Changing pattern of energy use in Indian agriculture and linkage between energy and commodity prices

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Abstract

The expenses on energy based inputs have registered a phenomenal increase since the 1990s in Indian agriculture. The use of energy intensive inputs is higher on marginal farms than on large farms. In view of increasing share of energy costs, this paper examined the transmission mechanism of increase in energy prices in agricultural commodity markets in India using monthly wholesale price indices during April 1994 to March 2014. In order to assess the effect of deregulation of some petroleum products since April 2002, study period was divided into two sub-periods (April 1994 to March 2004 and April 2004 to March 2014), besides analyzing for full period. The co-integration analysis indicated evidence of parallel movement between prices of energy and all selected agricultural commodities after deregulation, which means higher transmission between crude oil and these commodity prices.

Keywords: Agricultural commodity prices, Cost of cultivation, Crude oil prices, India, Multivariate co-integration

JEL codes: O13, Q11

1. Introduction

Shift in food consumption towards high-value commodities, global climate change and shrinking natural resource base are adding pressure on agricultural systems which are already facing the challenges in terms of improving food and nutritional security while reducing the environmental footprints. In a land-scarce, populous agrarian economy like India, additional production has to be achieved by intensification and judicious management of available resources. This will also entails change in the energy use pattern, with a marked shift from animal and human power to tractors, electricity and diesel. The consumption pattern of both direct (electricity and diesel) and indirect energy (fertilizers and pesticides) inputs has shown a sharp rise from 2.5 to 16.5 thousand Mega Joules per hectare during the last three decades (Jha *et al.*, 2012). The cost of cultivation data provided by the Directorate of Economics and Statistics (DES) also indicated that the expenses on energy based inputs have registered a phenomenal increase since the 1990s. Therefore, rising input costs is considered as one of the main reasons for vulnerabilities of rural economy (Raghavan, 2008). In view of increasing share of energy in the cost of cultivation, agricultural commodity prices are vulnerable to the rise in energy prices, particularly of crude oil.

International crude oil prices experienced a steady increase since 2003-2004, both due to demand pressures and supply constraints. After the global financial crisis, portfolio re-adjustment by international commodity speculators in the wake of persisting depreciation of the US dollar was a key factor in driving up crude oil prices. India, being a net oil importer, faced significant policy challenges in containing the adverse fallout of higher international crude oil prices on domestic inflation and output during this period. India has so far followed a near administered fuel pricing policy. In the recent past, in the face of dramatic changes in fuel prices, the need for domestic fuel price revision in line with these changes has been felt in many quarters. However, given the social implication as well as the political sensitivity of this issue in India, a policy shift from regulation to deregulation has happened only for some petroleum products since April 2002 while prices for some others continued to remain administered well below international prices. Against the above backdrop, this paper attempts to examine the co-movement between energy prices and agricultural commodity prices.

In case of agricultural commodities, prices are affected by the combination of adverse weather condition, diversion of some food commodities for biofuels production and most importantly higher costs of production due to higher energy prices. In developed countries, the linkages between energy and agricultural markets have recently received attention mainly due to the diversion of some food commodities to the production of biofuels (notably maize in the US and edible oils in Europe). However, the relationship between energy and agricultural commodity prices became relevant in Indian context due to increasing share of energy in the cost of cultivation of most agricultural commodity coupled with frequent and upward revision of energy prices in the wake of deregulation. Specifically, this paper analyzed the co-variability between crude oil pricess and selected agricultural commodities (foodgrains, rice, maize, oilseeds, soybeans, edible oils, fruits and vegetables).

Various studies on co-movement in commodity markets have been undertaken in case of developed countries. Yu *et al*. (2006) examined the relationship between crude oil prices and vegetable oils used in biodiesel production and found only one co-integrating vector, which is an indicator of the degree of substitutability among the vegetable oils. The study found that crude oil price shocks did not have a significant impact on changing vegetable oil prices. Campiche *et al*. (2007) investigated the co-variability between crude oil prices and corn, sorghum, sugar, soybeans, soybean oil and palm oil prices during 2003-07 through Johansen co-integration test and observed no co-integrating relationships over the full sample period. However, an analysis of the sub-sample 2006-07 period revealed that soybean and corn prices were co-integrated with crude oil. Natanelov *et al*. (2011) examined the co-movement of agricultural commodities futures prices and crude oil and revealed that biofuel policy buffers the co-movement of crude oil and corn futures until the crude oil prices surpass a certain threshold. Rosa and Vasciaveo (2012) tested the hypothesis of possible linkage between increased volatility in agricultural prices and crude oil prices in United States and Italy. However, not many studies on co-movement in commodity markets have been undertaken in the Indian context. Bhattacharya and Bhattacharya (2001) attempted to study the transmission mechanism of an increase in petroleum prices on the prices of other commodities and output in India using vector autoregression (VAR) model. Since the process of deregulation started from April, 2002 onward, our analysis for two periods corresponding to before and after deregulation, will provide a more clear picture of a potential link between the markets. The main aim of the study is to determine whether or not there is an increasing tendency for price changes in selected agricultural commodities due to corresponding price changes in energy prices.

The rest of the paper is organized as follows. The data and estimation methodology of the study are discussed in Section 2. Section 3 provides the changing pattern of energy use with respect to different farm categories. Section 4 presents the empirical findings of the co-movement between energy and agricultural commodity prices. Finally, Section 5 summarizes the main findings of the study.

2. Data and Methodology

2.1 Data Description

The study is completely based on secondary data. To study the energy-use pattern in the Indian agriculture, data were compiled from various issues of Cost of Cultivation of Principal Crops in India and Input Survey published by the Directorate of Economics and Statistics, Government of India, New Delhi. The data used in the co-integration analysis comprises monthly price indices of crude oil, high speed diesel oil, foodgrains, rice, maize, oilseeds, soybeans, edible oils, fruits and vegetables starting from April 1994 to March 2014. The price index of crude oil was obtained from International Monetary Fund website. The monthly price indices data on high speed diesel oil, foodgrains, rice, maize, oilseeds, soybeans, edible oils, fruits and vegetables were collected from the Ministry of Commerce, Government of India.

2.2 Methodology

A vector error correction model (VECM) was employed to examine the relationships between energy prices and agricultural commodity prices. This methodology accounts for the possibility of nonstationarity in price series and co-integration relationships among price series. VECM considers both the long-run and short-run relationships among variables. The technique of co-integration is widely used for analyzing issues associated with non-stationary time series data, while avoiding the problem of spurious regression. Spurious regression is an apparent significant long-run relationship between variables, when none is actually present. Co-integration between non-stationary variables occurs when the linear combination of the variables generates a stationary series (Engle and Granger, 1987).

