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Examining the Co-movement between Energy and Agricultural Commodity Prices in India

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SUMMARY

This paper examined the transmission mechanism of an increase in energy prices on the price of selected agricultural commodities 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 which was implemented since April, 2002, the sample data was divided into two periods (April 1994 - March 2004 and April 2004 - March 2014), besides analyzing for full period so that before and after period analysis will provide clearer picture of possible link between the two prices. To supplement the finding of Johansen co-integration analysis, we assessed the nature and extent of causal relationship between the variables. The results indicated evidence of parallel movement between prices of energy and all selected agricultural commodities after deregulation, which means higher transmission between crude oil and commodities prices. The results obtained are expected to help in understanding of transmission mechanism for policy makers to optimize and stabilize the markets.

Keywords: Agricultural commodity prices, Energy, Co-integration.

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.

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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.

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 empirical findings of the co-movement between energy and agricultural commodity prices. Finally, Section 4 summarizes the main findings of the study.

2. DATA AND METHODOLOGY

2.1 Data Description

The study is completely based on secondary data. The data used in the empirical analysis comprises monthly price indices of crude 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 foodgrains, rice, maize, oilseeds, soybeans, edible oils, fruits and vegetables was collected from Office of the Economic Advisor, Ministry of Commerce, Government of India. The data sets contain 240 data points (April, 1994 to March, 2014). Besides, analyzing for full period, the sample data was 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. Figures 1-4 show time plot of each selected agricultural commodity with crude oil 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. Table 1 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

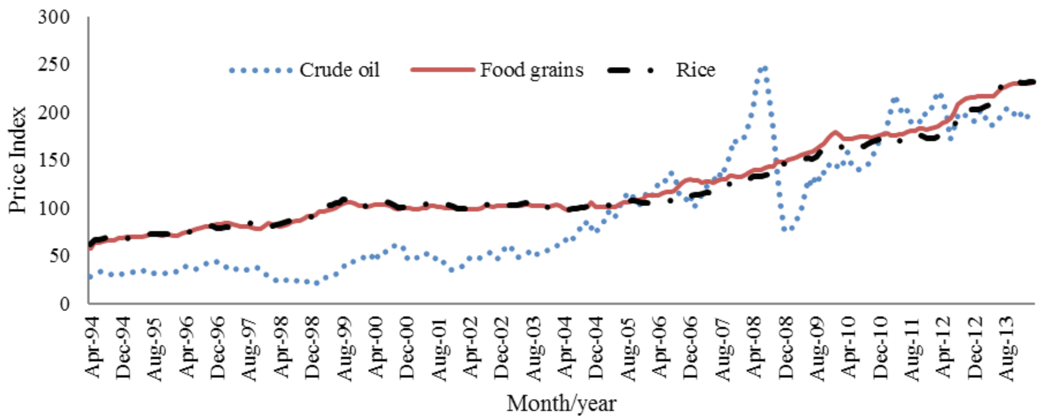

Fig. 1: Crude oil vs. foodgrains and rice indexed price (nominal 2004-05=100) evolution between April, 1994 to March, 2014.

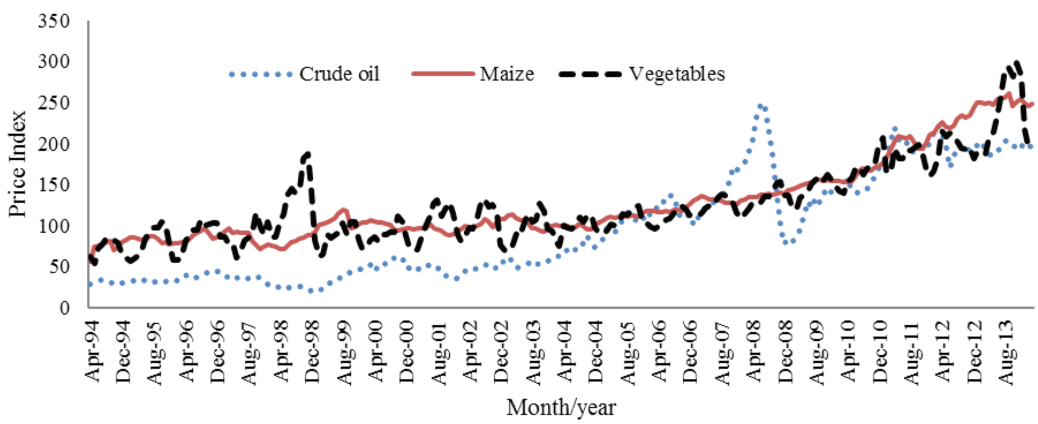

Fig. 2: Crude oil vs. maize and vegetables indexed price (nominal 2004-05=100) evolution between April, 1994 to March, 2014.

