method is to use Johansen's vector autoregressive (VAR) approach which explicitly incorporates both systematic spatial and temporal effects.[8] To this end define a VAR for the $n \times 1$ vector of market prices, $\underline{p}_t$:

$$\underline{p}_t = \underline{a}^0 + \sum_{i=1}^{k} \Phi_i \underline{p}_{t-i} + \sum_{j=0}^{l} \Psi_j X_{t-j} + u_t \ , \qquad t = 1,2,....,T \qquad (11)$$

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7 Since the rank of the matrix is determined as *r* there will be $r \times n$ elements, b_{ij} of matrix $\underline{b}$.

8 *Vide* Johansen (1991, 1995), Johansen and Julius (1992) and Pesaran and Pesaran (1997).

where $X = \{ \underline{q}, \underline{x}, \underline{z} \}$ represents all stationary non-price effects defined in (1) above. This relationship can therefore be interpreted as wholesale prices being determined by the history of prices and other factors which represent the marketable surplus. This relationship has an error correction (ECM) representation:

$$\Delta \underline{p}_t = \underline{a}^0 + \sum_{i=1}^{k-1} \Gamma_i \Delta \underline{p}_{t-i} + \Pi \underline{p}_{t-k} + \sum_{j=0}^{l} \Psi_j X_{t-j} + w_t \tag{12}$$

where $\Pi = \sum_{i=1}^{k} \Phi_i - \mathrm{I}$, with I denoting the identity matrix. This Π matrix is the equivalent to the Π matrix in relationship (9) extended to sum the over the distributed lag, $i = 1, 2, \ldots, k$.[9] Its rank, r, can be determined using Johansen's trace, eigenvalue and model selection criteria. Once this is determined the b_{ij} elements of the $\underline{b}$ matrix can be estimated with standard errors using full information maximum likelihood methods. The relationship between the Π and $\underline{b}$ matrices is given by:

$$\Pi = \underline{a}\underline{b}' \tag{13}$$

where the $\underline{b}$ matrix has dimension $r \times n$ and represents the long run steady state relationship between the equilibrium prices. Whilst the n prices $p_{j,t}$, $j = 1,2,....n$ are non-stationary in levels, $p_t \sim I(1)$ and stationary in first differences, $\Delta p_t \sim I(0)$, the relationship $\underline{b}'\underline{p}_t$ is stationary, $\underline{b}'\underline{p}_t \sim I(0)$. The $r \times 1$ relations given by $\underline{b}'\underline{p}_t$ are called the cointegrating vectors and if the prices are in Naperian log form, $p_i = \ln P_i$, $i = 1,2,....,n$ then the ratio of the coefficients $-\frac{b_i}{b_j}$ represent market equilibrium cross-price elasticities, e_{ij}, defined as:

$$-\frac{b_i}{b_j} = -\frac{\partial \ln P_i}{\partial \ln P_j} = -\frac{\partial P_i / P_i}{\partial P_j / P_j} = e_{ij} \tag{14}$$

It can be argued that the finding of significant market cross-price estimates in the cointegrating relationships characterise the extent of market price interdependencies in long run equilibrium. Finally, the $n \times r$ matrix $\underline{a}$ will also be of interest because it gives the estimated (error correction) responses of market prices to short run deviations from the long run equilibrium relationships.

[9] The matrices are equivalent for $k = 0$.

The simultaneous estimation, which is central to this paper, overcomes the objections of Ravallion (1986) and Baulch (1997a) and does away with the need to arbitrarily select a benchmark market whereby only pairwise comparisons can be made. This approach highlights the deficiency of previous cointegration studies which have been restricted to Engle-Granger type techniques. These single equation procedures are inconsistent with the simultaneity characteristics of the markets they are testing and contradict their purpose of testing for market integration. The paper will now estimate the steady state cointegrating relationships to derive the long run equilibrium cross-price elasticities.

5. Estimation of the Simultaneous Model for the Wholesale Prices of Wheat

Returning again to the end of month wholesale wheat prices, the important question is whether these observed co-movements of these prices reflect close behavioral interdependencies between markets or spurious temporal relationships due to common time trends. As mentioned in Section 2 the augmented Dickey-Fuller test found that all of the wheat prices appeared to be non-stationary.[10] However it is generally acknowledged that these test results have low power in relatively small sub-samples and tend to be biased in the presence of structural change and seasonality.[11] Whilst some of these factors can be incorporated into tests of stationarity, it is more sensible to assume the system of wholesale prices are non-stationary and to use Johansen's FIML cointegration estimation. The additional benefit of using the Johansen procedure is that it also checks the joint stationarity of all the market prices when full rank is found.[12]

To further account for these complicating factors, dummy variables were included in the stationary X matrix in specification (12) to capture seasonal and structural change effects. Eleven seasonal dummy variables were included for the months of January to November in addition to the constant term. A structural dummy variable took the value one for the period October, 1991 to March, 1993 and zero elsewhere. There was also high inflation in the reported period 1996-97 for production in 1995-96, due to speculation that there was going to be a shortfall in wheat production. Because this occurred towards the end of sample and there is a degrees of freedom constraint, no dummy variable was included for this effect.

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10 All variables are in Naperian logs to facilitate elasticity calculations in the cointegration analysis. Bahraich and Amritsar were only non-stationary if the trend was excluded from the ADF regression. There were large differences between the model selection criteria for Patna and Karnal.

11 *Vide* Perron (1989).

12 The procedure also allows over-identifying restrictions to test whether the possibly stationary market prices should be excluded from the cointegration analysis.

The first step in the estimation procedure is to determine the optimum lag length, k, of the VAR model specified in (12) above. Both the Schwarz Bayesian criterion (SBC) and the adjusted likelihood ratio test agree the optimum lag is order 1, which indicates there is only low order memory effects in the vector of month-end wholesale prices. This implies that wheat markets equilibrate relatively quickly, over one to two months, consistent with observed clearing of product surpluses and deficits by private and public buying and selling in these markets. Interestingly, it appears that inventories are not held for longer periods of time because they typically induce an autoregressive structure in the prices.

The first order cointegrating VAR with restricted intercept and no trend give mixed results for the determination of the rank of the system. The estimated eigenvalues are listed in descending order:

$$\{0.738, 0.629, 0.586, 0.470, 0.340, 0.289, 0.237, 0.168, 0.140\}$$

All model selection measures are flat over range with the Akaike Information criterion (AIC) and Hann-Quinn criterion (HQC) indicating a rank of eight. This large number of cointegrating vectors is supported by the likelihood ratio (LR) trace test which implies that seven to eight equations are required to explain the nine wholesale market prices. This surprisingly large rank condition is not supported by the eigenvalues, which would have to include such low values as 0.168 and 0.140. It appears that the degrees of freedom constraint is adversely affecting these measures. The Schwarz Bayesian criterion (SBC) tends to be the most reliable measure and indicates a rank of three. This preferred model selection criterion is also the most parsimonious and is consistent for large samples when the 'true' model is known. Under the assumption of efficient markets then all prices will be fully revealing and will therefore reflect the true unknown model and so this measure would consistently measure the number of cointegrating vectors. The LR maximal eigenvalue measure supports this with a rank of four, which agrees with the prior analysis of the price series in Figures 2 to 4. From these conflicting results there appear to be possibly four cointegrating vectors.

If this conclusion is accepted then four relationships explain all the market prices for the post-liberalisation period in agricultural marketing. To help interpret this result consider the wholesale price as the dependent variable in equation (12).[13] Here there is an equation for each of the nine markets which forms a VAR system of nine simultaneous equations. The estimation procedure used here, being FIML, takes account of the cross equation covariances as explained

[13] This equation can be thought of as the marketable surplus determining market price.

in the criticisms in Section 2 of this paper of the studies by Palaskas and Harris-White (1993), Alexander and Wyeth (1994), Dercon (1995) and others. The finding of cointegration indicates that linear combinations of these equations are stationary so that the prices for the different markets have a stationary long run equilibrium relationship. Note that this relationship allows differences between prices reflecting differences across markets in terms of such things like quality and productive efficiency. However for cointegration to exist these differences must be constant over time. Now a finding of rank of four indicates that the price relationships are not unique so that only four price equations are required to explain all the nine equilibrium market prices. This indicates a degree of market integration, as defined in the simultaneous model of Section 3, whereby the nine price vectors are linear combinations of each other so that they can be condensed into four representative vectors. The four estimated long run cointegrating vectors in $\hat{\underline{b}}$ and the associated short run error correction coefficients given by $\underline{\hat{a}}$ are detailed in Table 5. All of the significant error correction coefficients at the 5% level have the correct sign. However, these findings are not sufficient to conclude the markets for wheat are integrated and it is advisable to obtain more information about the interdependencies between the wholesale wheat prices.

The maximum likelihood estimates of the $\hat{\underline{b}}'\underline{p}$ matrix are also presented in Table 6. Remember that according to (14) the prices in logs derive the cross-price elasticities. These elasticities were calculated by identifying all of the cointegrated vectors and normalising each vector on a market wholesale price (which is listed in the left hand column) and estimating using maximum likelihood. That is for the m^{th} cointegrating vector, $1 \leq m \leq r$:

$$\left\{b_1^m p_1 + b_2^m p_2 + \ldots + b_i^m p_i + \ldots + b_j^m p_j + \ldots + b_n^m p_n\right\} = u \sim \mathrm{N}\left(0, s_u^2\right)$$

Taking expectations of both sides and normalising for p_i gives:

$$p_i = -\frac{b_1^m}{b_i^m} p_1 - \frac{b_2^m}{b_i^m} p_2 - \ldots - \frac{b_j^m}{b_i^m} p_j - \ldots - \frac{b_n^m}{b_i^m} p_n \,. \tag{15}$$

This relationship can then be identified by excluding the required number of variables with smallest coefficients.[14] Maximum likelihood estimation will give the elasticity estimate:

$$\hat{e}_{ij}^m = -\left({b_j^m} \big/ {b_i^m} \right) \tag{16}$$

[14] Exact identification required applying r restrictions on the price variables in each cointegrating vector. One of the restrictions was the normalisation which left r-1 zero restrictions. Where these restrictions coincided across the cointegrating coefficients, the next smallest coefficient was used the exclude that variable.

consistent with (14). Only the elasticity estimates that are significant at the 10% level are included in the table. Where the elasticities were significant for more than one cointegrating vector the value with the highest *t*-statistic was selected. The superscript denotes the relevant cointegrating vector from which the estimate is derived and the *t*-statistics are included in parentheses below the estimated coefficients. Each elasticity refers to the percent change in the equilibrium price for the market listed in the left hand column of that row, associated with a one percent increase in the equilibrium price for the market listed at the head of the relevant column. The exception is the final column, which shows the elasticities caused by non-price effects. It is important to note that these are not short run elasticities. They should be interpreted as measures of responsiveness of equilibrium market prices, calculated from the long run equilibrium cointegrating relationships, which characterise steady state.

