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Agricultural market integration in India: An analysis of select commodities ☆

C.S.C. Sekhar *

Institute of Economic Growth, University of Delhi Enclave, Delhi 110 007, India

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ABSTRACT

One of the main arguments against agricultural trade liberalization in India is that the markets are not sufficiently integrated. The present study makes a systematic attempt to assess the extent and degree of integration among select agricultural markets in India. We have used the common factor representation of the cointegrated series, called Gonzalo–Granger (G–G) model, to assess the extent of market integration. Degree of market integration has been assessed using the persistence profile approach. Our results indicate that the commodity markets that do not face inter-state or inter-regional movement restrictions, like gram and edible oils, appear well-integrated. On the contrary, rice market, subject to the maximum inter-state movement restrictions, does not show integration at the national level. The broad implication of the study is that the markets can play a more effective role if supplemented with more open policy initiatives.

Introduction

The issue of agricultural market integration is central to many contemporary debates on trade liberalization, price policy and reform of state trading agencies in the developing countries. In India, there has been very little external trade in food commodities except in the case of pulses and edible oils. Most of the external trade is canalised through state trading agencies. There are occasional inter-state restrictions on trade within the country and there is a predominant presence of the state agencies like Food Corporation of India (FCI) in grain procurement. The inefficiency and high cost of operations of FCI have led to a demand for reduction of the role of FCI (Ramaswami, 2002; Chand, 2005). There are arguments increasingly in favour of allowing a freer role for the market and greater participation of the private sector in foodgrain trade (Rashid et al., 2008; Landes, 2008). The rice export bans by India and the immediate turmoil in the world rice markets in 2008 have led to renewed calls for freer trade internationally.

The commonly advanced grounds against trade liberalization and continuing state intervention in India are the lack of market integration, risk mitigation, lack of institutional capacity and foreign exchange constraints (Timmer, 1989), imperfect nature of world agricultural markets (Sekhar, 2003) and higher volatility of agricultural prices in international markets (Nayyar and Sen, 1994; Sekhar, 2004). The present study attempts to assess the first of these four conditions in the Indian context i.e., market integration, which is an essential condition for efficient trade. Are price signals emanating in one market transmitted to other markets? What is the extent of such transmission, if any? These are the questions the present study attempts to explore. In particular, the study attempts to analyze the extent and degree of market integration in major Indian markets of important agricultural commodities.

Although there have been advances in the methodology of market integration analysis, majority of the earlier studies in Indian context have used less-advanced methods like the bivariate correlation coefficients or methods that remove the common integrating factor from the analysis such as cointegration. Also, almost all the earlier studies are either confined to one or two crops or to small geographical regions, which is inadequate to inform policymaking. The present study attempts to address these shortcomings by using a methodology that retains the common integrating factor (if any) and analyzes the extent (number of markets integrated) and degree of integration among major markets for most of the important commodities in the country. The main objective of the study is to assess the *potential* role of market in mitigating adverse effects of supply shocks.

Literature review

Much of the problem in market integration analysis revolves around the concept of 'market integration' itself and the empirical methodology of testing the same. At the conceptual level, there are

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* Tel.: +91 11 27667101, mobile: +91 9810724231; fax: +91 11 27667410.
E-mail addresses: sekharcsc@yahoo.com, csekhar@iegindia.org

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essentially two strands of thought. In the first, mainly in the macroeconomics and international economics literature, the conceptualization of market integration is centered around tradability i.e. transfer of excess demand from one market to another through actual or potential physical flows. Positive trade flows are sufficient to demonstrate that markets are integrated and prices need not equilibrate across markets. It is clear that this concept implies a Pareto inefficient distribution (Barrett, 2001). In the second framework of Enke–Samuelson–Takayama–Judge (ESTJ) spatial equilibrium model (Enke, 1951; Samuelson, 1952; Takayama and Judge, 1971), the dispersion of price in two locations for an otherwise identical good is bound from the above by cost of arbitrage when trade is unrestricted and, from below when trade quotas exist. However, market integration is not a sufficient condition for the Pareto optimality of the competitive equilibrium, in the sense that, it does not by itself, imply efficient allocation of resources (Newbery and Stiglitz, 1984; Ravallion, 1986). Nonetheless, market integration remains a necessary condition for Pareto optimality of the spatial competitive equilibrium (Ravallion, 1986).

The other conceptual issue in market integration studies is of the hypothesised market structure. There are different categories of empirical models, each based on a different hypothesis. For instance, the method of pairwise correlation coefficients (Lele, 1967; Jones, 1968) is based on the hypothesis that the markets are integrated pairwise. The method of cointegration rests on the assumption of a central market. The other methods emphasise the centrality of transfer costs (Baulch, 1997) in price formation.

Empirical testing of market integration has evolved over time from the early stages of using bivariate correlation coefficients to the more recent techniques that take into account non-stationarity, common trends and endogeneity of prices.[1] The empirical work on market integration can be divided into three broad categories.

(i) Early methods based on bivariate correlation coefficients.
(ii) Methods accounting for non-stationarity of prices.
(iii) Methods emphasizing transfer costs instead of comovement of prices (Barrett, 1996; Baulch, 1997).

After the influential work of Ravallion (1986), with the advances in time-series techniques, methods using Johansen cointegration gained popularity. In this framework, spatial price analysis is carried out by testing for long term cointegration and short-run error correction mechanism by using price data at different geographic locations. Some of the underlying assumptions of the model are linear pricing and stationary transaction costs. This methodology has drawn criticism on the grounds that the tests for market integration hypothesis become indistinguishable from tests of these abovementioned assumptions (Barrett, 1996; Baulch, 1997; Fackler and Goodwin, 2001). Alternate methods were proposed to overcome these limitations using mixture distribution estimation methods, integrating price data with transactions cost data and trade volume data (Baulch, 1997; Barrett and Li, 2002). However, there are major limitations to these methods since they rely on arbitrary distributional assumptions in estimation and typically ignore the time series properties of the data (Van Campenhout, 2007). One recent strand of literature uses panel unit root methods in combination with half life-cycle estimation of convergence (Jayasuriya et al., 2008). The panel unit root methods are expected to exploit the larger (and richer) panel datasets. However, there are some limitations to this approach. Firstly, panel unit root tests cannot disentangle the speed of convergence of individual time series (markets), which is a very important policy issue in market integration. Secondly, half-life estimation is based on Impulse Response Functions (IRF) and IRF s are not uniquely distinguishable when shocks to the system are correlated, which is precisely the case in spatially separated markets. A shock to one market is expected to be transmitted to other markets as well, depending on the degree of integration. Also, IRF s are not invariant to the ordering of the variables.

Literature on India

Majority of the empirical studies of agricultural market integration in India use simple bivariate correlation coefficients between prices as a measure of market integration (Mahendru, 1937; Lele, 1968; Jasdanwalla, 1966; Cummings, 1967). All these studies suffer from the limitation that they use raw price series data and as a result the calculated price correlations are biased upwards (Blyn, 1973; Harriss, 1979). The raw price series are more likely to include the influences of common factors such as climate patterns, inflation or any other shocks that affect all the markets. This is likely to conceal the true degree of integration. Harriss (1979) pointed out that the aggregation of individual price series over time may make these systemic effects more pronounced. A methodologically correct way of using correlation coefficients in spatial price analysis is to calculate the correlation coefficient of the *residuals* (Croxton and Cowden, 1955), after the trend and the seasonal components are purged from the raw price data. Blyn (1973) makes this correction for the data used by Cummings and shows that the average correlation coefficient is much lower than reported by Cummings.