Several methods are available to test for co-integration between variables, but the Engle-Granger and the Johansen approach are the most commonly used models. For this study, the Johansen and Juselius co-integration method was utilized. The Johansen and Juselius model involves a multivariate autoregressive method of estimating multiple cointegration relationships (Johansen, 1988; Johansen and Juselius,1990).

As indicated, in case of nonstationarity of the time series data, co-integration provides an appropriate statistical technique to examine if there is a statistically significant relationship between the nonstationary series. Accordingly, first step of our methodology includes determination of nonstationary nature of the price index (Y_t) used for our analysis. In time series econometrics, the price index integrated of order one is denoted by $Y_t \sim I(1)$ and the first difference of price index integrated of order zero is denoted by $\Delta Y_t \sim I(0)$. When price indices are found to be non-stationary in levels but stationary in first differences, co-integration tests may be applied. In this study, order of integration of price index was tested by using Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests. In order to determine whether co-integration relationships exist between the variables, lag length (k) and co-integration rank (r) must be determined. Johansen (1991) proposed a two-step method to first determine the lag length using either an information criterion or a likelihood ratio test and then to determine the co-integrating rank using a likelihood ratio test, such as the λ max test or the trace test. The Johansen co-integration procedure is based upon an unrestricted vector autoregressive (VAR) model specified in error-correction form as follows:

$$Y_t = A_1 Y_{t-1} + A_2 Y_{t-2} + \ldots + A_k Y_{t-k} + e_t$$

$$\Delta Y_t = \Pi Y_{t-1} + \sum_{i=1}^{k-1} \Gamma_i \Delta Y_{t-i} + e_t \qquad (1)$$

where

$$\Pi = -(I - A_1 - A_2 - \ldots - A_k)$$
$$\Gamma_i = (I - A_1 - A_2 - \ldots - A_i), \qquad i = 1, \ldots, k-1$$

Y_t include all p variables (for example price indices of crude oil, foodgrains etc.) of the model which are $\sim I(1)$, Π and Γ_i are parameter matrices to be estimated, e_t is a vector of random errors which follow a normal distribution with zero mean and constant variance.

The Johansen test for co-integration evaluates the rank (r) of the matrix Π. If $r = 0$, all variables are $I(1)$ and there is no co-integration at all. In this case, the suitable model is a VAR in the first differences. In case $r = p$ then all the variables are $I(0)$ and thus stationary, and any combination of stationary variables will also be stationary. This implies that there is no problem of spurious regression and a standard VAR in level can be used for estimation. If $0 < r < p$, then there exist r co-integrating vectors. Π matrix contains information on long-run relationship and is defined as the product of two matrices: θ and β', of dimension $(p \times r)$ and $(r \times p)$, respectively. The θ matrix represents the speed of adjustment to disequilibrium and β is a matrix of long-run coefficients of the co-integrating vectors (Natanelov *et al.*, 2011).

The Johansen co-integration method estimates the Π matrix through an unrestricted VAR and tests whether one can reject the restriction implied by the reduced rank of Π. Two methods of testing for reduced rank of Π are the trace test and the maximum eigenvalue test, respectively:

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

$$\lambda_{\max}(r, r+1) = -T \ln(1 - \hat{\lambda}_{r+1}) \tag{3}$$

where, λ_i is the estimated values of the ordered eigenvalues obtained from the estimated matrix and T is the number of the observations after the lag adjustment.

The trace statistics test the null hypothesis that the number of distinct co-integrating vectors (r) is less than or equal to r against a general alternative. The maximum eigenvalue tests the null hypothesis that the number of co-integrating vectors is r against the alternative of $r+1$ co-integrating vectors. If co-integration is detected, we test for causality by employing the appropriate types of causality tests.

The existence of cointegration in the bi-variate relationship implies Granger causality at least in one direction. This causality can be tested within the framework of Johansen cointegration by the Wald test under certain restrictions. If the θ matrix in the co-integration matrix Π has a complete column of zeros, no causal relationship exists since no co-integrating vector appears in that particular block. Pair wise causal relationship can be represented as follows:

$$\begin{bmatrix} \Delta Y_{1,t} \\ \Delta Y_{2,t} \end{bmatrix} = \begin{bmatrix} \mu_1 \\ \mu_2 \end{bmatrix} + \begin{bmatrix} \alpha_1 \\ \alpha_2 \end{bmatrix} \left(Y_{1,t-1} - \beta Y_{2,t-1} \right) + A_1 \begin{bmatrix} \Delta Y_{1,t-1} \\ \Delta Y_{2,t-1} \end{bmatrix} + \ldots + A_k \begin{bmatrix} \Delta Y_{1,t-k} \\ \Delta Y_{2,t-k} \end{bmatrix} + \begin{bmatrix} e_{1t} \\ e_{2t} \end{bmatrix} \tag{4}$$

Parameters contained in matrices A_k measure the short-run causality relationship, while β is the co-integrating parameter that explains the long-run equilibrium relationship between the series. Using Eq. (4), three possibilities for long-run causality may arise, (i) $\alpha_1 \neq 0, \alpha_2 \neq 0$; (ii) $\alpha_1 = 0, \alpha_2 \neq 0$; and (iii) $\alpha_1 \neq 0, \alpha_2 = 0$. Out of three cases, the first case indicates bi-directional causality, while the second and third imply uni-directional causality. Wald test with the null hypothesis that the joint contribution of the lags of endogenous variables is equal to zero has been applied to analyze for short-run causality. If the null hypothesis cannot be rejected it implies that the respective endogenous variables can be treated as exogenous in the system. In case of bi-variate models, the Johansen co-integration Eq. (1) can be rewritten as (Natanelov *et al.*, 2011)

$$\Delta Y_{1,t} = \mu_1 + \sum_{i=1}^{k1} \beta_i \Delta Y_{1,t-i} + \sum_{j=1}^{k2} \beta_j \Delta Y_{2,t-j} + \alpha_1 ECT_{t-1} + e_{t,1} \tag{5}$$

$$\Delta Y_{2,t} = \mu_2 + \sum_{i=1}^{k1} \beta_i \Delta Y_{1,t-i} + \sum_{j=1}^{k2} \beta_j \Delta Y_{2,t-j} + \alpha_1 ECT_{t-1} + e_{t,2} \tag{6}$$

where, $Y_{1,t}$ and $Y_{2,t}$ are time series (of prices) and ECT is the error correction term. The short run causality was tested using Eqs. (5) and (6) by examining the significance of all lagged dynamic terms.

