International Linkages of Agri-Processed and Energy commodities traded in India

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Abstract: The current study focuses on the linkages in agri-processed (soy oil and crude palm oil) and energy commodities (natural gas and crude oil) traded on commodity exchanges of India (NCDEX; MCX) and their corresponding international commodity exchanges(Chicago Board of Trade; Bursa Malaysia Derivative Exchange; New York Mercantile Exchange). This paper examines the linkages in futures price, return and volatility of a commodity across commodity exchanges with the help of three models – (a) Price – Co-integration methodology and Error Correction Mechanism Model (b) Return and Volatility – Modified GARCH model (c) Return and Volatility – ARMA-GARCH in mean model (Innovations Model). The study indicates that there are strong linkages in price, return and volatility of futures contracts traded across commodity exchanges of India and their corresponding international commodity exchanges. Given the level of linkages, the study argues against the imposition of Commodity Transaction Tax (CTT) on sellers at the time of trading in agri-processed and energy commodities. The tax would lead to lower trading volumes thereby defeating the purpose of price discovery via commodity exchanges.

Keywords: Futures, Commodity Transaction Tax, GARCH, Crude oil

JEL Codes:L61,Q02,G19,G13

1. Introduction

The Indian government has notified that it will levy a Commodity Transaction Tax on various commodities (including agri-processed commodities, energy commodities, base metals and precious metals) traded on Indian Commodity Exchanges from July 1, 2013. Commodity Transaction Tax (CTT) is similar to Securities Transaction Tax (STT), levied on buy or sale transactions of securities. CTT was proposed in the Union Budget 2008 but was not imposed on commodity transactions then. CTT will be levied on the seller in the trading of commodity futures.

The imposition of the tax is expected to lower trading volumes in Indian Commodity Exchanges, leading to movement from Indian Commodity Exchanges to International Commodity Exchanges to escape from the increase in transaction costs in India. This makes it necessary to study the linkages of Indian Commodity Exchanges with their corresponding International Commodity Exchanges.

In this study, the price behaviour of four commodities (agri processed commodities – crude palm oil and soy oil and energy commodities – natural gas and crude oil) which are traded on commodity exchanges of India (Multi Commodity Exchange, MCX and National Commodity Exchange, NCDEX) and respective International commodity exchange (Bursa Malaysia Derivative Exchange, Chicago Board of Trade, CBOT and New York Mercantile Exchange, NYMEX) is analysed (Refer to Table 1). The paper attempts to investigate the linkages in price, return and volatility across the markets for the four commodities through three models - (a) Price – Co-integration methodology and Error Correction Mechanism Model (ECM) (b) Return and Volatility – Modified GARCH model (c) Return and Volatility –ARMA-GARCH in mean model – Innovations Model.

Table 1: Agri Processed Commodities and Energy Commodities investigated in the study

Commodity	**Domestic commodity Exchange**	**International commodity exchange**	**Time period for study**
Agri Processed Commodities			
Soy oil	NCDEX, India	Chicago Board of Trade, United States of America	December 4, 2008 to June 28, 2013
Crude Palm oil	MCX, India	Bursa Malaysia Derivative Exchange, Malaysia	June 6, 2008 to June 28, 2013
Energy Commodities			
Natural Gas	MCX, India	New York Mercantile Exchange, United States of America	August 1, 2006 to June 28, 2013
Crude Oil	MCX, India	New York Mercantile Exchange, United States of America	May 6, 2005 to June 28, 2013

Figure 1: Comovement in Futures Prices of Commodities traded on commodity exchanges of India and corresponding International commodity exchanges

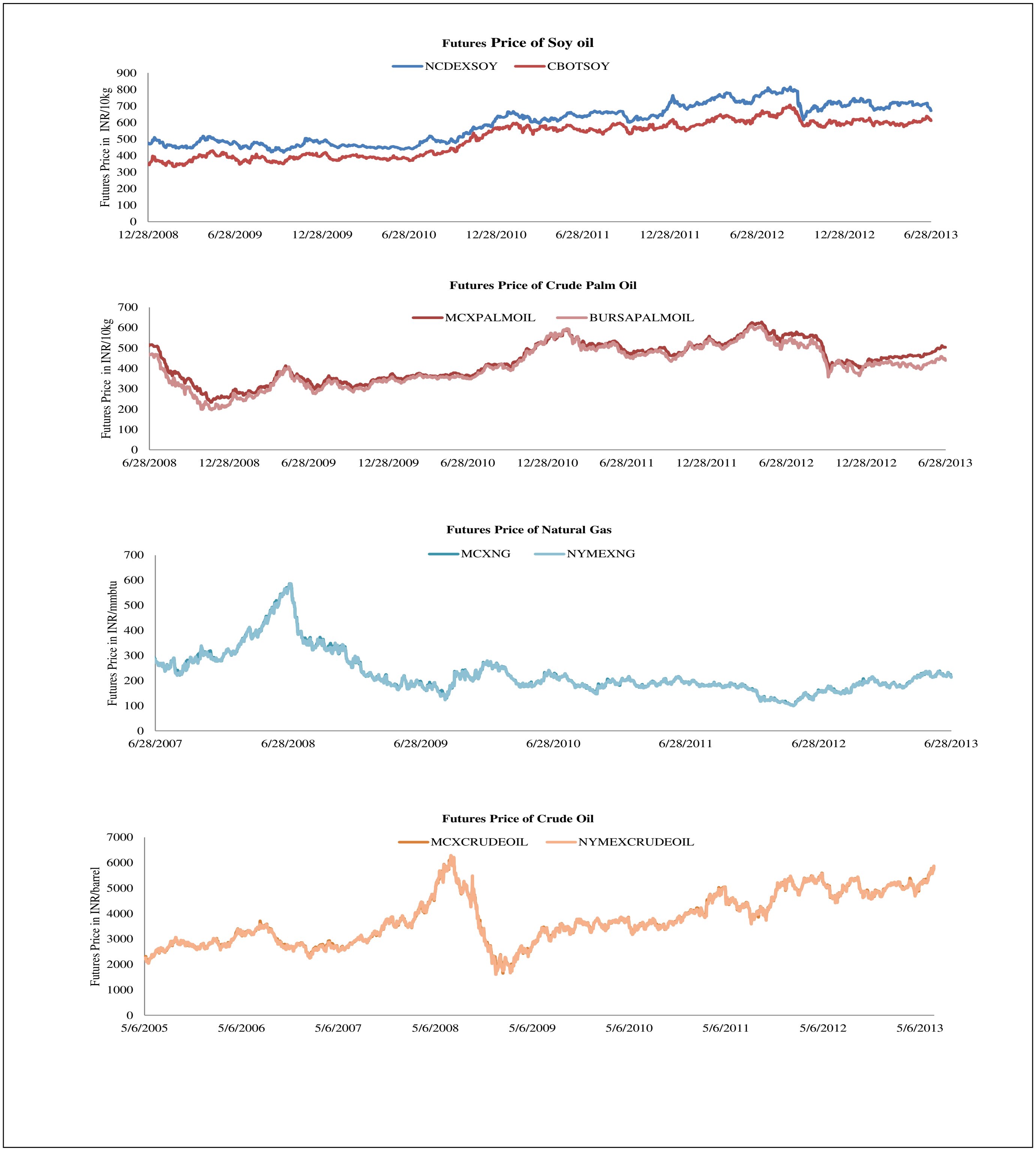

Figure 1 demonstrates the co-movement in futures prices of the four commodities traded in the domestic commodity exchanges of India and their corresponding international commodity exchange. From the figure it can be observed that the futures prices of a commodity move in tandem with each other across exchanges. In case of soy oil, futures price of contract traded in NCDEX (India) remained higher than price of contract traded on CBOT(US) throughout the period of study. While that of futures price of crude palm oil, natural gas and crude oil, prices moved together in the period of study.

2. Literature Survey

Vast amount of literature is available which is focussed on the impact of one stock market in one country on another stock exchange in another country. With respect to commodities, the existing literature discusses linkages in price and return of commodity future contracts traded with contracts traded in other parts of the world. A number of studies discuss the effect of one commodity on the other commodity traded in the same market. In the literature section of the study, we discuss the studies pertaining to the agricultural, agri processed and energy commodities.

Fung et al (2013) employ 16 commodity futures contracts which are traded in commodity exchanges of China and their corresponding foreign markets in US(Chicago Mercantile Exchange), UK (London Metal Exchange and Intercontinental Exchange), Japan (Tokyo Commodity Exchange) and Malaysia (Bursa Malaysia Derivative Exchange). The commodities include - aluminium, copper, zinc, gold, natural rubber, rice, sugar, hard white wheat, strong gluten wheat, cotton, soybean, soybean meal, crude soybean oil, corn and palm oil. The Chinese exchanges include Shanghai Futures Exchange, Zhengzhou Commodity Exchange, and Dalian Commodity Exchange. The authors perform analysis for trading returns (for close to open, open to close, close-close) to assess the relationship between Chinese and foreign markets using variance ratio analysis. Tests for cointegration of prices are also performed in the study. Causality tests are used in the study to analyse the impact of foreign day time returns on day time as well as open- close futures returns of Chinese commodity contracts. The authors find that there is absence of lead lag relationships between Chinese futures markets and their corresponding foreign markets, thereby concluding that Chinese futures markets are information efficient and absorb local market information during the trading sessions.

Kumar and Pandey (2011) analyse the cross market linkages in terms of return and volatility spill-overs of nine commodities (soybean, maize, gold, silver, aluminium, copper, zinc, crude oil and natural gas) traded in Indian Commodity Exchanges (MCX and NCDEX) and their respective International Commodity Exchanges (LME, NYMEX and CBOT). The authors examine the linkages using cointegration test and weak exogeneity test, followed by VECM, Granger Causality tests and Variance Decomposition of forecast error. The authors also employ BEKK GARCH model to estimate volatility spill-over. They find that for all nine commodities cointegration exists between Indian Markets and International Markets. They find unidirectional causality from international to domestic markets from Granger Causality tests. They conclude that bidirectional volatility spill-over exists in case of agricultural commodities, gold, aluminium and zinc whereas unidirectional volatility spill-over exists in crude oil.

Kao and Wan (2009) argue that price series of natural gas traded on markets of US and UK are cointegrated and the two countries are found to contribute equally in the process of price discovery using the Hasbrouck model. They find US markets to be more efficient than UK markets.

The movement of information between US (CBOT and NYMEX) and Chinese commodity futures markets (Shanghai Futures Exchange, Dalian Commodity Exchange and Zhengzhou Commodity Exchange) for copper, soybean and wheat is studied with a bivariate GARCH model by Fung, Leung, and Xu (2003). The authors also test whether cointegration relationship exists between futures prices of commodity futures listed in US and China. With respect to pricing of copper and soybean futures, authors find that US market has a strong impact on Chinese market. But they do not find similar results in case of wheat because of protection policy of the Government of China. Volatility spillover from US to China is observed in all the three commodity futures.