With the advances in time-series and econometric techniques, recent studies in the Indian context have started using the cointegration methodology (Behura and Pradhan, 1998; Wilson, 2001; Kumar and Sharma, 2003). Behura and Pradhan (1998) use Engle–Granger cointegration for fish prices in 6 markets in the state of Orissa. The limitations of Engle–Granger method in case of more than two variables are well established and therefore not discussed here. Wilson (2001) used the monthly wholesale prices of wheat, jowar, paddy rice, groundnut and rapeseed-mustard to analyze the degree of integration among different markets both before and after liberalization (in 1992) using Johansen cointegration method. The major drawback of Wilson's study is the categorization of pre and post liberalization period. Although structural reforms were initiated in Indian economy in the early 1990s, Indian agriculture remained virtually insulated until 1994, when edible oil imports were liberalized. All other major food commodities continued to remain under controls of various forms even after 1994. Therefore, Wilson's analysis using 1992 as the break point is open to question. Kumar and Sharma (2003) also used the Johansen cointegration method to assess the market efficiency but their findings at the micro level are quite unsatisfactory due to the very low explanatory power of the models fitted. Jha et al. (2005) tested for market integration in 55 wholesale rice markets in India using monthly data from 1970 to 1999. They have used the same model as in the present study and their findings suggest that the rice market integration in India is incomplete probably because of excessive government interference. Jayasuriya et al. (2008) examined the nature of international price transmission

[1] See for instance literature on static price correlations or regression coefficients – Lele, 1967; Cummings, 1967; Jones, 1968; Mahendru, 1937; Jasdanwalla, 1966 and their critiques Blyn, 1973, Harriss, 1979) (ii) Cointegration and error-correction models – Ravallion, 1986; Alexander and Wyeth, 1994; Palaskas and Harriss-White, 1993; Dercon, 1995; Harriss, 1979; Ardeni, 1989; Goodwin and Schroeder, 1991; Badiane and Shively, 1998; Behura and Pradhan, 1998; Wilson, 2001; Kumar and Sharma, 2003; Yavapolkul et al., 2004; Jha et al., 2005). (iii) Threshold autoregreesion and threshold cointegration models – Obstfeld and Taylor, 1997; Prakash and Taylor, 1997; Goodwin and Grennes, 1998; Abdulai, 2000; Goodwin and Piggott, 2001; Sanogo and Amadou, 2010). (iv) Methods using transfer costs and trade volumes – Barrett, 1996; Baulch, 1997; Fackler and Goodwin, 2001; Barrett and Li, 2002). (v) Common trends (Gonzalez-Riviera and Helfand, 2001).

into Indian rice markets before and after the liberalization in 1994 using panel unit root methods in combination with half life-cycle estimation. Their findings suggest that the integration of domestic market with international market improved significantly after the liberalization.

Summing up, most of the studies in Indian context are either confined to a single commodity or to a limited geographical region (with the exception of Wilson, 2001) or have used less advanced methods like correlation coefficients or Engle–Granger cointegration. In view of these limitations, we attempt an alternate empirical methodology within the broad theoretical framework of ESTJ.

Methodology

Theoretical framework

The theoretical framework used in the study is the standard spatial equilibrium framework of Enke–Samuelson–Takayama–Judge (ESTJ) that is at the heart of most trade theory. A generalised version of ESTJ equilibrium condition is

$$p^0 \leqslant p^1 + \tau^{10} \text{ if } q^{10} = 0 \tag{1}$$

$$p^0 = p^1 + \tau^{10} \text{ if } q^{10} \in (0, q^{-10}) \tag{2}$$

and

$$p^0 > p^1 + \tau^{10} \text{ if } q^{10} = q^{-10} \tag{3}$$

where p^0 and p^1 are the prices in markets 0 and 1, respectively, τ^{10} is the cost of transportation from market 1 to market 0, q^{10} is the quantity transported from 1 to 0 and q^{-10} is the maximum trade volume permitted (trade quota) between the two markets.

In this model, a competitive general equilibrium exists in a set of n regions among which trade occurs at fixed transport costs (Takayama and Judge, 1971). If trade takes place between any two regions, then the price in the importing region equals the price in the exporting region plus the unit transportation cost. If this condition holds, then the markets are said to be 'integrated'. Trade is neither necessary nor sufficient for ESTJ equilibrium. This notion of efficiency implies not only firm-level profit maximization but also a perfectly competitive long-run equilibrium, in which, there is no incentive for entry, because the marginal profits to arbitrage are minimised.

Barrett (2001) and Barrett and Li (2002) point out that it is essential to distinguish between efficiency (price equilibrium) and integration as denoted by tradability. Although this line of reasoning appears appealing, there are two reasons why we have chosen not to use this approach. Firstly, the Barrett and Li (2002) model and the Baulch (1997) model (on which Barrett and Li model is based) are static in nature and rely on arbitrary distributional assumptions in estimation and ignore the time series properties of the data[2]. As a result, they do not permit the analysis of the dynamic adjustment process of short-run deviation from long-run equilibrium which is important (Ravallion, 1986). The second reason is the non-availability of transaction costs data. Non-inclusion of transactions cost data may lead to inconsistent estimates. In the ESTJ model that we have used here, τ^{10} appears as an additive term. But, if transaction costs are not accounted for while estimating the model, this variable enters the error term. Transaction cost contains various components like transportation cost, variable costs (insurance, hedging, contracting etc.), duties levied and other unmeasurable costs (search costs, risk premia etc.). By their very nature, components like insurance costs and ad-valorem duties depend on price. When these components enter the error term, it is a violation of the basic assumption of the general linear model (that the explanatory variables and error term are uncorrelated). This will yield inconsistent estimates. However, the data on almost all these variables is virtually nonexistent in India (Landes and Burfisher, 2009) where even the basic price data across major markets is not easily available over a reasonable length of time. One component of transactions cost data that is available in India is the data on applied tariffs. However, these data are available only at annual frequency whereas the prices used in the study are of monthly frequency. Also, there is very little variation in applied tariffs data (which remain constant for several years) precluding the usability of this data for our purpose. Alternately if use annual data for all the variables, the number of observations is inadequate to satisfy the econometric requirements of non-stationarity and cointegration tests.

Therefore, we have restricted our analysis to prices and retained the ESTJ spatial equilibrium model as the basic framework. If trade occurs and is unrestricted, then marginal trader earns zero profits and prices in the two markets co-move perfectly. This is the condition we attempt to test in this study. The assumptions underpinning the model are that the market structure is competitive and marginal costs are constant. Although the present exercise in a strict sense constitutes testing for market efficiency (Barrett and Li, 2002), we choose to retain the term *market integration* in order to be able to posit the present study in the extant literature.

Econometric methodology

The following steps are involved in assessing the extent and degree of market integration in the present study.

(a) Assessing the extent of market integration i.e., number of markets integrated over a long-run, using the G–G model.
(b) Measuring the degree of market integration in the short-run using 'Persistence Profiles' (Pesaran and Shin, 1996), defined as the reaction time to remove a disequilibrium or shock.

The technical details of the methods are provided in Appendix A. To follow the analysis and discussion of the results in rest of the paper, understanding the technical details is not necessary.

Extent of market integration

In most of the recent literature, extent of market integration is assessed in a cointegration framework. In the standard cointegration approach, the idea is that there is a common stochastic trend among variables (here prices) and by purging that common trend, the long-run equilibrium relationship (among prices at different locations) can be identified. Each price is expressed as a function of *all* the prices. Since the integrating factor is eliminated when the cointegrating relation is estimated, no attention is paid to finding the common long run component that gives rise to cointegrated prices.

Therefore, in this paper, we have used a slightly different approach (the common factor representation of the cointegrated series), called Gonzalo–Granger (G–G) model. In this approach, linear combination(s) of a *subset(s)* of prices, acting as a common factor(s), underlie the entire constellation of prices. This model, in a sense, is an extension of the Ravallion's (1986) model with a *single central market*. Instead of a single central market, in the G–G model there is a set of markets influencing the prices all over. Unlike cointegration approach, in this method the common stochastic factor is not eliminated. The empirical estimation of the model is relatively simple. We can estimate the standard VECM model and then use those estimates to determine the number of common factors and also identify the specific markets influencing price formation (Gonzalez-Riviera and Helfand, 2001; Gonzalo and Granger,

[2] For a good critique of these methods see Campenhout (2007).

1995). We use this model to assess market integration for all the major commodities in India across all the major markets.