3. Changing pattern of energy use

Increasing focus on farm mechanization has changed the structure of energy consumption in the Indian agriculture, with a marked shift from traditional to commercial energy sources for different farming operation. The cost of cultivation data provided by the DES clearly indicate that the expenses on farm inputs put together have registered a phenomenal increase since the 1990s (Table 1). Table 2 presents the costs on machine labour as a proportion of average cost of cultivation in major rice and wheat growing states of the country. A perusal of Table 2 suggests that the contribution of machine labour costs has increased tremendously in recent years and accounts for the second largest component after wages, in the operational costs of cultivation. The machine labour costs, which were less than 4 per cent of the operational cost in 1970-71, rose tremendously to 24 per cent in 2011-12 in the case of wheat. This may be due to widespread mechanization of agriculture, as well as frequent upward revision of diesel prices and electricity tariffs. It is worth mentioning that in states like Tamil Nadu, the average cost of cultivation of rice on machine labour was 11 per cent during 2000s as compared to only 2 per cent in 1980s (Jha, 2013). Moreover, farmers even in the poorer states depend more on machine labour (Table 2). On the other hand, fertilizer charges which used to be the second largest component of the operational cost, though, increased in absolute terms, its per cent share has decelerated over time. Also there are sizeable inter-state differences in the application of fertilizers (Table 3).

The agricultural input survey data of 2006-07 shows substantial increase in the use of tractors and cultivators, especially on small and marginal farms that constitute four-fifth of the total number of operational holdings in the country. The growth rate in the number of farm equipments used between 1996-97 and 2006-07 was computed with the help of input survey data and is presented in Table 4. There is 54 per cent increase in the use of tractors and cultivators on marginal farms. It reveals that more than half of the agricultural land is mechanically tilled, and three-fourths of them use hired services (Jha, 2013). Further, the share of hired services is more on small and marginal farms. The indirect energy-use in the form of fertilizers was the maximum in the marginal category and it declined with increase in the farm-size. The marginal farmers (operational holding < 1 ha) applied 55 kg of fertilizers per hectare during 1981-82 which was double of the fertilizer-use in case of large farmers (>10 ha).

4. Co-integration analysis beteen energy and agricultural commodity prices

In this section, the co-integration analysis and the corresponding causal relationship in the long run were analyzed by estimating a vector error correction model (VECM) suggested by Johansen (1991). Figure 1-4 show time plot of some selected agricultural commodity with energy price indices. Crude oil series clearly indicates its historical maximum in nominal terms of July 2008 and volatility in recent years. Figures also indicate the parallel movement between energy and selected agricultural commodity prices after 2004. The data sets contain 240 data points (April, 1994 to March, 2014). Besides, analyzing for full period, the sample data were divided into two equal periods (April 1994-March 2004 and April 2004-March 2014), so that before and after analysis will better capture the impact of deregulation measures initiated by Government of India since 2002. Table 5 presents summary statistics of the price returns for each commodity (multiplied by 100). The returns are defined as $r_t = \log(Y_t/Y_{t-1})$, where Y_t is the price of the commodities at month t and Y_{t-1} is the previous month's price. The logarithmic transformation is a good approximation for net returns for a given commodity and is usually applied in empirical investigation to obtain a convenience support for the distribution of error terms. The advantage of looking at log returns of a series is that it can be observed as the relative change in a given variable and compare with other variables whose values may have very different base values. The returns of all variables appear to follow non-normal distribution and are leptokurtic in nature. Crude oil returns has a standard deviation more than double of the high speed diesel oil (HSDO). This clearly reflects the administrative fuel price policy of the country. Vegetables returns show maximum variability out of the selected commodities for this study.

In order to ensure robustness of the results, Augmented Dickey Fuller (ADF) and Phillips-Perron (PP) tests were performed to determine the stationarity for all the series. For all time series except vegetable series of the first period, the tests indicated the existence of one unit root, I(1). Thus the difference of each time series except vegetables series can be regarded as stationary. In order to identify a possible influence of crude oil prices on various agricultural commodity prices, each agricultural commodity time series was paired with crude oil price, resulting into 8 bi-variate systems for each period. Since the time series are integrated of the same order, cointegration techniques can be used to determine whether a stable long-run relationship exists between each pair. Since vegetables series is stationary during April 1994 to March 2004, hence this data set was not used for co-integration analysis.

Johansen's co-integration tests were performed on all the three sets of data series, viz., April 1994-March 2014, April 1994-March 2004 and April 2004-March 2014. The vector autoregression (VAR) specification was estimated by applying one to twelve lags. The Schwartz information criterion was utilized to select optimal lag length. Table 6 presents optimal lag length for crude oil for three periods.

To carry out the co-integration rank test, one needs to choose from the five possible specifications, the one that seems most plausible for the data in hand. For this study, we have used third and fourth option of EViews 7 software, which allow for linear deterministic trend in data. Both the model provided similar results. Tables 7, 8 and 9 show detailed results of co-integration analysis between crude oil and selected agricultural commodities for the full period (April 1994-March 2014), first period (April 1994-March 2004) and second period (April 2004-March 2014), respectively. The trace and maximum eigenvalues tests are based on likelihood ratio from the estimated restricted VAR model. Table 10 offers a summary of the results comparing the three analyses. The results indicate that fruits and vegetables price series are co-integrated with crude oil over the full sample period, which implies that the prices of these commodities move together with crude oil in the long run (Table 7). In the period April 1994-March 2004, we observed foodgrains, maize and fruits prices are co-integrated with crude oil prices (Table 8). The co-integration tests revealed that all the eight selected agricultural commodity price series were co-integrated with the crude oil price during April 2004-March 2014 (Table 9). The contrast between the first and second period is remarkable and may be due to deregulation of some petroleum products.

Table 11 presents the following parameter estimates: the speed of adjustment from the estimated Johansen VAR (restricted VAR model), t-tests for the co-integrating vector and the speed of adjustment of crude oil prices with various agricultural commodities prices, respectively. The main highlight of the results of the full period (April 1994-March 2014) is the relatively small and consistent parameter estimate (β) for two co-integrated pair, crude oil-fruits and crude oil-vegetables. In the time period April 1994-March 2004, parameter estimate (β) of crude oil-foodgrains pair was relatively large. This implies that crude oil prices and foodgrains prices are strongly linked in this period. The estimates of the period April 2004-March 2014 are consistent with moderate value, all co-integrated pair in this period are moderately linked.

VECM results shows that, ECT estimates are fairly consistent throughout all the three periods. The ECT for foodgrains-crude oil pair in the period April 1994-March 2004 is relatively small, which confirms the strong relationship between the two commodity prices.

