Linkages between Gold Futures Traded in Indian Commodity Futures Market and International Commodity Futures Market

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Abstract

Given that gold futures contracts are one of the most actively traded commodity futures in the Indian Commodity market, it is of crucial importance to study the price, return and volatility spillover behaviour of gold traded in the Indian commodity market with respect to the International commodity market. The current study tries to study the linkages in Gold futures which are traded on Indian commodity exchange – Multi Commodity Exchange (MCX) and International commodity exchange – New York Mercantile Exchange are analysed. The study attempts to demonstrate the linkages in price, return and volatility across the two markets for the precious metal 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. Empirical analysis indicates that there is a presence of a long run relationship between prices of Gold futures contracts traded in MCX and NYMEX. Apart from cointegration in prices, return and volatility spillovers between MCX and NYMEX are found to be significant and bi-directional.

Keywords: Futures, Gold, Spillover, Transaction costs

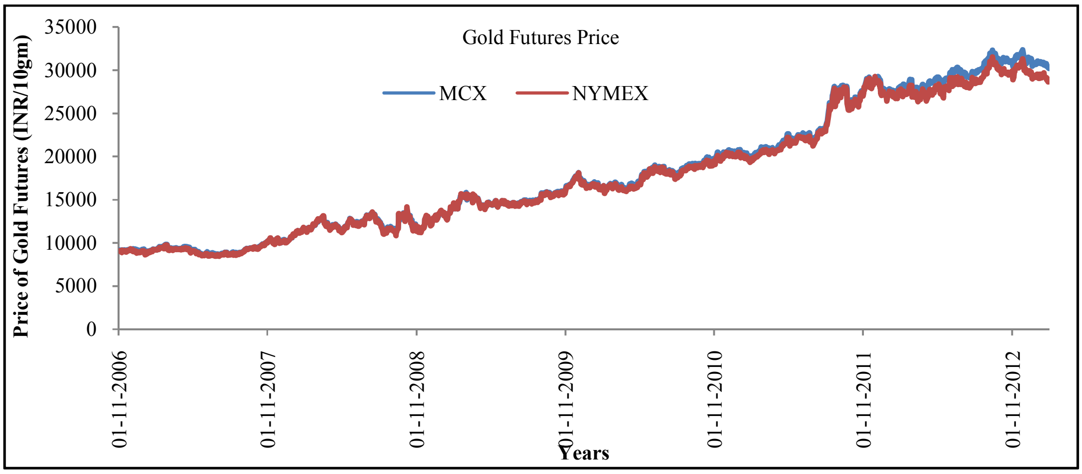
JEL Codes: G15, G14, Q02, L61

1 Introduction

Over the years, India has continued to play a significant role in the global production chain of precious metals including gold and silver. The Forwards Market Commission initiated trading in gold and silver futures on Indian Commodity exchanges in 2003-04. In 2012-13, Gold was traded at Multi Commodity Exchange (MCX) and Indian Commodity Exchange (ICEX). Various contracts were traded on the commodity exchanges including Gold (1kg), Gold (100 gms), Gold Mini (10gms), Gold Guinea (8 gms), and Gold Petal (1gm).

In this study, the linkages in Gold futures which are traded on Indian commodity exchange – Multi Commodity Exchange (MCX) and International commodity exchange – New York Mercantile Exchange are analysed. The study attempts to demonstrate the linkages in price, return and volatility across the two markets for the precious metal 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.

The study uses futures price of Gold futures traded Multi Commodity Exchange (MCX) and New York Mercantile Exchange (NYMEX) for the period of study November 1, 2006 to January 30, 2013. Figure 1 demonstrates the co-movement in futures prices of the gold traded on the MCX NYMEX of US. From the figure it can be observed that the futures prices of gold (traded on MCX and NYMEX) move in tandem with each other.



Source: Authors Work

Figure 1: Comovements in Futures Prices of Gold traded on MCX and NYMEX

2 Literature Review

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 chapter, we discuss the studies pertaining to linkages with respect to gold.

Aruga and Managi (2011a) checked whether law of one price holds true in case of Platinum and Palladium traded on US and Japanese futures market. Causality tests were also run during the study. The authors empirically prove that the US market leads the Japanese market in transmission of information. Aruga and Managi (2011b), in another study, investigated the law of one price and ran causality tests for Gold and Silver futures contracts traded on the US and Japanese exchanges. They found results of this study similar to their previous study on Platinum and Palladium.

A bivariate GARCH model is used by Xu and Fung (2005) to examine whether prices of futures contracts of Gold, Silver and Platinum traded in US (NYMEX) and Japan (TOCOM) are linked. They utilise both daily and intraday data points for the study. They conclude that volatility spillover effects for Gold run in both directions, from US to Japan and vice versa. In case of Platinum and Silver futures, the US has a stronger effect on Japan. The intraday data analysis depicts that information from the foreign market is confined in the domestic market to within one day of trading.

Dhillon et al. (1997) also study the futures market of Gold traded on US and Japanese futures market using regression of returns and comparisons of intraday volatilities. Kumar and Pandey (2011) analyse the cross market linkages in terms of return and volatility spillovers 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 co-integration 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 spillover. They find that for all nine commodities co-integration 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 spillover exists in case of agricultural commodities, Gold, Aluminium and Zinc, whereas unidirectional volatility spillover exists in Crude Oil.