A market is said to be integrated if there exists a *single common factor* (single linear combination of a subset of prices). For a set of n markets to be integrated, we should have $n-1$ cointegrating vectors. We make use of this property to identify the set of integrated markets in this study. Gonzalez-Riviera and Helfand (2001), and Jha et al. (2005) used this model to assess the rice market integration in Brazil and India respectively. It needs to be noted here that cointegration need not always imply integration (Lence and Falk, 2005). However, this critique is not binding in Indian case as Indian markets have not had any major restrictions on domestic trade among regions or states during the study period (except in case of rice for few years).

Degree of market integration

Degree of market integration may be understood as the time span needed for a shock to dissipate. We have attempted to assess the degree of integration using the persistence profile (PP) approach of Pesaran and Shin (1996). A PP characterizes the response of a cointegrating relation to a system-wide shock. PPs are unique functions which allow us to quantify the degree of integration among the locations that belong to the same economic market.

A 'persistence profile' is defined as the scaled difference between the conditional variances of the n-step and the $(n-1)$-step-ahead forecasts, and is a function of n, the forecast horizon. This measure readily captures the essential difference that exists between cointegrated and noncointegrated relations, and provides unique time profiles of the effect of shocks to the cointegrating relations. In the case of relations between $I(1)$ variables that are not cointegrated, the effect of a shock persists forever, while in the case of cointegrated relations the impact of a shock will be transitory and eventually disappear as the economy returns to its steady trend or its long-run equilibrium.

Degree of market integration is traditionally assessed by looking at the adjustment coefficient (γ) or the statistical significance of the lag structure Γ_i in the VECM. To jointly evaluate the effects of shocks, impulse response functions (IRFs) are normally used. The main drawback of the IRF s is that they are not unique when errors in different equations are correlated. In a study of spatial market integration, it is highly probable that the errors at different locations are correlated since the movements in prices at these locations are generally correlated. Even the Cholesky decomposition does not address the issue as this decomposition is dependent on the ordering of the variables that enter the VECM. Changing the order of the variables can significantly alter the IRFs. Therefore we have used the PP approach.

Data and commodity coverage

The data used is monthly wholesale market price data from 1986/1987–2006/2007 for the major Indian and international markets. Indian data is not readily available in machine-readable form and has been collected manually from various publications, mainly *Agricultural Situation in India* and *Agricultural Prices in India*. The international price data has been collected from the *International Financial Statistics* (IFS) of the International Monetary Fund (IMF). The study period starts from 1986/1987 since some major changes started occurring in the Indian edible oil markets around that time.

We have selected rice, castor oil, oilcakes, tea and coffee on the export side for our analysis. On the imports side we have selected gram, groundnut oil and mustard oil. The selection of commodities is based on their importance in the trade basket and also on the availability of long time series of official published data on monthly domestic prices. Therefore, although palm oil and soybean oil are prominent edible oils on the import side, they could not be selected due to non-availability of monthly price data. However, this need not be a major limitation because of the high degree of substitutability on the consumption side. This can be judged from the fact that although palm oil and soybean oil are imported the most, the crops that suffered the maximum decline in area after edible oil import liberalization are groundnut and rapeseed-mustard.

As for the selection of the markets, all the markets for which monthly price data is available over the study period have been chosen. The locations thus chosen are not always contiguous enjoying little communication disruption but also include some of the distant markets as well. For example, two of the markets in south zone are Hyderabad and Trivandrum. These markets are almost 1400 km apart – only 150 km less than the distance between Hyderabad and Delhi, located in the northern region of the country.

As for the definition of integration, Gonzalez-Riviera and Helfand (2001) identify two basic requirements for market integration – (i) existence of trade among the locations (ii) a common integrating factor among the prices of these locations. Our main focus in the study is to identify the latter i.e. to find a common integrating factor. The first element, that is, the existence of trade has been verified from the published official data for some of the years. It has been found that trade exists in most of the locations for the study commodities. For instance, there are trade flows from almost all the rice-producing states during the triennium ending with 2001 (GoI, 2003a, table 22). Similar is the situation with gram (GoI, 2003b, p. 31). Therefore, if a common integrating factor can be identified, these locations can be said to be integrated.

Import and export share of commodities (in.%)

Commodity	Value share
	(Average 2000/2001 to 2006/2007)
Imports	
Cereals and preparations	1.66
Wheat	1.08
Pulses	12.23
Edible oils	44.70
Total	59.67
Exports	
Tea	4.37
Coffee	3.18
Rice	12.80
Nuts and seeds	8.27
Oil meals	8.04
Marine products	16.18
Cotton raw incl. waste	3.78
Total	56.63

Source: *Agricultural; statistics at a glance 2007*, DES, Ministry of Agriculture, Government of India.

Agricultural markets in India: an overview

Before we proceed to discuss the results, a brief overview of the Indian agricultural markets is in place here. The structure of agricultural product markets in India varies from commodity to commodity and has been mainly influenced by the government policy. Intervention by the government in commodity markets takes several forms in India. The main instruments are the price and trade-related measures (domestic and international).

On the price front, the farmers of wheat and rice are provided a minimum support price (MSP). The government procures at this price and provides grain to poor consumers at a price below the prevailing market price. Thus, administered price is in force for a sizeable portion of production and for a small portion of consumption of these two cereals. On the other hand pulses and edible oils are not provided the price support, either on the production or on the consumption side.

As regards the domestic market structure and trade, an important feature has been that private trade maintains a large share of the market, notwithstanding several government regulations (Acharya, 2004). The share of private trade is quite large in the marketing of both cereals and pulses. Of the estimated marketed surplus of cereals, the share of private trade is about 70–75%. Similarly about 75% of the market share in pulses is held by the private trade. The marketing of cereals for the public sector is undertaken by public agencies like the food corporation of India (or the FCI) and NAFED for pulses. NAFED also undertakes limited price support operations for oilseeds but the vegetable oil trade is almost completely controlled by the private trade. However, none of the public agencies other than FCI procures and stores large quantities of the produce and this affects the price formation in the two markets to some extent. The agencies for other commodities are not as active in procurement or distribution. Thus, in these commodity markets, private sector's incentive structure is not adversely affected to a major extent.

The Indian government regulates majority of the marketing activities through various legal instruments put in force from time to time. Some of the important ones are the Essential Commodities Act (ECA), Agricultural Produce Marketing Committees (APMC) act, zoning and compulsory levy on rice millers and sugar producers. The ECA attempts to regulate supply, demand and prices by strictly controlling stocking, transporting and selling of agricultural products by the private sector. The APMC Act stipulates that all agricultural products be sold only in government-regulated markets resulting in much lower level of private investment in marketing infrastructure. The policy of zoning, adopted by few state governments, and the levy policies have the effect of constraining the farmers' incentives to a large extent.

Results and analysis

The correlation coefficients[3] of the market prices of rice, gram, groundnut oil and mustard oil are quite high, mostly above 0.8. However, high correlation coefficients are not sufficient to conclude that the markets are integrated. Hence, the need for a more refined method of testing for market integration. The crucial insight provided by the Gonzalo–Granger model (GG) is that, in an integrated market, there is a single common factor (of prices) driving the entire system. Therefore, when a set of n markets is integrated, there are $n-1$ cointegrating vectors. Using this result we start with an appropriately large number (n_1) markets out of a total number of n markets such that $n_1 < n$. We then test for the number of cointegrating vectors in this set of markets. If the number of cointegrating vectors is $n_1 - 1$, then we add one more market to the set and again test for the number of cointegrating vectors. If the number of cointegrating vectors is still $n_1 - 1$ (instead of n_1) then we drop the newly included market and try another market. This process is continued till we have the largest set (say n_2) of integrated markets. If all the n markets are integrated, then $n_2 = n$.