Overall there are 42 out of a possible 72 pairwise elasticities (nearly 60%) which are significant. Remember that each estimate has been derived from the simultaneous estimation over all markets which takes into account all possible interdependencies. As shown in Table 4 of Section 2 the number of significant pairwise relationships fall dramatically when simultaneous effects are netted out. In this sense there are a surprising number of significant relationships, although it is expected the magnitudes of the estimates could be sensitive to the specification of the system.

Twenty-five of these estimates have positive sign indicating an increase in the equilibrium price in one market is associated with an increase in the equilibrium price of another market in the long run. Ten of these measures are inelastic ranging in value from 0.18 to 0.86, whilst the remaining elastic measures range from 1.12 to 3.79.[15] There are many possible examples which explain this long run positive relationship in prices. One is an excess demand in a market causing an arbitraging import of produce from another market, which causes prices to rise in both markets. Another example is a common increase in demand for wheat across markets causing a general increase in prices. Interestingly the elasticity between two markets is the inverse of the reverse elasticity estimate only when both measures are calculated from the same cointegrating vector. More significant effects from other cointegrating relationships can therefore derive asymmetric responses between markets in the long run. For example the long run cross-price elasticity effect of Amritsar on Karnal is 0.86 whilst the reverse effect of Karnal on Amritsar is double this at 1.74.

[15] This excludes the relatively high elasticity estimates for Patna, which range from -10.42 to 8.99.

Table 5

Estimated Cointegrating Vectors: Wheat

January, 1992 to June, 1998. Restricted Intercepts and No Trends in the VAR. Number of Cointegrating Vectors, r = 4.

Vector 1	{-0.1331Patna + 0.8931 Rajkot -2.9165 Karnal +0.3580 Indore - 0.-4133 Hapur - 0.76740 Kanpur +1.7731 Bahraich -1.1110 Delhi +2.3402 Amritasr -0.2862} ~ *I*(0)
Vector 2	{-0.3731 Patna + 0.1444 Rajkot +0.9198 Karnal - 0.4001 Indore - 3.0814 Hapur +2.5226 Kanpur - 1.4375 Bahraich +0.8085 Delhi +0.4242 12.12 Amritsar + 0.6969} ~ *I*(0)
Vector 3	{-0.1230 Patna -1.2676 Rajkot -2.1285 Karnal + 0.7269 Indore - 0.3839 Hapur + 2.0426 Kanpur - 1.4635 Bahraich +1.3752 Delhi + 0.8336 Amritsar +2.2151} ~ I(0)
Vector 4	{-0.4607 Patna + 0.9293 Rajkot - 0.8427 Karnal - 0.6342 Indore +0.4550 Hapur - 0.9355 Kanpur -2.0551 Bahraich +2.3491 Delhi +0.8183 Amritsar +2.1913} ~ I(0)

Estimated Short Run Error Correction Coefficients: Wheat [1]

	Patna	Rajkot	Karnal	Indore	Hapur	Kanpur	Bahraich	Delhi	Amritsar
ECM (Vector 1)	-0.020 (-0.31)	-0.193 * (-2.90)	-0.215 * (-4.31)	-0.222 * (-2.98)	-0.180 * (-3.47)	-0.172 * (-3.02)	0.030 (0.50)	-0.156 * (-3.06)	-0.060 (-1.03)
ECM (Vector 2)	-0.103 (-1.57)	-0.237 * (-3.56)	-0.076 (-1.53)	-0.032 (-0.43)	-0.265 * (-5.11)	-0.052 (-0.90)	-0.004 (-0.07)	-0.008 (-0.17)	-0.026 (-0.45)
ECM (Vector 3)	-0.039 (-0.60)	-0.211 * (-3.17)	-0.120 * (-2.42)	-0.160 * (-2.15)	-0.014 (-0.29)	-0.105 (-1.85)	-0.065 (-1.07)	-0.026 (-0.52)	-0.050 (-0.86)
ECM (Vector 4)	-0.021 (-0.01)	-0.075 (-1.13)	-0.056 (-1.13)	-0.143 (-1.92)	-0.052 (-1.01)	-0.095 (-1.67)	-0.162 * (-2.65)	-0.042 (-0.82)	-0.171 (-0.29)
R^2	0.28	0.59	0.57	0.52	0.61	0.53	0.50	0.45	0.42
$F_{15, 62}$	1.62	6.05	5.41	4.41	6.58	4.72	4.16	3.40	3.03
$F_{SC: 12, 50}$ [2]	1.27	0.72	2.33	2.03	1.00	1.38	1.30	1.10	1.22

Notes: [1] Figures in parenthesis below the estimated elasticities are *t*-statistics. * Represents the elasticity is significant at the 5% level.
[2] F_{SC} is the modified LM test statistic for serial correlation.

Table 6

Estimated Equilibrium Elasticities: Wheat [a]

January, 1992 to June, 1998. Restricted Intercepts and No Trends in the VAR. Number of Cointegrating Vectors, r = 4.

	Patna	Rajkot	Karnal	Indore	Hapur	Kanpur	Bahraich	Delhi	Amritsar	Intercept [b]
Patna		5.47 [3] (3.01)	-10.42 [3] (-2.01)			-6.16 [3] (-2.51)	5.24 [3] (1.77)		8.99 [3] (2.14)	10.57[4] (1.72)
Rajkot	0.18 [3] (3.05)		1.90 [3] (3.10)			1.12 [3] (4.63)	-0.95 [3] (-2.71)	3.45 [4] (1.67)	-1.64 [3] (-4.00)	
Karnal	-0.10 [3] (-2.00)	0.52 [3] (3.10)		0.26 [1] (3.29)		-0.59 [3] (-2.68)	0.50 [1] (3.03)		0.86 [3] (6.82)	
Indore		2.15 [4] (2.00)	3.79 [1] (3.29)			-2.70 [4] (-1.65)	-1.92 [1] (-3.68)		-2.28 [1] (-2.64)	
Hapur						1.28 [3] (3.02)				
Kanpur		0.73 [3] (5.31)			1.31 [2] (3.01)		1.42 [3] (5.07)	-1.08 [3] (-2.57)	0.79 [3] (1.86)	-0.93 [3] (-3.00)
Bahraich		-0.51 [3] (-4.75)	1.97 [1] (2.78)	-0.57 [1] (-1.99)		0.70 [3] (5.07)		0.80 [4] (5.35)	-1.13 [1] (-2.53)	0.85 [4] (4.51)
Delhi		0.68 [3] (3.17)				-0.92 [3] (-2.56)	1.24 [4] (5.35)			-1.05 [4] (-3.26)
Amritsar		-0.93 [3] (-2.12)	1.74 [1] (4.14)	-0.31 [2] (-1.78)		1.26 [3] (1.86)	-0.88 [1] (-2.53)			

Notes: [a] Each elasticity shows the percent change in the wholesale price for the market listed in the first column due to a + 1% change in the wholesale price for the market shown at the head of each column.
The superscripts denote which cointegrating vector is used to estimate the coefficients.
Figures in parentheses indicate the estimated *t*-statistics. Blank cells indicate coefficients are not significant at the 10% level.
[b] The elasticities in this column show the percent change in the wholesale equilibrium prices for the markets listed in the first column due to a +1% change in factors other than market wholesale prices

There are seventeen elasticities with negative sign, with nine being inelastic in the range -0.10 to -0.95 and the rest elastic with values ranging from –1.13 to –2.70 (ignoring Patna). This is consistent with the partial correlation findings reported in Table 4. The two-way negative elasticities for Patna and Karnal, Rajkot and Bahraich, Indore and Bahraich, Rajkot and Amritsar and the one-way negative elasticity for Kanpur to Indore are all reflected in the respective negative partial correlations of Table 4.

An elasticity with negative sign implies that the steady state equilibrium prices move in opposite directions. However there are other possible interpretations of these coefficients. The first is the negative sign could be due to the data definitions and collection. The reporting conventions for wheat are unlike any other agricultural products in India. The marketing season for wheat is April to March and the figures quoted for wheat production are lagged one year. So wheat production quoted for the 1995-96 season refers to actual wheat production in 1994-95. Given that the prices are quoted as 'end of month' it is possible that the timing of the recording of the reported wheat prices is not fully synchronised across markets. Preliminary exploration of leading and lagging some of the market price series by a month do affect coefficient estimates so the timing of data could be contributing to the negative signs.

Another possible reason for the negative signs is that they reflects changes in long run relative prices. To see this, consider relationship (15) which was used to derive the elasticities:

$$p_i + \frac{b_j^m}{b_i^m} p_j = -\frac{b_1^m}{b_i^m} p_1 - \frac{b_2^m}{b_i^m} p_2 - .... - \frac{b_n^m}{b_i^m} p_n$$

Denote the right hand side by the function $\Theta\left(\underset{\sim}{p}\right)$ which is a linear function of prices included in the relationship. Substituting the left hand side with prices in Naperian logs, $p_k = \ln P_k$ gives $\ln\left(\frac{P_i}{P_j^{-\frac{b_j}{b_i}}}\right) = \Theta\left(\underset{\sim}{p}\right)$ and exponentiating derives the relative price $\frac{P_i}{P_j^{-\frac{b_j}{b_i}}} = e^{\Theta\left(\underset{\sim}{p}\right)}$. This relationship shows that it is possible that even though both prices are moving in the same direction, the ratio may be increasing or decreasing depending on the movement in relative prices. The outcome will depend not only on the signs of b_i and b_j but also on the temporal behaviour of the function of all other prices, $e^{\Theta\left(\underset{\sim}{p}\right)}$. For this reason it would be unwise to rule out the possibility of significant negative price relationships in the long run. Indeed these findings could be demonstrating important equilibrium relationships like the transfers of factors of production across markets which have differing influences on market costs and prices. For example, consider markets facing different relative growths in production and/or marketing productivities. The markets losing productive resources would face increasing costs and prices relative to the factor importing markets. Whilst productivity is increasing in both markets, market costs will change and it would be expected that relative prices could also vary negatively or positively. In this case, the movements of these factors represent another important form of market integration which has not yet received adequate attention. This important economic question will be briefly considered in Section 7.