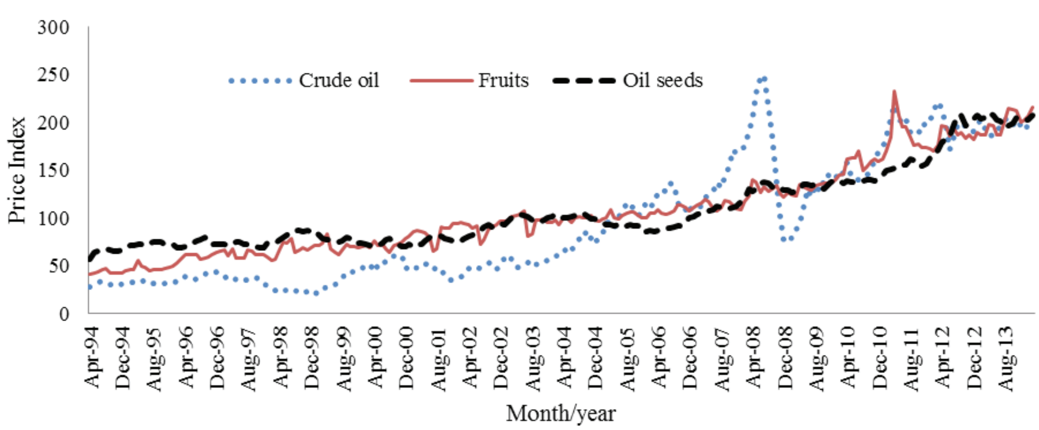

Fig. 3: Crude oil vs. fruits and oilseeds indexed price (nominal 2004-05=100) evolution between April, 1994 to March, 2014.

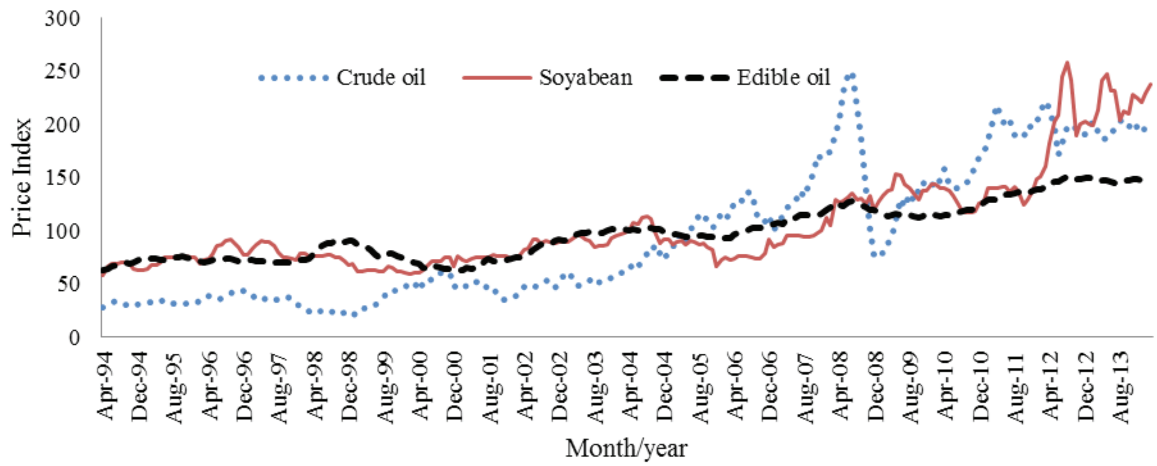

Fig. 4. Crude oil vs. soybean and edible oil indexed price (nominal 2004-05=100) evolution between April, 1994 to March, 2014.

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.

2.2 Methodology

A vector error correction model (VECM) was employed to examine relationships between energy prices and agricultural commodity prices. This methodology accounts for the possibility of nonstationarity in prices and co-integration relationships among price series. VECM considers both the long-run and short-run relationships among variables. To avoid the problem of spurious regression co-integration has become a widely used technique for analyzing issues associated with non-stationary time series data.