Once co-integration between time series is established it is of interest to analyze for causality of each co-integrating pair. Long run causality from the estimated Johansen VECM is analyzed through a likelihood ratio (LR) test by restricting the disequilibrium error term. Table 12 indicates long-run unidirectional causality from crude oil prices to fruits and vegetables prices. In the period April 1994-March 2004, long-run causality are found in crude oil-food grains and crude oil-fruits. In the period April 2004-March 2014, we found only one unidirectional causality from crude oil prices to foodgrains prices in short run and in long-run crude oil-edible oils causality are present. Lastly, the correlation analysis among the price series indicated the positive linear correlation between the crude oil and selected agricultural commodity except vegetables in the first period suggesting the comovement between the price series. A comparison across two periods indicated that crude oil and agricultural commodity markets became more interconnected in the more recent period of observation with higher positive correlation for all markets in the period April 2004-March, 2014.

5. Conclusion

The study has shown that the cost of machine labour has increased tremendously in the recent years and it accounts for the second largest share after wages in the costs of cultivation, mainly due to widespread mechanization and frequent upward revision of energy prices. Crude oil being one of the most important source of energy, an effort was made to investigate the long-run relationship between crude oil and selected agricultural commodity prices. This issue assumed importance in view of increasing share of energy in the cost of cultivation of agricultural commodities along with frequent and upward revision of energy prices. In order to provide insight on the dynamics of energy prices on agricultural commodity prices, the concept of co-integration and the extent of price causality were analyzed using monthly price indices during April, 1994 – March, 2014. The entire period was divided into two equal periods in order to assess the impact of deregulation of petroleum prices initiated since April, 2002. Co-integration analysis indicated that all selected agricultural commodity prices series have long-run steady relationship with crude oil prices for the past two decades, which indicates strong linkages between crude oil and these markets. The co-movement of commodity prices is a temporal concept and should be treated accordingly. Parallel movement between energy prices and fruits prices was found for all the three periods.

In general, we can conclude that agricultural commodity markets exhibit co-movement with crude oil in the long-run since 2004 when prices of some petroleum products began to adjust frequently in line with changes in international crude prices. In recent years, similar trend was also observed in case of world price of some food and energy products. The price transmission is expected to increase progressively in future once the government decides to deregulate prices of all petroleum products. However, we must note that changing economic structure, policy interventions, rising global population, changing climatic pattern, geopolitics and change in price interaction not only increase uncertainty and volatility, but instigate the complexity of price dynamics between crude oil and agricultural commodities. Better understanding of transmission mechanism is essential for policy makers to prescribe measures to optimize and stabilize the markets in order to ensure food security for the poor.

Figure 1: Crude oil, high speed diesel oil and foodgrains price indices (nominal 2004-05=100)

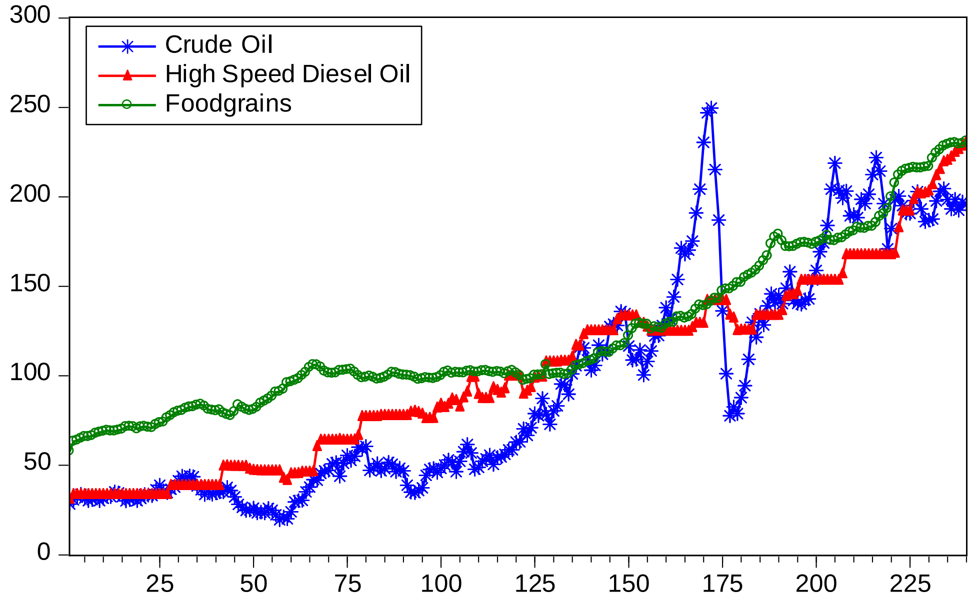

Figure 2: Crude oil, high speed diesel oil and Edible oil price indices (nominal 2004-05=100)

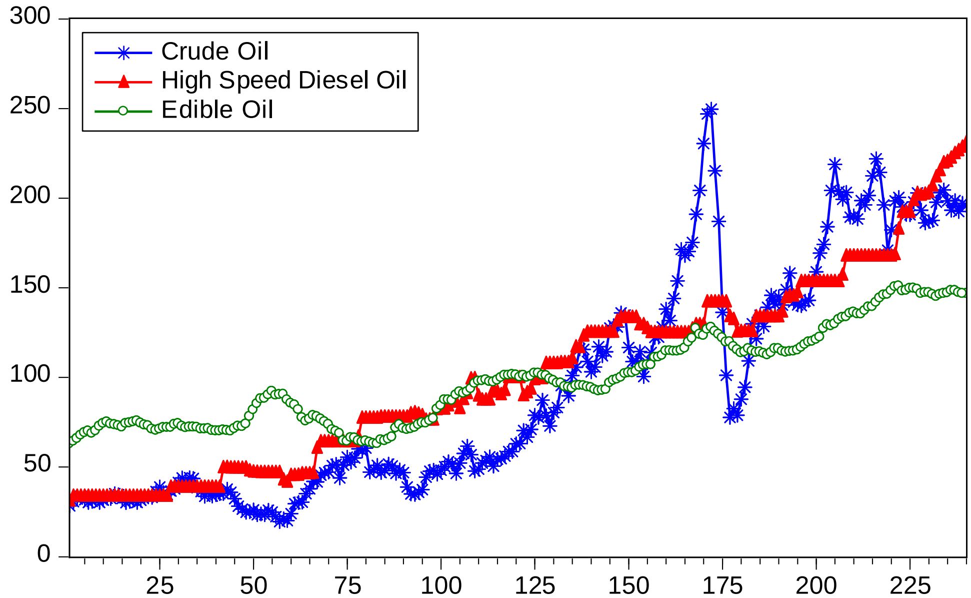

Figure 3: Crude oil, high speed diesel oil and fruits price indices (nominal 2004-05=100)