Starting with different sets of markets will provide different answers to the question as to how many markets are integrated. We start with a set of n_1 important markets in each state (or region) based on our prior knowledge. Obviously this leads to some degree of arbitrariness. To address the potential problems with this initial selection, we have experimented with different orders. The results (the no of cointegrating vectors) have remained largely invariant to the order of initial selection. Also, we tested for non-stationarity of the residuals using ADF tests to assess the robustness of the cointegrating relations. The ADF tests have conclusively rejected non-stationarity of the residuals for all the commodities and markets (Table 8). However, the econometric problems with such sequential selection are one potential area for future research.

While testing for integration with the international market, we fix the international market and sequentially test the domestic markets for integration with the international market. Suppose that we have one international market and n_1 domestic markets. If we find n_1 cointegrating vectors, then there are $n_1 + 1$ integrated markets in all. Since international market is already fixed, we conclude that all the n_1 domestic markets are integrated with the international market.

The sequential procedure followed in testing market integration is given below.

(i) Markets within a state.
(ii) Markets within a region (south, west, north, east).
(iii) Markets in the entire country.
(iv) All the domestically integrated markets with the international market.

We have used the following vector error-correction (VECM) model for each commodity – $\Delta p_t = \gamma\alpha' p_{t-1} + \sum_{i=1}^{\infty}\Gamma_i \Delta p_{t-i} + WPI_t + MD_t + \varepsilon_t$ where $\Delta = I - L$ with L being the lag operator and p_t is a vector of prices at n markets (of order $n \times 1$). α = cointegrating vectors, γ = weights (speed of adjustment) of the cointegrating equations, Γ_i is the vector of short-run coefficients and ε is the error term. We have also included two exogenous variables i.e. wholesale price index (WPI_t) of the commodity and monthly dummies (MD_t) to control for the general price movements in the commodity and seasonal fluctuations in market prices respectively. WPI is used because only few commodities are procured in the major states. Also WPI shows more variability as compared to minimum support price (MSP). The effect of stocks is assumed to be implicitly captured by price variable. All the variables are tested for order of integration and found to be $I(1)$.

The persistence profile measuring the degree of market integration i.e. the time horizon in months for a shock to dissipate in various markets is presented in Table 7. Detailed plots of persistence profiles are provided in Figs. 1–10. The set of cointegrating vectors includes all the possible long-run relationships among the variables. This set of cointegrating vectors is arranged in most econometric software packages in the decreasing order of eigen values (from which the vectors are derived). Therefore, we have presented PP graphs for the first few important cointegrating vectors.

The commodity-wise results are as follows.

Major commodities

Rice

The extent of integration at the national level is lower (only 75%) among rice markets as compared to other crops. The speed of adjustment is also relatively longer in rice markets (Table 7) as compared to other markets. At the regional level, south and west show better intra-regional integration than north and east (Table 1a). In the south, out of a total of 13 markets tested, 11 are integrated (10 cointegrating vectors) and the corresponding numbers for the western region are 8 and 6, respectively. In Eastern India, out of a total number of 15 markets only 11 are integrated and in the northern region, out of a total of 8 markets only 5 are integrated. In all, out of a total of 44 markets all over India, 33 (75%) are

[3] The detailed list of markets analyzed for each commodity and the correlation coefficient matrices of the prices can be had from author upon request.

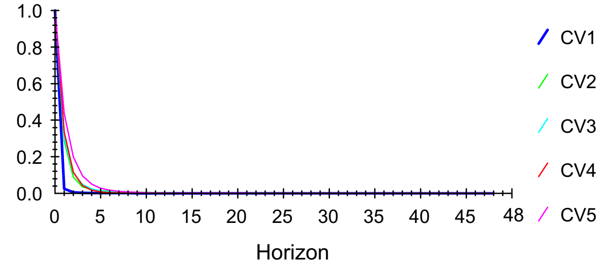

Fig. 1. Persistence profile of the effect of a system-wide shock-rice (south India).

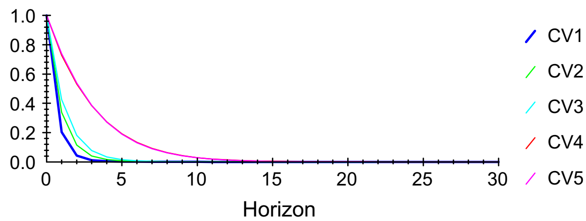

Fig. 2. Persistence profile of the effect of a system-wide shock-rice (west India).

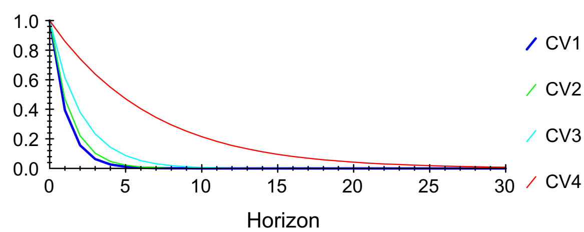

Fig. 3. Persistence profile of the effect of a system-wide shock-rice (north India).

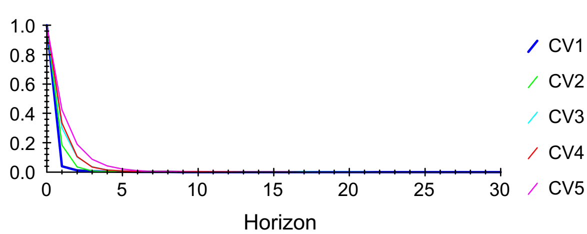

Fig. 4. Persistence profile of the effect of a system-wide shock-rice (east India).

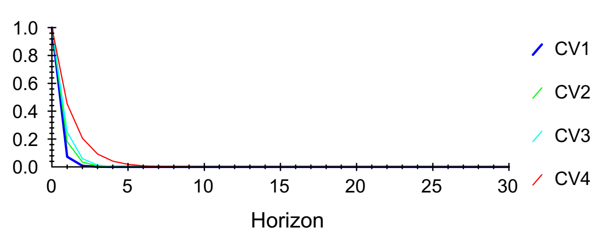

Fig. 5. Persistence profile of the effect of a system-wide shock-gram (western Region).

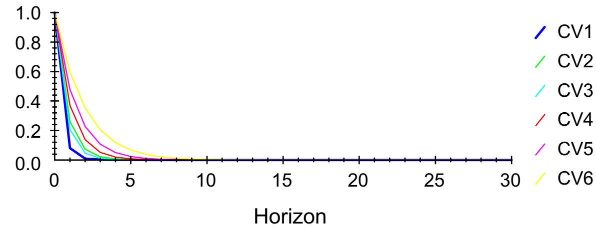

Fig. 6. Persistence profile of the effect of a system-wide shock-gram (northern Region).

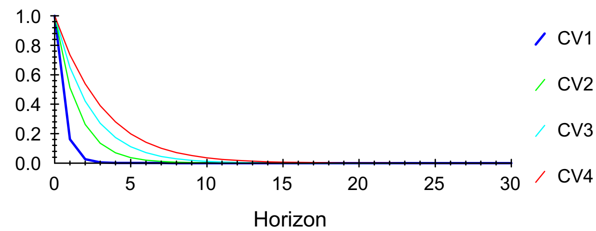

Fig. 7. Persistence profile of the effect of a system-wide shock gram (eastern Region).

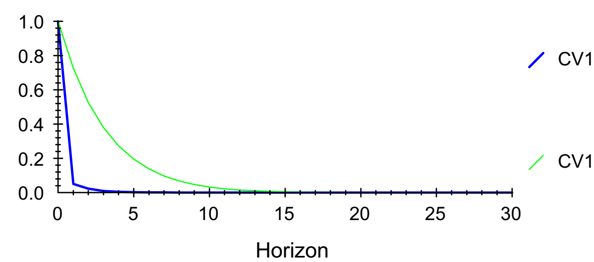

Fig. 8. Persistence profile of the effect of a system-wide shock-gram (all India).

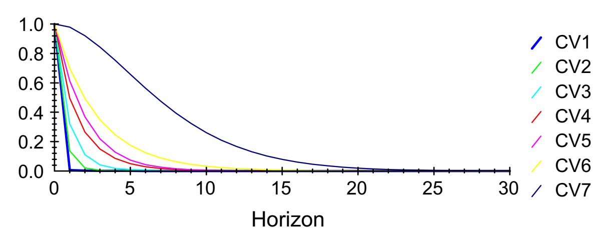

Fig. 9. Persistence profile of the effect of a system-wide shock-groundnut (all India).