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 co-integration 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.

Sahoo and Kumar (2008) use a three equation structural model to examine the relationship between transaction cost, volatility and trading activity of commodity futures traded in India. The commodities studied include Gold, Copper, Crude Oil, Soya Oil, and Chana. The authors bring out the impact of the imposition of the commodities transaction tax by assuming a change in transaction cost. In the study, a levy of 0.017% of CTT leads to a rise in transaction cost of Rs 2.00 per lakh to Rs 19.25 per lakh and the transaction cost is proxied by increase in bid ask spread. The authors run simulations for three situations, i.e., imposition of tax by 0.0125%, 0.017% and 0.02%. The study concludes that an indirect relationship exists between transaction cost and trading volume and a direct relationship exists between transaction cost and volatility. Soya oil, and chana are found to have the least impact of the levying of CTT, which is attributed to the commodities being traded domestically.

Applying the VAR-GARCH model Mensi et al (2013) analyse the influence of S&P 500 on the commodity price indices including gold, energy, food, as well as beverage. They find that there exists a transmission between S&P 500 and the four indices. Fluctuations in S&P 500 are found to have an impact on the prices of oil and gold.

Zhang and Wei (2010) try to understand the price spillover from the oil market to the gold market and vice versa by using Granger causality tests for the period ranging from January 4, 2000 to March 31, 2008. They find that there exists a cointegration relationship between the two commodities and find that there exists one way causality from oil to gold prices and not vice versa.

3 Data and Methodology

The study uses futures price of Gold futures traded Multi Commodity Exchange (MCX) and New York Mercantile Exchange (NYMEX) for the period of study November 1, 2006 to January 30, 2013.

The near month futures prices are chosen for the period of study, they are the most traded contracts in commodity exchanges. Data for futures prices of Gold has been extracted from Bloomberg. Exchange rate for conversion to INR from NYMEX in US Dollar has been taken from Data Base for Indian Economy, RBI.

Table 1 shows the summary statistics of the prices of futures contracts in gold traded on MCX and NYMEX in the period chosen for the study.

Table 1: Summary Statistics of Prices of Gold Futures Contracts traded on NYMEX and MCX

Summary Statistics	Futures Price of Gold traded on MCX	Futures Price of Gold traded on NYMEX
Mean	18030.24	17705.75
Median	16595	16354.55
Maximum	32359	31542.42
Minimum	8597	8453.845
Std. Dev.	7262.8	6953.097
Skewness	0.489	0.443

Kurtosis	1.951	1.905
Jarque-Bera	125.661	121.145
Probability	(0.0000)	(0.0000)
ADF(4,t)^	-2.753	-3.013

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

Table 1 includes the results of the unit root test (ADF test) conducted on the price series of gold futures traded on MCX and NYMEX, respectively. The price series is found to be non-stationary (contain a unit root) at level.

3.1 Linkages in price of Gold traded across exchanges

The price series are found to be non-stationary at level and stationary at first difference, this indicates that the futures price series follow the I(1) process. Thus, Johansen's co-integration test is considered suitable to model the relationship between the futures price series of gold traded at MCX and NYMEX. The co-integration test is followed by modelling the relationship between futures price series into Error Correction Mechanism Model (ECM). The ECM model for the futures price series can be represented as:

$$\Delta PAUMCX_t = a_{10} + b_{IND}\,ECM_{t-1} + \sum_{i=1}^{p} c_{1i}\,\Delta PAUMCX_{t-i} + \sum_{i=1}^{p} d_{1i}\,\Delta PAUNYMEX_{t-i} + \epsilon_{1t} \quad (Equation\ 1)$$

$$\Delta PAUNYMEX_t = a_{20} + b_{INT}\,ECM_{t-1} + \sum_{i=1}^{p} c_{2i}\,\Delta PAUMCX_{t-i} + \sum_{i=1}^{p} d_{2i}\,\Delta PAUNYMEX_{t-i} + \epsilon_{2t} \quad (Equation\ 2)$$

Where, PAUMCX and PAUNYMEX represent the futures price series of gold traded on the MCX and NYMEX, respectively. ECM_{t-1} is the error correction term in the two equations. The coefficients of the error correction term are b_{IND} and b_{INT} in Equation 1 and Equation 2, respectively, and they measure the speed of adjustment at which deviation for long run relationship between the price series is corrected by change in price of the two markets. ε_{1t} and ε_{2t} are stationary disturbances. The coefficients of $\Delta PAUMCX_{t-i}$ and $\Delta PAUNYMEX_{t-i}$ in Equation 1 and Equation 2 respectively, represent short run adjustments in futures price of commodities.

3.2 Linkages in return on Gold traded across exchanges

For the next three sub sections (3.2, 3.3, 3.4) returns (calculated using futures prices) of Gold are utilised. Return is calculated as the log difference in price. Subsequently, stationarity of return series is checked using Augmented Dickey Fuller Test.

Rolling Correlations Curve

Rolling correlations assess the time varying relationships between futures markets and are adopted in the current study to examine the time varying relationship between return on MCX and corresponding NYMEX for Gold. In case of rolling correlations, the correlation of first 60 observations is estimated. This is followed by dropping of the earliest observation and inclusion of a new data point, and calculating correlation. 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 considered to be a considerable period to capture changes in the futures market. Thus, using these correlations, rolling correlation curve is plotted for Gold.