As indicated, in case of nonstationarity of the time series, co-integration provides an appropriate statistical techniques to investigate if there is a statistically significant relationship between the nonstationary time 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, then 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.

Table 1. Summary statistics for monthly returns (April-1994 to March-2014)

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

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:

$$Y_t = A_1Y_{t-1} + A_2Y_{t-2} + \ldots + A_kY_{t-k} + e_t$$

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

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 thus not cointegrated. In case $0 < r < p$, there exist r co-integrating vectors. If $r = p$ then all the variables are $I(0)$ and thus stationary. 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:

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

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

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. 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, which can be tested within the framework of Johansen cointegration under certain restrictions by the Wald test. In the co-integration matrix Π, if the θ matrix has a complete column of zeros, no causal relationship exists since, there is no co-integrating vector appears in that particular block. Pair wise causal relationship of the variable can be represented as follows:

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

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. From Eq. (4), three possibilities for long-run causality may be identified, (i) $\alpha_1 \neq 0, \alpha_2 \neq 0$; (ii) $\alpha_1 = 0, \alpha_2 \neq 0$; and (iii) $\alpha_1 \neq 0, \alpha_2 = 0$. In the above 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. (4) can be rewritten as (Natanelov *et al.* 2011)

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

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

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

3. EMPIRICAL FINDINGS

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)* (Table 2-4). Thus the difference of each time series except vegetables series can be regarded as stationary.

Table 2. Unit root test using the augmented Dickey-Fuller and Phillip-Perron (April 1994-March 2014)

Series		Augmented Dickey-Fuller		Phillip-Perron	
		t-statistic	Prob.	t-statistic	Prob.
Crude oil	Level	-1.167	0.689	-1.156	0.693
	1st difference	-14.086	<0.001	-9.952	<0.001
Foodgrains	Level	-0.628	0.861	2.207	0.984
	1st difference	-14.143	<0.001	-10.381	<0.001
Rice	Level	-0.354	0.913	2.666	0.998
	1st difference	-12.151	<0.001	-10.010	<0.001
Maize	Level	-0.688	0.846	0.811	0.987
	1st difference	-14.377	<0.001	-13.044	<0.001
Oilseeds	Level	-0.807	0.815	1.131	0.998
	1st difference	-13.096	<0.001	-12.070	<0.001
Soybeans	Level	-0.869	0.797	0.095	0.965
	1st difference	-18.465	<0.001	-13.597	<0.001
Edible oils	Level	-1.565	0.499	-0.297	0.922
	1st difference	-13.227	<0.001	-10.786	<0.001
Fruits	Level	-0.926	0.779	0.928	0.996
	1st difference	-13.166	<0.001	-22.229	<0.001
Vegetables	Level	-0.534	0.881	-2.305	0.171
	1st difference	-6.587	<0.001	-11.776	<0.001

Table 3. Unit root test using the augmented Dickey-Fuller and Phillip-Perron (April 1994-March 2004)

Series		Augmented Dickey-Fuller		Phillip-Perron	
		t-statistic	Prob.	t-statistic	Prob.
Crude oil	Level	-1.228	0.660	-1.231	0.659
	1st difference	-9.464	<0.001	-9.929	<0.001
Foodgrains	Level	-1.857	0.351	-2.488	0.121
	1st difference	-9.345	<0.001	-7.958	<0.001
Rice	Level	-1.584	0.487	-2.119	0.238
	1st difference	-8.352	<0.001	-7.641	<0.001
Maize	Level	-2.324	0.166	-3.285	0.018
	1st difference	-10.967	<0.001	-10.219	<0.001
Oilseeds	Level	-1.124	0.704	-1.225	0.662
	1st difference	-8.526	<0.001	-8.027	<0.001
Soybeans	Level	-1.831	0.363	-1.873	0.344
	1st difference	-10.125	<0.001	-9.742	<0.001
Edible oils	Level	-1.009	0.748	-0.850	0.801
	1st difference	-6.611	<0.001	-6.603	<0.001
Fruits	Level	-2.018	0.278	-1.588	0.485
	1st difference	-2.018	<0.001	-26.263	<0.001
Vegetables	Level	-5.291	<0.001	-3.906	0.003
	1st difference	-8.211	<0.001	-7.819	<0.001