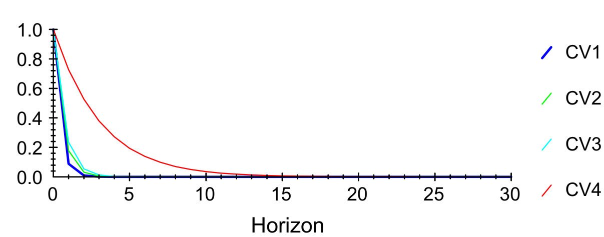

Fig. 10. Persistence profile of the effect of a system-wide shock-mustard oil (all India).

integrated. All the markets within each of the major states are well integrated. In terms of integration with international market, i.e. Bangkok market, southern and western regions perform the best. In the southern region all the 11 domestically integrated markets are also integrated with the international market. In the western region, all the 6 domestically integrated markets are integrated with international market (Table 2). North follows next with 4 of

Table 1a
Rice–domestic market integration (intra-regional).

Region	λ_{trace}	No. of CVs	No. of integrated domestic markets	Total no. of domestic markets	No. of non-integrated domestic markets
South	15.63*	10	11	13	2
West	18.54*	5	6	8	2
North	18.58*	4	5	8	3
East	5.83*	10	11	15	4
All-India			33	44	11

Table 1b
Rice–domestic market integration (inter-regional).

Region	Total no. of markets	No. of CVs needed for integration	No. of actual CVs	Remarks
South-West	17	16	14	**No integration between southern and western regions**. None of the markets in the western region are integrated with the southern region
South-East	22	21	13	**No integration between southern and eastern regions**. Bankura and Saithia in WB and Ranchi in Bihar markets in the western region are not integrated with any market in the southern region
South–North	16	15	8	**No integration between southern and northern regions**. None of the markets in the western region are integrated with the southern region
North-East	16	15	9	**No integration between northern and eastern regions.** Varanasi and Dehradun in UP in the northern region are not integrated with any market in the eastern region
North-West	11	10	5	**No integration between northern and western regions**. Varanasi and Dehradun in UP in the northern region are the only markets integrated with markets in the eastern region

the 5 markets being integrated with the international market. Eastern region shows relatively poor integration with international market. In this region, out of a total of 11 domestically integrated markets, only 8 are integrated with the international market. The ADF tests on the residuals of all the 32 cointegrating vectors reject the null hypothesis of non-stationarity, showing the robustness of the cointegrating equations (Table 8).

The PP plot of rice shows that the adjustment for the 1st cointegrating vector from 1 unit shock is complete within a time period of 1 month in the southern and eastern regions of the country (Figs. 1 and 4). In western India, the period is slightly longer with 3 months (Fig. 2) followed by northern India (Fig. 3). However, the adjustment of the entire system of cointegrating vectors seems to take much longer as can be seen from Figs. 1–4.

The inter-regional integration (Table 1b) is much lower than the intra-regional integration, showing that none of the regions is integrated with other regions. This is probably because paddy or rice is traded between markets within the same state or to the adjoining states (GoI, 2003a). The better integration within the southern and western regions and also the better integration of these regions with international market are mainly due to better road infrastructure in these regions and their proximity to major ports respectively, as compared to the other two regions. The shorter period of shock dissipation in the southern and eastern regions appears to be linked to the production profile. They are the predominant rice-growing regions where most of the major rice-producing states are located.

Gram

Gram appears to be completely integrated, both regionally and nationally (Table 3a). In the western, northern and eastern regions there are in all 5, 7 and 5 markets respectively and all of them are integrated. Even across regions, there is clear inter-regional integration of markets (Table 3b). The ADF tests on the residuals of all the 16 cointegrating vectors conclusively reject the null hypothesis of non-stationarity (Table 8). In terms of persistence profile, the adjustment of the first cointegrating vector appears to take 1–3 months (Figs. 5–7) in the west, north and east. At the all-India level also the pattern is similar (Fig. 8). The PP plots for the entire system of cointegrating vectors shows that the gram markets are reasonably integrated (Figs. 5–7). It takes about 5–15 months for any price shock to dissipate at the regional level. The western and northern regions show a maximum of 5 months for any disequilibrium to dissipate while the period is longer in the eastern region (15 months). Overall, the maximum period at the all-India level is about 10 months.

Gram is the main pulse crop in the country and faces virtually no restrictions on domestic trade as India always experienced a persistent supply–demand gap in pulses. This is perhaps the factor behind the extent of integration among gram markets both regionally and nationally. The better integration in the pulses sector–both within and across regions is also due to the domestic market structure. Although there are only 12–15 major pulse importers accounting for 60–70% of the total pulse imports, the importers are not involved in domestic marketing. The domestic marketing

Table 2
Rice – integration with international market.

Region	λ_{trace}	No. of CVs	Total no. of markets integrated domestically	Integrated domestically and also with international market	Integrated domestically but not with international market
South	75.86*	11	11	11	0
West	19.89*	6	6	6	0
North	31.27*	4	5	4	1
East	75.86*	8	11	8	3
All-India			33	29	4

Table 3a
Gram–domestic market integration (intra-regional).

Region	λ_{trace}	No. of CVs	No. of integrated domestic markets	Total no. of domestic markets	No. of non-integrated domestic markets
West	60.14**	4	5	5	0
North	47.07**	6	7	7	0
East	19.15**	4	5	5	0
All-India	15.89**		17	17	0

is mainly undertaken by the wholesalers and there is significant price competition among the wholesalers, which perhaps results in better response to arbitrage opportunities. Looking at the production profile of the states, the major gram producing states (as of 2008) are Maharashtra, Gujarat and Madhya Pradesh (western region); Karnataka and AP (southern region) and UP (northern region) accounting for about 90% of gram production in the country. The eastern region's share is negligible. It is therefore not surprising that the period of shock dissipation is the longest in the eastern region.

Oils

The case of two edible oils is similar to that of gram. All the 8 markets of groundnut oil are integrated and all the 5 markets of mustard oil are also integrated (Table 4). The ADF tests on the residuals of all the 7 cointegrating vectors of groundnut oil and 4 cointegrating vectors of mustard oil conclusively reject the null hypothesis of non-stationarity (Table 8). In case of mustard oil, the data on the international price of mustard oil is not available. Therefore, we have used the price of soybean oil in our analysis. The results show that all the 5 domestically integrated mustard oil markets are integrated with the international market as well (Table 4). Turning to the degree of integration, in the case of groundnut oil, the period of adjustment varies between 1 and 20 months with the average being 8 months (Fig. 9). The period of adjustment for the first cointegrating vector is about 1 month. The degree of market integration for the mustard oil market is much higher with the average period of adjustment being 3 months (Fig. 10). The period of adjustment for the first cointegrating vector is 2 months.

The difference in the adjustment periods between groundnut oil and mustard oil is linked to the pattern of production and consumption of these commodities. Over the period 1986/1987 to 2005/2006, the average share of groundnut production is about 41% as compared to only 23% of rapeseed-mustard. Groundnut is grown in fewer states mainly in Gujarat, A.P., Tamilnadu, Karnataka, Rajasthan and Maharashtra but consumed over the entire country whereas rapeseed and mustard is cultivated in over seven states (Rajasthan, Uttar Pradesh, Madhya Pradesh, Haryana, Gujarat, and West Bengal) with consumption being limited to fewer states than groundnut oil. This probably accounts for the longer period of price shock dissipation in case of groundnut oil.