Taking care when interpreting individual cells in the matrix of Table 6, it can be seen that there are many significant cross-price elasticities. Overall, these results indicate there are important interdependencies between market prices which imply a degree of market integration for wheat. In terms of the columns it is clear that the Rajkot, Karnal, Kanpur, Bahraich and Amritsar markets are influential whilst the rows show these effects are spread over all markets. Hapur is the exception which only links (elastically) with Kanpur.

The cross-price elasticities are summed across the relevant rows in Table 6 for each market and included in the left hand column of Table 7. The total elasticities for Patna, Rajkot and Kanpur are much higher than for the other markets which have the range of 0.88 to 1.45 for Karnal, Hapur, Bahraich, Delhi and Amritsar. Indore is the only market with negative, almost unitary, total elasticity. The own-price elasticities listed in the next column of Table 7 measure the responsiveness of the proportionate change in equilibrium prices for each market caused by a 1% price increase in the same market. These estimates, $1-p_{ii}$, $i=1,2,...,n$ are obtained from the diagonal elements of the long run multiplier matrix, p_{ii}, and indicate the degree to which equilibrium prices change in each market.[16] All equilibrium prices are increasing with Rajkot, Kanpur, Karnal and Hapur being the most responsive.

The equilibrium total non-price elasticities in the next column of Table 7 show the intercept terms from the regressions (reproduced from the last column in Table 6). These estimates indicate the proportional response of the equilibrium price each market to changes in factors other than those captured in the equilibrium price changes within and across markets. The data shows that these effects are not significant for Rajkot, Indore, Amritsar, Karnal and Hapur. There are relatively large non-price effects on Patna's equilibrium price, whilst the other markets have variable effects. This implies the cross-price and own-price effects dominate the non-price effects in equilibrium.

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16 Unfortunately no standard errors are available for these estimates.

Table 7

Estimated Elasticities: Wheat [1]

January, 1992 to June, 1998

Market	Equilibrium Total Cross-Price Elasticity [2]	Equilibrium Total Own-Price Elasticity [3]	Equilibrium Total Non-Price Elasticity [4]	Equilibrating Price Elasticity [5]
Patna	3.12	1.02	10.57	-
Rajkot	4.06	1.54	-	-0.24
Karnal	1.45	2.00	-	-0.21
Indore	-0.96	1.30	-	-0.22
Hapur	1.28	1.92	-	-0.27
Kanpur	3.17	1.57	-0.93	-0.17
Bahraich	1.26	1.38	0.85	-
Delhi	1.00	1.31	-1.05	-0.16
Amritsar	0.88	1.20	-	-

Notes: [1] Only coefficients (except the equilibrium total own price elasticities) that are significant at the 10% level are included in this summary table.
[2] Defined as the total proportionate change in the equilibrium wholesale market price relative to the sum of the proportionate changes in the prices of all other markets.
[3] Defined as the proportionate change in the equilibrium wholesale market price relative to a proportionate change in the same market price in the previous equilibrium.
[4] Defined as the proportionate change in the equilibrium wholesale market price relative to a proportionate change in factors other than market wholesale prices.
[5] Defined as the proportionate equilibrating change in the market price due to a proportionate positive divergence from the equilibrium price.

The last column lists the equilibrating price elasticities. The estimates with the highest *t*-statistics were selected from the error corrections in Table 5 and all entries in this table are significant at the 5% level. These coefficients measure the proportional response of a market price to market disequilibrium, which is defined as a 1% divergence in the market price from the equilibrium level. Stability requires the elasticities to be negative so that a price higher (lower) than equilibrium will cause the price to subsequently fall (rise). Indeed most markets show significant inelastic and negative responses, with over 20% of price disequilibrium eliminated in the first month for the Rajkot, Indore, Karnal and Hapur markets. Whilst these elasticities imply slower than expected responses to disequilibrium they are in addition to all the price and non-price effects previously discussed, which in turn affect equilibrium market prices.

Finally, in order to provide further information on the interactions of these markets, Granger causality tests for the month-end wholesale market prices were conducted. The procedure involved testing the restriction of excluding each individual price from the vector autoregression specification (11) for all the market prices. These tests are therefore not simple pairwise Granger causality tests but involve each market price being tested against the system of all market prices and classified as either Granger causal or non-causal. There was no evidence of Granger causality at the 5% level implying the interdependent effects across markets occurred within the same month. The results of the more discriminating 1% level of significance are summarised schematically in Figure 5. The Rajkot, Hapur, Kanpur and Amritsar markets were found to Granger cause wheat prices whilst the Delhi, Bahraich Karnal, Indore and Patna markets follow.

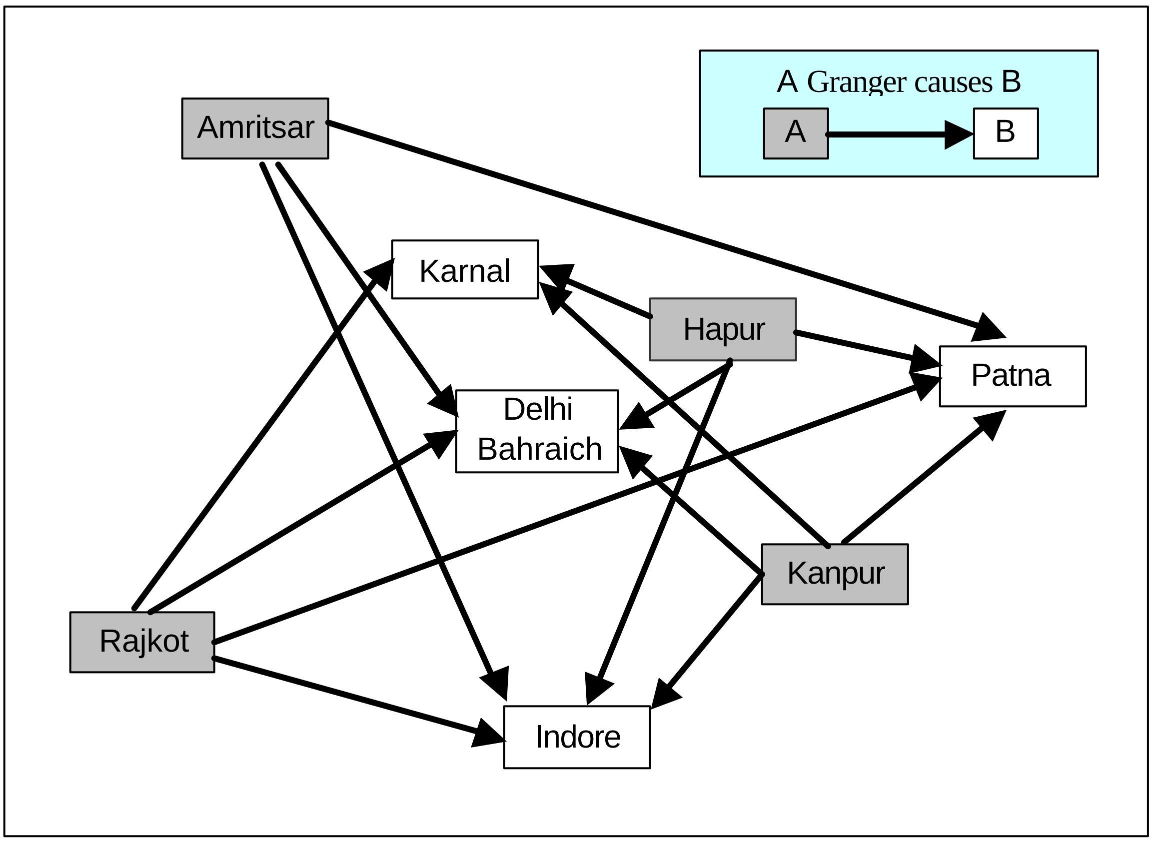
It is tempting to compare these Granger causality results with the elasticity estimates in Tables 6 and 7. However the Granger causality tests were conducted on the first difference of the logged price data, which represent the growth rates of prices. This is very different to

Figure 5

Granger Causality Tests: Wheat

(*1% Level of Significance*)

January, 1992 to June, 1998



cointegration results based on the levels of the log prices. With this in mind, the columns of Table 6 show that Rajkot, Kanpur and Amritsar are also dominant in terms of the size of their affects on other markets. The large elasticities in the rows for Patna and Indore in Table 6 confirm that other markets significantly affect these markets. Whilst there are exceptions (in particular Hapur), these outcomes are remarkably consistent with the Granger causality results. Wilson's (1999) dynamic simulations of the responses of Indian wholesale wheat prices to shocks at the market, national and international levels also support these findings. The body of evidence on wheat market integration therefore appears robust to the different estimation methodologies.

The next section applies the analysis to other important Indian commodities in the 1980's and 1990's.

6. *Analysis of Indian Wheat, Jower, Paddy Rice, Groundnut, Rapeseed and Mustard Seed: Pre and Post Liberalisation* [17]

Wheat

Wheat is further analysed for the earlier period January, 1982 to June, 1988 in order to provide a comparison with the results presented in Section 5 for the period January, 1992 to June, 1998.

The augmented Dickey-Fuller tests for the first sample show that the Karnal and Hapur wholesale prices appear non-trended with the test statistic indicating they are stationary *I* (0). Whilst the prices in the Kanpur and Delhi markets are also possibly stationary *I* (0) they become non-stationary *I* (1) when the linear trend is excluded from the ADF test. The prices in the remaining markets all appear to be non-stationary, so only the Karnal and Hapur markets were excluded from the cointegration analysis. As for the post liberalisation period, eleven seasonal dummy variables were included for the months of January to November in addition to the constant term. To further correctly specify the relationship a structural change dummy variable was included for the period March, 1984 to July, 1985 to captured the active government buying and selling of wheat in the markets during this time.

The econometric results for all the markets excluding Karnal and Hapur show the optimum VAR lag is order one, which indicates that inventories are not normally held for long periods. These observations are consistent with wheat markets surpluses and deficits equilibrating relatively quickly.

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[17] The results reported in this section for wheat, jower and paddy come from Wilson and Swami (1999).

The calculated eigenvalues in descending order are:

$$\{0.551,\ 0.510,\ 0.426,\ 0.308,\ 0.296,\ 0.179,\ 0.067,\ 0.032\}$$

and the tests for the number of cointegrating relationships show mixed results, ranging from three to five with some evidence for a rank of three. It is concluded that three relationships explain all the long run equilibrium market prices for the period January, 1982 to June, 1988. All the significant error correction coefficients at the 5% level have the correct sign and the Lagrange multiplier (LM) test indicates that serial correlation is not a problem in these regressions.