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 Gold futures traded in International commodity exchange on the return and volatility of Gold futures traded in Indian 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 utilised for maximum likelihood estimation in the three models. In the full model and the pure volatility model, squared returns (calculated by squaring of returns) are used in the variance equation as a measure of volatility in the foreign market.

3.3.1 *Full Model*

In this variant of the model we try to assess the impact of lagged return of Gold futures traded on domestic market and the impact of return of Gold traded on foreign market on the current return of Gold traded on domestic market. It also tries to capture the impact of past return volatility of Gold traded on domestic market (GARCH effect) and impact of return volatility of Gold traded on foreign market on volatility of Gold traded on domestic market.

The full model is estimated once considering MCX as domestic market and the NYMEX as the foreign market (Full Model I: Equation 3 and Equation 4). The same model is also estimated considering NYMEX as domestic market and MCX as foreign market (Full Model II: Equation 5 and Equation 6).

The following two equations represent the model when we consider MCX to be domestic market and NYMEX to be foreign market:

Full Model -I
Mean equation: $r_{IND,t} = k_1 + k_2 r_{IND,t-1} + k_3 r_{INT,t} + \varepsilon_{IND,t}$; $\varepsilon_{IND,t} \sim N(0, h_{IND,t})$ (Equation.3)
Variance equation: $h_{IND,t} = k_4 + k_5 \varepsilon^2_{IND,t-1} + k_6 h_{IND,t-1} + k_7 r^2_{INT,t}$ (Equation 4)

Where $r_{IND,t}$ and $r_{INT,t}$ are current returns on price of a Gold traded on MCX and Gold traded on NYMEX at time t respectively in the mean equation (Equation 3). $r_{IND,t-1}$ is lagged return of a Gold traded on MCX. The coefficient of lagged return Gold traded on MCX is k_2 and the coefficient of Gold traded on NYMEX is k_3. $h_{IND,t}$ represents the volatility in Gold traded on MCX in the variance equation (Equation 4). $\varepsilon^2_{IND,t-1}$ and $h_{IND,t-1}$ represent ARCH and GARCH effects respectively. The coefficients of ARCH and GARCH terms are k_5 and k_6 in Equation 4 (variance equation). $r^2_{INT,t}$ represents the squared returns of Gold traded on NYMEX. The coefficient of squared return of Gold traded on NYMEX is k_7.

The following two equations (Full Model II: Equation 5 and Equation.6) represent the model when we consider NYMEX to be the domestic market and MCX to be foreign market:

Full Model -II
Mean equation: $r_{INT,t} = k_8 + k_9 r_{INT,t-1} + k_{10} r_{IND,t} + \varepsilon_{INT,t}$; $\varepsilon_{INT,t} \sim N(0, h_{INT,t})$ (Equation 5)
Variance equation: $h_{INT,t} = k_{11} + k_{12} \varepsilon^2_{INT,t-1} + k_{13} h_{INT,t-1} + k_{14} r^2_{IND,t}$ (Equation 6)

Where $r_{IND,t}$ and $r_{INT,t}$ are returns on Gold traded on MCX and Gold traded on NYMEX at time t, respectively, in the mean equation (Equation 5). $r_{INT,t-1}$ is lagged return on Gold traded on NYMEX. The coefficient of lagged return of Gold traded on NYMEX is k_9 and the coefficient of return of Gold traded on MCX is k_{10}. $h_{INT,t}$ represents the volatility of Gold traded on NYMEX in the variance equation (Equation 6). $\varepsilon^2_{INT,t-1}$ and $h_{INT,t-1}$ represent ARCH and GARCH effects, respectively. The coefficients of ARCH and GARCH terms are k_{12} and k_{13} in Equation 6 (variance equation). $r^2_{IND,t}$ represent the squared returns of Gold traded on MCX (used as a proxy for volatility in foreign market in this variant). The coefficient of squared return of Gold traded on MCX is k_{14}.

3.3.2 *Pure Mean Model*

The Pure Mean model focuses on the impact of lagged return of Gold traded in the domestic market and impact of return of Gold traded in the foreign market on the return of Gold traded in the domestic market. This specification captures ARCH and GARCH effect but ignores the possible transmission of volatility from one market to the other.

The Pure Mean model is estimated once considering MCX as the domestic market and NYMEX as the foreign market (Pure Mean Model I: Equation 3 and Equation 7). The Pure Mean model is also estimated considering the NYMEX as domestic market and the MCX as foreign market (Pure Mean Model II: Equation 5 and Equation 8)

The following two equations represent the Pure Mean model (Pure Mean Model – I) when we consider MCX to be domestic market and NYMEX market to be foreign market:

Pure Mean Model - I

Mean equation: $r_{IND,t} = k_1 + k_2 r_{IND,t-1} + k_3 r_{INT,t} + \varepsilon_{IND,t}$; $\varepsilon_{IND,t} \sim N(0, h_{IND,t})$ (Equation 3)

Variance equation: $h_{IND,t} = k_4 + k_5 \varepsilon_{2IND,t-1} + k_6 h_{IND,t-1}$ (Equation 7)

Where $r_{IND,t}$ and $r_{INT,t}$ are returns on price of a Gold traded on MCX and NYMEX at time t, respectively, in the mean equation (Equation 3). $r_{IND,t-1}$ is lagged return of Gold traded on MCX. The coefficient of lagged return of Gold traded on MCX is k_2 and the coefficient of return of Gold traded on NYMEX is k_3. $h_{IND,t}$ represents the volatility in MCX in the variance equation (Equation 7). $\varepsilon^2_{IND,t-1}$ and $h_{IND,t-1}$ represent ARCH and GARCH effects respectively. The coefficients of ARCH and GARCH terms are k_5 and k_6 in Equation 7 (variance equation).