Summing up, the results show the following broad features: (i) The extent and degree of integration among rice markets is lower than those among markets of gram or edible oils. (ii) At the crop level, the extent and degree of integration is not uniform across regions. These differences across crops can be understood better when analyzed in the backdrop of the policy framework and production/consumption profile. Rice, which is the staple diet for majority of Indian population, faces much larger degree of regulation at the central and state level. Private rice mills are required to deliver from 7% to 75% of their output to FCI and state governments for the public distribution system and buffer stocks. Only after meeting the levy commitments, are the rice mills allowed to sell rest of their output in the open market. On the consumption side, the state governments sell rice at below-market prices, to support food distribution and price stabilization programs. Some states, such as Andhra Pradesh, Tamil Nadu, Orissa and West Bengal impose additional movement restrictions. Internal trade in rice is amongst the most repressed sectors of the economy even today (Jha et al., 2005). Paddy or rice is despatched to markets within the same state or to the adjoining states (GoI, 2003a). There are controls and restrictions exercised by multiple authorities at various levels. As a result of these restrictions the all-India market is fragmented. (Jha et al., 2005). Jayasuriya et al., (2008) shows that this low level of internal trade in rice is not because of infrastructure constraints. They are mainly rooted in the state intervention in food procurement and pricing in some of the surplus states of rice. There are also stipulations on the volume of foodgrain stock that private traders can hold, depending on the supply and price scenario. These limits are lifted and re-imposed as deemed necessary. This plethora of regulations shows that rice/paddy market faces relatively more restrictions as compared to other markets. As a result the distant rice markets are less integrated as is shown in our results. Our results show that the markets within a region are fairly well-integrated but inter-regional integration and also integration at the national level is relatively low in rice markets. On the other hand, gram is the main pulse crop in the country and faces virtually no restrictions on domestic trade. The state of Delhi, which is one of the major assembling markets of gram, exports large quantities to far-flung states such as Tamil Nadu and Assam (GoI, 2003b). Our results also confirm that the gram markets within a state, across regions and at the national level are fairly well-integrated. It is noteworthy in this context that the restrictions on internal and external trade of gram are much lower as compared to rice. Similarly edible oils face very little restriction in domestic trade. Gram and edible oils also face very low tariffs at the border as compared to rice. These are perhaps some of the factors behind better market integration witnessed in gram and edible oils.

Other commodities

Castor oil and castor oilcake, with 4 and 3 markets respectively are well integrated (Table 5). Similarly, the mustard oilcake and groundnut oilcake markets with 4 markets each, are well inte-

Table 3b
Gram–domestic market integration (inter-regional).

Region	Total no. of markets	No. of CVs needed for integration	No. of actual CVs	Remarks
North-East	12	11	11	Northern and eastern regions are completely integrated
North-West	12	11	11	Northern and western regions are completely integrated
East–West	10	9	9	Eastern and western regions are completely integrated

Table 4
Edible oils–domestic and international market integration.

Commodity	λ_{trace}	No. of CVs	No. of integrated domestic markets	Total no. of domestic markets	No. of non-integrated domestic markets
Domestic integration					
Groundnut oil	23.53**	7	8	8	0
Mustard oil	37.78**	4	5	5	0
Integration with international market					
Groundnut oil	30.02*	7	7	8	1
Mustard oil	21.86*	5	5	5	0

Table 5
Oilcakes–domestic market integration.

Commodity	λ_{trace}	No. of CVs	No. of integrated domestic markets	Total no. of domestic markets	No. of non-integrated domestic markets
Castor oil	23.78**	3	4	4	0
Groundnut oilcake	25.88**	3	4	4	0
Mustard oilcake	27.49**	3	4	4	0
Castor oilcake	43.90**	2	3	3	0

Table 6
Tea and coffee – integration of Coimbatore market (India) with international markets.

Commodity	λ_{trace}	No. of CVs	No. of integrated international markets	Total no. of international markets	No. of non-integrated international markets
Coffee		3	3	4	1
Brazil	21.85**	1	1		
Brazil (New York)	15.41*	1	1		
Other Milds	15.41**	1	1		
Uganda	9.93	0			
Tea		2	2	2	0
Sri Lanka	15.41**	1	1		
London	15.41**	1	1		

grated. The ADF tests on the residuals of all the cointegrating vectors of these commodities conclusively reject the null hypothesis of non-stationarity (Table 8).In the case of coffee and tea, since there is only one market (Coimbatore) for which a long time series data on wholesale prices is available, domestic market integration is not relevant. Therefore, we have tested only for integration with the international market (Table 6). For coffee, we tested with four international prices and the Indian coffee price is found to be integrated with three of them. Only the Ugandan coffee price shows movements different from that of the Indian market. The ADF tests on the residuals of the 3 cointegrating vectors conclusively reject the null hypothesis of non-stationarity (Table 8). In case of Tea, we have tested with Sri Lankan and London markets and the Indian market is found to be integrated with both these international markets. The ADF tests on the residuals of both the cointegrating vectors reject the null hypothesis of non-stationarity (Table 8).

Conclusions and broad policy implications

The rice markets are integrated within the states and also within regions but the integration between regions and at the national level is not as high. This result is broadly in agreement with other studies on Indian rice markets (Kumar and Sharma, 2003, Jha et al., 2005, Jayasuriya et al., 2008). Out of the domestically integrated markets, majority are also integrated with the international market. In case of gram, edible oils and oilcakes, the markets are well integrated domestically. Edible oils, tea and coffee, for which integration with international market could be tested, have been found to be integrated with international markets. The assessment of the degree of integration, using the persistence profile approach, also shows that in rice markets the speed of adjustment is relatively longer. In other markets, the period of dissipation of a price shock is much shorter. Overall, the study results show that the markets for groundnut oil, mustard oil and gram are completely integrated while for rice a large number of markets are integrated although the speed of adjustment is longer.

The results indicate the importance of the trade policy in ensuring market efficiency (Results and analysis). On the basis of the trade policy, internal and external, commodities in the study can be broadly categorized as follows: (1) commodities with liberal border and domestic trade polices (gram, tea, coffee, oilcakes, castor oil) (2) commodities with border regulation but open domestic trade (edible oils) (3) commodities subject to strict regulations on domestic as well as external trade (rice). The markets appear well-integrated in the first two categories while the same cannot be said about the third category. The commodities that do not face inter-state or inter-regional movement restrictions, like gram and edible oils, appear well-integrated. On the contrary, rice market, subject to the maximum inter-state movement restrictions, does not show integration at the national level.[4] The transport bottlenecks appear to pose much less of a problem than is normally believed. Domestic markets of all commodities, except rice, appear well-integrated. Use of only price data (without including the transaction costs) should normally lead to the rejection of market efficiency hypothesis (Barrett, 2001). Thus, a finding in support of the null hypothesis for a majority of commodities (with a parsimonious model using only

[4] Absence of integration at the national level could also be due to the fact that rice is grown virtually in all the regions of the country, unlike wheat. This may preclude the possibility of physical flows across regions (although not across states).

Table 7
Number of months for a price shock to dissipate in Indian markets.

S. no.	Commodity	Southern region	Western region	Northern region	Eastern region	Overall
1	Rice	1	2	5	1	3
2	Gram	–	1	2	3	2
3	Groundnut oil	–	–	–	–	1
4	Mustard oil	–	–	–	–	2

Table 8
ADF tests on the residuals of cointegrating vectors.