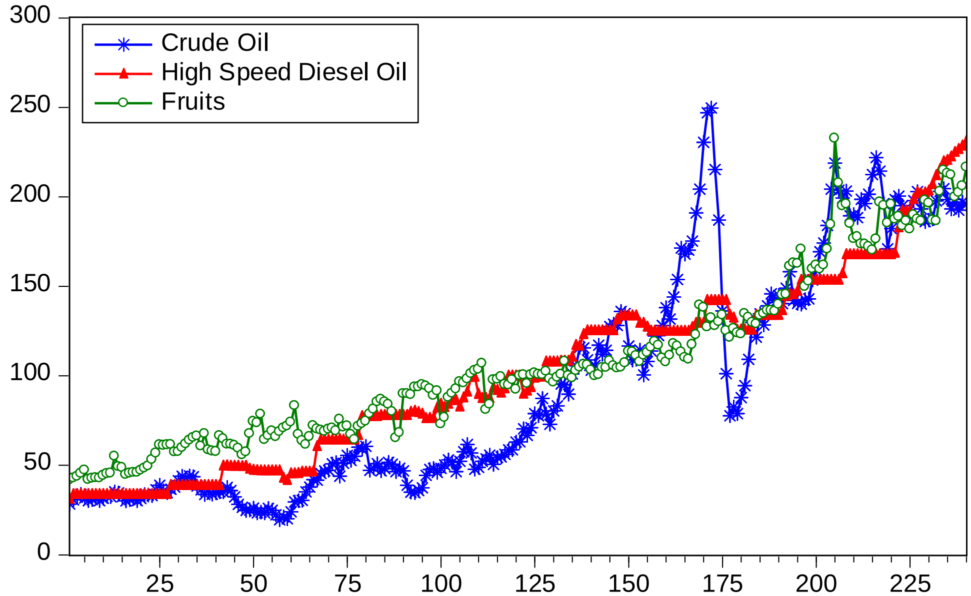

Figure 4: Crude oil, high speed diesel oil and vegetables price indices (nominal 2004-05=100)

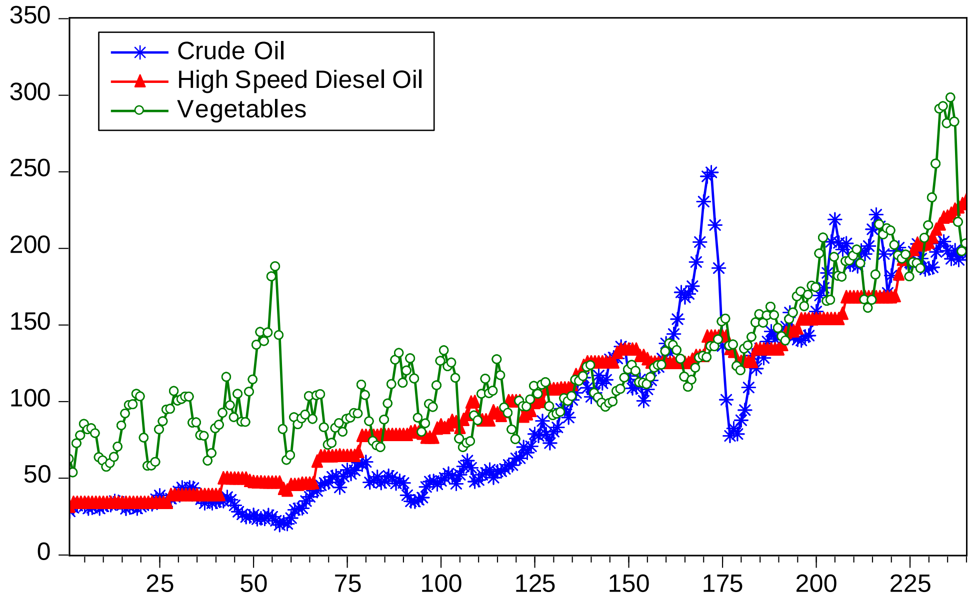

Table 1: Average cost of cultivation of rice and wheat across the selected states during 1981-2011

States	1981-91	1991-2001	2001-10	2011-12
				Rs/hectare
Rice				
Andhra Pradesh	6202.99	21708.85	36329.36	58027.19
Karnataka	4663.46	19647.55	33162.80	54810.01
Odisha	2920.63	10456.16	21348.39	35972.50
Punjab	7516.88	16792.16	35601.63	53813.93
Tamil Nadu	4809.26	27034.15	36357.59	59767.05
Uttar Pradesh	3940.90	11437.62	22663.57	40146.68
West Bengal	4038.24	16326.00	28821.49	49142.99
Wheat				
Haryana	4840.67	14334.45	30267.37	51170.51
Madhya Pradesh	2944.39	9058.85	18872.12	33396.15
Punjab	5397.15	15683.10	29870.44	49298.84
Rajasthan	4296.45	12777.09	24659.74	40286.20
Uttar Pradesh	4635.32	12073.90	24942.16	42383.57

Source: Based on data in DES, New Delhi

Table 2: Changing share of machine labour charges in the cost of cultivation of rice and wheat across the selected states during 1981-2011

% of average cost of cultivation				
States	1981-91	1991-2001	2001-10	2011-12
				In per cent
Rice				
Andhra Pradesh	4.01	5.49	8.33	10.64
Karnataka	1.11	5.92	8.58	13.18
Odisha	0.24	1.00	2.69	3.27
Punjab	7.43	9.49	10.24	8.12
Tamil Nadu	1.81	7.37	11.83	13.45
Uttar Pradesh	2.83	6.05	7.80	7.61
West Bengal	0.38	1.81	3.24	5.21
Wheat				
Haryana	12.44	11.69	13.97	13.25
Madhya Pradesh	4.53	8.28	11.35	13.54
Punjab	12.33	10.72	15.03	13.66
Rajasthan	8.30	9.84	10.48	11.30
Uttar Pradesh	9.15	10.63	13.89	12.18

Source: Based on data in DES, New Delhi

Table 3: Changing share of fertilizer costs in the cost of cultivation of rice and wheat across the selected states during 1981-2011