The following two equations (Equation 5 and Equation 8) represent the Pure Mean Model (Pure Mean Model – II) when we consider NYMEX to be domestic market and MCX to be foreign market:

Pure Mean Model - II

Mean equation: $r_{INT,t} = k_8 + k_9 r_{INT,t-1} + k_{10} r_{IND,t} + \varepsilon_{INT,t}$; $\varepsilon_{INT,t} \sim N(0, h_{INT,t})$(Equation 5)

Variance equation: $h_{INT,t} = k_{11} + k_{12} \varepsilon^2_{INT,t-1} + k_{13} h_{INT,t-1}$ (Equation 8)

Where $r_{IND,t}$ and $r_{INT,t}$ are returns on price of Gold traded on MCX and NYMEX at time t, respectively, in the mean equation (Equation 5). $r_{INT,t-1}$ is lagged return of Gold traded on NYMEX. The coefficient of lagged return of Gold traded on NYMEX is k_9 and the coefficient of return of Gold futures traded on MCX is k_{10}. $h_{INT,t}$ represents the volatility in NYMEX in the variance equation (Equation 8). $\varepsilon^2_{INT,t-1}$ and $h_{INT,t-1}$ represent ARCH and GARCH effects respectively. The coefficients of ARCH and GARCH terms are k_{12} and k_{13} in Equation 8 (variance equation).

3.3.3 *Pure Volatility Model*

This model concentrates on the impact of lagged return volatility of Gold futures traded in domestic market and the impact of current volatility of Gold futures traded in foreign market on today's volatility of Gold futures traded in the domestic market. The mean equation includes the impact of yesterday's return of Gold futures traded in the domestic market on today's return and ignores the possible effect of return in foreign market on today's return on Gold futures traded in the domestic market.

The Pure Volatility model is estimated once considering MCX market as the domestic market and the NYMEX as the foreign market (Pure Volatility Model I: Equation 9 and Equation 4). The same model is also estimated considering the NYMEX as domestic market and MCX as foreign market (Pure Volatility Model II: Equation 10 and Equation 6).

The following two equations represent the model (Pure Volatility Model – I) when we consider MCX to be domestic market NYMEX to be the foreign market.

Pure Volatility Model - I
Mean equation: $r_{IND,t}= k_1 + k_2 r_{IND,t-1} + \varepsilon_{IND,t}$ $\quad \varepsilon_{IND,t} \sim N(0, h_{IND,t})$ (Equation 9)
Variance equation: $h_{IND,t}= k_4 + k_5\varepsilon^2_{IND,t-1} + k_6 h_{IND,t-1} + k_7 r^2_{INT,t}$ (Equation 4)

Where $r_{IND,t}$ represents returns on price of Gold futures traded on MCX at time t in the mean equation (Equation 9). $r_{IND,t-1}$ is lagged return of Gold futures traded on MCX. The coefficient of lagged return of Gold futures traded on MCX is k_2. $h_{IND,t}$ represents the volatility in Gold futures market in the variance equation (Equation 4). $\varepsilon^2_{IND,t-1}$ and $h_{IND,t-1}$ represent ARCH and GARCH effects respectively. The coefficients of ARCH and GARCH terms are k_5 and k_6 in Equation 4 (variance equation). $r^2_{INT,t}$ represents the squared returns of Gold futures traded on NYMEX (used as proxy for volatility in foreign market in this variant). The coefficient of squared return of Gold futures traded on NYMEX is k_7.

The following two equations represent the model (Pure Volatility Model – II) when we consider NYMEX to be the domestic market and MCX to be the foreign market:

Pure Volatility Model - II
Mean equation: $r_{INT,t} = k_8 + k_9 r_{INT,t-1} + \varepsilon_{INT,t}$; $\varepsilon_{INT,t} \sim N(0, h_{INT,t})$(Equation 10)
Variance equation: $h_{INT,t} = k_{11} + k_{12}\varepsilon^2_{INT,t-1} + k_{13}h_{INT,t-1} + k_{14}r^2_{IND,t}$ (Equation.6)

Where $r_{IND,t}$ and $r_{INT,t}$ represent current returns of Gold futures traded on MCX and NYMEX at time t, respectively. $r_{INT,t-1}$ is lagged return of Gold futures traded on the NYMEX in the mean equation (Equation 10). The coefficient of lagged return of Gold futures traded on NYMEX is k_9. $h_{INT,t}$ represents the volatility in NYMEX in the variance equation (Equation 6). $\varepsilon^2_{INT,t-1}$ and $h_{INT,t-1}$ depict ARCH and GARCH effects respectively. The coefficients of ARCH and GARCH terms are k_{12} and k_{13} in Equation 6 (variance equation). $r^2_{IND,t}$ represents the squared returns of Gold futures traded on MCX (used as proxy for volatility in the foreign market in this variant). The coefficient of squared return of Gold futures traded on MCX is k_{14}.