Cointegrating vector (CV)	Rice	Gram	Groundnut oil	Mustard oil	Castoroil	Groundnut oilcake	Mustard oilcake	Castoroil cake	Coffee	Tea
CV1	-8.98^{**}	-5.91^{**}	-5.33^{**}	-5.83^{**}	-6.91^{**}	-6.11^{**}	-7.16^{**}	-4.58^{**}	-5.88^{**}	-5.54^{**}
CV2	-6.35^{**}	-6.45^{**}	-6.18^{**}	-4.98^{**}	-6.59^{**}	-5.69^{**}	-5.01^{**}	-5.02^{**}	-6.09^{**}	-5.72^{**}
CV3	-7.69^{**}	-6.18^{**}	-5.8^{**}	-6.3^{**}	-6.78^{**}	-5.94^{**}	-6.35^{**}		-6.16^{**}	
CV4	-8.29^{**}	-5.92^{**}	-6.03^{**}	-5.36^{**}						
CV5	-6.04^{**}	-5.64^{**}	-5.64^{**}							
CV6	-6.51^{**}	-5.19^{**}	-6.67^{**}							
CV7	-7.62^{**}	-5.71^{**}	-11.38^{**}							
CV8	-9.17^{**}	-6.45^{**}								
CV9	-6.47^{**}	-6.44^{**}								
CV10	-7.76^{**}	-4.71^{**}								
CV11	-8.28^{**}	-6.12^{**}								
CV12	-8.15^{**}	-7.04^{**}								
CV13	-7.2^{**}	-5.95^{**}								
CV14	-6.23^{**}	-6.34^{**}								
CV15	-7.81^{**}	-5.75^{**}								
CV16	-7.29^{**}	-5.75^{**}								
CV17	-7.48^{**}									
CV18	-7.64^{**}									
CV19	-6.55^{**}									
CV20	-7.18^{**}									
CV21	-7.15^{**}									
CV22	-8.07^{**}									
CV23	-7.35^{**}									
CV24	-7.5^{**}									
CV25	-8.21^{**}									
CV26	-8.61^{**}									
CV27	-7.18^{**}									
CV28	-6.92^{**}									
CV29	-5.89^{**}									
CV30	-7.91^{**}									
CV31	-7.46^{**}									
CV32	-8.41^{**}									

** Significant at 1% level.

price data) suggests market efficiency for most of the markets other than rice, which in turn may be linked to the regulations on rice market. Therefore, if the regulations in rice market are relaxed and a more open domestic trade policy is adopted, markets can play a more effective role and partly supplant some of the functions currently carried out by the state.

There are some important implications for international trade as well. Apart from pulses, no other major food item in India has had a consistently open import regime over the study period. In contrast, rice imports were subject to quantitative restrictions until the mid-1990s and, since then, have been assigned high tariffs that prohibit trade. Also, export controls were imposed whenever there were signs of a price rise in the international market, as witnessed in 2007. Such restrictiveness of rice trade has resulted in India aggravating the world market crisis in 2007 and also not being able to earn export revenues even while running surpluses in the domestic market. Also, our results suggest that the commodities that have been subject to fewer export restrictions such as tea and coffee appear to be well-integrated with the international markets unlike rice. This underlines the need for a relatively open trade policy for rice.

Imports of vegetable oil, now India's largest agricultural import, were restricted because of state trading until 1994, but since then have been freely traded subject to tariffs that now range from 45–75%. Although edible oil markets appear integrated at present, there is scope for welfare improvements mainly by reducing bound tariffs of some of the edible oils that have a lot of 'water' in the tariffs.[5] The comparatively low 45% bound tariff on soybean oil has effectively precluded the scope for upward adjustment of applied tariffs on other oils. Therefore, edible oil bound tariffs need some downward adjustment, which may allow India to renegotiate bound tariffs on some other crucial commodities such as sugar (Sekhar, 2004).

Patterns of price volatility at the regional level have not been studied in the present study. However, there is evidence of a much lower degree of agricultural price variability at the national level in Indian markets, as compared to the world markets (Nayyar and Sen, 1994; Chand, 2001; Sekhar, 2004). It may not be unreasonable to partly attribute this lower degree of variability to the better domestic market integration witnessed in the study.

One limitations of the study is that the study does not include the transactions costs for reasons already mentioned. A fruitful area for future research could be to analyze the issue by including

[5] Tariff water is the difference between bound and applied duties and provides relevant information on domestic trade policy and WTO trade negotiations.

the transactions cost data whenever such data become available, because such an analysis can considerably advance our understanding of the market integration issues in India.

Appendix A

Testing. for extent of market integration

The G–G model is basically in the framework of factor analysis and can be easily derived by estimating a standard Vector Error Correction Model (VECM).

Let X_t be a vector of P prices of order $(P \times 1)$ and each element of X_t be $I(1)$ with mean 0. Let the elements of X_t be cointegrated with rank r. In other words, there exists a matrix $\alpha_{p\times r}$ of rank r such that $\alpha' X_t$ is $I(0)$. There are two features of X_t.

(i) X_t has an error-correction (VECM) representation of the following form – $\Delta X_t = \gamma_{p\times r}\alpha'_{r\times p}X_{t-1} + \sum_{i=1}^{\infty}\Gamma_i \Delta X_{t-i} + \varepsilon_t$, where$\Delta = I - L$ with L being the lag operator

where $\gamma_{p\times r}$ is a matrix of the weights (speed of adjustment) of the cointegrating equations, $\alpha_{p\times r}$ is the matrix of cointegrating vectors and Γ_i is the vector of short-run coefficients. ε is the error term.

This is the standard feature that finds application in most of the literature on market integration. We have made use of the second feature in this study, which is the following.

(ii) The elements of X_t can be expressed in terms of a *smaller* number $(p - r)$ of $I(1)$ variables, called the common factors and denoted by f_t, plus some stationary $I(0)$ components.

$X_{t_{p\times 1}} = A_{1_{p\times k}} f_{t_{k\times 1}} + \tilde{X}_{t_{p\times 1}}$ where $k = p - r$.

This is similar to standard factor analysis. In factor analysis the main objective is to estimate the loading matrix A_1 and the number of common factors k. In the VECM representation above, these two are already known. A_1 is any basis of the null space of the cointegrating vector α such that $\alpha' A_1 = 0$ and k is equal to $p - r$ where r is the cointegrating rank. The goal of the G–G methodology is to estimate f_t. The standard restrictions used in factor analysis are not adequate in this case since the data are non-stationary. The following additional conditions are imposed to identify f_t.

(a) f_t is a linear combination of elements of X_t.
(b) $A_1 f_t$ and $\tilde{X}_t$ are the permanent and transitory components respectively of X_t. According to this condition the only shocks that can affect the long-run forecast of X_t are those coming from u_{pt} i.e. the error term of the permanent component $A_1 f_t$. From these conditions, after substantial manipulation, one can obtain $f_{t_{k\times 1}} = \gamma'_{L_{k\times p}} X_{t_{p\times 1}}$ such that $\gamma'_L \gamma = 0$ and $k = p - r$.

The f_t s are the linear combinations of X_t that have the common feature of not containing the levels of the error-correction term z_{t-1} in them. Once f_t s are identified, inverting the matrix $(\gamma_L, \alpha)'$ we obtain the permanent-transitory decomposition of X_t.

$$X_{t_{p\times 1}} = A_{1_{p\times k}} \gamma'_{L_{k\times p}} X_{t_{p\times 1}} + A_{2_{p\times r}} \alpha'_{r\times p} X_{t_{p\times 1}}$$

where $A_{1_{p\times k}} = \alpha_{L_{p\times k}}(\gamma'_{L_{k\times p}}\alpha_{L_{p\times k}})^{-1}, A_{2_{p\times r}} = \gamma_{p\times r}(\alpha'_{r\times p}\gamma_{p\times r})^{-1}$.

Therefore the decomposition of X_t into permanent and transitory components is complete $X_{t_{p\times 1}} = [A_{1_{p\times k}} f_{t_{k\times 1}}] + [A_{2_{p\times r}} z_{t_{r\times 1}}]$ in which the first term is the permanent component and the second is the transitory component.

$f_{t_{k\times 1}} = \gamma'_{L_{k\times p}} X_{t_{p\times 1}} = \mathrm{I}(1)$ common factor.
$z_{t_{r\times 1}} = \alpha'_{r\times p} X_{t_{p\times 1}} = \mathrm{I}(0)$ stationary component.
$\gamma_{p\times r}$ = weights (speed of adjustment) of the cointegrating equations.
$\gamma_{L_{p\times k}}$ = orthogonal matrices of γ.
$\alpha_{p\times r}$ = cointegrating vectors.
$\alpha_{L_{p\times k}}$ = orthogonal matrices of α.
p = order of X_t (number of elements in vector X_t), r = number of cointegrating vectors, $k = p - r$.