Table 8 details the estimated long run equilibrium cross-price elasticities which are significant at the 10% level. Seventeen have positive sign with seven having an elastic range from 1.12 to 3.57. The remaining ten inelastic measures range from 0.30 to 0.95. There are eight negative elasticities, with four being elastic in the range -1.35 to -3.44 and four in the range –0.32 to –0.74. As explained with the post liberalisation period, the table presents the most significant elasticities from the source cointegrating vector identified in the superscript. The Amritsar market has only one significant link with another market, whilst Kanpur appears highly integrated with many markets. Bahraich has an elastic and positive affect on Patna and Kanpur, whilst these markets plus Rajkot and Mehasana effect it inelastically. Note that the effects can be asymmetric with Delhi having elastic effects on Patna, Mehasana, Indore and Kanpur, whilst only being inelastically affected by Indore.

Compare these results in Table 8 with those shown in Table 6 for the second period. Noting there are different markets across the to samples with the second period including Karnal and Hapur and excluding Mehasana, there are many more significant elasticities for the post liberalisation period. Overall, these results imply there are more interdependencies between markets and therefore a higher degree of market integration for the second period. This is certainly true for Amritsar and Bahraich and there is the emerging importance of the Rajkot, Karnal and Kanpur markets.

Also compare the results for the two periods which are summarised in Tables 7 and 9. The equilibrium total cross-price elasticities are the sums of all the cross-price elasticities for each market in Tables 6 and 8. The elasticities for Patna, Rajkot and Kanpur are much higher than for the other markets in the second period with Rajkot increasing fivefold whilst Patna and Kanpur marginally decrease and increase respectively.

Table 8

Estimated Equilibrium Elasticities: Wheat [a]

January, 1982 to June, 1988. Restricted Intercepts and No Trends in the VAR. Number of Cointegrating Vectors, r = 3.

	Patna	Rajkot	Mehasana	Indore	Kanpur	Bahraich	Delhi	Amritsar	Intercept [b]
Patna			0.91 [2] (1.94)	-1.46 [2] (-2.15)	-1.92 [1] (-4.04)	2.14 [1] (5.10)	3.57 [2] (3.41)		4.30 [1] (1.82)
Rajkot								0.78 [3] (3.23)	
Mehasana	0.95 [2] (2.12)			1.25 [2] (1.94)	0.92 [2] (1.90)		-3.44 [1] (-2.25)		4.19 [2] (1.95)
Indore			0.80 [2] (1.94)		-0.74 [2] (-1.78)		2.75 [2] (2.49)		-3.35 [2] (-2.72)
Kanpur	-0.52 [1] -(3.84)	-0.34 [2] -(1.79)	0.36 [1] (2.15)	-1.35 [1] (-1.81)		1.12 [2] (9.50)	3.72 [2] (3.35)		1.69 [1] (3.78)
Bahraich	0.46 [1] (4.94)	0.30 [3] (1.83)	-0.32 [1] (-2.20)		0.89 [1] (9.50)				-1.50 [1] (-3.88)
Delhi				0.39 [2] (3.01)					4.80 [3] (1.64)
Amritsar		1.21 [3] (3.46)							5.31 [3] (2.33)

Notes: [a] Each elasticity shows the percent change in the wholesale price for the market listed in the first column due to a + 1% change in the wholesale price for the market shown at the head of each column.
The superscripts denote which cointegrating vector is used to estimate the coefficients.
Figures in parentheses indicate the estimated *t*-statistics. Blank cells indicate coefficients are not significant at the 10% level.
[b] The elasticities in this column show the percent change in the wholesale equilibrium prices for the markets listed in the first column due to a +1% change in factors other than market wholesale prices

Table 9

Estimated Elasticities: Wheat [1]

January, 1982 to June, 1988

Market	Equilibrium Total Cross-Price Elasticity [2]	Equilibrium Total Own-Price Elasticity [3]	Equilibrium Total Non-Price Elasticity [4]	Equilibrating Price Elasticity [5]
Patna	3.24	1.13	4.30	-0.11
Rajkot	0.78	1.31	-	-0.22
Mehasana	-0.32	1.07	4.19	-
Indore	2.81	1.30	-3.35	-0.25
Kanpur	2.99	1.27	1.69	-0.13
Bahraich	1.33	1.42	-1.50	-0.22
Delhi	0.39	1.42	4.80	0.13
Amritsar	1.21	1.11	5.31	-0.09

Notes: [1] Only coefficients (except the equilibrium total own price elasticities) that are significant at the 10% level are included in this summary table.
[2] Defined as the total proportionate change in the equilibrium wholesale market price relative to the sum of the proportionate changes in the prices of all other markets.
[3] Defined as the proportionate change in the equilibrium wholesale market price relative to a proportionate change in the same market price in the previous equilibrium.
[4] Defined as the proportionate change in the equilibrium wholesale market price relative to a proportionate change in factors other than market wholesale prices.
[5] Defined as the proportionate equilibrating change in the market price due to a proportionate positive divergence from the equilibrium price.

The own-price elasticities listed in the next column of Tables 7 and 9 show little differences between the two periods with Rajkot, Kanpur, Karnal and Amritsar being the most responsive in the second period. The equilibrium total non-price elasticities, which are significant at the 10% level, indicate that non-price effects are not important for Rajkot for both periods and for Indore, Amritsar, Karnal and Hapur in the second period. There are relatively large non-price effects on Patna's equilibrium price in both periods. Whilst the other markets have variable effects it is clear that the non-price proportional effects are generally smaller in magnitude for the second period. This implies the cross-price and own-price effects dominate the non-price effects in equilibrium.

The last columns in Tables 7 and 9 list the equilibrating price elasticities which are selected from the most significant error correction estimates at the 5% level. These estimates measure the proportional response of a market price to market disequilibrium, in addition to all the price and non-price effects. Stability requires the elasticities to be negative so that a price higher (lower) than equilibrium will cause the price to subsequently fall (rise). Most markets show inelastic responses with over 20% of price disequilibrium eliminated in the first month for the Rajkot, Indore, Karnal and Hapur markets.

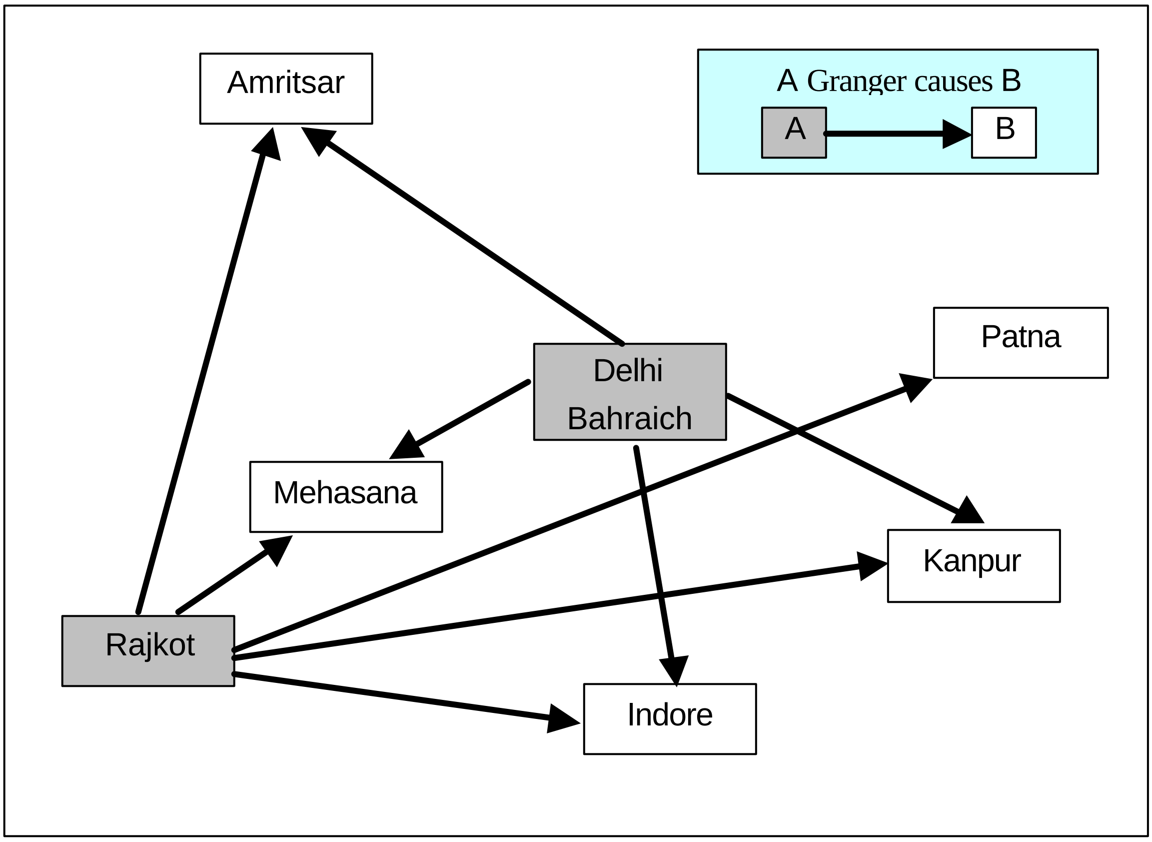
Finally, simultaneous Granger causality tests were also conducted for the first period January, 1982 to June, 1988. The Rajkot, Bahraich and Delhi markets were found to Granger cause the total system of all the market prices at the 5% level of significance. Compare the schematics in Figure 6 with Figure 5 for the second period. Rajkot and Delhi are the leading markets in terms of price changes in the first period. For the second period, Rajkot remains a leading market whilst Delhi switches to a following market and Hapur, Kanpur, and Amritsar switch from followers to leaders. Patna and Indore follow the other markets for both periods.

Figure 6

Granger Causality Tests: Wheat

(5% *Level of Significance*)

January, 1982 to June, 1988



In summary, despite the reliance on price data alone in this study, there is a clear message that dramatic changes have occurred in the way wheat markets interact since liberalisation. The markets, which previously demonstrated a high degree of interaction, have certainly become more integrated with Rajkot, Kanpur and Amritsar dominant in terms of the significance of the size and timing of affects across markets. On the other hand Patna and Indore are affected by other markets, both in terms of the size and timing of effects.

Jower

End of month wholesale price data was collected for two sub-samples October, 1981 to February, 1988 and October, 1991 to February, 1998. The augmented Dickey-Fuller test was used to determine the stationarity of the price series in Naperian logs. In the first period, prices for the Kolhapur market appear stationary I (0) when the trend is excluded. In comparison, prices are non-stationary I (1) when the trend is excluded for the Patan and Indore markets and when the trend is included for Madurai. The remaining market prices appear non-stationary. Similarly for the second period, there is no firm evidence that any of the prices are definitely stationary. Whilst prices in the Nandyal, Patan, Salem and Bahraich markets are possibly stationary, as explained in the previous section it is better to allow the possibility of non-stationarity and to include them in the cointegration analysis.[18] Accordingly, only Kolhapur was excluded from the subsequent cointegration analysis for the first period, leaving six markets, whilst all eleven markets were included for the second period.