3.4 ARMA – GARCH in mean model - Innovations Model

In this part of the study, two stage modified GARCH models are utilised to examine the linkage between returns and volatility of futures price of Gold across MCX and NYMEX[1]. In the first stage, return series of Gold futures is modelled using ARMA(1)-GARCH(1,1) in mean model (a conditional variance term is an explanatory variable in the mean equation).

First stage of the model for Gold traded on MCX:
Mean equation: $r_{IND,t} = n_1 + n_2 r_{IND,t-1} + n_3\varepsilon_{IND,t-1} + n_4 h_{IND,t} + \varepsilon_{IND,t}$; $\varepsilon_{IND,t} \sim N(0, h_{IND,t})$ (Equation 11)
Variance equation: $h_{IND,t} = n_5 + n_6\varepsilon^2_{IND,t-1} + n_7 h_{IND,t-1}$ (Equation 12)

Where $r_{IND,t}$ represents return of Gold futures traded on MCX market at time t. $r_{IND,t-1}$ is term for lagged return on Gold futures traded on MCX, this is the auto regressive term (AR), while $\varepsilon_{IND,t-1}$ is the moving average (MA) term in the mean equation (Equation 11). n_2 and n_3 are coefficients of AR and MA terms. n_4 is the coefficient of the conditional variance term in the mean equation. $\varepsilon_{IND,t}$ is the residual term. $h_{IND,t}$ describes the return volatility in Gold futures traded in MCX in

[1] To check whether or not GARCH models can be employed for the commodity daily return series, ARCH-LM tests were performed using the commodity daily return series.

variance equation (Equation 12). $\varepsilon^2_{IND,t-1}$ and $h_{IND,t-1}$ represent ARCH and GARCH terms in the variance equation. n_6 and n_7 are the coefficients of ARCH and GARCH terms respectively.

The first stage of the model for Gold futures traded on NYMEX is described with the model specification given below in Equation 13 and Equation 14.

First stage of the model for Gold traded on NYMEX:
Mean equation: $r_{INT,t} = n_8 + n_9 r_{INT,t-1} + n_{10}\varepsilon_{INT,t-1} + n_{11}h_{INT,t} + \varepsilon_{INT,t}$; $\varepsilon_{INT,t} \sim N(0,h_{INT,t})$ (Equation 13)
Variance equation: $h_{INT,t} = n_{12} + n_{13}\varepsilon^2_{INT,t-1} + n_{14}h_{INT,t-1}$ (Equation 14)

Where $r_{INT,t}$ describes current return on Gold futures traded on NYMEX at time t. $r_{INT,t-1}$ are lagged returns on Gold futures traded on NYMEX, this is the auto regressive (AR) term, while $\varepsilon_{INT,t-1}$ is the moving average term (MA) in mean equation (Equation 13). n_9 and n_{10} are coefficients of AR and MA terms. n_{11} is the coefficient of the conditional variance term in the mean equation. $\varepsilon_{INT,t}$ is the residual term. $h_{INT,t}$ describes the return volatility in Gold futures traded in NYMEX in variance equation (Equation 14). $\varepsilon^2_{INT,t-1}$ and $h_{INT,t-1}$ represent ARCH and GARCH terms in the variance equation. n_{13} and n_{14} are the coefficients of ARCH and GARCH terms, respectively.

A standardised residual series is obtained after running the ARMA(1)-GARCH(1,1) in mean model specified in Equation 11 and Equation 12 for Gold traded on MCX. Similarly, a standardised residual series is obtained after running the ARMA(1)-GARCH(1,1) in mean model specified in Equation 13 and Equation 14 for Gold traded on NYMEX.

This is followed by squaring of the two standard residual series obtained to attain the respective squared standardised residual series. This completes the first stage of the model. The first stage of the model is run for both the return series (MCX and NYMEX).

The second stage of the model involves the estimation of return and volatility spillover effects of Gold futures traded across the two 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 Gold futures traded on MCX (from the first stage) are used in second stage of commodity futures traded on 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 return spillover effect from these markets, while the squared residual series in the variance equation is used to capture the volatility spillover effect. The model of the second stage (model specification for Gold futures traded on MCX – Equation 15 and Equation.16) is as follows:

Second Stage-To assess the impact of Gold futures traded on NYMEX on the Gold futures traded on MCX:
Mean equation: $r_{IND,t} = w_1 + w_2 r_{IND,t-1} + w_3 \varepsilon_{IND,t-1} + w_4 h_{IND,t} + w_5 e_{INT,t} + \varepsilon_{IND,t}$; $\varepsilon_{IND,t} \sim N(0, h_{IND,t})$ (Equation 15)
Variance equation: $h_{IND,t} = w_6 + w_7 \varepsilon^2_{IND,t-1} + w_8 h_{IND,t-1} + w_9 e^2_{INT,t}$ (Equation 16)

Where $r_{IND,t}$ is return of Gold futures traded on MCX. $r_{IND,t-1}$ is lagged return on price of Gold futures traded on MCX, i.e., the auto regressive (AR) term in the equation. While $\varepsilon_{IND,t-1}$ is the moving average term (MA) in mean equation (Equation 15). w_2 and w_3 are coefficients of AR and MA terms, respectively. w_4 is the coefficient of the conditional variance term in the mean equation. $\varepsilon_{IND,t}$ is the residual term. $h_{IND,t}$ describes the return volatility in Gold futures traded in MCX in the variance equation (Equation 16). Equation 15 and Equation 16 use the standardised residual series ($e_{INT,t}$) and squared standardised residual series ($e^2_{INT,t}$), respectively, obtained from the first stage of Gold traded on NYMEX (model specified in Equation 13 and Equation 14). $\varepsilon^2_{IND,t-1}$ and $h_{IND,t-1}$ represent ARCH and GARCH terms in the variance equation respectively. The coefficients of ARCH and GARCH terms are w_7 and w_8 in Equation 16 (variance equation) respectively.