Table 4. Unit root test using the augmented Dickey-Fuller and Phillip-Perron (April 2004-March 2014)

Series		Drift		Trend	
		t-statistic	Prob.	t-statistic	Prob.
Crude oil	Level	-2.347	0.159	-2.205	0.206
	1st difference	-7.532	<0.001	-6.784	<0.001
Foodgrains	Level	-0.559	0.874	0.918	0.996
	1st difference	-9.797	<0.001	-7.884	<0.001
Rice	Level	0.344	0.979	1.755	1.000
	1st difference	-8.494	<0.001	-7.403	<0.001
Maize	Level	-0.441	0.897	0.384	0.982
	1st difference	-8.123	<0.001	-8.316	<0.001
Oilseeds	Level	0.546	0.987	0.531	0.987
	1st difference	-8.668	<0.001	-8.772	<0.001
Soybeans	Level	-0.249	0.927	-0.184	0.936
	1st difference	-10.619	<0.001	-9.578	<0.001
Edible oils	Level	-0.310	0.918	-0.339	0.915
	1st difference	-7.862	<0.001	-8.283	<0.001
Fruits	Level	-0.640	0.856	0.176	0.970
	1st difference	-10.876	<0.001	-14.423	<0.001
Vegetables	Level	0.726	0.992	-1.421	0.570
	1st difference	-7.462	<0.001	-8.509	<0.001

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 5 presents optimal lag length for crude oil for three periods.

To carry out the co-integration rank test, we have used EViews 7 software. Table 6 shows 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). The trace and maximum eigenvalues tests are based on likelihood ratio from the estimated restricted VAR model. Table 7 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

Table 5. Lag length using Schwarz information criterion (SIC) for cointegrated model

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

run (Table 6). In the period April 1994-March 2004, we observed foodgrains, maize and fruits prices are co-integrated with crude oil prices (Table 6). 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 6). The contrast between the first and second period is remarkable and may be due to deregulation of some petroleum products.

Table 6. Bi-variate Johansen cointegration rank test

Crude oil vs	April 1994-March 2014		April 1994-March 2004		April 2004-March 2014	
	Test statistic	Prob.	Test statistic	Prob.	Test statistic	Prob.
Foodgrains						
λ_{trace}						
$H_0: r = 0$ vs $H_1: r \geq 1$	7.69	0.49	16.91	0.03	18.44	0.01
$H_0: r \leq 1$ vs $H_1: r \geq 2$	0.08	0.77	5.47	0.06	0.82	0.36
λ_{max}						
$H_0: r = 0$ vs $H_1: r \geq 1$	7.60	0.41	11.44	0.13	17.61	0.01
$H_0: r \leq 1$ vs $H_1: r \geq 2$	0.08	0.77	5.47	0.07	0.82	0.36
Rice						
λ_{trace}						
$H_0: r = 0$ vs $H_1: r \geq 1$	6.36	0.65	15.11	0.05	16.18	0.03
$H_0: r \leq 1$ vs $H_1: r \geq 2$	0.38	0.53	3.91	0.05	0.03	0.84
λ_{max}						
$H_0: r = 0$ vs $H_1: r \geq 1$	5.97	0.61	11.20	0.14	16.14	0.02
$H_0: r \leq 1$ vs $H_1: r \geq 2$	0.38	0.53	3.91	0.04	0.05	0.84
Maize						
λ_{trace}						
$H_0: r = 0$ vs $H_1: r \geq 1$	6.56	0.62	20.79	<0.01	16.81	0.03
$H_0: r \leq 1$ vs $H_1: r \geq 2$	0.01	0.98	4.01	0.05	0.34	0.55
λ_{max}						
$H_0: r = 0$ vs $H_1: r \geq 1$	6.56	0.54	16.77	<0.01	16.46	0.02
$H_0: r \leq 1$ vs $H_1: r \geq 2$	0.01	0.98	4.01	0.06	0.34	0.55
Oilseeds						
λ_{trace}						
$H_0: r = 0$ vs $H_1: r \geq 1$	6.18	0.67	5.23	0.78	22.77	0.01
$H_0: r \leq 1$ vs $H_1: r \geq 2$	0.01	0.95	0.35	0.55	0.05	0.90
λ_{max}						
$H_0: r = 0$ vs $H_1: r \geq 1$	6.18	0.58	4.88	0.75	22.76	0.01
$H_0: r \leq 1$ vs $H_1: r \geq 2$	0.01	0.95	0.35	0.55	0.06	0.90
Soybeans						
λ_{trace}						
$H_0: r = 0$ vs $H_1: r \geq 1$	6.97	0.58	11.35	0.19	16.43	0.03
$H_0: r \leq 1$ vs $H_1: r \geq 2$	0.28	0.59	2.03	0.15	0.51	0.47