The cointegration pre-tests unambiguously show that the optimum lag in the vector autoregression (VAR) is one for the first period. Like wheat, this implies that production variations in Jower are quickly cleared in markets which show no significant stockpiling. The cointegration with eleven seasonal dummy variables and a constant derived the eigenvalues:

$$\{0.527,\ 0.361,\ 0.165,\ 0.143,\ 0.095,\ 0.063\}$$

The number of cointegrating vectors is one according to the trace, maximum eigenvalue and SBC measures. The error corrections coefficients show the Patan and Indore markets exhibit relatively rapid adjustments to disequilibrium.

[18] The test for Coimbatore gave ambiguous results in the form of large differences in the model selection criteria.

Table 10

Estimated Equilibrium Elasticities: Jower [a]

October, 1981 to February, 1988. Restricted Intercepts and No Trends in the VAR. Number of Cointegrating Vectors, r = 1.

	Nandyal	Patan	Gulbarga	Indore	Nagpur	Madurai	Intercept [b]
Nandyal							
Patan			1.36 [1] (3.49)	2.01 [1] (4.95)		-1.27 [1] (-2.77)	-5.34 [1] (-2.42)
Gulbarga		0.73 [1] (3.49)		-1.48 [1] (-2.72)		0.94 [1] (2.23)	3.93 [1] (2.53)
Indore		0.50 [1] (4.95)	-0.68 [1] (-2.72)			0.63 [1] (4.25)	2.66 [1] (2.26)
Nagpur							
Madurai		-0.79 [1] (-2.77)	1.07 [1] (2.23)	1.58 [1] (4.25)			-4.19 [1] (-1.65)

Notes: [a] Each elasticity shows the percent change in the wholesale price for the market listed in the first column due to a + 1% change in the wholesale price for the market shown at the head of each column.
The superscripts denote which cointegrating vector is used to estimate the coefficients.
Figures in parentheses indicate the estimated *t*-statistics. Blank cells indicate coefficients are not significant at the 10% level.
[b] The elasticities in this column show the percent change in the wholesale equilibrium prices for the markets listed in the first column due to a +1% change in factors other than market wholesale prices

Table 11

Estimated Equilibrium Elasticities: Jower [a]

October, 1991 to February, 1998. Restricted Intercepts and No Trends in the VAR. Number of Cointegrating Vectors, r = 4.

	Nandyal	Hyderabad	Patan	Gulbarga	Indore	Kolhapur	Nagpur	Coimbatore	Salem	Kanpur	Bahraich	Intercept
Nandyal												
Hyderabad												
Patan												
Gulbarga						0.45 [1] (2.76)						
Indore								2.67 [4] (2.58)				
Kolhapur				2.20 [1] (2.76)								
Nagpur												
Coimbatore					0.37 [4] (2.58)							
Salem												
Kanpur	3.56 [3] (2.26)											
Bahraich												

Notes: [a] Each elasticity shows the percent change in the wholesale price for the market listed in the first column due to a + 1% change in the wholesale price for the market shown at the head of each column. The superscripts denote which cointegrating vector is used to estimate the coefficients.
Figures in parentheses indicate the estimated *t*-statistics. Blank cells indicate coefficients are not significant at the 10% level.

Table 10 lists the estimated cross-price elasticities for each market for the first period October, 1981 to February, 1988. Only elasticities which are significant at the 10% level are included in the table and care needs to be exercised when examining individual matrix cells. Each elasticity represents the proportionate change in the equilibrium wholesale price for the market listed to the left of the relevant row, due to a one percent increase in the equilibrium wholesale price for the market listed at the head of the column. Whilst the Nandyal and Nagpur markets appear isolated the remaining markets, namely, Patan, Gulbarga, Indore and Madurai appear to be highly interdependent. In particular, Patan is elastically affected by these markets (ranging from 1.27 to 2.01 in absolute terms) whilst Indore is inelastically affected. This pattern is reversed for Patan having inelastic effects and Indore having elastic effects (1.48 to 2.01 in absolute terms). The elasticities for Gulbarga and Madurai are mixed in terms of size and sign. The intercept terms for these markets also show strong non-price elasticity effects on all markets except Nandyal and Nagpur.

The results of the cointegration analysis for the second period October, 1991 to February, 1998 show a less clear picture of market interdependencies. The end of month wholesale price data exhibit structural change to varying degrees approximately around early 1993. A dummy variable which took the value one for the first sub-period October, 1991 to March, 1993 and zero for the remainder of the sample, was included along with eleven seasonal dummy variables and a constant term. The tests for the optimum lag in the vector autoregression are ambiguous so it is possible that the number of lags may be zero, one or four. The unusual behaviour of the AIC measure and the adjusted LR test indicate they are sensitive to the lack of degrees of freedom. The SBC parsimonious measure of lag one is therefore adopted. The results for the tests for the number of cointegrating variables are also ambiguous ranging from no cointegration according to the SBC measure, 4 to 7 cointegrating vectors according to the trace and maximum eigenvalue statistics, and up to 10 cointegrating vectors if the AIC measure can be believed. With this wide range in mind, perusal of the eigenvalues:

$$\{0.685,\ 0.668,\ 0.639,\ 0.510,\ 0.448,\ 0.384,\ 0.335,\ 0.277,\ 0.186,\ 0.101,\ 0.033\}$$

shows that, whilst there are many possible vectors, there are at least three to five. In order to keep the analysis tractable the rank of four was selected although the number could be as high as seven.

Table 12

Estimated Elasticities: Jower [1]

Market	Equilibrium Total Cross-Price Elasticity [2]	Equilibrium Total Own-Price Elasticity [3]	Equilibrium Total Non-Price Elasticity [4]	Equilibrating Price Elasticity [5]
October, 1981 to February, 1988				
Nandyal	-	1.00	-	-
Patan	2.10	1.18	-5.34	-0.33
Gulbarga	0.19	1.08	3.93	-0.11
Indore	0.45	1.56	2.66	-0.51
Nagpur	-	1.01	-	-
Madurai	1.86	1.07	-4.19	-
October, 1991 to February, 1998				
Nandyal	-	1.32	-	-0.26
Patan	-	1.30	-	0.53
Gulbarga	0.45	1.85	-	-0.63
Indore	2.67	1.43	-	-0.65
Nagpur	-	1.07	-	-0.16
Kolhapur	2.20	1.41	-	-0.46
Hyderabad	-	1.81	-	-0.43
Coimbatore	0.37	1.30	-	-0.17
Salem	-	1.08	-	-0.12
Kanpur	3.56	1.17	-	-0.42
Bahraich	-	1.08	-	0.18

Notes: [1] Only coefficients (except the equilibrium total own price elasticities) that are significant at the 10% level are included in this summary table.

[2] Defined as the total proportionate change in the equilibrium wholesale market price relative to the sum of the proportionate changes in the prices of all other markets.

[3] Defined as the proportionate change in the equilibrium wholesale market price relative to a proportionate change in the same market price in the previous equilibrium.

[4] Defined as the proportionate change in the equilibrium wholesale market price relative to a proportionate change in factors other than market wholesale prices.

[5] Defined as the proportionate equilibrating change in the market price due to a proportionate positive divergence from the equilibrium price.

In comparison with the single cointegrating vector found for the first period, these markets in the second period appear to be behaving very differently. Whilst Nandyal, Patan, Gulbarga Indore and Nagpur markets are included in both samples, the second sample excludes Madurai and includes Kolhapur, Hyderabad, Coimbatore, Salem, Kanpur and Bahraich.[19] Consistent with the more complex behaviour of these markets, they exhibit significantly more rapid equilibrating adjustments.

The relatively few estimates of the cross-price elasticities in Table 11 show that there do not appear to be any important market interactions during the period October, 1991 to February, 1998. Keeping in mind the table only reports elasticities which are significant at the 10% level it is interesting to note that the first three cointegrating vectors, which are ranked in declining order of importance, supply only three significant elasticities. With the existence of some forms of structural change in the price series early in the sample, it is difficult to identify reasons for this apparent lack of interdependence in these markets. The summary in Table 12 shows that despite this, the Gulbarga and Indore markets have larger total cross-price elasticities in the second period, whilst Patan has less. The Kolhapur and Kanpur total cross-price elasticities are also larger than the total average for the two periods. The total own price elasticities for the Nandyal, Patan, Gulbarga and Nagpur markets are higher in the second period, with the exception of Indore. Generally speaking the other markets in the second period demonstrate relatively high total own price elasticities.

Indeed, the observation that the markets included in this study demonstrate little significant integration for the second period is supported by the results in Table 12. The last column shows that these markets, with only a few exceptions, equilibrate rapidly. They are also responsive to own-price changes in equilibrium, (as shown in the second column). Both of these results demonstrate the ability of these markets to equilibrate by themselves in the second period. This observation is consistent with both the lack of significant external non-price effects on each market equilibrium price (column three) and with the reported lack of significant equilibrium price responsiveness across markets (column one). Due to the lack of observed market interrelationships for the second period, no Granger causality tests were conducted.

19 The study was limited to markets which had reliable wholesale price data available for the common sample periods prior to and after liberalisation in 1991. Three markets included in both samples, Patan, Indore and Kolhapur were found to be stationary according to the ADF test and were therefore excluded from the analysis. This further reduced the conjoint sample.

The results do not support the hypothesis of market integration for Jower for the second period. In comparison, the markets for jower appeared to be more integrated prior to liberalisation. These results, if accurate, whilst agreeing with the findings for wheat in that there have been dramatic changes to the way markets interact since liberalisation, they contrast dramatically with the observed increasing interdependence of wheat markets.