The model of the second stage (model specification for Gold futures traded on NYMEX – Equation 17 and Equation 18) is as follows:

Second Stage-To assess the impact of Gold traded on MCX on Gold futures traded on NYMEX:
Mean equation: $r_{INT,t} = w_{10} + w_{11} r_{INT,t-1} + w_{12} \varepsilon_{INT,t-1} + w_{13} h_{INT,t} + w_{14} e_{IND,t} + \varepsilon_{INT,t}$; $\varepsilon_{INT,t} \sim N(0, h_{INT,t})$ (Equation 17)
Variance equation: $h_{INT,t} = w_{15} + w_{16} \varepsilon^2_{INT,t-1} + w_{17} h_{INT,t-1} + w_{18} e^2_{IND,t}$ (Equation 18)

Where $r_{INT,t}$ are returns of Gold futures traded on NYMEX. $r_{INT,t-1}$ are lagged returns of Gold futures traded on NYMEX, i.e., the auto regressive (AR) term in the equation. While $\varepsilon_{INT,t-1}$ is the moving average term (MA) in mean equation (Equation 17). w_{11} and w_{12} are coefficients of AR and MA terms. w_{13} is the coefficient of the conditional variance term in the mean equation. $\varepsilon_{INT,t}$ is the residual term. $h_{INT,t}$ describes the return volatility in Gold futures traded in MCX in variance equation (Equation 18). Equation 17 and Equation 18 use the standardised residual series ($e_{IND,t}$) and squared standardised residual series ($e^2_{IND,t}$), respectively, obtained from the first stage of Gold traded on MCX (model specified in Equation 11 and Equation.12). $\varepsilon^2_{INT,t-1}$ and $h_{INT,t-1}$ represent ARCH and GARCH terms in the variance equation (Equation 18) respectively. The coefficients of ARCH and GARCH terms are w_{16} and w_{17}, respectively.

4 Empirical Results

4.1 Linkages in price of Gold traded across exchanges

Table 2 reports the results of Johansen Co-integration Test for Gold futures.

Table 2: Results of Johansen Co-integration Test

Gold	**Lags**	**Ho, r is number of co-integrating relation**	**Trace Statistic**	**Critical Value at 5%**	**Probability**	**Max Eigen Statistic**	**Critical Value at 5%**	**Probability**
	4	r≤0	25.186	15.495	0.001	25.186	14.265	0.001
		r≤1	0.0004	3.841	0.984	0.000	3.841	0.984

Coefficients marked in bold indicate rejection at 5% level of significance

From the above table, it can be said that both the trace statistics and max Eigen statistics show for Gold traded across the two commodity exchanges, near month futures price series are co-integrated with one co-integrating vector. This implies that the futures prices of Gold traded on MCX and NYMEX, 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 Gold using Error Correction Mechanism with one co-integration relation (r=1).

Results of Error Correction Mechanism Model

Table 3 demonstrates the result of ECM for futures price of Gold traded on MCX and NYMEX in the period chosen for the study from 1 November 2006 to 30 January 2013.

Table 3: ECM results for Gold (Equation 1 and Equation 2)

	Dependent variable - ΔPAUMCX		Dependent variable – ΔPAUNYMEX	
Independent variable	**Coefficient**	**p value**	**Coefficient**	**p value**
$ECM_{(t-1)}$	-0.015	(0.5005)	-0.0512	(0.0737)
$\Delta PAUMCX_{(t-1)}$	0.095	(0.0928)	-0.6011	(0.0000)
$\Delta PAUMCX_{(t-2)}$	-0.150	(0.0131)	-0.2354	(0.0002)
$\Delta PAUMCX_{(t-3)}$	-0.065	(0.2805)	-0.1433	(0.0211)
$\Delta PAUMCX_{(t-4)}$	-0.050	(0.3558)	-0.0541	(0.3189)
$\Delta PAUNYMEX_{(t-1)}$	-0.070	(0.1513)	0.6650	(0.0000)
$\Delta PAUNYMEX_{(t-2)}$	0.052	(0.3263)	0.1752	(0.0156)
$\Delta PAUNYMEX_{(t-3)}$	0.075	(0.1452)	0.1130	(0.117)
$\Delta PAUNYMEX_{(t-4)}$	0.054	(0.2365)	0.0886	(0.1751)
Constant	15.396	(0.0044)	12.4189	(0.0553)
Wald Test Result for short run causality (Chi Square and p value)	8.1595 (0.0859)		**100.4354** (0.0000)	

Coefficients marked in bold are significant at 5% significance level

In Table 3, Columns 2 and 3 present the results obtained from Equation 1 and Columns 4 and 5 present the results obtained from Equation 2, when futures prices of Gold traded on MCX and NYMEX are used. The table shows that ECM_{t-1} term is insignificant and negative in both the equations (Equation 1 and Equation 2) at 5% level.