Lin and Tamvakis (2001) examine the interaction between the two prominent crude oil markets - New York Mercantile Exchange (New York) and International Petroleum Exchange (London) for the period from January 4, 1994 to June 30, 1997 using GARCH Models. They conclude that NYMEX incorporates the information from IPE but not vice versa during non overlapping hours. In terms of mean spillover during overlapping trading hours, they find that the spillover is more in case of IPE to NYMEX than from NYMEX to IPE.

Booth et al (1998) investigate using cointegration tests whether relationship exists between wheat futures markets of Chicago Board of Trade (US) and Winnipeg Commodities Exchange (Canada). A long term relationship is found to exist across the two markets. Causality tests suggest that unidirectional causality from CBOT to WCE exists because of a larger volume traded on CBOT. Similar methodology has been taken up by Hua and Chen (2007).

A number of studies have investigated the interdependencies across commodities traded in a single commodity exchange. Chng (2010) examines futures contracts of five commodities - gasoline, kerosene, crude oil, palladium and natural rubber, which are traded on Tokyo Commodity Exchange (TOCOM of Japan) to understand the economic linkages between the chosen commodities and gasoline returns using VECM and VAR estimation. The author finds that a high degree of co-movement exists between gasoline and natural rubber. Chng (2009) investigates the trading dynamics (volume-volatility effects) in futures contracts of natural rubber, palladium and gasoline traded on Tokyo Commodity Exchange using VAR and BEKK-GARCH model. The author concludes that dynamics exist between natural rubber futures and gasoline and natural rubber futures also affect palladium futures. Whereas palladium futures do not influence natural rubber or gasoline.

Bhar and Hamori (2006) investigate linkages among four commodity futures (corn, red bean, soybean and sugar) for the period from August 1994 to December 2003 using cointegration tests. They conclude that there exists no cointegration among time series of agricultural commodity prices for the total sample period. When the sample period is segregated into two periods 1994-2000 and 2000-2003, it is found that in 1990s there is absence of cointegration but from 2000 to 2003, cointegration relationship is found to exist across commodity futures.

In another study, Dawson and White (2002) examine interdependencies across five commodities (barley, cocoa, coffee, sugar and wheat) traded on London International Financial Futures Exchange (LIFFE) using cointegration and VAR model and Clark Price indices for the period from December 9, 1991 to April 3, 2000. The study concludes that there is evidence of interdependence of Clark price indices for wheat and barley only. Cointegration tests suggest that long run relationships exists between agricultural commodity futures prices on LIFFE.

In a paper by Low et al (1999) the joint dynamics of futures prices of sugar and soybean traded on Tokyo Grain Exchange (Japan) and Manila International Futures Exchange (Philippines) from October 1992 to March 1994 have been studied. The authors evaluate whether a relationship exists between the two markets with standard cointegration methodology. The results of cointegration indicate that a relationship does not exist between the two markets in case of sugar and soybean prices.

Linkages between stock exchanges of Germany and US are studied by Baur and Jung (2006) using a GARCH model. They use squared returns on futures as a proxy for volatility of stock exchanges. The study considers a full GARCH model, a pure mean GARCH model and a pure volatility GARCH model to assess the linkage. Our study employs a similar methodology to assess the relationship between commodity futures traded in India and corresponding International Commodity Exchanges in the second section of the study.

Mean spill-over effect and volatility spill-over effect from stock exchanges of giants like US and Japan on stock markets of Hong Kong, Singapore, Taiwan and Thailand are investigated by Liu and Pan(1997). ARMA-GARCH model is employed by the authors in the study. A two stage procedure is followed including unobservable innovations. The study concludes that after the 1997 crash spill-over effects deepened and the effects of US market on the Asian markets increased to a large extent than the Japanese stock market. Using the ARMA-GARCH framework the current study on commodity futures takes into account the impact of unobservable innovations in commodity futures returns in the third section of the paper.

3. Data and Methodology

The study uses daily futures price data of four commodities (soy oil, crude palm oil, natural gas and crude oil) traded on domestic commodity exchanges (of India) and corresponding international commodity exchanges. Among the futures contracts traded on a commodity, the near month futures contract is found to be the most traded, hence price data series of near month contracts are used in the current study. Data for futures prices of the commodities has been extracted from Bloomberg. Exchange rate for conversion to INR of respective currency (soy oil of CBOT, natural gas and crude oil of NYMEX in US Dollar, crude palm oil – Malaysian Ringgit) has been taken from Bloomberg and Data Base for Indian Economy, RBI. Table 2 shows the summary statistics of the prices of futures contracts of the four commodities traded on domestic commodity exchanges (of India) and corresponding international commodity exchanges.

Table 2: Summary Statistics of Prices of Futures Contracts on Agri Processed and Energy Commodities

Summary Statistics	Futures Price of Soyoil traded on NCDEX	Futures Price of Soyoil traded on CBOT	Futures Price of Crude Palm Oil traded on MCX	Futures Price of Crude Palm traded on Bursa Malaysia Derivative Exchange	Futures Price of Natural Gas traded on MCX	Futures Price of Natural Gas traded on NYMEX	Futures Price of Crude Oil traded on MCX	Futures Price of Crude Oil(WTI) traded on NYMEX
Unit	**INR/10kg**	**INR/10kg**	**INR/10kg**	**INR/10kg**	**INR/mmbtu**	**INR/mmbtu**	**INR/barrel**	**INR/barrel**
Mean	594.9032	505.8266	435.1468	413.553	240.0402	238.2864	3768.384	3757.773
Median	622.075	554.675	441.800	416.519	210.8	210.009	3597	3591.475
Maximum	815.6	706.825	628.7	610.1183	587.3	587.8841	6245	6291.057
Minimum	418.5	309.4691	232.3	195.5903	100.2	98.95995	1641	1594.6
Std. Dev.	116.3504	104.4867	93.85703	97.05993	86.51184	86.05721	993.9841	1000.036
Skewness	0.019017	-0.223035	-0.088336	-0.145997	1.272189	1.288841	0.289537	0.27134
Kurtosis	1.508506	1.472959	1.976015	2.198852	4.877031	4.962149	1.999963	2.021182
Jarque-Bera	129.6645	147.3154	69.6894	46.92815	878.4956	922.6386	139.7162	131.0517
Probability	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ADF(4,t)^	-2.227709	-2.477052	-2.801821	-2.366999	-2.38442	-2.436002	-2.269278	-2.400788

^The critical value at 5% level for ADF (4 with trend) is -3.41

Table 2 includes the results of the unit root tests conducted on the price series of each of the four commodities traded on domestic commodity and corresponding international commodity exchanges. The eight price series are found to be non stationary (contain a unit root) at level.

3.1 Linkages in price of commodities traded across exchanges

The price series are found to be non stationary at level and stationary at first difference, indicating that the futures price series follows I(1) process. The Johansen's co-integration test is used to model the relationship between the futures price series of a commodity traded on domestic commodity exchanges of India and their corresponding international commodity exchanges. The co-integration test is followed by modelling the relationship between futures price series with Error Correction Mechanism (ECM) model. A similar methodology is employed by Hua and Chen (2007). The ECM model for the futures price series can be represented as:

$$\Delta PDOM_t = a_{10} + b_D ECM_{t-1} + \sum_{i=1}^{p} c_{1i}\, \Delta PDOM_{t-i} + \sum_{i=1}^{p} d_{1i}\, \Delta PINT_{t-i} + \in_{1t} \ldots \quad (1)$$

$$\Delta PINT_t = a_{20} + b_I ECM_{t-1} + \sum_{i=1}^{p} c_{2i}\, \Delta PDOM_{t-i} + \sum_{i=1}^{p} d_{2i}\, \Delta PINT_{t-i} + \in_{2t} \ldots \quad (2)$$

Where, PDOM and PINT represent the futures price series traded on domestic exchanges of India (NCDEX for soy oil, MCX for crude palm oil, natural gas, and crude oil) and their corresponding international commodity exchanges (CBOT for soy oil, Bursa Malaysia Derivative Exchange for crude palm oil, NYMEX for natural gas and crude oil). The coefficients of the error correction term (ECM_{t-1}) are b_D and b_I in Equation 1 and Equation 2 respectively, they measure the speed of adjustment at which deviation for long run relationship between price series is corrected by change in price series of the two markets. ε_{1t} and ε_{2t} are stationary disturbances. The coefficients of $\Delta PINT_{t-i}$ and $\Delta PDOM_{t-i}$ in Equation1 and Equation 2 respectively, represent short run adjustments in futures price of commodities.

3.2 Linkages in return on price of commodities across two exchanges

For the next three sections (3.2, 3.3, 3.4) returns (calculated using futures prices) of commodities are utilised. For each of the eight price series (four for domestic commodity exchange of India and four for international commodity exchanges), return is calculated as the log difference in price. Subsequently, stationarity of return series is checked using Augmented Dickey Fuller Test.

To test the linkage in returns on price of commodities across the two exchanges respectively, regression is run to calculate the value of R squared for the period of study for each of the four commodities separately. For each commodity, the return on price of futures contracts traded on domestic commodity exchange (NCDEX and MCX) is the dependent variable and the return on price of futures contracts traded on international commodity exchanges (CBOT, Bursa Derivative, NYMEX) is the independent variable and vice versa to the study the opposite effect.

This is followed by plotting of rolling correlation curves of returns of commodities traded on domestic commodity exchanges and corresponding international commodity exchanges. Li and Zhang (2008) employ rolling correlations to assess the time varying relationships between futures markets. Similar methodology is adopted in the current study, to examine the time varying relationship between return on commodity exchanges for the four commodities. In case of rolling correlations, the correlation of first 60 observations is estimated followed by dropping of the earliest observation and inclusion of a new data point, and calculating correlation respectively. The set of 60 observations are rolled and the process is continued till all the observations are exhausted. 60 days (equivalent to 10 weeks) is a considerable period to capture changes in the futures market. Using the correlations calculated by rolling over the period, rolling correlation curves are plotted for the four commodities.

3.3 Linkages in return and volatility of commodities traded across exchanges

The focus of this section is to investigate the effect of returns and volatility of a commodity traded in international commodity exchange on return and volatility of commodity traded in domestic commodity exchange and vice versa. This section uses three variants of a modified GARCH model – full model, pure mean model and pure volatility model. The Berdnt-Hall-Hall-Hausman algorithm is employed for maximum likelihood estimation in the three variants. The focus of Baur and Jung (2006) is to investigate return and volatility spill over between stock exchanges of US and Germany, a similar methodology is used in this study for commodity exchanges.

In the full model and the pure volatility model, squared returns are used in the variance equation of the model to measure volatility in the commodity exchange (International/Domestic).