As may be seen, the order of f_t is $k \times 1$ where $k = p - r$. Therefore, if $r = p - 1$ which means that there are $p - 1$ cointegrating relations among p variables, then there is a single common factor among the p variables i.e. $k = 1$ and f_t is a single element vector. In case of integrated markets, we expect to find a single common factor (of prices) driving the entire system. It needs to be noted here that a 'single factor' does not imply a 'single market' but a 'single linear combination' of a subset of markets of X_t. Therefore for a set of n markets to be integrated, we should have $n - 1$ cointegrating vectors. We make use of this property to identify the set of integrated markets in this study. Gonzalez-Riviera and Helfand (2001), and Jha et al. (2005) used this model to assess the rice market integration in Brazil and India respectively.

We start with an appropriately large number (n_1) markets out of a total number of n markets such that $n_1 < n$. We then test for the number of cointegrating vectors in this set of markets. If the number of cointegrating vectors is $n_1 - 1$, then we add one more market to the set and again test for the number of cointegrating vectors. If the number of cointegrating vectors is still $n_1 - 1$ (instead of n_1) then we drop the newly included market and try another market. This process is continued till we have the largest set (say n_2) of integrated markets. If all the n markets are integrated, then $n_2 = n$.

While testing for integration with the international market, we fix the international market and sequentially test the domestic markets for integration with the international market. Suppose that we have one international market and n_1 domestic markets. If we find n_1 cointegrating vectors, then there are $n_1 + 1$ integrated markets in all. Since international market is already fixed, we conclude that all the n_1 domestic markets are integrated with the international market.

The sequential procedure followed in testing market integration is given below.

(i) Markets within a state.
(ii) Markets within a region (south, west, north, east).
(iii) Markets in the entire country.
(iv) All the domestically integrated markets with the international market.

Degree. of market integration

Degree of market integration may be understood as the time span needed for a shock to dissipate. Degree of market integration is traditionally assessed by looking at the adjustment coefficient (γ) or the statistical significance of the lag structure Γ_i in the VECM. To jointly evaluate the effects of innovations in one equation on the entire system represented by the VECM, impulse response functions (IRF) are normally used. IRF s trace the impact of a shock in location j on the price of i over time. The main drawback of the IRF s is that they are not unique when errors in different equations are correlated. In a study of spatial market integration, it is highly probable that the errors at different locations are correlated since the movements in prices at these locations are generally correlated. The solution attempted in the literature to overcome this problem is the Cholesky decomposition, but this solution is crucially dependent on the ordering of the variables that enter the VECM. Changing the order of the variables can significantly alter the IRFs. Therefore, we attempted the persistence profile (PP) approach of Pesaran and Shin (1996). A PP characterises the response of a cointegrating relation to a system-wide shock. PP s are unique functions which allow us to quantify the degree of integration among the locations that belong to the same economic market.

A 'persistence profile' may be defined as the scaled difference between the conditional variances of the n-step and the $(n-1)$-step-ahead forecasts, and is a function of n, the forecast horizon. This measure readily captures the essential difference that exists between cointegrated and noncointegrated relations, and provides unique time profiles of the effect of shocks to the cointegrating relations. In the case of relations between $I(1)$ variables that are not cointegrated, the effect of a shock persists forever, while in the case of cointegrated relations the impact of a shock will be transitory and eventually disappear as the economy returns to its steady trend or its long-run equilibrium. The existing tests of cointegration focus on the limiting value of the persistence profile and only test whether this measure tends to zero as the horizon of the profile, n, tends to infinity (Pesaran and Shin, 1996).

Persistence profile characterises the response of the cointegrating relation $Z_t = \alpha' X_t$ to a system-wide, rather than to an individual shock, where the response is measured in units of variance. The system-wide shocks may be understood as shocks drawn from a multivariate distribution of ε_t s without any need to orthogonalise the shocks.

The persistent profile (unscaled) is defined as follows.

$H_X(n) = V(X_{t+n}|I_{t-1}) - V(X_{t+n-1}|I_{t-1})$ for $n = 0,1,2,\ldots$,where H(.) denotes the variance up to time horizon n, conditional on the information available up to $t-1(I_{t-1})$. Since $V(X_{t+n}|I_{t-1}) = V\{[X_{t+n} - E(X_{t+n}|I_{t-1})]|I_{t-1}\} = V(\eta_{t+n}|I_{t-1})$, where η_{t+n} is the n-step ahead forecast error of X_t, PP can also be viewed as the change in variance of forecasting X_{t+n} as compared to that of forecasting X_{t+n-1} given the information I_{t-1}. A scaled persistent profile $h_X(n)$ is defined as $h_X(n) = H_X(n)/H_X(0)$ which has a value of unity on impact i.e. at $n = 0$.

The concept of PP of a variable X_t can be easily extended to that of cointegrated system Z_t The information content of the whole time profile of $h_z(n)$ is of much greater interest in economic analysis than the mere knowledge that $Z_t = \alpha' X_t$ forms a cointegrating relation. The profile of $h_z(n)$, as n is allowed to increase, provides important information on the speed with which the effect of a system-wide shock on the cointegrating relation $Z_t = \alpha' X_t$ disappears (even through these shocks generally have lasting effects on each of the individual variables in the vector X_t). Also looking at $h_z(n)$ for $n = 0,1,2,\ldots$ allows us to discern the short-run dynamic properties of the cointegrating vector as well as their long-run properties.

Appendix B

List of integrated and non-integrated markets

Zone	Integrated markets	Non-integrated markets
Rice–domestic market integration		
South Zone	Kakinada, Nizamabad, Tadepalligudem, Hyderabad, Shimoga, Trivandrum, Kozhikode, Kumbakonam, Madras, Tirunelveli, Tiruchirapalli	Bhimavaram, Alleppey
East Zone	Guahati, Ranchi, Dumka, Jamshedpur, Arrah, Gaya, Jeypore, Santhia, Bankura, Contai, Calcutta	Hailkandi, Balasore, Agartala, Patna
West Zone	Bulsar, Raipur, Durg, Indore, Nagpur, Gondia,	Rajkot, Jabalpur
North Zone	Kanpur, Nowgarh, Varanasi, Dehradun, Allahabad.	Karnal, Azamgarh, Delhi
Rice–international market integration		
	Integrated Domestic Markets which are also Integrated with Bangkok Market	Integrated Domestic Markets Not Integrated with Bangkok Market
South Zone	Kakinada, Nizamabad, Tadepalligudem, Hyderabad, Shimoga, Trivandrum, Kozhikode, Kumbakonam, Madras, Tirunelveli, Tiruchirapalli	None
East Zone	Guahati, Ranchi, Dumka, Jamshedpur, Arrah, Gaya, Jeypore, Santhia, Bankura, Contai, Calcutta	Arrah, Jeypore, Contai
West Zone	Bulsar, Raipur, Durg, Indore, Nagpur, Gondia,	None
North Zone	Kanpur, Nowgarh, Varanasi, Dehradun, Allahabad.	Nowgarh

Gram

		Integrated Markets	Non-Integrated Markets
East Zone	Patna, Arrah, Coimbatore, Sainthia, Calcutta	None	
West Zone	Jabalpur, Sagar, Aurangabad, Sriganganagar, Jaipur	None	

North Zone	Rohtak, Abohar, Hapur, Bahraich, Kanpur, Banda, Delhi	None

Other commodities

Commodity	Integrated Markets	Non-Integrated Markets
Mustard Oil	Moga, Kanpur, Hapur, Calcutta, Delhi	None
Groundnut Oil	Nandyal, Hyderabad, Rajkot, Bangalore, Bombay, Madras, Calcutta, Delhi	None
Castor Oil	Hyderabad, Madras, Kanpur, Calcutta	None
Mustard Oilcake	Moga, Kanpur, Calcutta, Delhi	None
Groundnut Oilcake	Hyderabad, Rajkot, Bombay, Madras	None
Castor Oilcake	Hyderabad, Salem, Kanpur	None
Tea[a]	London, Sri Lanka	None
Coffee[b]	Brazil, New York, Other milds	Uganda

[a,b] Only one domestic market (Coimbatore) has been considered and integration with international markets has been tested.

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