% of average cost of cultivation				
States	1981-91	1991-2001	2001-10	2011-12
				In per cent
Rice				
Andhra Pradesh	14.35	11.67	8.67	8.74
Karnataka	15.97	15.70	13.94	13.55
Odisha	9.79	10.19	9.04	8.13
Punjab	13.74	9.95	7.36	6.20
Tamil Nadu	15.50	10.89	10.36	12.11
Uttar Pradesh	9.30	8.83	8.59	8.79
West Bengal	9.03	8.49	8.09	7.87
Wheat				
Haryana	13.89	11.61	8.16	7.56
Madhya Pradesh	7.99	9.14	6.84	6.67
Punjab	16.50	12.84	9.64	9.07
Rajasthan	7.70	8.01	7.60	7.04
Uttar Pradesh	12.32	12.22	8.81	8.78

Source: Based on data in DES, New Delhi

Table 4. Growth rate in the number of farm equipments used between 1996-97 and 2006-07

(in per cent)

Farm-size groups	Power-operated plant protection equipments	Wells and irrigation equipments	Tractors and cultivators	Power-driven tillage and planting equipments	Power-driven harvesting and threshing equipments
Marginal (<1 ha)	19.6	8.5	54.0	9.7	14.9
Small (1-1.99 ha)	13.2	4.7	29.2	13.7	18.7
Semi-medium (2-3.99 ha)	8.6	2.2	15.7	8.3	15.5
Medium (4.0-9.99 ha)	5.2	-0.1	7.3	6.1	11.2
Large (10 ha & above)	3.4	-3.1	2.1	2.2	4.1
All groups	14.2	4.5	30.4	17.6	14.5

Source: Various issues of *Input Survey*, Govt. of India

Table 5: Summary statistics for monthly returns (April-1994 to March-2014)

	Crude oil	Edible oils	Foodgrains	Fruits	HSDO	Maize	Oilseeds	Rice	Soybeans	Vegetables
Mean	0.40	0.20	0.30	0.30	0.40	0.30	0.20	0.20	0.30	0.20
Median	0.90	0.10	0.20	0.30	0.00	0.30	0.20	0.20	0.10	0.60
Maximum	8.80	3.00	3.90	12.10	11.30	13.00	5.20	3.30	9.20	14.00
Minimum	-13.70	-2.60	-2.30	-12.00	-4.60	-8.50	-3.20	-1.60	-10.60	-24.30
Std. Dev.	3.50	0.80	0.60	2.70	1.60	1.70	1.10	0.60	2.30	5.00
Skewness	-0.90	0.23	0.90	-0.36	3.15	0.73	0.20	1.01	-0.27	-0.79
Kurtosis	4.90	4.66	9.32	7.88	22.61	19.56	4.91	7.84	6.39	6.15
Jarque-Bera	68.01	29.57	430.20	242.02	4224.74	2752.02	37.88	273.90	117.24	123.30
Probability	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

Table 6: Lag length using Schwarz information criterion (SIC)

Crude Oil vs	April 1994-Mar 2014	April 1994-Mar 2004	April 2004-Mar 2014
Foodgrains	2	2	2
Rice	2	1	2
Maize	2	1	2
Oilseeds	2	1	2
Soybeans	1	1	2
Edible oils	2	2	2
Fruits	1	1	2
Vegetables	2	2	2

Table 7: Bi-variate Johansen cointegration rank test (April-1994 to March-2014)

Crude Oil vs	**Model 3**			**Model 4**		
	Test statistics	**Critical value**	**Prob.**	**Test statistics**	**Critical value**	**Prob.**
Foodgrains						
λ_{trace} $H_0: r = 0 vs H_1: r \geq 1$ $H_0: r \leq 1 vs H_1: r \geq 2$	7.69 0.08	15.49 3.84	0.49 0.77	16.09 2.23	25.87 12.51	0.48 0.95
$\lambda_{\max}$ $H_0: r = 0 vs H_1: r \geq 1$ $H_0: r \leq 1 vs H_1: r \geq 2$	7.60 0.08	14.26 3.84	0.41 0.77	13.85 2.23	19.38 12.51	0.26 0.95
Rice						

λ_{trace} $H_0: r = 0 vs H_1: r \geq 1$ $H_0: r \leq 1 vs H_1: r \geq 2$	6.36 0.38	15.49 3.84	0.653 0.5347	16.18 2.28	25.87 12.51	0.4779 0.9486
$\lambda_{\max}$ $H_0: r = 0 vs H_1: r \geq 1$ $H_0: r \leq 1 vs H_1: r \geq 2$	5.97 0.38	14.26 3.84	0.61 0.53	13.89 2.28	19.38 12.51	0.26 0.94
Maize						
λ_{trace} $H_0: r = 0 vs H_1: r \geq 1$ $H_0: r \leq 1 vs H_1: r \geq 2$	6.56 0.01	15.49 3.84	0.62 0.98	17.26 4.20	25.87 12.51	0.39 0.71
$\lambda_{\max}$ $H_0: r = 0 vs H_1: r \geq 1$ $H_0: r \leq 1 vs H_1: r \geq 2$	6.56 0.01	14.26 3.84	0.54 0.98	13.06 4.20	19.38 12.51	0.32 0.71
Oilseeds						
λ_{trace} $H_0: r = 0 vs H_1: r \geq 1$ $H_0: r \leq 1 vs H_1: r \geq 2$	6.18 0.01	15.49 3.84	0.67 0.95	19.14 4.21	25.87 12.51	0.27 0.71
$\lambda_{\max}$ $H_0: r = 0 vs H_1: r \geq 1$ $H_0: r \leq 1 vs H_1: r \geq 2$	6.18 0.01	14.26 3.84	0.58 0.95	14.92 4.21	19.38 12.51	0.19 0.71
Soybeans						
λ_{trace} $H_0: r = 0 vs H_1: r \geq 1$ $H_0: r \leq 1 vs H_1: r \geq 2$	6.97 0.28	15.49 3.84	0.58 0.59	18.22 5.66	25.87 12.51	0.32 0.50
$\lambda_{\max}$ $H_0: r = 0 vs H_1: r \geq 1$	6.69	14.26	0.52	12.55	19.38	0.36