Paddy Rice

The periods chosen to compare the interrelationships between markets for paddy rice were October, 1981 to February, 1988 and October, 1991 to February, 1998. Only five markets were included in the first period due to the lack of continuous wholesale price data being available. Unfortunately this limits the direct comparison of markets for the two periods to Raipur, Kolhapur, Amritsar and Bahraich. The augmented Dickey-Fuller tests for stationarity indicate that Bahraich is stationary *I* (0) with trend in the first period with the other markets non-stationary *I* (1) without trend.[20] For the second period the Tadepalgudam, Raipur, Kolhapur, Bahraich and Manipur markets are non-stationary. The Nizamabad, Purnea and Darbhanga markets are stationary with trend. However, Palakkad, Simoga, Durg, Amritsar, Thanjavur, Kanpur and Attara, whilst stationary with trend, are non-stationary when the trend is excluded. Since excluding the trend misspecifies the ADF specification the prices for these markets are most likely stationary. Inspection of the price time series however shows a structural break around early 1995. Plots of the series characterised them as trended in the period to mid 1994 and then non-trended after early 1995. This change in structure is certainly the cause of the mixed stationary results. Whilst it is tempting to include these markets in the analysis, there is the binding constraint of insufficient number of observations to run the cointegration analysis for twelve markets. Excluding these markets leaves five markets which give enough degrees of freedom to obtain sensible estimates. However only Raipur and Kolhapur are non-stationary in both periods, which limits the ability to directly compare markets before and after liberalisation of agricultural marketing.

The cointegration analysis for the first period included a constant, eleven seasonal dummy variables and a dummy variable for the relatively short period July, 1982 to October, 1983. Like wheat and jower the optimum lag for the vector autoregression (VAR) was one.

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20 Large differences were found between the model selection criteria for the Amritsar market. The lower SBC value was chosen.

The eigenvalues, listed in descending order:

{0.349, 0.247. 0.179, 0.052}

and rank tests, indicate at most only one cointegrating vector. The error correction equilibrating adjustments, whilst relatively slow, are significant at 10% for Raipur and Kolhapur and 5% for Jatni and Amritsar.

The estimated equilibrium cross-price elasticities are shown in Table 13 for the first period. Clearly Amritsar is the only market which influences other markets at the 10% level of significance. Whilst these effects on Raipur and Kolhapur are elastic, with values 1.44 and 4.75 respectively, their feedback effects on Amritsar are inelastic (0.69 and 0.21 respectively). There are no observed interdependencies between Raipur and Kolhapur and no cross-price effects at all for Jatni. The non-price elasticities shown in the last column of Table 13 have no effect on market equilibrium prices.

Table 13

Estimated Equilibrium Elasticities: Paddy Rice [a]

October, 1981 to February, 1988. Restricted Intercepts and No Trends in the VAR.
Number of Cointegrating Vectors, r = 1.

	Raipur	Kolhapur	Jatni	Amritsar	Intercept [b]
Raipur				1.44 [1] (3.10)	
Kolhapur				4.74 [1] (1.94)	
Jatni					
Amritsar	0.69 [1] (3.09)	0.21 [1] (1.94)			

Notes: [a] Each elasticity shows the percent change in the wholesale price for the market listed in the first column due to a + 1% change in the wholesale price for the market shown at the head of each column.
The superscripts denote which cointegrating vector is used to estimate the coefficients.
Figures in parentheses indicate the estimated *t*-statistics. Blank cells indicate coefficients are not significant at the 10% level.
[b] The elasticities in this column show the percent change in the wholesale equilibrium prices for the markets listed in the first column due to a +1% change in factors other than market wholesale prices

Table 14

Estimated Equilibrium Elasticities: Paddy Rice [a]

October, 1991 to February, 1998. Restricted Intercepts and No Trends in the VAR. Number of Cointegrating Vectors, r = 3.

	Tadepalgu-dam	Raipur	Kolhapur	Bahraich	Manipur	Intercept [b]
Tadepalgu-dam		1.28 [3] (3.45)		2.24 [1] (4.33)	1.63 [2] (2.35)	-7.80 [1] (-2.25)
Raipur	0.78 [3] (3.45)			1.74 [1] (3.12)		
Kolhapur					3.01 [2] (2.41)	
Bahraich		0.57 [3] (3.12)			0.70 [1] (4.77)	3.37 [1] (3.41)
Manipur	0.61 [2] (2.35)		0.36 [1] (1.63)	1.40 [1] (4.77)		-4.76 [1] (-2.42)

Notes: [a] Each elasticity shows the percent change in the wholesale price for the market listed in the first column due to a + 1% change in the wholesale price for the market shown at the head of each column.
The superscripts denote which cointegrating vector is used to estimate the coefficients.
Figures in parentheses indicate the estimated *t*-statistics. Blank cells indicate coefficients are not significant at the 10% level.
[b] These elasticities show the percent change in the wholesale equilibrium prices for the markets listed in the first column due to a +1% change in factors other than market wholesale prices

The cointegration specifications for the second period October, 1991 to February, 1998 include a constant, eleven seasonal dummy variables and a structural dummy variable which accounts for the observed change in trend by taking value one for the start of the period October, 1991 to January, 1995, and zero elsewhere. The optimum lag for the VAR is unambiguously one and the number of cointegrating variables is either two or three. Selecting three vectors based on the eigenvalues:

$$\{0.417,\ 0.327,\ 0.243,\ 0.132,\ 0.043\}$$

gives all markets, except Manipur, rapid and significant corrections to equilibrium. Table 14 shows the estimated equilibrium cross-price elasticities for the second period. There are twice as many significant elasticities than for the first period indicating a higher degree of market interdependencies. Whilst Tadepalgudam affects Raipur and Manipur inelastically (0.71 and 0.61 respectively) it is affected elastically by Raipur (1.29), Bahraich (2.24) and Manipur (1.63). Similarly Bahraich elastically affects all markets except Kolhapur and is affected inelastically by Raipur (0.57) and Manipur (0.70).

Table 15

Estimated Elasticities: Paddy Rice [1]

Market	Equilibrium Total Cross-Price Elasticity [2]	Equilibrium Total Own-Price Elasticity [3]	Equilibrium Total Non-Price Elasticity [4]	Equilibrating Price Elasticity [5]
October, 1981 to February, 1988				
Raipur	1.44	1.13	-	-0.12
Kolhapur	4.74	1.05	-	-0.15
Jatni	-	1.06	-	-0.15
Amritsar	0.90	1.33	-	-0.21
October, 1991 to February, 1998				
Tadepalgudam	5.16	1.34	-7.80	-0.71
Raipur	2.52	1.22	-	-0.80
Kolhapur	3.01	1.13	-	-0.60
Bahraich	1.27	1.57	3.37	-1.94
Manipur	2.37	1.14	-4.76	-0.03

Notes: [1] Only coefficients (except the equilibrium total own price elasticities) that are significant at the 10% level are included in this summary table.
[2] Defined as the total proportionate change in the equilibrium wholesale market price relative to the sum of the proportionate changes in the prices of all other markets.
[3] Defined as the proportionate change in the equilibrium wholesale market price relative to a proportionate change in the same market price in the previous equilibrium.
[4] Defined as the proportionate change in the equilibrium wholesale market price relative to a proportionate change in factors other than market wholesale prices.
[5] Defined as the proportionate equilibrating change in the market price due to a proportionate positive divergence from the equilibrium price.

Table 15 summarises these results for the two periods and it can be seen, with the exception of Kolhapur, total cross-price elasticities are larger in the second period reflecting a high degree of interdependence between markets. The markets for paddy rice therefore appear to be increasingly integrated in the period October, 1991 to February, 1998. The external effects of non-price effects are also large in the second period (as shown in column 3). The ability for these markets to clear is significantly higher in the second period with the own equilibrium price adjustments (shown in column 2) being higher in the second period. The strong support for this conclusion is given by the large adjustments to equilibrium (shown in the last column). These rates of adjustment are very high, unlike most of those found for wheat and jower. Note the instability of the Bahraich market with an adjustment coefficient of -1.94 implying that the price adjustment overshoots the equilibrium.

Groundnut

The periods to be analysed are the same as for paddy and jower, namely October, 1981 to February, 1988 and October, 1991 to February, 1998. The Nandyal, Rajkot, Bombay, Chennai and Kanpur markets are common to both periods whilst the post-liberalisation period includes the Viziangram, and Kapadwanj markets. All market prices were found to be non-stationary using the ADF test with and without trend.[21] The search for the optimum lag in the VAR showed it also equal to one according to the SBC and adjusted LR tests for both periods. In order to correctly specify the VAR, seasonal dummy variables were included, as were special dummy variables for the periods of atypical behaviour from March, 1986 to February, 1988 and November, 1993 to August, 1995. The rank of the system of prices for the first period was unambiguously determined by the SBC, trace and maximal eigenvalue statistics as three. The eigenvalues were calculated as:

$$\{0.511,\ 0.411, 0.295, 0.169, 0.008\}$$

and the estimates of the elasticities, which are significant at 10%, are shown in Table 16. All are positive and show pairwise relationships of market prices, for example, Nandyal with Rajkot and Bombay, Chennai with Bombay and Kanpur with Rajkot. Four of these measures are inelastic whilst the remaining five are elastic with some larger values in the range 3.6 to 4.9 for the Nandyal market.

The rank for the post-liberalisation period was less easily determined. The eigenvalues tend to be flat:

$$\{0.478,\ 0.424,\ 0.388,\ 0.339,\ 0.259,\ 0.205,\ 0.010\}$$

and the SBC, AIC and HQC statistics tend to point to the ends of the range. The maximal eigenvalue and trace statistics indicate a rank of four to five. It was decided to select the rank of four based on these eigenvalues.[22]

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21 The Bombay market was I(0) for the first period when the trend was included in the ADF regression.

22 The SBC criterion indicated no cointegrating vectors whilst the AIC and HQC measures were maximised at a rank of six. The value of four is also a weighted average of these values.

Table 16

Estimated Equilibrium Elasticities: Groundnut [a]

October, 1981 to February, 1988. Restricted Intercepts and No Trends in the VAR. Number of Cointegrating Vectors, r = 3.

	Nandyal	Rajkot	Bombay	Chennai	Kanpur	Intercept [b]
Nandyal		0.28 [1] (2.50)	0.62 [2] (2.93)			
Rajkot	3.60 [1] (2.50)				0.72 [2] (5.47)	
Bombay	1.70 [1] (1.89)			0.66 [2] (2.16)		2.56 [3] (1.65)
Chennai			1.51 [2] (2.16)			
Kanpur	4.89 [1] (1.97)	1.38 [2] (5.47)				

Notes: [a] Each elasticity shows the percent change in the wholesale price for the market listed in the first column due to a + 1% change in the wholesale price for the market shown at the head of each column.
The superscripts denote which cointegrating vector is used to estimate the coefficients.
Figures in parentheses indicate the estimated *t*-statistics. Blank cells indicate coefficients are not significant at the 10% level.
[b] These elasticities show the percent change in the wholesale equilibrium prices for the markets listed in the first column due to a +1% change in factors other than market wholesale prices

The estimated equilibrium elasticities are reported in Table 17. Similar to the earlier period, most of the significant elasticities indicate pairwise relationships, for example the Rajkot market with the Bombay and Kapadwanj markets and the Chennai and Kanpur markets. However, despite there being two additional markets for the post-liberalisation period there are only eight significant cross-price elasticities compared to nine for the first period. The comparison shows that the number of significant elasticities for the markets, common to both periods, has fallen from nine to five.