Considering the short run dynamics, from the results of Wald Test conducted on the cross terms in Equation 1, we do not reject the hypothesis that they are simultaneously zero at the 5% level since the p value 0.0859 is more than 0.05. This suggests that there is an absence of short run causality from NYMEX Gold futures price to MCX Gold futures price. The Wald Test results conducted on the cross terms in Equation 1 reject the hypothesis that the coefficients are simultaneously zero at the 5% level, as the p value is less than 0.05. This leads to the conclusion that there is a presence of short run causality from MCX Gold futures price to NYMEX Gold futures price.

4.2 Linkages in return on Gold traded across exchanges

Table 4 demonstrates the summary statistics of returns on futures price of Gold traded on MCX and NYMEX.

Table 4: Summary Statistics of Returns on Gold Futures Contracts traded on NYMEX and MCX

Summary Statistics of Return Series	Return on Futures Price of Gold traded on MCX	Return on Futures Price of Gold traded on NYMEX
Mean	0.0008	0.0008
Median	0.0009	0.0010
Maximum	0.0812	0.0800
Minimum	-0.0640	-0.0647
Std. Dev.	0.0115	0.0142
Skewness	-0.1231	-0.1879
Kurtosis	8.9425	5.9478
Jarque-Bera	2160.755	539.4167
Probability	(0.0000)	(0.0000)
ADF(4,t)^	-18.102	-18.021

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

In Table 4, the mean daily returns for gold traded on MCX and NYMEX during the period from 1 November 2006 to 30 January 2013 is found to be averaging at 0.008. The distribution is leptokurtic for both the series since value of kurtosis is found to be more than 3. The return series for Gold traded on MCX and NYMEX are found to be stationary since there is absence of unit root at level.

Rolling Correlations Curves

Figure 2 depicts the rolling correlation between returns on futures price of Gold traded on MCX and NYMEX.

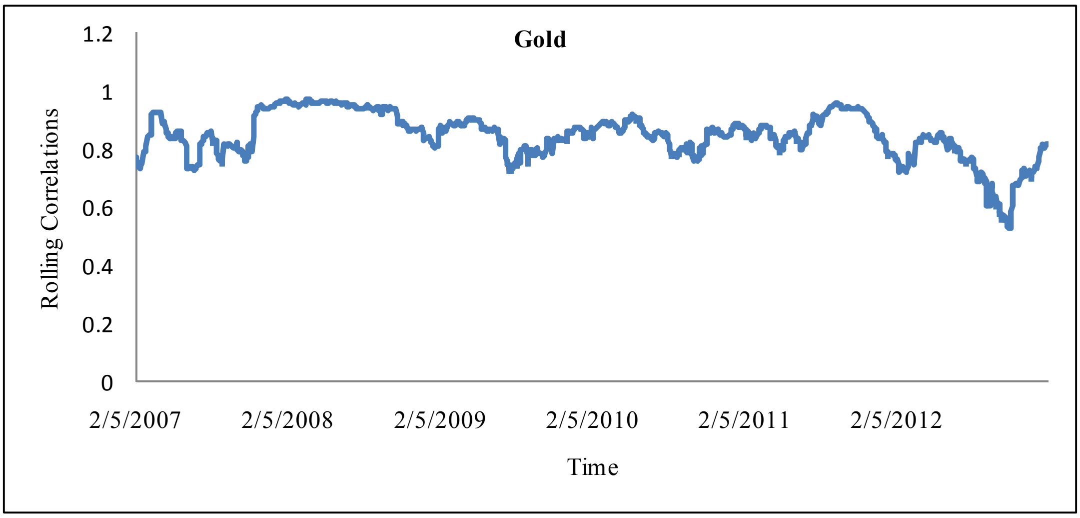


Figure 2: Comovements in Futures Prices of Gold traded on MCX and NYMEX

4.3 Linkages in return and volatility of commodities traded across exchanges

The results of Modified GARCH Model are reported – Section 4.3.1 discusses results of full model, Section 4.3.2 for pure mean model and Section 4.3.3 for pure volatility model of Gold futures.

4.3.1 Full Model

Full Model – I

Table 5 demonstrates the results of the Full model (Equation 3 and Equation 4) with return on futures price of Gold traded on MCX (here domestic market is MCX) as the dependent variable. The mean equation includes lagged return of Gold traded on MCX and return of Gold traded on NYMEX (here foreign market is NYMEX). The variance equation in the full model includes squared return on futures prices of Gold traded on NYMEX (considered to be a proxy of volatility in price return of futures contracts traded in foreign market).