$H_0: r \leq 1 vs H_1: r \geq 2$	0.28	3.84	0.59	5.66	12.51	0.50
Edible oils						
λ_{trace}						
$H_0: r = 0 vs H_1: r \geq 1$	7.94	15.49	0.47	17.04	25.87	0.41
$H_0: r \leq 1 vs H_1: r \geq 2$	0.15	3.84	0.69	4.71	12.51	0.63
$\lambda_{\max}$						
$H_0: r = 0 vs H_1: r \geq 1$	7.78	14.26	0.40	12.33	19.38	0.38
$H_0: r \leq 1 vs H_1: r \geq 2$	0.15	3.84	0.69	4.71	12.51	0.63
Fruits						
λ_{trace}						
$H_0: r = 0 vs H_1: r \geq 1$	12.31	15.49	0.14	50.36	25.87	<0.01
$H_0: r \leq 1 vs H_1: r \geq 2$	0.62	3.84	0.42	9.86	12.51	0.13
$\lambda_{\max}$						
$H_0: r = 0 vs H_1: r \geq 1$	11.68	14.26	0.12	40.49	19.38	<0.01
$H_0: r \leq 1 vs H_1: r \geq 2$	0.62	3.84	0.42	9.86	12.51	0.13
Vegetables						
λ_{trace}						
$H_0: r = 0 vs H_1: r \geq 1$	20.07	15.49	<0.01	41.71	25.87	<0.01
$H_0: r \leq 1 vs H_1: r \geq 2$	0.80	3.84	0.36	10.44	12.51	0.10
$\lambda_{\max}$						
$H_0: r = 0 vs H_1: r \geq 1$	19.26	14.26	<0.01	31.27	19.38	<0.01
$H_0: r \leq 1 vs H_1: r \geq 2$	0.80	3.84	0.36	10.44	12.51	0.10

Model 3 – linear determinstic trend model
Model 4 – linear trend in the cointegrating space

Table 8: Bi-variate Johansen cointegration rank test (April-1994 to March-2004)

Crude Oil vs	Model 3			Model 4		
	Test statistics	Critical value	Prob.	Test statistics	Critical value	Prob.
Foodgrains						
λ_{trace} $H_0: r = 0 vs H_1: r \geq 1$ $H_0: r \leq 1 vs H_1: r \geq 2$	16.91 5.47	15.49 3.84	0.03 0.06	19.24 5.59	25.87 12.51	0.26 0.51
$\lambda_{\max}$ $H_0: r = 0 vs H_1: r \geq 1$ $H_0: r \leq 1 vs H_1: r \geq 2$	11.44 5.47	14.26 3.84	0.13 0.07	13.65 5.59	19.38 12.51	0.27 0.51
Rice						
λ_{trace} $H_0: r = 0 vs H_1: r \geq 1$ $H_0: r \leq 1 vs H_1: r \geq 2$	15.11 3.91	15.49 3.84	0.05 0.05	0.05 0.06	25.87 12.51	0.37 0.71
$\lambda_{\max}$ $H_0: r = 0 vs H_1: r \geq 1$ $H_0: r \leq 1 vs H_1: r \geq 2$	11.20 3.91	14.26 3.84	0.14 0.04	13.34 4.20	19.38 12.51	0.30 0.71
Maize						
λ_{trace} $H_0: r = 0 vs H_1: r \geq 1$ $H_0: r \leq 1 vs H_1: r \geq 2$	20.79 4.01	15.49 3.84	<0.01 0.05	26.20 8.18	25.87 12.51	<0.01 0.23
$\lambda_{\max}$ $H_0: r = 0 vs H_1: r \geq 1$ $H_0: r \leq 1 vs H_1: r \geq 2$	16.77 4.01	14.26 3.84	<0.01 0.06	18.01 8.18	19.38 12.51	<0.01 0.23
Oilseeds						

λ_{trace} $H_0: r = 0 vs H_1: r \geq 1$ $H_0: r \leq 1 vs H_1: r \geq 2$	5.23 0.35	15.49 3.84	0.78 0.55	11.27 4.88	25.87 12.51	0.85 0.61
$\lambda_{\max}$ $H_0: r = 0 vs H_1: r \geq 1$ $H_0: r \leq 1 vs H_1: r \geq 2$	4.88 0.35	14.26 3.84	0.75 0.55	6.39 4.88	19.38 12.51	0.93 0.61
Soybeans						
λ_{trace} $H_0: r = 0 vs H_1: r \geq 1$ $H_0: r \leq 1 vs H_1: r \geq 2$	11.35 2.03	15.49 3.84	0.19 0.15	15.62 5.45	25.87 12.51	0.52 0.53
$\lambda_{\max}$ $H_0: r = 0 vs H_1: r \geq 1$ $H_0: r \leq 1 vs H_1: r \geq 2$	9.31 2.03	14.26 3.84	0.26 0.15	10.17 5.45	19.38 12.51	0.59 0.53
Edible oils						
λ_{trace} $H_0: r = 0 vs H_1: r \geq 1$ $H_0: r \leq 1 vs H_1: r \geq 2$	3.86 0.06	15.49 3.84	0.91 0.84	8.11 2.47	25.87 12.51	0.98 0.93
$\lambda_{\max}$ $H_0: r = 0 vs H_1: r \geq 1$ $H_0: r \leq 1 vs H_1: r \geq 2$	3.83 0.05	14.26 3.84	0.87 0.84	5.64 2.47	19.38 12.51	0.96 0.93
Fruits						
λ_{trace} $H_0: r = 0 vs H_1: r \geq 1$ $H_0: r \leq 1 vs H_1: r \geq 2$	8.67 1.57	15.49 3.84	0.39 0.20	32.05 5.25	25.87 12.51	<0.01 0.56
$\lambda_{\max}$ $H_0: r = 0 vs H_1: r \geq 1$	7.09	14.26	0.47	26.79	19.38	<0.01

$H_0: r \leq 1 vs H_1: r \geq 2$	1.57	3.84	0.20	5.25	12.51	0.56
Vegetables	**Cointegration analysis was not feasible**					

Model 3 – linear determinstic trend model
Model 4 – linear trend in the cointegrating space

Table 9: Bi-variate Johansen cointegration rank test (April-2004 to March-2014)

Crude Oil vs	**Model 3**			**Model 4**		
	Test statistics	**Critical value**	**Prob.**	**Test statistics**	**Critical value**	**Prob.**
Foodgrains						
λ_{trace} $H_0: r = 0 vs H_1: r \geq 1$ $H_0: r \leq 1 vs H_1: r \geq 2$	18.44 0.82	15.49 3.84	0.01 0.36	28.24 8.70	25.87 12.51	0.02 0.19
$\lambda_{\max}$ $H_0: r = 0 vs H_1: r \geq 1$ $H_0: r \leq 1 vs H_1: r \geq 2$	17.61 0.82	14.26 3.84	0.01 0.36	19.53 8.70	19.38 12.51	0.04 0.19
Rice						
λ_{trace} $H_0: r = 0 vs H_1: r \geq 1$ $H_0: r \leq 1 vs H_1: r \geq 2$	16.18 0.03	15.49 3.84	0.03 0.84	25.38 6.02	25.87 12.51	0.05 0.45
$\lambda_{\max}$ $H_0: r = 0 vs H_1: r \geq 1$ $H_0: r \leq 1 vs H_1: r \geq 2$	16.14 0.05	14.26 3.84	0.02 0.84	19.35 6.02	19.38 12.51	0.04 0.45
Maize						
λ_{trace} $H_0: r = 0 vs H_1: r \geq 1$	16.81 0.34	15.49 3.84	0.03 0.55	22.27 5.51	25.87 12.51	0.13 0.52