Table 18 further summarises the results for the two periods. The total cross-price elasticities tend to be larger for the first period, consistent with a relatively higher degree of price interdependencies. The second and third columns show the markets tend to equilibrate themselves with own-price elasticities all positive and elastic, with the exception of the Bombay market. The external effects, which are not captured in the groundnut prices, are only significant for two markets. The equilibrating price elasticities listed in the final column of Table 18 have the highest *t*-values out of the elasticities which are significant at 10% level.

Table 17

Estimated Equilibrium Elasticities: Groundnut [a]

October, 1991 to February, 1998. Restricted Intercepts and No Trends in the VAR. Number of Cointegrating Vectors, r = 4.

	Nandyal	Rajkot	Bombay	Chennai	Kanpur	Viziangram	Kapadwanj	Intercept [b]
Nandyal								
Rajkot			0.61 [3] (2.15)				0.86 [2] (2.01)	
Bombay		1.64 [3] (2.15)						
Chennai		1.14 [1] (1.65)			0.53 [1] (1.89)			
Kanpur				1.88 [1] (1.89)				
Viziangram								
Kapadwanj		1.27 [2] (2.19)	0.80 [4] (1.67)					-1.99 [4] (1.96)

Notes: [a] Each elasticity shows the percent change in the wholesale price for the market listed in the first column due to a + 1% change in the wholesale price for the market shown at the head of each column.
The superscripts denote which cointegrating vector is used to estimate the coefficients.
Figures in parentheses indicate the estimated *t*-statistics. Blank cells indicate coefficients are not significant at the 10% level.

[b] The elasticities in this column show the percent change in the wholesale equilibrium prices for the markets listed in the first column due to a +1% change in factors other than market wholesale prices

Table 18

Estimated Elasticities: Groundnut [1]

Market	Equilibrium Total Cross-Price Elasticity [2]	Equilibrium Total Own-Price Elasticity [3]	Equilibrium Total Non-Price Elasticity [4]	Equilibrating Price Elasticity [5]
October, 1981 to February, 1988				
Nandyal	0.90	1.39	-	-
Rajkot	4.32	1.24	-	-0.16
Bombay	4.92	1.82	2.56	0.28
Chennai	1.51	1.03	-	0.12
Kanpur	6.27	1.21	-	-0.21
October, 1991 to February, 1998				
Nandyal	-	1.16	-	-0.12
Rajkot	1.47	1.57	-	0.22
Bombay	1.64	0.89	-	-
Chennai	1.67	1.43	-	0.24
Kanpur	1.88	1.25	-	-0.20
Viziangram	-	1.48	-	0.49
Kapadwanj	2.07	1.48	-1.99	0.30

Notes: [1] Only coefficients (except the equilibrium total own price elasticities) that are significant at the 10% level are included in this summary table.
[2] Defined as the total proportionate change in the equilibrium wholesale market price relative to the sum of the proportionate changes in the prices of all other markets.
[3] Defined as the proportionate change in the equilibrium wholesale market price relative to a proportionate change in the same market price in the previous equilibrium.
[4] Defined as the proportionate change in the equilibrium wholesale market price relative to a proportionate change in factors other than market wholesale prices.
[5] Defined as the proportionate equilibrating change in the market price due to a proportionate positive divergence from the equilibrium price.

Unlike the other commodities examined in this paper, there are unstable disequilibrium effects for the Bombay and Chennai markets in the first period and the Rajkot, Chennai, Viziangram, and Kapadwanj markets in the second period. These positive disequilibrium elasticities allow the possibility of price bubbles, in that during disequilibrium, the market prices tend to move away from the long run equilibrium value for periods of time.

In summary, the markets for groundnut do not show a high degree of integration in terms of significant observable interdependent wholesale price movements. Indeed the observed relationships appear to be mostly pairwise and becoming relatively less important after agricultural marketing liberalisation. The behaviour of the markets are also different to the other markets in terms of the relatively small number of cross-price elasticities have large elastic values. Some of these markets allow the possibility of bubble price behaviour.

Rapeseed and Mustard Seed

The same periods have been selected as those for groundnut, paddy and jower. Wholesale end of month price data is available for the Nowgong, Purnea, Kanpur, Hapur, Calcutta, Delhi and Mehasana markets. Unfortunately only complete data was available for Mehasana for the post-liberalisation period. Stationarity tests of the data series for each market using the ADF procedure showed all time series were non-stationary at the 5% level, with and without trends. As for the other crops, the optimum lag for the VAR was one for both periods. Dummy variables were constructed for the periods December, 1983 to August, 1985 and October, 1991 to March, 1993. As for the analyses of the other crops, monthly seasonal dummy variables were also included. The determination of the rank of the system was problematic for both periods. The eigenvalues for the first period imply a rank of around three:

$$\{0.532,\ 0.435,\ 0.335,\ 0.282,\ 0.196,\ 0.023\}$$

This value was selected as midway between the SBC statistic which indicates a low rank of one to two whilst the other measures indicate values of four or five. This rank was also chosen for the second period which had slightly larger eigenvalues:

$$\{0.605,\ 0.512,\ 0.377,\ 0.307,\ 0.227,\ 0.164\}$$

Whilst the maximal eigenvalue statistic showed a rank of three, the other measures ranged from two to an unrealistically high rank of seven, which includes very low eigenvalues.

The elasticities for the first and second periods are reported in Tables 19 and 20 respectively. There is only one significant relationship in the first period between the Nowgong and Hapur wholesale prices. The lack of significant relationships here imply there was little market price interdependencies before liberalisation. The second period has seven significant cross-price elasticities reflecting mostly pairwise market relationships of Kanpur with Hapur, Hapur with Mehasana, Mehasana with Hapur and Calcutta, and Calcutta with Mehasana and Delhi. These relationships imply a higher degree of market price interdependencies in the post-liberalisation period. Note that a number of these elasticities are quite large as are the total cross-price elasticities shown in Table 21.

Table 19

Estimated Equilibrium Elasticities: Rapeseed and Mustard Seed[a]

October, 1981 to February, 1988. Restricted Intercepts and No Trends in the VAR. Number of Cointegrating Vectors, r = 3.

	Nowgong	Purnea	Kanpur	Hapur	Calcutta	Delhi	Intercept[b]
Nowgong				3.60[2] (1.80)			
Purnea							
Kanpur							
Hapur	0.28[2] (1.80)						
Calcutta							
Delhi							

Notes: [a] Each elasticity shows the percent change in the wholesale price for the market listed in the first column due to a + 1% change in the wholesale price for the market shown at the head of each column.
The superscripts denote which cointegrating vector is used to estimate the coefficients.
Figures in parentheses indicate the estimated *t*-statistics. Blank cells indicate coefficients are not significant at the 10% level.
[b] The elasticities in this column show the percent change in the wholesale equilibrium prices for the markets listed in the first column due to a +1% change in factors other than market wholesale prices

Table 20

Estimated Equilibrium Elasticities: Rapeseed and Mustard Seed[a]

October, 1991 to February, 1998. Restricted Intercepts and No Trends in the VAR. Number of Cointegrating Vectors, r = 3.

	Nowgong	Purnea	Kanpur	Hapur	Calcutta	Delhi	Mehasana	Intercept[b]
Nowgong			-3.41[3] (-2.15)					
Purnea								
Kanpur				0.92[1] (1.63)				
Hapur			1.09[1] (1.63)				-4.19[1] (-1.77)	
Calcutta						0.73[3] (2.21)	1.28[1] (2.50)	
Delhi					1.38[3] (2.21)			
Mehasana				-0.24[1] (-1.77)	0.78[1] (2.50)			

Notes: [a] Each elasticity shows the percent change in the wholesale price for the market listed in the first column due to a + 1% change in the wholesale price for the market shown at the head of each column.
The superscripts denote which cointegrating vector is used to estimate the coefficients.
Figures in parentheses indicate the estimated *t*-statistics. Blank cells indicate coefficients are not significant at the 10% level.
[b] The elasticities in this column show the percent change in the wholesale equilibrium prices for the markets listed in the first column due to a +1% change in factors other than market wholesale prices

Table 21

Estimated Elasticities: Rapeseed and Mustard Seed [1]

Market	Equilibrium Total Cross-Price Elasticity [2]	Equilibrium Total Own-Price Elasticity [3]	Equilibrium Total Non-Price Elasticity [4]	Equilibrating Price Elasticity [5]
October, 1981 to February, 1988				
Nowgong	3.60	1.30	-	0.30
Purnea	-	1.07	-	-0.17
Kanpur	-	1.64	-	0.27
Hapur	0.28	1.76	-	0.41
Calcutta	-	1.14	-	0.12
Delhi	-	1.13	-	0.13
October, 1991 to February, 1998				
Nowgong	-3.41	1.11	-	0.18
Purnea	-	1.47	-	-0.33
Kanpur	0.92	1.66	-	-0.27
Hapur	-3.10	1.09	-	-
Calcutta	2.01	1.55	-	-0.17
Delhi	1.38	1.32	-	-0.12
Mehasana	0.54	1.54	-	0.18

Notes: [1] Only coefficients (except the equilibrium total own price elasticities) that are significant at the 10% level are included in this summary table.
[2] Defined as the total proportionate change in the equilibrium wholesale market price relative to the sum of the proportionate changes in the prices of all other markets.
[3] Defined as the proportionate change in the equilibrium wholesale market price relative to a proportionate change in the same market price in the previous equilibrium.
[4] Defined as the proportionate change in the equilibrium wholesale market price relative to a proportionate change in factors other than market wholesale prices.
[5] Defined as the proportionate equilibrating change in the market price due to a proportionate positive divergence from the equilibrium price.

The negative values for the Kanpur/ Nowgong and Hapur/ Mehasana pairs are also interesting and like the case for wheat require careful interpretation. The own-price measures are all elastic and there are no significant non-price effects. Similar to the error correction findings for some of the groundnut markets there are positive equilibrating elasticities. However most of these effects are in the first period and the only two positive values for the Nowgong and Mehasana markets in the second period are relatively smaller. Overall these markets, whilst starting from a very low level of integration, demonstrate a significant increase in the degree of market price relationships in the post-liberalisation period. Like groundnut, some of these elasticities are large and like wheat, a few are negative in value. The apparent price bubble behaviour is less than for groundnut and reducing in the second period. Some of these important characteristics will now be considered in the concluding section.