3.3.1 Full Model

This variant of the model tries to assess the impact of previous day's return of commodity traded on domestic commodity exchange market and impact of previous day's return of commodity traded on international commodity exchange on today's return of commodity traded on the domestic commodity exchange and vice versa. It also tries to capture the impact of previous day's volatility of commodity traded on domestic commodity exchange (GARCH effect) and previous day's volatility of commodity traded on international commodity exchange on volatility (measured by squared returns) of commodity traded on domestic commodity exchange and vice versa.

The following two equations represent the model when we test the impact of international commodity exchange on domestic commodity exchange:

Mean equation: $r_{DOM,t} = k_1 + k_2 r_{DOM,t-1} + k_3 r_{INT,t-1} + \varepsilon_{DOM,t}$... (3)

Variance equation: $h_{DOM,t} = k_4 + k_5 \varepsilon^2_{DOM,t-1} + k_6 h_{DOM,t-1} + k_7 r_{INT}^{2}{}_{,t-1}$... (4)

The following two equations represent the model when we test the impact of domestic commodity exchange on international commodity exchange:

Mean equation: $r_{INT,t} = k_8 + k_9 r_{INT,t-1} + k_{10} r_{DOM,t-1} + \varepsilon_{L,t}$... (5)

Variance equation: $h_{INT,t} = k_{11} + k_{12} \varepsilon^2_{INT,t-1} + k_{13} h_{INT,t-1} + k_{14} r_{DOM}^{2}{}_{,t-1}$... (6)

Where $r_{DOM,t}$ and $r_{INT,t}$ are returns on price of a commodity traded on domestic commodity exchange of India and returns on price of a commodity traded on international commodity exchange respectively. $r_{DOM}{}^{2}{}_{,t-1}$ and $r_{INT}{}^{2}{}_{,t-1}$ are lagged squared returns on price of a commodity traded on domestic commodity exchange of India and corresponding international commodity exchange (used as proxy for volatility). The coefficients of ARCH and GARCH terms in Equation 4 (variance equation) are k_5 and k_6 respectively. k_{12} and k_{13} are coefficients of ARCH and GARCH terms in Equation 6 (variance equation) respectively.

3.3.2 Pure Mean Model

The Pure Mean model focuses on the impact of previous day's return of commodity traded on domestic commodity exchange and previous day's return of commodity traded on international commodity exchange on today's return of commodity traded in domestic market and vice versa. It captures ARCH and GARCH effect but ignores the possible transmission of volatility from one market to the other.

The following two equations represent the model when we test the impact of international commodity exchange on domestic commodity exchange:

Mean equation: $r_{DOM,t}= k_1 + k_2 r_{DOM,t-1} + k_3 r_{INT,t-1} + \varepsilon_{DOM,t} \ldots$ (7)

Variance equation: $h_{DOM,t}= k_4 + k_5 \varepsilon^2_{DOM,t-1} + k_6 h_{DOM,t-1} \ldots$ (8)

The following two equations represent the model when we test the impact of domestic commodity exchange on international commodity exchange:

Mean equation: $r_{INT,t}= k_8 + k_9 r_{INT,t-1} + k_{10} r_{DOM,t-1} + \varepsilon_{INT,t} \ldots$ (9)

Variance equation: $h_{INT,t}= k_{11} + k_{12} \varepsilon^2_{INT,t-1} + k_{13} h_{INT,t-1} \ldots$ (10)

Where $r_{DOM,t}$ and $r_{INT,t}$ are returns on price of a commodity traded on domestic commodity exchange and returns on price of a commodity traded on international commodity exchange respectively. k_5 and k_6 are coefficients of ARCH and GARCH terms in Equation 8(variance equation) respectively. k_{12} and k_{13} are coefficients of ARCH and GARCH terms in Equation 10 (variance equation) respectively.

3.3.3 Pure Volatility Model

This model concentrates on the impact of previous day's volatility of commodity on today's volatility of a commodity traded in the domestic exchange and corresponding international commodity exchange. The following two equations represent the model when we consider the domestic commodity exchange to be home market and international commodity exchange to be foreign market:

Mean equation: $r_{DOM,t} = k_1 + k_2 r_{DOM,t-1} + \varepsilon_{DOM,t}$... (11)

Variance equation: $h_{DOM,t} = k_4 + k_5 \varepsilon^2_{DOM,t-1} + k_6 h_{DOM,t-1} + k_7 r_{INT}{}^2{}_{,t-1}$.... (12)

The following two equations represent the model when we consider international commodity exchange to be home market and domestic exchange of India to be foreign market:

Mean equation: $r_{INT,t} = k_8 + k_9 r_{INT,t-1} + \varepsilon_{INT,t}$... (13)

Variance equation: $h_{INT,t} = k_{11} + k_{12} \varepsilon^2_{INT,t-1} + k_{13} h_{INT,t-1} + k_{14} r_{INT}{}^2{}_{,t-1}$.... (14)

Where $r_{DOM,t}$ and $r_{INT,t}$ are returns on price of a commodity traded on domestic commodity exchange and international commodity exchange respectively. $r_{DOM}{}^2{}_{,t-1}$ and $r_{INT}{}^2{}_{,t-1}$ are lagged squared returns on price of a commodity traded on domestic commodity exchange and international commodity exchange respectively. The coefficients of ARCH and GARCH terms in Equation 12 (variance equation) are k_5 and k_6 respectively. k_{12} and k_{13} are coefficients of ARCH and GARCH terms in Equation 14 (variance equation) respectively.

3.4 ARMA – GARCH in mean model - Innovations Model

In this part of the study, two stage modified GARCH models are used to study the linkage between returns and volatility of futures price of a commodity across two exchanges. A variant of this model is employed by Liu and Pan (1997) to study linkages across stock exchanges. In the first stage, return series of futures price of a commodity is modelled using ARMA(1)-GARCH(1,1) in mean model (a GARCH term is an explanatory variable in the mean equation as well as variance equation).

The first stage of the model is represented as follows:

First stage of the model for commodity traded on domestic commodity exchange:

Mean equation: $r_{DOM,t} = n_1 + n_2 r_{DOM,t-1} + n_3 \varepsilon_{DOM,t-1} + n_4 h_{DOM,t} + \varepsilon_{DOM,t}$... (15)

Variance equation: $h_{DOM,t} = n_5 + n_6 \varepsilon^2_{DOM,t-1} + n_7 h_{DOM,t-1}$ ... (16)

Where $r_{DOM,t}$ are returns on price of a commodity traded on domestic commodity exchange. $r_{DOM,t-1}$ are lagged returns on price of a commodity traded on domestic commodity exchange, this is the auto regressive (AR) term in Equation 15. While $\varepsilon_{DOM,t-1}$ is the moving average term in Equation 15.The coefficients of ARCH and GARCH terms in Equation 16 (variance equation) are n_6 and n_7 respectively.

First stage of the model for a commodity traded on international commodity exchange:

Mean equation: $r_{INT,t} = n_8 + n_9 r_{INT,t-1} + n_{10}\varepsilon_{INT,t-1} + n_{11}h_{INT,t} + \varepsilon_{INT,t}$... (17)

Variance equation: $h_{INT,t} = n_{12} + n_{13}\varepsilon^2_{INT,t-1} + n_{14}h_{INT,t-1}$ ... (18)

where $r_{INT,t}$ are returns on price of a commodity traded on international commodity exchange. $r_{INT,t-1}$ are lagged returns on price of a commodity traded on international commodity exchange, this is the auto regressive (AR) term in Equation 17. While $\varepsilon_{INT,t-1}$ is the moving average term in Equation 17. The coefficients of ARCH and GARCH terms in Equation 18 (variance equation) are represented by n_{13} and n_{14}, respectively.

A standardised residual series is obtained after running the ARMA(1)-GARCH(1,1) in mean model specified in Equations 15 and 16 for commodities traded on domestic market. Similarly, a standardised residual series is obtained after running the ARMA(1)-GARCH(1,1) in mean model specified in Equations 17 and 18 for a commodity traded on international commodity exchange. This is followed by squaring of the two standard residual series obtained to attain two squared standard residual series. This completes the first stage of the model. The first stage of the model is run for the eight return series for four commodities under consideration (four return series of commodities traded on domestic commodity exchange and four return series of the same commodities traded on corresponding international commodity exchanges).

The second stage of the model involves the estimation of return and volatility spill-over effects of a commodity traded across the markets. The second stage uses the standard residual series and squared standard residual series obtained from the first stage. The residual series and squared standard residual series obtained from commodities traded on domestic exchanges (MCX/NCDEX) (from the first stage) are used in second stage of commodities traded on international commodity exchanges (Bursa Malaysia /CBOT/NYMEX) and vice versa.

In the second stage, the residual series are used in the mean equation of the ARMA-GARCH in mean model to capture mean spill-over effect from these markets while the squared residual series in the variance equation to capture the volatility spill-over effect. As Liu and Pan (1997) reveal that the standardised residuals and squared standardised residuals can be considered as proxies for unobservable innovations. The model of the second stage is as follows:

To assess the impact of a commodity traded on international commodity exchange on commodity traded on corresponding domestic commodity exchange:

Mean equation: $r_{DOM,t} = w_1 + w_2 r_{DOM,t-1} + w_3\varepsilon_{DOM,t-1} + w_4 h_{DOM,t} + w_5 e_{INT,t-1}$ ... (19)

Variance equation: $h_{DOM,t} = w_6 + w_7\varepsilon^2_{DOM,t-1} + w_8 h_{DOM,t-1} + w_9 e^2_{INT,t-1}$... (20)

where $r_{DOM,t}$ are returns on price of a commodity traded on domestic commodity exchange. $r_{DOM,t-1}$ are lagged returns on price of a commodity traded on domestic commodity exchange, the auto regressive (AR) term in the equation. While $\varepsilon_{DOM,t-1}$ is the moving average term in Equation 19. Equation 19 and Equation 20use the standardised residual series ($e_{INT,t-1}$) and squared standardised residual series ($e^2_{INT,t-1}$) respectively, obtained from the first stage of commodities traded on international commodity exchange. The coefficients of ARCH and GARCH terms are w_7 and $w_8$in Equation 20 (variance equation) respectively.