Crude oil vs	**April 1994-March 2014**		**April 1994-March 2004**		**April 2004-March 2014**	
	Test statistic	**Prob.**	**Test statistic**	**Prob.**	**Test statistic**	**Prob.**
λ_{max} $H_0: r = 0 \ vs \ H_1: r \geq 1$ $H_0: r \leq 1 \ vs \ H_1: r \geq 2$	6.69 0.28	0.52 0.59	9.31 2.03	0.26 0.15	15.92 0.51	0.02 0.47
Edible oils						
λ_{trace} $H_0: r = 0 \ vs \ H_1: r \geq 1$ $H_0: r \leq 1 \ vs \ H_1: r \geq 2$	7.94 0.15	0.47 0.69	3.86 0.06	0.91 0.84	27.06 0.40	0.01 0.52
λ_{max} $H_0: r = 0 \ vs \ H_1: r \geq 1$ $H_0: r \leq 1 \ vs \ H_1: r \geq 2$	7.78 0.15	0.40 0.69	3.83 0.05	0.87 0.84	26.66 0.40	0.01 0.52
Fruits						
λ_{trace} $H_0: r = 0 \ vs \ H_1: r \geq 1$ $H_0: r \leq 1 \ vs \ H_1: r \geq 2$	12.31 0.62	0.14 0.42	8.67 1.57	0.39 0.20	16.35 0.37	0.03 0.53
λ_{max} $H_0: r = 0 \ vs \ H_1: r \geq 1$ $H_0: r \leq 1 \ vs \ H_1: r \geq 2$	11.68 0.62	0.12 0.42	7.09 1.57	0.47 0.20	15.98 0.37	0.02 0.53
Vegetables						
λ_{trace} $H_0: r = 0 \ vs \ H_1: r \geq 1$ $H_0: r \leq 1 \ vs \ H_1: r \geq 2$	20.07 0.80	<0.01 0.36	Co-integration analysis was not feasible because series was stationary at level		18.30 2.22	0.01 0.13
λ_{max} $H_0: r = 0 \ vs \ H_1: r \geq 1$ $H_0: r \leq 1 \ vs \ H_1: r \geq 2$	19.26 0.80	<0.01 0.36			16.07 2.22	0.02 0.13

Table 7. Summary of Bi-variate Johansen cointegration test

Crude oil vs	**April 1994-March 2014**	**April 1994-March 2004**	**April 2004-March 2014**
	$r = 1$	$r = 1$	$r = 1$
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 because the series is stationary. Here, the null hypothesis is series are co-integrated. Rejection of null hypothesis means series are not cointegrated.

Table 8. Estimate of long run and the speed of adjustment from ECM for crude oil vs different agricultural commodity

Models	Regressors	April 1994 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 8 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 whole 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.

Table 9. 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

Table 10. Pearson correlation coefficients (April-1994 to March-2014)

	Crude oil	Foodgr-ains	Rice	Maize	Vegetables	Fruits	Oilseeds	Soybeans	Edible oils
Crude oil	1.00	.887**	.85**	.87**	.77**	.90**	.87**	.79**	.91**
Foodgrains		1.00	.99**	.97**	.88**	.96**	.96**	.91**	.92**
Rice			1.00	.97**	.90**	.95**	.96**	.91**	.90**
Maize				1.00	.88**	.94**	.97**	.92**	.91**
Vegetables					1.00	.87**	.88**	.84**	.84**
Fruits						1.00	.94**	.88**	.93**
Oilseeds							1.00	.96**	.95**
Soybean								1.00	.88**
Edible oils									1.00

** Significant at 1% level

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 8 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 (Table 9) 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 (Table 10). 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.

4. CONCLUSION

This paper examined the interaction between energy prices and selected agricultural commodity prices. This issue became relevant 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 period 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. 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 disadvantage section of the society.

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