7. Summary and Conclusions

This paper has focussed on the analysis of spatial and intertemporal integration of food markets because more closely integrated markets imply the more efficient allocation of resources and products across regions and time necessary to achieve sustainable agricultural development. This will allow the benefits of technical change and productivity improvements to alleviate poverty and help achieve food security. However the more recent national and international experience of structural change in agriculture and the liberalisation of food crop marketing have changed how markets interact in unknown ways.

Given the importance of this topic it is to be expected that there is a growing body of international research on market integration. What is surprising is the lack of agreement about the research methodologies which are appropriate to analysing market integration. The early findings based on correlation analysis were criticised as representing spurious relationships caused by temporal trends in the data, rather than behavioural interdependencies. The wide adoption of the Engle-Granger cointegration techniques was in response to the problem of non-stationary data. This approach has also been criticised in turn for two reasons, it relies on price data only and the finding of cointegration is not a true test of market integration. These criticisms have been damning and it is true that micro-based studies using a spectrum of data are required to fully identify the degree of market integration. However there is the problem that this data does not exist in a consistent format across regions and time. Its collection is expensive and piecemeal and whilst providing detailed specific insights it does not give policy makers a general picture of the degree of market integration at regional and national levels. On the other hand market price data is readily available.

This paper adopts this constraint and asks the questions: using monthly price data what is appropriate methodology to analyse market integration and what conclusions (if any) can be sensibly drawn from these results? The contribution of this paper is that it addresses the problem conceptually and technically and in doing so provides a critique of existing procedures. The research provides an alternative analytic structure which appears successful in examining the degree of market integration for Indian wheat, jower and paddy rice during the 1980's and 1990's.

Central to this approach is the idea that the correlation and cointegration methodologies used in previous studies are inappropriate and the conclusions and recommendations are flawed. Whilst this paper shows in Section 2 that spurious relations in end of month wholesale prices are problematic for wheat in India during the 1990's its severity is overstated. What is far more damaging is the simultaneity between wheat prices which is complicated and difficult to disentangle, yet central to the analysis of market integration. This important characteristic of markets has been almost completely ignored in previous studies which have analysed interdependencies on a pairwise basis. It is shown by simple examples that measured pairwise relationships may either hide complicated cumulative effects over a range of markets or inflate the actual pairwise link by double counting other market interdependencies. To this end these studies may understate or overstate the degree of market integration.

This paper therefore develops a conceptual framework which explicitly models multiple price interdependencies across markets in Section 3 and which allows for trending data in Section 4. The system of simultaneous price equations is identified in terms of the minimum amount of information required to fully determine all market prices in steady state. This is in the form of the rank of the price system, which is the number of linearly independent price vectors which explain all the market prices. Importantly, the vectors allow the calculation of long run cross-price, own-price, non-price and short run equilibrating elasticities using Johansen's VAR procedure. The full information maximum likelihood estimation provides standard errors which allow valid statistical inference.

The rank of the price system and the price elasticities were estimated for Indian wheat, jower, paddy, groundnut, rapeseed and mustard seed using end of month wholesale prices for important markets where continuous data was available. The periods considered were January, 1982 to June, 1988 and January, 1992 to June, 1998 for wheat, whilst jower, paddy, groundnut, rapeseed and mustard seed had common periods October, 1981 to February, 1988 and October, 1991 to February, 1998.

The ranks for wheat were calculated to be three (out of eight markets) for the first period and four (out of nine markets) for the second, implying that approximately 40% of the prices explain all wheat prices in these markets in the long run. Noting there are different markets across the to samples with the second period including Karnal and Hapur and excluding Mehasana, there are many more identified price relationships for the post liberalisation period. The proportion of significant equilibrium cross-price elasticities increased from 45% to 58% over the two periods. Overall, these results imply there are more interdependencies between markets and a higher degree of market integration for the second period. This is certainly true for Amritsar and Bahraich and there is the emerging importance of the Rajkot, Karnal and Kanpur markets. The magnitudes showed differences between the two periods with Rajkot, Kanpur, Karnal and Amritsar being the most responsive in the second period.

The calculation of significant equilibrium total non-price elasticities indicate that non-price effects are not important for Rajkot for both periods and for Indore, Amritsar, Karnal and Hapur in the second period. There are relatively large non-price effects on Patna's equilibrium price in both periods. Whilst the other markets have variable effects, it is clear that the non-price proportional effects are generally smaller in magnitude for the second period. This implies the cross-price and own-price effects dominate the non-price effects in equilibrium. The significant equilibrating price elasticities show that most markets have inelastic responses with over 20% of price disequilibrium eliminated in the first month for the Rajkot, Indore, Karnal and Hapur markets. The optimum lags showed that the markets equilibrate relatively fast with little evidence of inventory accumulation.

Simultaneous Granger causality tests were also conducted on the wholesale wheat prices for both periods. Rajkot and Delhi were the leading Granger causing markets in the first period, whilst in the second period, Rajkot remains a leading market whilst Delhi switches to a following market and Hapur, Kanpur, and Amritsar switch from followers to leaders. Patna and Indore follow the other markets for both periods. These findings appear robust to the different estimation methodologies. In summary, despite the reliance on price data alone in this study, there is a clear message that dramatic changes have occurred in the way wheat markets interact since liberalisation. The markets, which previously demonstrated a high degree of interaction, have certainly become more integrated with Rajkot, Kanpur and Amritsar dominant in terms of the significance of the size and timing of affects across markets. On the other hand Patna and Indore are affected by other markets, both in terms of the size and timing of effects.

The case for jower is very different to that for wheat. The ranks were calculated as one (for six markets) in the first period increasing to four (for eleven markets) in the second period. However the number of significant cross-price elasticities fell from 53% to a very low 4% over the same periods. The very few significant cross-price elasticities show that there do not appear to be any important market interactions during the period October, 1991 to February, 1998. Whilst the Nandyal, Patan, Gulbarga Indore and Nagpur markets are included in both samples, the second sample excludes Madurai and includes Kolhapur, Hyderabad, Coimbatore, Salem, Kanpur and Bahraich. Consistent with the more complex behaviour, these markets exhibit significantly more rapid equilibrating adjustments. They are also responsive to own-price changes in equilibrium which demonstrate their ability to equilibrate by themselves in the second period. This observation is consistent with the lack of significant external non-price effects on each market equilibrium price. Whilst the markets for jower appeared to be more integrated prior to liberalisation, the results do not support the hypothesis of market integration for jower for the second period. These results contrast dramatically with the observed increasing interdependence of wheat markets.

The estimated ranks for paddy rice, like jower, increased from one (out of four available markets) to three (out of five available markets) in the second period. This implies that the proportion of prices required to explain all market prices in the sample increased from 25% to 60% over the two periods. However, unlike jower the proportion of significant cross-price elasticities increased from 33% in the first period to 70% in the second period. With the exception of Kolhapur, total cross-price elasticities are larger in the second period reflecting the higher degree of interdependence between markets. The markets for paddy therefore appear to be increasingly integrated in the period October, 1991 to February, 1998. The significant non-price effects are also larger in the second period. The ability for these markets to clear is increasing over the two periods with the own equilibrium price elasticities and the adjustments to disequilibrium being higher in the second period. These latter rates of adjustment are very high (unlike those for wheat and jower) with some evidence that the Bahraich price may tend to overshoot the equilibrium level.

The markets for groundnut required a rank of three for the first period, increasing to four for the post-liberalisation period, to describe the system of prices. Since the number of markets analysed are larger for the second period these ranks imply approximately 60% of all the groundnut prices are required to explain the price system for both periods. The number of significant cross-price elasticities fall from nine out of 20 (45%) to eight out of 42 (19%) between the two periods. The size of the total cross-price elasticities also fall for the Rajkot, Bombay and Kanpur markets. As for jower, the degree of market integration therefore appears to have fallen (or at best remained static) over the two periods. Unlike the other commodities analysed so far, some of the groundnut markets displayed disequilibrium bubble price behaviour. Disequilibrium in the Chennai, Rajkot, Viziangram and Kapadwanj markets caused prices to further deviate from equilibrium over time. This effect increased in these markets in the post-liberalisation period.

The markets for rapeseed and mustard seed, whilst starting from an apparent very low degree, demonstrate an increase in market integration over time. A rank of three is required to explain the six and seven markets for the two periods. Only the Nowgong and Hapur market prices appear related in the first period with one significant pairwise cross-price elasticity. The number of significant elasticities increase to nine in the second period which essentially represent four market pairwise relationships. Like groundnut, some of these elasticities are large and like wheat, three are negative in sign. The disequilibrium behaviour, whilst prevalent in the first period, is restricted to the Nowgong and Mehasana markets with much lower disequilibrium coefficients after liberalisation. Similar to paddy, the markets for rapeseed and mustard seed demonstrate an increasing degree of market integration although they start from a low base.

In summary the body of evidence shows the increasing degree of market integration for Indian wheat, paddy rice, rapeseed and mustard seed which contrasts with the findings for jower and groundnut in the post-liberalisation period of the 1990's. These results are derived from a comprehensive analytic framework which explicitly incorporates simultaneous interdependencies between market prices. This new methodology, by focussing on the behavioural system of market prices rather than just the temporal characteristics of prices, overcomes the criticisms of previous market integration studies.

The additional important outcome of this new approach is the finding of both positive and negative long run equilibrium relationships for wheat prices and to a lesser extent for rapeseed and mustard seed prices. These relationships may be interpreted in terms of long run elasticities or changes in equilibrium relative prices. The positive findings are easily interpreted as reflecting common effects across markets like increasing demand for the commodity and simple long term arbitrage across increasingly integrated commodity markets.

The negative or inverse findings are more complex and there are a number of possible explanations. One explanation is the presence of uneven technological change across markets affect production costs and product prices differently. If this is true then there must be impediments to the dispersion of these productivity increases across markets in the long term, which implies a relatively low level of factor market integration in wheat and perhaps rapeseed and mustard seed production. Another explanation is the movements of factors of production between markets are in response to technical change and other factors. The production costs and product prices for markets losing productive resources inversely mirror the changes in costs and prices relative to the factor importing markets. This second example, in contrast with the first explanation, implies that factor markets will be relatively integrated.

The consequences of these alternative views for the integration of factor markets are crucial to the efficient allocation of resources. The effective interdependencies between factor markets will also determine how the benefits of technical change are distributed across regions and time to reduce poverty and achieve food security. The analysis of the integration of factor markets for food crops has not received adequate attention and should be given urgent priority.

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