To assess the impact of commodity traded on domestic exchanges (MCX/NCDEX)on commodity traded on international commodity exchanges (CBOT, Bursa, NYMEX):

Mean equation: $r_{INT,t} = w_{10} + w_{11} r_{INT,t-1} + w_{12} \varepsilon_{INT,t-1} + w_{13} h_{INT,t} + w_{14} e_{DOM,t-1} \ldots$ (21)

Variance equation: $h_{INT,t} = w_{15} + w_{16} \varepsilon^2_{INT,t-1} + w_{17} h_{INT,t-1} + w_{18} e^2_{DOM,t-1} \ldots$ (22)

Where $r_{INT,t}$ are returns on price of a commodity traded on international commodity exchange. $r_{INT,t-1}$ are lagged returns on price of a commodity traded on international commodity exchange, i.e. the auto regressive (AR) term in the equation. While $\varepsilon_{INT,t-1}$ is the moving average term in Equation 21. Equation 21 and Equation 22 use the standardised residual series ($e_{DOM,t-1}$) and squared standardised residual series ($e^2_{DOM,t-1}$) respectively obtained from the first stage of a commodity traded on domestic commodity exchange. The coefficients of ARCH and GARCH terms are w_{16} and w_{17}in Equation 22 (variance equation) respectively.

4. Empirical Results

4.1 Co-integration and ECM Model

The futures price series are found to be non stationary at level and stationary at first difference, thus indicating that the futures price series of commodities traded across the exchanges follow an I(1) process. Table 3 reports the results of Johansen Co-integration Test for the four commodities.

Table 3 : Results of Johansen Co-integration Tests for the four commodities

Test	Commodity	Lags	Ho, r is number of co-integrating relation	Trace Statistic	Critical Value at 5%	Probabil-ity	Max Eigen Statistic	Critical Value at 5%	Probabil-ity
1	Soy oil	4	r≤0	19.82592**	15.4947	0.0104	17.8643**	14.26460	0.0129
			r≤1	1.961647	3.84147	0.1613	1.96165	3.841466	0.1613
2	Crude Palm oil	4	r≤0	36.17943**	15.4947	0.0000	32.8927**	14.26460	0.0000
			r≤1	3.286693	3.84147	0.0698	3.28669	3.841466	0.0698
3	Natural gas	4	r≤0	254.1601**	15.4947	0.0001	250.4205**	14.26460	0.0001
			r≤1	3.739546	3.84147	0.0531	3.73955	3.841466	0.0531
4	Crude oil	4	r≤0	271.5767**	15.4947	0.0001	269.720**	14.26460	0.0001
			r≤1	1.856126	3.84147	0.1731	1.85612	3.841466	0.1731

** Denotes rejection at 5% level

Both the trace statistics and max eigen statistics show that for each of the four commodities traded on across exchanges, near month futures price series are co-integrated with one co-integrating vector. This implies that the futures prices of commodities traded on domestic commodity exchanges and corresponding international commodity exchanges respectively move together in the long run, even though they may be found to be drifting apart in the short run. Further we study the causal relationship between the futures price of commodities using Error Correction Mechanism with one co-integration relation (r=1) for each of the four commodities.

Results of Error Correction Mechanism Model

Since the futures price series are found to be co-integrated, ECM model is used to represent the relationship for the four pairs of futures price series of commodities. The results of ECM model for each of the four commodities are shown from Table 4 to Table 7.

1. Soy oil - ECM Results

   Table 4 demonstrates the result of ECM for futures price of soy oil traded on NCDEX, India and CBOT, USA in the period from December 4, 2008 to June 28, 2013.

Table 4:ECM results for Soy oil

	Dependent variable - ΔPSOYIN (Equation 1)		Dependent variable – ΔPSOYUS (Equation 2)	
Independent variable -	**Coefficient**	**p value**	**Coefficient**	**p value**
$ECM_{(t-1)}$	-0.023024	0.0002	-0.011053	0.1468
$\Delta PSOYIN_{(t-1)}$	-0.090821	0.0008	0.05766	0.0538
$\Delta PSOYIN_{(t-2)}$	-0.016997	0.5261	0.063334	0.0331
$\Delta PSOYIN_{(t-3)}$	-0.014936	0.5627	0.009958	0.7275
$\Delta PSOYIN_{(t-4)}$	-0.012732	0.6079	-0.002624	0.9239
$\Delta PSOYUS_{(t-1)}$	0.254757	0.0000	-2.845645	0.0045
$\Delta PSOYUS_{(t-2)}$	0.25968	0.0000	-0.459548	0.6459
$\Delta PSOYUS_{(t-3)}$	0.131283	0.0000	-1.558286	0.1194
$\Delta PSOYUS_{(t-4)}$	0.042318	0.1082	-0.061362	0.9511
Constant	0.029318	0.8522	1.200961	0.23
Wald Test Result for short run causality (Chi Square and p value)	182.0272 (0.0000)		7.497013 (0.118)	

In Table 4, Column 2&3 present the results obtained from Equation 1 and Column 4&5 present the results obtained from Equation 2, when futures prices of soy oil traded on NCDEX and CBOT are used. Table 4 shows that ECM_{t-1} term is significant and negative in Equation 1, indicating that disequilibrium errors are an important factor for changes in the futures price of soy oil traded on NCDEX. When the futures price of the commodity traded in the Indian market deviate from their equilibrium level, the error correction term, ECM_{t-1} term being significant, futures price will correct the deviation and move towards equilibrium price level. Since the error correction term is negative, the soy oil futures price will increase on an average. Thus investors can exploit the information given by the error correction terms to predict the changes in futures price of soy oil traded on NCDEX.

Considering the short run dynamics, from the results of Wald Test conducted on the cross terms in Equation 1, we reject the hypothesis, that they are simultaneously zero at the 5% level since the p value 0.0000. This suggests that there is presence of short run causality from futures price of soy oil traded on CBOT to futures price of soy oil traded on NCDEX. The Wald Test results conducted on the cross terms in Equation 2, accept the hypothesis that the coefficients are simultaneously zero at the 5% level, the p value (0.1118) is more than 0.05. This leads to the conclusion that there is absence of short run causality from futures price of soy oil traded on NCDEX to futures price of soy oil traded on CBOT.

2. Crude Palm oil – ECM Results

Table 5 demonstrates the result of ECM for futures price of crude palm oil traded on MCX and Bursa Malaysia Derivative Exchange in the period from June 6, 2008 to June 28, 2013.

Table 5:ECM results for Crude Palm oil

	Dependent variable - ΔPCPOIN(Equation 1)		**Dependent variable - ΔPCPOMAL(Equation 2)**	
Independent variable -	**Coefficient**	**p value**	**Coefficient**	**p value**
ECM(t-1)	-0.038922	0.0000	0.005042	0.6381
ΔPCPOIN(t-1)	-0.001051	0.9735	0.251546	0.0000
ΔPCPOIN(t-2)	0.002524	0.9368	0.177665	0.0001
ΔPCPOIN(t-3)	0.034907	0.2672	0.059429	0.1701
ΔPCPOIN(t-4)	0.023656	0.4456	0.062137	0.1457
ΔPCPOMAL(t-1)	0.051639	0.0296	-0.120871	0.0002
ΔPCPOMAL(t-2)	0.093502	0.0001	-0.024667	0.4497
ΔPCPOMAL(t-3)	0.01215	0.6082	-0.104642	0.0014
ΔPCPOMAL(t-4)	-0.015332	0.5106	-0.077956	0.0152
Constant	-0.0066	0.9557	-0.022039	0.8928
Wald Test Result for short run causality (Chi Square and p value)	19.40736 (0.0007)		46.68690 (0.0000)	

In Table 5, column 2&3 present the results obtained from Equation 1 and Column 4&5 present the results obtained from Equation 2 when futures prices of crude palm oil traded on MCX and Bursa Malaysia Derivative Exchange are used. Table 5 shows that ECM_{t-1} term is significant (p value is 0.0000) and negative in Equation 1, indicating that disequilibrium error is an important factor for the change in the futures price of crude palm oil traded on MCX. When the futures price of the commodity traded in MCX deviate from their equilibrium level the deviation will get corrected since $ECM_{t-1,}$error correction term is significant. Since the error correction term is negative, the crude palm oil futures price traded on MCX will increase on an average. The error correction term in the Equation 2 is insignificant (here p value is 0.6381 which is greater than 0.05) price in Bursa Malaysia Derivative Exchange.

Considering the short run dynamics, from the results of Wald Test conducted on the cross terms in Equation 1, we reject the hypothesis that they are simultaneously zero at the 5% level since the p value (0.0007) is less than 0.05. This suggests that there is presence of short run causality from futures price of crude palm oil traded on Bursa Malaysia Derivative Exchange to futures price of crude palm oil traded on MCX. The Wald Test results conducted on the cross terms in Equation 2, find that the coefficients are not simultaneously zero at the 5% level, the p value (0.0000) is less than 0.05. This leads to the conclusion that there is presence of short run causality from futures price of crude palm oil traded on MCX to futures price of crude palm oil traded on Bursa Malaysia Derivative Exchange.

3. Natural Gas - ECM Results

Table 6:ECM results for Natural Gas

	Dependent variable - ΔPNGIN(Equation 1)		**Dependent variable - ΔPNGUS(Equation 2)**	
Independent variable -	**Coefficient**	**p value**	**Coefficient**	**p value**
ECM(t-1)	-0.061768	0.0683	-0.337422	0.0000
ΔPNGIN(t-1)	0.062804	0.1043	0.526536	0.0000
ΔPNGIN(t-2)	0.013829	0.7414	0.0945	0.0003
ΔPNGIN(t-3)	0.023307	0.5631	-0.010834	0.6687
ΔPNGIN(t-4)	-0.046644	0.2118	-0.108256	0.0000
ΔPNGUS(t-1)	-0.001891	0.9626	-0.117683	0.0000
ΔPNGUS(t-2)	-0.012523	0.7461	0.029538	0.2243
ΔPNGUS(t-3)	0.039504	0.2682	0.053279	0.0175
ΔPNGUS(t-4)	-0.008277	0.6914	0.027481	0.036
Constant	-0.047541	0.7494	-0.028465	0.7607
Wald Test Result for short run causality (Chi Square and p value)	2.425254 (0.6581)		642.7351 (0.0000)	

Table 6 demonstrates the result of ECM for futures price of natural gas traded on MCX and NYMEX in the period, from August 1st, 2006 to June 28th, 2013.

In Table 6, column 2&3 present the results obtained from Equation 1 and column 4&5 present the results obtained from Equation 2 when futures prices of natural gas traded on MCX and NYMEX are used. Table 6 shows that ECM_{t-1} term is insignificant (p value is 0.0683) and negative in Equation 1, indicating that the long run dynamics do not exist futures market of natural gas traded on MCX. The error correction term in Equation 2 is significant and negative, indicating that disequilibrium error is an important factor for the change in the futures price of crude palm oil traded on NYMEX. When the futures price of the commodity traded in NYMEX deviate from their equilibrium level the deviation will get corrected since $ECM_{t-1,}$ error correction term is significant.