$H_0: r \leq 1 vs H_1: r \geq 2$						
$\lambda_{\max}$ $H_0: r = 0 vs H_1: r \geq 1$ $H_0: r \leq 1 vs H_1: r \geq 2$	16.46 0.34	14.26 3.84	0.02 0.55	16.75 5.51	19.38 12.51	0.11 0.52
Oilseeds						
λ_{trace} $H_0: r = 0 vs H_1: r \geq 1$ $H_0: r \leq 1 vs H_1: r \geq 2$	22.77 0.05	15.49 3.84	<0.01 0.90	33.77 8.91	25.87 12.51	<0.01 0.18
$\lambda_{\max}$ $H_0: r = 0 vs H_1: r \geq 1$ $H_0: r \leq 1 vs H_1: r \geq 2$	22.76 0.06	14.26 3.84	<0.01 0.90	24.86 8.91	19.38 12.51	<0.01 0.18
Soybeans						
λ_{trace} $H_0: r = 0 vs H_1: r \geq 1$ $H_0: r \leq 1 vs H_1: r \geq 2$	16.43 0.51	15.49 3.84	0.03 0.47	31.69 10.30	25.87 12.51	<0.01 0.11
$\lambda_{\max}$ $H_0: r = 0 vs H_1: r \geq 1$ $H_0: r \leq 1 vs H_1: r \geq 2$	15.92 0.51	14.26 3.84	0.02 0.47	21.38 10.30	19.38 12.51	0.02 0.11
Edible oils						
λ_{trace} $H_0: r = 0 vs H_1: r \geq 1$ $H_0: r \leq 1 vs H_1: r \geq 2$	27.06 0.40	15.49 3.84	<0.01 0.52	31.46 4.29	25.87 12.51	<0.01 0.69
$\lambda_{\max}$ $H_0: r = 0 vs H_1: r \geq 1$ $H_0: r \leq 1 vs H_1: r \geq 2$	26.66 0.40	14.26 3.84	<0.01 0.52	27.17 4.29	19.38 12.51	<0.01 0.69
Fruits						

λ_{trace} $H_0: r = 0 vs H_1: r \geq 1$ $H_0: r \leq 1 vs H_1: r \geq 2$	16.35 0.37	15.49 3.84	0.03 0.53	29.79 12.66	25.87 12.51	0.01 0.04
$\lambda_{\max}$ $H_0: r = 0 vs H_1: r \geq 1$ $H_0: r \leq 1 vs H_1: r \geq 2$	15.98 0.37	14.26 3.84	0.02 0.53	17.13 12.66	19.38 12.51	0.10 0.06
Vegetables						
λ_{trace} $H_0: r = 0 vs H_1: r \geq 1$ $H_0: r \leq 1 vs H_1: r \geq 2$	18.30 2.22	15.49 3.84	0.01 0.13	37.38 16.06	25.87 12.51	<0.01 0.06
$\lambda_{\max}$ $H_0: r = 0 vs H_1: r \geq 1$ $H_0: r \leq 1 vs H_1: r \geq 2$	16.07 2.22	14.26 3.84	0.02 0.13	21.31 16.06	19.38 12.51	0.02 0.06

Model 3 – linear determinstic trend model
Model 4 – linear trend in the cointegrating space

Table 10: Summary of Bi-variate Johansen cointegration test

Crude oil vs	April 1994-March 2014	April 1994-March 2004	April 2004-March 2014
Foodgrains	Rejected	Not rejected	Not rejected
Rice	Rejected	Rejected	Not rejected
Maize	Rejected	Not rejected	Not rejected
Oil seeds	Rejected	Rejected	Not rejected
Soybeans	Rejected	Rejected	Not rejected
Edible oils	Rejected	Rejected	Not rejected
Fruits	Not rejected	Not rejected	Not rejected
Vegetables	Not rejected	-	Not rejected

Note: - denotes analysis has not been performed

Table 11: Estimate of long run and the speed of adjustment from ECM for crude oil vs different agricultural commodity

Models	Regressors	April1994 to March-2014			April 1994 to March-2004			April 2004 to March-2014		
Crude Oil vs		Parameter estimates	t-test	p-value	Parameter estimates	t-test	p-value	Parameter estimates	t-test	p-value
Foodgrains	β	–	–		5.28	3.16	<0.01	-1.11	-6.60	<0.01
	ECT_{t-1}				-0.002	-3.22	<0.01	-0.01	-1.49	0.13
Rice	β	–	–		–	–		-1.21	-5.91	<0.01
	ECT_{t-1}							-0.01	-1.73	0.09
Maize	β	–	–		-0.33	-3.81	<0.01	-1.27	-6.55	<0.01
	ECT_{t-1}				-0.05	-1.26	0.18	0.01	0.03	0.40
Oilseeds	β	–	–		–	–		-1.50	-7.00	<0.01
	ECT_{t-1}							-0.01	-1.82	0.08
Edible oils	β	–	–		–	–		-0.65	-9.30	<0.01
	ECT_{t-1}							-0.02	-2.28	0.03
Soybeans	β	–	–		–	–		-2.10	-5.07	<0.01
	ECT_{t-1}							-0.01	-1.49	0.13
Fruits	β	-0.59	-7.87	<0.01	0.11	1.69	0.10	-1.12	-6.52	<0.01
	ECT_{t-1}	-0.05	-2.45	0.02	-0.43	-5.31	<0.01	-0.01	-0.96	0.25
Vegetables	β	-0.39	-5.66	<0.01	–	–	–	-1.19	-6.09	<0.01
	ECT_{t-1}	-0.13	-4.40	<0.01				-0.04	-1.80	0.08

Table 12: Short-run causality between crude oil vs different agricultural commodity

Crude oil vs	April 1994-March 2014		April 1994-March 2004		April 2004-March 2014	
	F-statistic	Prob.	F-statistic	Prob.	F-statistic	Prob.
Foodgrains	-	-	2.28	0.10	4.52	0.01
Rice	-	-	-	-	2.13	0.12
Maize	-	-	0.15	0.69	1.42	0.24
Oilseeds	-	-	-	-	0.04	0.95
Soybeans	-	-	-	-	0.04	0.95
Edible oils	-	-	-	-	1.09	0.33
Fruits	1.06	0.30	0.15	0.69	1.94	0.14
Vegetables	1.08	0.33	-	-	0.31	0.72

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