Considering the short run dynamics, from the results of Wald Test conducted on the cross terms in Equation 1, we accept the hypothesis that they are simultaneously zero at the 5% level since the p value (0.6581) is more than 0.05. This suggests that there is absence of short run causality from NYMEX natural gas futures price to MCX natural gas futures price. The Wald Test results conducted on the cross terms in Equation 2, finds that the coefficients are not simultaneously zero at the 5% level, the p value (0.0000) is less than 0.05. This leads to the conclusion that there is presence of short run causality from futures price of natural gas traded on MCX to futures price of natural gas traded on NYMEX.

4. Crude Oil- ECM Results

Table 7 demonstrates the result of ECM for futures price of crude oil traded on MCX and NYMEX in the period from May 6, 2005 to June 28, 2013.

Table 7: ECM results for Crude Oil

	Dependent variable - ΔPCROIN(Equation 1)		Dependent variable - ΔPCROUS(Equation 2)	
Independent variable -	**Coefficient**	**p value**	**Coefficient**	**p value**
ECM(t-1)	-0.190863	0.0000	-0.214639	0.0000
ΔPCROIN(t-1)	-0.155062	0.0003	-0.033269	0.5181
ΔPCROIN(t-2)	-0.051095	0.2201	-0.012409	0.8022
ΔPCROIN(t-3)	-0.038317	0.3243	-0.029628	0.5215
ΔPCROIN(t-4)	-0.061681	0.0672	-0.02743	0.4936
ΔPCROUS(t-1)	0.160165	0.0001	0.003139	0.9481
ΔPCROUS(t-2)	0.070724	0.0686	0.028409	0.5383
ΔPCROUS(t-3)	0.006275	0.8622	0.007132	0.8683
ΔPCROUS(t-4)	0.061136	0.0516	0.038799	0.2987
Constant	1.412256	0.2638	1.461502	0.3308
Wald Test Result for short run causality (Chi Square and p value)	21.79853 (0.0002)		0.902534 (0.9242)	

In Table 7 column 2&3 present the results obtained from Equation 1 and Column 4&5 present the results obtained from Equation 2 when crude oil futures prices traded on MCX and NYMEX are used. Table 7 shows that ECM_{t-1} term is significant and negative in both the equations, in Equation 1 (p value is 0.0000) and the in Equation 2 (p value is 0.0000) at 5% level, indicating that disequilibrium errors are an important factor for the changes in the futures price of crude oil traded on MCX and in the futures price of crude oil traded on NYMEX. When the futures price of the crude oil traded in the two markets deviate from their equilibrium level, ECM_{t-1} the significant error correction term, indicates that the price will get adjusted to the equilibrium level. Since the error correction term is negative, the crude oil futures price will increase on an average. Thus investors can exploit the information given by the error correction terms to predict the changes in futures price of crude oil traded on MCX and NYMEX.

Considering the short run dynamics, from the results of Wald Test conducted on the cross terms in Equation 1, we reject that they are simultaneously zero at the 5% level since the p value (0.0002) is less than 0.05. This suggests that there is presence of short run causality from futures price of crude oil traded on NYMEX to futures price of crude oil traded on MCX. The Wald Test results conducted on the cross terms in Equation 2, find that the coefficients are not simultaneously zero at the 5% level, the p value (0.9242) is more than 0.05. This leads to the conclusion that there is absence of short run causality from MCX crude oil futures price to NYMEX crude oil futures price.

Table 8: Summary of Results of ECM

Futures price of contracts traded on Domestic Commodity Exchange is dependent variable and corresponding International Commodity Exchange is independent variable(Equation 1)		
	ECM term (LR)(Adjusts to equilibrium)	**Wald Test(SR)**
Soy oil	-0.023024 (0.0002)	182.0272 (0.0000)
Crude Palm Oil	-0.038922 (0.0000)	19.40736 (0.0007)
Natural Gas	-0.061768 (0.0683)	2.425254 (0.6581)
Crude Oil	-0.190863 (0.0000)	21.79853 (0.0002)
Futures price of contracts traded on International Commodity Exchange is dependent variable and corresponding Domestic Commodity Exchange is independent variable(Equation 2)		
	ECM term (LR)(Adjusts to equilibrium)	**Wald Test(SR)**
Soy Oil	-0.011053 (0.1468)	7.497013 (0.118)
Crude Palm Oil	0.005042 (0.6381)	46.6869 (0.0000)
Natural Gas	-0.337422 (0.0000)	642.7351 (0.0000)
Crude Oil	-0.214639 (0.0000)	0.902534 (0.9242)

From the results of co-integration test, economically speaking there is a long term relationship between futures price of commodities traded across exchanges. Summarising the results of ECM for the four commodities in Table 8. In the upper panel of Table 8, the significant error term suggests the futures price of contracts traded on Indian commodity Exchanges (soy oil, natural gas and crude oil) adjust to the equilibrium level in the long run. The significant result of Wald Test in case of soy oil, crude palm oil and crude oil, suggests that there is presence of short run causality from prices of futures contract traded on International exchanges to prices of futures contract traded on corresponding domestic exchanges of India. Whereas in the lower panel of Table 8, the ECM term is significant in case of natural gas and crude oil, which indicates that price will get adjusted to the equilibrium level after deviation. In case of soy oil and crude palm oil, the ECM term is not significant. The results of Wald Test of crude palm oil and natural gas are significant, implying that short run causality exists from futures price of contracts traded on MCX to prices of futures contract traded on corresponding international exchanges respectively.

4.2 Regression Analysis and Rolling Correlations of Returns

Table 9 demonstrates the summary statistics of returns on futures price of agri-processed and energy commodities traded in domestic commodity exchanges in India and corresponding international commodity exchanges.

Table 9: Summary Statistics of Returns on Prices of Futures Contracts on Agri Processed and Energy commodities

Summary Statistics	Return on Futures Price of Soyoil traded on NCDEX	Return on Futures Price of Soyoil traded on CBOT	Return on Futures Price of Crude Palm Oil traded on MCX	Return on Futures Price of Crude Palm traded on Bursa Malaysia Derivative Exchange	Return on Futures Price of Natural Gas traded on MCX	Return on Futures Price of Natural Gas traded on NYMEX	Return on Futures Price of Crude Oil traded on MCX	Return on Futures Price of Crude Oil(WTI) traded on NYMEX
Mean	0.000127	0.0002	-0.0000123	-0.0000224	-0.000101	-0.000104	0.000161	0.000166
Median	0.000	0.000	0.000	0.000	-0.000253	0.000	0.000335	0.000
Maximum	0.030381	0.028737	0.02581	0.043838	0.106283	0.116809	0.103789	0.074117
Minimum	-0.045458	-0.031371	-0.020594	-0.046423	-0.055002	-0.064681	-0.040993	-0.057367
Std. Dev.	0.004574	0.005825	0.005087	0.007681	0.012084	0.013214	0.008073	0.009408
Skewness	-0.479256	0.08816	0.028063	-0.275096	0.76426	0.912281	0.74933	0.141374
Kurtosis	12.85228	5.657721	5.881874	9.010878	8.840485	10.42462	16.64877	9.871135
Jarque-Bera	5703.607	412.9632	536.2347	2351.47	3202.837	5136.65	19717.59	4946.001
Probability	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ADF(4,t)^	-15.69202	-17.57631	-14.82925	-17.44217	-21.28234	-21.12894	-22.27307	-22.07061

^The critical value at 5% level for ADF(4 with trend) is -3.41

From Table 9, the maximum daily returns are found to be 11-12% in case of natural gas futures contracts traded on MCX and NYMEX. The distribution is leptokurtic for all the eight return series since value of kurtosis is found to be more than 3. The return series for all the commodities traded on domestic and international commodity exchanges are found to be stationary since there is absence of unit root at level.

Table 10: Regression Analysis of Returns on Futures Prices of agri processed and energy commodities

Model	Dependent Variable: Return on Futures Price of contracts traded in domestic exchanges	Independent Variable: Return on Futures Price of contracts traded in international exchanges	Value of R^2
I	**Soy oil**	0.194157 (0.0000)	0.061131
II	**Crude Palm oil**	0.371039 (0.0000)	0.313815
III	**Natural Gas**	0.665559 (0.0000)	0.529682
IV	**Crude oil**	0.637699 (0.0000)	0.552189

Table 10 reports results of regression on the return series keeping return series of futures contracts traded on domestic commodity exchanges as dependent variable and return series of futures contracts traded on international commodity exchanges as independent variable. The regression analysis is performed for all the four commodities chosen. Regression models are run separately for each commodity. The coefficient of return on futures price of contracts traded on international exchanges is varied for the four commodities; it is lower in case of agricultural processed commodities (soy oil and crude palm oil) compared to energy commodities (natural gas and crude oil).

Table 11:Regression Analysis of Returns on Futures Prices of Commodities

Model	Dependent Variable: Return on Futures Price of contracts traded in international exchanges	Independent Variable: Return on Futures price of contracts traded in international exchanges	Value of R^2
I	Soy oil	0.314852 (0.0000)	0.061131
II	Crude Palm oil	0.845774 (0.0000)	0.313815
III	Natural Gas	0.795845 (0.0000)	0.529682
IV	Crude oil	0.865909 (0.0000)	0.552189

Table 11 displays results of regression when the dependent variable is return on futures price of a commodity traded on international commodity exchange and independent variable is return on futures price of commodity traded on corresponding domestic commodity exchange. The coefficient of returns to futures price of all the commodities traded on domestic commodity exchange are found to be significant.

Rolling Correlations Curves

Figure 2 depicts the rolling correlation between returns on futures price of commodities (soy oil, crude palm oil, natural gas and crude oil) traded on domestic commodity exchanges of India and international commodity exchanges.

For soy oil, the rolling correlation of returns is found to be moving in the range of-0.07 and 0.62 over the entire period. The average rolling correlation of returns for soy oil is 0.23. For crude palm oil, the rolling correlation of returns is seen to be moving in the range from as low as 0.08 to a maximum of 0.84. On an average the rolling correlation of returns of crude palm oil is 0.54. For natural gas, the rolling correlation of returns reaches as low as 0.23 and attains a maximum of 0.95. The average of rolling correlation for the entire period is 0.77. For crude oil, the minimum value of rolling correlation for 60 day window is 0.42, whereas the maximum level of rolling correlation of returns attained by crude oil is 0.92, while the average is 0.77. Thus comparing the averages of rolling correlation of returns, lowest correlation is in case of soy oil.

Figure 2: Results of rolling correlations of returns of futures prices of commodities traded on domestic and international commodity exchanges

4.3 Results of Modified GARCH

4.3.1 Full Model - I

Table 12: Results of Full Model (Equation 3 and 4) - Impact on price return of commodity traded in domestic commodity exchange

Return on Futures Price (Domestic Exchange) - Dependent Variable	Soy oil (i)	Crude Palm Oil (ii)	Natural gas (iii)	Crude oil (iv)
Mean Equation				
Mean Constant	6.86E-05 (0.5721)	0.000195 (0.0823)	-0.000105 (0.6557)	2.21E-04 (0.0826)
Return on Futures Price (Domestic exchange)(t-1)	-0.055993 (0.0605)	0.019404 (0.5783)	-0.148354 (0.0000)	-0.229578 (0.0000)
Return on Futures Price (International exchange)(t-1)	0.201591 (0.0000)	0.056501 (0.0142)	0.172693 (0.0000)	0.281686 (0.0000)
Variance Equation				
Variance constant	3.42E-07 (0.0000)	1.26E-07 (0.0176)	1.37E-06 (0.0001)	5.17E-07 (0.0000)
ARCH	0.012698 (0.0004)	0.035168 (0.0000)	0.005994 (0.3202)	0.022236 (0.0006)
GARCH	0.928189 (0.0000)	0.927637 (0.0000)	0.950087 (0.0000)	0.948601 (0.0000)
Squared Return on Futures Price(International exchange)(t-1)	0.024229 (0.0000)	0.015607 (0.0000)	0.028248 (0.0000)	0.013893 (0.0003)
Log Likelihood	5635.155	6175.346	6459.467	8922.56

Table 12 demonstrates the results of the Full model (Equation 3 and Equation 4) with return on futures price of commodities traded on domestic commodity exchanges of India (NCDEX for soy oil, MCX for crude palm oil, natural gas and crude oil) as the dependent variable. The mean equation includes lagged return on futures price of a commodity traded on domestic commodity exchange and a term of lagged return on futures price of a commodity traded on international commodity exchange (CBOT for soy oil, Bursa Malaysia Derivative Exchange for crude palm oil and NYMEX for natural gas and crude oil). The variance equation in the full model includes lagged squared return on futures prices of commodities traded on international commodity exchange (considered to be a proxy of volatility in price return of futures contracts traded in foreign market). The model is run separately for each of the four commodities.

It is found from the results of mean equation that return of futures price of natural gas and crude oil traded on MCX are influenced by their own lagged return respectively. While the return on futures prices of soy oil, crude palm oil, natural gas and crude oil traded on domestic commodity exchange are affected by lagged return of futures price of soy oil, crude palm oil, natural gas and crude oil traded on corresponding international commodity exchange respectively.

From the variance equation, for three of the four return series (soy oil, crude palm oil and crude oil), ARCH effects are found to be significant. Whereas, the GARCH effect is significant in case of all the four return series (soy oil, crude palm oil, natural gas and crude oil). The coefficient of lagged squared returns of futures prices of all commodities traded on international commodity exchange is found to be significant (p value less than 0.05 for all). This suggests that as per the full model, there is presence of impact of volatility of commodities traded on international commodity exchanges on volatility of futures price of commodities traded on corresponding domestic commodity exchange respectively.

4.3.1 – Full Model – II

Table 13: Results of Full Model (Equation 5 and 6) - Impact on price return of commodity traded in international commodity exchange

Return on Futures Price (International Exchange) - Dependent Variable	Soy oil (i)	Crude Palm Oil (ii)	Natural gas (iii)	Crude oil (iv)
Mean Equation				
Mean Constant	1.84E-04 (0.1797)	0.00013 (0.4028)	-0.000171 (0.4865)	2.79E-04 (0.0097)
Return on Futures Price (International exchange)(t-1)	-0.091587 (0.0031)	-0.102405 (0.0023)	-0.238285 (0.0000)	-0.232435 (0.0000)
Return on Futures Price (Domestic exchange) (t-1)	0.084883 (0.0165)	0.256695 (0.0000)	0.2362 (0.0000)	0.188037 (0.0000)
Variance Equation				
Variance constant	3.60E-07 (0.0037)	2.55E-07 (0.0056)	1.96E-06 (0.0002)	9.03E-06 (0.0000)
ARCH	0.034565 (0.0000)	0.026344 (0.0000)	0.026188 (0.0000)	0.025027 (0.0200)
GARCH	0.949972 (0.0000)	0.947485 (0.0000)	0.932264 (0.0000)	0.080191 (0.0000)
Squared Return on Futures Price(Domestic exchange)(t-1)	0.005402 (0.301)	0.043824 (0.0000)	0.033979 (0.0000)	1.221079 (0.0000)
Log Likelihood	5275.224	5586.726	6312.21	9018.607

Table 13 represents the results of the Full model (Equation 5 and Equation 6) with return on futures price of commodities traded on international commodity exchange as the dependent variable. The mean equation includes lagged return on futures price of commodities traded on international commodity exchange and a term of lagged return on futures price of commodities traded on domestic commodity exchange. The variance equation in the full model includes lagged squared return on futures prices of commodities traded on domestic commodity exchange (proxy of volatility in price return of futures contracts). The model is run separately for each commodity.

It is found from the results of mean equation that return of futures price of soy oil, crude palm oil, natural gas and crude oil traded on international commodity exchange are influenced by their own lagged return. The return on futures prices of soy oil, crude palm oil, natural gas and crude oil traded on international commodity exchange are also affected by lagged return of futures price of soy oil, crude palm oil, natural gas and crude oil traded on corresponding domestic commodity exchange respectively.

From the variance equation, for all the four return series, ARCH and GARCH effects are found to be significant. The coefficient of lagged squared returns of futures prices of crude palm oil, natural gas and crude oil traded on domestic exchange is found to be significant (p value less than 0.05 for all). This suggests that as per the full model, there is presence of impact of volatility of crude palm oil, natural gas and crude oil traded on domestic exchange on volatility of futures price of crude palm oil, natural gas and crude oil traded on international commodity exchange respectively.

4.3.2 Mean Model - I

Table 14: Results of Mean Model (Equation 7 and 8) - Impact on price return of commodity traded in domestic commodity exchange

Return on Futures Price (Domestic Exchange) - Dependent Variable	Soy oil (i)	Crude Palm Oil (ii)	Natural gas (iii)	Crude oil (iv)
Mean Equation				
Mean Constant	8.70E-05 (0.4827)	0.000218 (0.0524)	-1.85E-05 (0.9341)	2.79E-04 (0.0228)
Return on Futures Price (Domestic exchange)(t-1)	-0.059934 (0.048)	0.012542 (0.7059)	-0.153493 (0.0000)	-0.229361 (0.0000)
Return on Futures Price (International exchange)(t-1)	0.196802 (0.0000)	0.056759 (0.0037)	0.168795 (0.0000)	0.273648 (0.0000)
Variance Equation				
Variance constant	6.03E-07 (0.0000)	1.38E-07 (0.0036)	1.11E-06 (0.0004)	4.90E-07 (0.0000)
ARCH	0.018307 (0.0000)	0.053265 (0.0000)	0.036758 (0.0000)	0.042277 (0.0000)
GARCH	0.949734 (0.0000)	0.942155 (0.0000)	0.955327 (0.0000)	0.948871 (0.0000)
Log Likelihood	5606.236	6165.259	6449.629	8916.586

Table 14 represents the results of the Pure Mean model (Equation 7 and Equation 8) with return on futures price of commodities traded on domestic commodity exchange as the dependent variable. The mean equation includes lagged return on futures price of commodities traded on domestic commodity exchange and a term of lagged return on futures price of commodities traded on corresponding international commodity exchange. The variance equation contains only ARCH and GARCH terms. The model is run separately for each of the four commodities.

It is found from the results of mean equation that return of futures price of soy oil, natural gas and crude oil traded on domestic commodity exchange are influenced by their own lagged return. Return on futures price of crude palm oil traded on MCX remains unaffected by its own lagged return. While the return on futures prices of soy oil, crude palm oil, natural gas and crude oil traded on domestic exchange are affected by lagged return of futures price of soy oil, crude palm oil, natural gas and crude oil traded on corresponding international commodity exchange respectively. From the variance equation, for all the four commodity return series, ARCH and GARCH effects are found to be significant.

This suggests that as per the mean model, there is presence of impact of return on soy oil, crude palm oil, natural gas and crude oil traded on international commodity exchange on return of futures price of soy oil, crude palm oil, natural gas and crude oil traded on corresponding domestic commodity exchange respectively.

4.3.2 Mean Model - II

Table 15: Results of Mean Model (Equation 9 and 10) - Impact on price return of commodity traded in international commodity exchange

Return on Futures Price (International Exchange) - Dependent Variable	Soy oil (i)	Crude Palm Oil (ii)	Natural gas (iii)	Crude oil (iv)
Mean Equation				
Mean Constant	1.75E-04 (0.2026)	0.000169 (0.2649)	-3.81E-05 (0.8735)	2.97E-04 (0.0462)
Return on Futures Price (International exchange)(t-1)	-0.091665 (0.0030)	-0.106093 (0.0015)	-0.262117 (0.0000)	-0.106423 (0.0000)
Return on Futures Price (Domestic exchange) (t-1)	0.084505 (0.0123)	0.256618 (0.0000)	0.273049 (0.0000)	0.088457 (0.0002)
Variance Equation				
Variance constant	3.44E-07 (0.0030)	2.60E-07 (0.0009)	1.74E-06 (0.0001)	6.96E-07 (0.0002)
ARCH	0.033437 (0.0000)	0.041231 (0.0000)	0.046012 (0.0000)	0.04679 (0.0000)
GARCH	0.954944 (0.0000)	0.953796 (0.0000)	0.943402 (0.0000)	0.943619 (0.0000)
Log Likelihood	5274.779	5579.443	6301.605	8530.038

Table 15 shows the results of the Pure Mean model (Equation 9 and Equation 10) with return on futures price of commodities traded on international commodity exchange as the dependent variable. The mean equation includes lagged return on futures price of commodities traded on international commodity exchange and a term of lagged return on futures price of commodities traded on corresponding domestic commodity exchange. The variance equation contains only ARCH and GARCH terms. The model is run separately for each of the four commodities.

It is found from the results of mean equation that return of futures price of soy oil, crude palm oil, natural gas and crude oil traded on international commodity exchange are influenced by their own lagged return. While the return on futures prices of soy oil, crude palm oil, natural gas and crude oil traded on international commodity exchange are affected by lagged return of futures price of soy oil, crude palm oil, natural gas and crude oil traded on domestic commodity exchange respectively. From the variance equation, for all the four return series, ARCH and GARCH effects are found to be significant.

This suggests that as per the mean model, there is presence of impact of return soy oil, crude palm oil, natural gas and crude oil traded on domestic commodity exchange on return of futures price of soy oil, crude palm oil, natural gas and crude oil traded on corresponding international commodity exchange.

4.3.3. Pure Volatility Model -I

Table 16: Results of Volatility Model (Equation 11 and 12) - Impact on price return of commodity traded in domestic commodity exchange

Return on Futures Price (Domestic Exchange) - Dependent Variable	Soy oil (i)	Crude Palm Oil (ii)	Natural gas (iii)	Crude oil (iv)
Mean Equation				
Mean Constant	9.45E-05 (0.4479)	0.000193 (0.0865)	-0.000115 (0.6299)	2.45E-04 (0.0579)
Return on Futures Price (Domestic exchange)(t-1)	0.006636 (0.8322)	0.06458 (0.0341)	-0.010721 (0.6600)	0.016074 (0.4350)
Variance Equation				
Variance constant	3.74E-07 (0.0000)	1.21E-07 (0.0205)	1.37E-06 (0.0001)	5.42E-07 (0.0000)
ARCH	0.01161 (0.0011)	0.034159 (0.0000)	0.006719 (0.2526)	0.026332 (0.0000)
GARCH	0.925959 (0.0000)	0.929118 (0.0000)	0.950927 (0.0000)	0.947048 (0.0000)
Squared Return on Futures Price(International exchange)(t-1)	0.027402 (0.0000)	0.015562 (0.0000)	0.027379 (0.0000)	0.01252 (0.0005)
Log Likelihood	5596.084	6172.024	6445.233	8871.919

Table 16 represents the results of the Pure Volatility model (Equation 11 and Equation 12) with return on futures price of commodities traded on domestic commodity exchange as the dependent variable.

The mean equation includes lagged return on futures price of commodities traded on domestic commodity exchange. The variance equation in the Pure Volatility model includes lagged squared return on futures prices of commodities traded on international commodity exchange (proxy of volatility in foreign market). The model is run separately for each of the four commodities.

It is found from the results of mean equation that return of futures price of crude palm oil traded on MCX are influenced by their own lagged return. The return of futures price of soy oil, natural gas and crude oil are not influenced by their own lagged return.

From the variance equation, for return series of soy oil, crude palm oil and crude oil, ARCH effects are found to be significant. Whereas, for the return series of the four commodities, GARCH effects are observed to be significant for all. The coefficient of lagged squared returns of futures prices of soy oil, crude palm oil, natural gas and crude oil traded on international commodity exchange is found to be significant (p value is less than 0.05 for all). This suggests that as per the Pure Volatility Model, there is impact of lagged price return volatility of soy oil, crude palm oil, natural gas and crude oil traded on international commodity exchange on price return volatility of soy oil, crude palm oil, natural gas and crude oil traded on corresponding domestic commodity exchange respectively.

4.3.3. Pure Volatility Model -II

Table 17: Results of Volatility Model (Equation 13 and 14) - Impact on price return of commodity traded in international commodity exchange

Return on Futures Price (International Exchange) - Dependent Variable	Soy oil (i)	Crude Palm Oil (ii)	Natural gas (iii)	Crude oil (iv)
Mean Equation				
Mean Constant	1.94E-04 (0.1571)	0.000167 (0.2878)	-0.000201 (0.4193)	3.06E-04 (0.0049)
Return on Futures Price (International exchange)(t-1)	-0.075594 (0.0110)	-0.002959 (0.9214)	-0.072526 (0.0039)	-0.116872 (0.0000)
Variance Equation				
Variance constant	3.68E-07 (0.0029)	2.66E-07 (0.0042)	2.19E-06 (0.0001)	8.61E-06 (0.0000)
ARCH	0.03381 (0.0000)	0.027358 (0.0000)	0.020136 (0.0001)	0.023463 (0.0275)
GARCH	0.950114 (0.0000)	0.945709 (0.0000)	0.927237 (0.0000)	0.106623 (0.0000)
Squared Return on Futures Price(Domestic exchange)(t-1)	0.005957 (0.2686)	0.046284 (0.0000)	0.046507 (0.0000)	1.183322 (0.0000)
Log Likelihood	5272.226	5571.693	6293.911	8998.257

Table 17 represents the results of the Pure Volatility model (Equation 13 and Equation 14) with return on futures price of commodities traded on international commodity exchange as the dependent variable.

The mean equation includes lagged return on futures price of commodities traded on international commodity exchange. The variance equation in the Pure Volatility model includes lagged squared return on futures prices of commodities traded on domestic commodity exchange (proxy of volatility). The model is run separately for each of the four commodities. It is found from the results of mean equation that return of futures price of soy oil, natural gas and crude oil traded on international commodity exchange are influenced by their own lagged return. The return of futures price of crude palm oil is not influenced by own lagged return.

From the variance equation, for the four return series, ARCH and GARCH effects are found to be significant. The coefficient of lagged squared returns of futures prices of crude palm oil, natural gas and crude oil traded on international commodity exchange is found to be significant (p value is less than 0.05). Whereas, the coefficient of lagged squared returns of futures prices of soy oil traded on international commodity exchange is not found to be significant (p value is more than 0.05). This suggests that as per the Pure Volatility model, there is impact of lagged price return volatility of crude palm oil, natural gas and crude oil traded on domestic exchange on price return volatility in crude palm oil, natural gas and crude oil traded on corresponding international commodity exchange respectively.

Table 18 presents a summary of results of modified GARCH model, it is suggested from the results obtained from Pure Mean Model and Pure Volatility Model are found to be consistent with the results obtained from Full Model.

Table 18: Summary of Results of Modified GARCH Model

Returns of Futures contracts traded on domestic exchange is dependent variable				
	Full Model		**Pure Mean Model– Impact on Mean**	**Pure Volatility Model– Impact on Volatility**
	Mean Return	**Volatility**		
Soy oil	0.201591 (0.0000)	0.024229 (0.0000)	0.196802 (0.0000)	0.027402 (0.0000)
Crude Palm oil	0.056501 (0.0142)	0.015607 (0.0000)	0.056759 (0.0037)	0.015562 (0.0000)
Natural Gas	0.172693 (0.0000)	0.028248 (0.0000)	0.168795 (0.0000)	0.027379 (0.0000)
Crude Oil	0.281686 (0.0000)	0.013893 (0.0003)	0.273648 (0.0000)	0.01252 (0.0005)
Returns of Futures contracts traded on International exchange is dependent variable				
	Full Model		**Pure Mean Model – Impact on Mean**	**Pure Volatility Model – Impact on Volatility**
	Mean Return	**Volatility**		
Soy oil	0.084883 (0.0165)	0.005402 (0.3010)	0.084505 (0.0123)	0.005957 (0.2686)
Crude Palm oil	0.256695 (0.0000)	0.043824 (0.0000)	0.256618 (0.0000)	0.046284 (0.0000)
Natural Gas	0.2362 (0.0000)	0.033979 (0.0000)	0.273049 (0.0000)	0.046507 (0.0000)
Crude Oil	0.188037 (0.0000)	1.221079 (0.0000)	0.088457 (0.0002)	1.183322 (0.0000)

4.4 Results of ARMA – GARCH in mean model – The Innovation Model

4.4.1.1First Stage of Model-I

Table 19: Results of First Stage(Domestic Exchange) of ARMA GARCH in Mean Model (Equation 15 and 16)

Dependent Variable – Return on Futures Price of commodity traded on domestic exchange	Soy oil (i)	Crude Palm oil (ii)	Natural Gas (iii)	Crude Oil (iv)
Mean Equation				
Mean constant	0.000551 (0.3107)	0.000769 (0.0000)	0.001504 (0.0070)	0.000357 (0.0744)
Coefficient of AR(1)	0.05776 (0.9853)	0.109406 (0.8091)	-0.50922 (0.3407)	-0.159718 (0.9272)
Coefficient of MA(1)	-0.052746 (0.9866)	-0.053589 (0.9064)	0.495942 (0.3568)	0.171126 (0.9219)
Coefficient of GARCH	-21.7107 (0.4069)	-32.77115 (0.0003)	-12.92771 (0.0023)	-1.31465 (0.7220)
Variance Equation				
Mean constant	7.97E-07 (0.0001)	1.78E-07 (0.0007)	1.37E-06 (0.0001)	5.26E-07 (0.0000)
ARCH	0.019289 (0.0001)	0.05374 (0.0000)	0.034073 (0.0000)	0.044808 (0.0000)
GARCH	0.941073 (0.0000)	0.938997 (0.0000)	0.955361 (0.0000)	0.946224 (0.0000)
Log Likelihood	5564.983	6161.294	6428.736	8866.433

Table 19 reports the results of First Stage of ARMA-GARCH in mean model (Equation 15 and Equation 16) run on the return series of commodities traded on domestic commodity exchange. This is run to estimate the standardised residual which is used in the second stage of the model. The table clearly shows significant ARCH and GARCH effects in return series of the four commodities traded on domestic commodity exchange.

4.4.1.2 First Stage of Model-II

Similarly Table 20 reports the results of First Stage of ARMA-GARCH in mean model (Equation 17 and Equation 18) run on the returns of commodities traded on international commodity exchanges. This is run to estimate the standardised residual which is used in the second stage of the model.

Table 20: First Stage (International Exchange) (Equation 17 and 18) of ARMA-GARCH in Mean Model

Dependent Variable – Return on Futures Price of commodity traded on International exchange	Soy oil (i)	Crude Palm oil (ii)	Natural Gas (iii)	Crude Oil (iv)
Mean Equation				
Mean constant	-3.61E-05 (0.9181)	0.000412 (0.1079)	-0.000345 (0.5272)	0.000652 (0.0055)
Coefficient of AR(1)	-0.744896 (0.0000)	0.695768 (0.2794)	-0.729867 (0.0000)	0.002603 (0.9953)
Coefficient of MA(1)	0.690297 (0.0001)	-0.679875 (0.3029)	0.666076 (0.0000)	-0.047971 (0.9141)
Coefficient of GARCH	7.409659 (0.5120)	-5.425979 (0.3277)	2.646497 (0.4631)	-6.205282 (0.0527)
Variance Equation				
Mean constant	3.61E-07 (0.0015)	2.80E-07 (0.0004)	1.84E-06 (0.0001)	7.66E-07 (0.0000)
ARCH	0.032673 (0.0000)	0.042586 (0.0000)	0.043813 (0.0000)	0.046329 (0.0000)
GARCH	0.954961 (0.0000)	0.952185 (0.0000)	0.945549 (0.0000)	0.942836 (0.0000)
Log Likelihood	5272.758	5564.733	6275.144	8524.435

The standardised residuals derived from first stage are used in the second stage of the model in the mean equation of the model. Squared standardised residuals are included in the variance equation of the second stage of the model. Standardised residuals and squared standardised residuals are a proxy for un-observed innovation in foreign market in part one of the model (Model 4.4.2.1), this considers international commodity exchange as foreign market and here domestic commodity exchange is considered as home market. While part two of the model (Model 4.2.2), considers domestic commodity exchange as foreign market and international commodity exchange is considered as home market.

4.4.2.1 Second Stage Stage of Model - I

To assess the impact of international commodity exchange on domestic commodity exchange

Table 21: Second Stage - ARMA GARCH in Mean Model (Equation 19 and 20)

Dependent Variable - Return on Futures Price of commodity traded on domestic exchange	Soy oil (i)	Crude Palm oil (ii)	Natural Gas (iii)	Crude Oil (iv)
Mean Equation				
Mean constant	0.000413 (0.1493)	0.000384 (0.0457)	-0.00057 (0.1135	0.000582 (0.0000)
Coefficient of AR(1)	-0.029715 (0.9201)	0.914796 (0.0000)	0.03967 (0.7200)	0.003024 (0.0000)
Coefficient of MA(1)	-0.064431 (0.8266)	-0.869071 (0.0000)	-0.24705 (0.0230)	-0.36284 (0.0000)
Coefficient of GARCH	-18.99356 (0.2197)	-15.01201 (0.1094)	3.856941 (0.2138)	-5.663172 (0.0278)
Residual of International Exchange (t-1)	0.001188 (0.0000)	0.000217 (0.0738)	0.002635 (0.0000)	0.003024 (0.0000)
Variance Equation				
Mean constant	-3.00E-07 (0.0000)	-5.29E-07 (0.0000)	-4.76E-06 (0.0000)	8.72E-06 (0.0000)
ARCH	0.008692 (0.0003)	0.026546 (0.0000)	0.006252 (0.1292)	0.142133 (0.0000)
GARCH	0.968577 (0.0000)	0.955333 (0.0000)	0.960896 (0.0000)	0.072308 (0.0000)
Square of Residual of International Exchange(t-1)	7.15E-07 (0.0000)	9.20E-07 (0.0000)	9.01E-06 (0.0000)	3.66E-05 (0.0000)
Log Likelihood	5633.381	6216.437	6583.231	9248.207

Table 21 presents the results of the second stage of ARMA-GARCH in mean model (Equation 19 and Equation 20) with return on futures price of commodities traded on domestic commodity exchange as the dependent variable. The mean equation includes AR term, MA term and GARCH term. The mean equation of the model also includes lagged standardised residual (standardised residuals obtained from ARMA-GARCH in mean model of commodities traded on international commodity exchange-Table 20 – First stage) .The variance equation in the model includes ARCH and GARCH term. The variance equation of the model also contains lagged squared standardised residual (obtained from first stage). These residuals are included to assess the impact of innovation in foreign market on home market.

It is found from the results of mean equation that the lagged standardised residual of soy oil, natural gas and crude oil traded on international commodity exchange influence returns of soy oil, natural gas and crude oil traded on domestic commodity exchange respectively, thus suggesting that commodities(soy oil, natural gas and crude oil) traded on international commodity exchange have mean spill-over effects of innovation on return of commodities(soy oil, natural gas and crude oil) traded on corresponding domestic commodity exchange.

From the variance equation, ARCH effects are found to be significant in soy oil, crude palm oil and crude oil. ARCH effects are not observed to be significant in case of return series of natural gas traded on domestic commodity exchange. Whereas, GARCH effects are seen to be significant for the four commodities. The coefficient of lagged squared standardised residual for the four commodities is found to be significant in the variance equation, implying that soy oil, crude palm oil, natural gas and crude oil traded on international commodity exchange have volatility spill over effects of innovation on soy oil, crude palm oil, natural gas and crude oil traded on corresponding domestic commodity exchange respectively.

4.4.2.2 Second Stage of Model - II

To assess the impact of domestic commodity exchange on international commodity exchange

Table 22:Second Stage: ARMA-GARCH in Mean Model (Equation 21 and 22)

Dependent Variable - Return on Futures Price of commodity traded on International exchange	Soy oil (i)	Crude Palm oil (ii)	Natural Gas (iii)	Crude Oil (iv)
Mean Equation				
Mean constant	0.000129 (0.7114)	0.000406 (0.0770)	-0.00027 (0.1757)	0.000415 (0.0000)
Coefficient of AR(1)	0.230251 (0.3066)	-0.664402 (0.0000)	0.005865 (0.8770)	0.069906 (0.0579)
Coefficient of MA(1)	-0.329273 (0.1294)	0.582247 (0.0000)	-0.385287 (0.0000)	-0.47329 (0.0000)
Coefficient of GARCH	1.879568 (0.8684)	-6.92143 (0.1899)	2.004211 (0.2012)	-0.807148 (0.5033)
Residual of domestic exchange (t-1)	0.000472 (0.0042)	0.000927 (0.0000)	0.003993 (0.0000)	0.002782 (0.0000)
Variance Equation				
Mean constant	3.11E-07 (0.0202)	-4.47E-07 (0.0002)	1.84E-05 (0.0000)	3.23E-06 (0.0000)
Coefficient of ARCH	0.035636 (0.0000)	0.037315 (0.0000)	0.087608 (0.0000)	0.194585 (0.0000)
Coefficient of GARCH	0.948643 (0.0000)	0.947196 (0.0000)	0.033293 (0.0000)	0.232083 (0.0000)
Square of Residual of domestic exchange (t-1)	1.76E-07 (0.1720)	1.18E-06 (0.0000)	0.000141 (0.0000)	4.68E-05 (0.0000)
Log Likelihood	5269.75	5597.706	6751.235	8816.495

Table 22 presents the results of the second stage of ARMA-GARCH in mean model (Equation 21 and Equation 22) with return on futures price of commodities traded on international commodity exchange (here home market is international commodity exchange) as the dependent variable. The mean equation includes AR term, MA term and GARCH term. The mean equation of the model also includes lagged standardised residual (standardised residuals obtained from ARMA-GARCH in mean model of commodities traded on domestic commodity exchange-Table 19.The variance equation in the model includes ARCH and GARCH term. The variance equation of full model also contains lagged squared standardised residual (obtained from first stage of model). These residuals are included to assess the impact of innovation in foreign market on home market.

It is found from the results of mean equation that the lagged standardised residual of soy oil, crude palm oil, natural gas and crude oil traded on domestic commodity exchange influence returns of soy oil, crude palm oil, natural gas and crude oil traded on corresponding international commodity exchange respectively (p value is less than 0.05). Thus suggesting that soy oil, crude palm oil, natural gas and crude oil traded on domestic commodity exchange have mean spill-over effects of innovation on return of soy oil, crude palm oil, natural gas and crude oil traded on corresponding international commodity exchange.

From the variance equation, for all the four commodities price return series, ARCH and GARCH effects are found to be significant. The coefficient of lagged squared standardised residual for crude palm oil, natural gas and crude oil traded is found to be significant in the variance equation. Whereas coefficient of lagged squared standardised residual for soy oil is found to be insignificant. This implies that crude palm oil, natural gas and crude oil traded on domestic exchange have volatility spill over effects of innovation on crude palm oil, natural gas and crude oil traded on corresponding international commodity exchange.

5. Conclusion

The findings of the three models discussed in the study can be summarised as follows. The price series of each of the four pairs of commodities (soy oil, crude palm oil, natural gas and crude oil) traded on domestic exchange(soy oil – NCDEX and crude palm oil, natural gas, crude oil – MCX) and international commodity exchange(soy oil – CBOT, crude palm oil – Bursa Malaysia Derivative Exchange, natural gas and crude oil – NYMEX) are found to be co-integrated implying that there exists a long run relationship between futures contracts of soy oil, crude palm oil, natural gas and crude oil traded on domestic commodity exchanges of India and contracts on these commodities traded on corresponding international commodity exchanges respectively.

A deviation of futures price from its equilibrium long run level is corrected in case of crude oil futures contracts traded on MCX and NYMEX respectively. Whereas for soy oil and crude palm oil, deviation from equilibrium is corrected in case of futures contracts traded on domestic commodity exchange of India and not in case of futures contracts traded on international commodity exchange. For natural gas, deviation from equilibrium is corrected in case of futures contracts traded on international commodity exchange (NYMEX) and not in case of futures contract traded on domestic commodity exchange (MCX).

For soy oil and crude oil, causality in price runs in one direction, from futures contracts traded on international commodity exchange to futures contracts on domestic commodity exchange of India but not in the opposite direction that is from domestic commodity exchange to international commodity exchange. Whereas for natural gas, causality in price also runs in one direction, but from futures contracts traded on domestic commodity exchange to futures contracts on international commodity exchange. Short term causality in futures price of crude palm oil is observed to run in both the directions, from MCX to Bursa Malaysia Derivative Exchange and vice versa.

Using the variants of modified GARCH model, it is found that the return and volatility on futures prices for soy oil, crude palm oil, natural gas and crude oil traded on domestic exchange are influenced by contracts traded on corresponding international commodity exchanges. The returns on futures price of soy oil, crude palm oil, natural gas and crude oil traded on international commodity exchange are affected by futures contracts traded on domestic exchange respectively. Whereas the return volatility of crude palm oil, natural gas and crude oil traded on international commodity exchange are affected by futures contracts traded on corresponding domestic commodity exchange. The return volatility of soy oil traded on CBOT remains unaffected by return volatility of soy oil traded on NCDEX.

The results of the ARMA-GARCH in mean model indicate that there is mean spill over effect of innovation from futures contracts traded on international commodity exchange towards the futures contracts traded on domestic commodity exchange for soy oil, natural gas and crude oil when lagged standardised residuals are included in the mean equation. Whereas, volatility spill over effect of innovation from futures contracts traded on international commodity exchange to futures contracts traded on domestic commodity exchange is significant in case of the four commodities when lagged squared standardised residuals are included in the variance equation. In case of futures contracts traded on international commodity exchange, mean spill over effect of innovation from futures contracts traded on domestic commodity exchange towards the futures contracts traded on international commodity exchange is observed for soy oil, crude palm oil, natural gas and crude oil when lagged standardised residuals are included in the mean equation. Whereas, volatility spill over effect of innovation from futures contracts traded on domestic commodity exchange to futures contracts traded on international commodity exchange is significant in case of crude palm oil, natural gas and crude oil when lagged squared standardised residuals are included in the variance equation. The volatility spill over effect of innovation of futures contracts traded on NCDEX on futures contracts traded on CBOT is insignificant for soy oil.

Thus, given the level of integration of prices, return and volatility in futures contracts of agri-processed and energy commodities traded on domestic commodity exchanges of India and corresponding international commodity exchange. The policy decision proposed by Indian Government to impose Commodity Transaction Taxes on sellers of commodity futures (agri-processed and energy commodities) is likely to result in fall in trading volume of commodities as participants of the exchange would prefer investing in international Markets (e.g. CBOT, Bursa Malaysia Derivative Exchange and NYMEX) instead of Indian Markets (e.g. NCDEX, MCX) in order to escape the higher cost of transaction. This movement from Indian to the International commodity markets would defeat the aim of the government of enhancing revenue by imposition of commodity transaction tax. This movement away from the domestic commodity exchanges would go against the objective of price discovery in the commodity exchanges in India, due to lower trading volume.

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