Table 5: Results of Full Model (Equation 3 and Equation 4) - Impact on return of Gold traded on MCX

Return on Futures Price $(MCX)_{(t)}$ - Dependent Variable	**Gold**
Mean Equation	
Constant	**0.0004** (0.0004)

Lagged Gold Return on Futures Price (MCX)	0.0017 (0.8808)
Gold Return on Futures Price (NYMEX)	**0.6910** (0.0000)
Variance Equation	
Constant	**6.54E-07** (0.0000)
ARCH	**0.0428** (0.0000)
GARCH	**0.8629** (0.0000)
Squared Return on Gold Futures Price(NYMEX)	**0.0069** (0.0000)
Log Likelihood	5604.97

p value is in parenthesis; Coefficients marked in bold are significant at 5% significance level

It is found from the results of mean equation that return of futures price of Gold traded on MCX is not influenced by its own lagged return. While the return on futures prices of Gold traded on MCX is affected by return of futures price of Gold traded on NYMEX. From the variance equation, ARCH and GARCH effects are found to be significant. The coefficient of squared returns of futures prices of Gold traded on NYMEX is found to be significant. This suggests that as per the full model, there is presence of impact of return and volatility of futures price of Gold traded on NYMEX on the return and volatility of futures price of Gold traded on MCX, respectively.

Full Model – II

Table 6 represents the results of the Full model (Equation 5 and Equation 6) with return on futures price of Gold traded on NYMEX (here domestic market is NYMEX) as the dependent variable.

The mean equation includes lagged return on futures price of Gold traded on NYMEX (here domestic market is NYMEX) and return on futures price of Gold traded on MCX (here foreign market is MCX). The variance equation in the full model includes squared return on futures prices of Gold traded on MCX (proxy of volatility in price return of futures contracts traded in foreign market).

Table 6: Results of Full Model (Equation 5 and Equation 6) - Impact on return of Gold traded on NYMEX

Return on Futures Price (NYMEX)-Dependent Variable	**Gold**
Mean Equation	
Constant	-0.0001 (0.2687)
Lagged Return on Futures Price (NYMEX)	**-0.0956** (0.0000)
Return on Futures Price (MCX)	**1.0771** (0.0000)
Variance Equation	
Constant	**1.75E-06** (0.0000)
ARCH	**0.1246** (0.0000)
GARCH	**0.8156** (0.0000)
Squared Return on Futures Price(MCX)	**0.0048** (0.0020)
Log Likelihood	5336.160

p value is in parenthesis; Coefficients marked in bold are significant at 5% significance level

It is found from the results of mean equation that return of futures price of Gold traded on NYMEX is influenced by its own lagged return. Also, the return on futures prices of Gold is affected by return of futures price of Gold traded on MCX. From the variance equation, ARCH and GARCH effects are found to be significant. The coefficient of squared returns of futures prices of Gold traded on MCX 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 return and volatility of Gold traded on MCX on the return and return volatility of futures price of Gold traded on NYMEX respectively.

4.3.2 Pure Mean Model

Pure Mean Model-I

Table 7 represents the results of the Pure Mean model (Equation 3 and Equation 7) with return on futures price of Gold traded on MCX (here domestic market is MCX) as the dependent variable.

Table 7: Results of Mean Model I (Equation 3 and Equation 7) - Impact on return of Gold Futures traded on MCX

Return on Futures Price $(MCX)_{(t)}$- Dependent Variable	**Gold**
Mean Equation	
Constant	0.0002 (0.0869)
Return on Futures Price $(MCX)_{(t-1)}$	**0.0366** (0.0017)
Return on Futures Price $(NYMEX)_{(t)}$	**0.7050** (0.0000)
Variance equation	
Constant	**1.26E-06** (0.0000)
ARCH	**0.1123** (0.0000)
GARCH	**0.8559** (0.0000)
Log Likelihood	5585.994

p value is in parenthesis; Coefficients marked in bold are significant at 5% significance level

It is found from the results of mean equation that return of futures price of Gold traded on MCX is influenced by its own lagged return. The return on futures prices of Gold are affected by return of futures price of Gold traded on NYMEX. From the variance equation, 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 Gold (traded on NYMEX) on the return of futures price of Gold (traded on MCX).

Pure Mean Model-II

Table 8 shows the results of the Pure Mean model (Equation 5 and Equation 8) with return on futures price of Gold traded on NYMEX (here domestic market is NYMEX) as the dependent variable. The mean equation includes lagged return on futures price of Gold traded on NYMEX and return on futures price of Gold traded on MCX (here foreign market is MCX). The variance equation contains only ARCH and GARCH terms.

Table 8: Results of Mean Model II (Equation 5 and Equation 8) - Impact on return of Gold traded on NYMEX

Return on Futures Price $(NYMEX)_{(t)}$ - Dependent Variable	**Gold**
Mean Equation	
Constant	8.45E-05 (0.5341)
Return on Futures Price $(NYMEX)_{(t-1)}$	**-0.0906** (0.0000)
Return on Futures Price $(MCX)_{(t)}$	**1.0762** (0.0000)
Variance Equation	
Constant	**2.41E-06** (0.0000)
ARCH	**0.1623** (0.0000)
GARCH	**0.8031** (0.0000)
Log Likelihood	5332.346

p value is in parenthesis; Coefficients marked in bold are significant at 5% significance level

It is found from the results of mean equation that return of futures price of Gold traded on NYMEX is influenced by its own lagged return. Also, the return on futures prices of Gold are affected by return of futures price of Gold traded on MCX. From the variance equation, 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 Gold traded on MCX on the return of futures price of Gold traded on NYMEX.

4.3.3 Pure Volatility Model

Pure Volatility Model-I

Table 9 represents the results of the Pure Volatility model (Equation 9 and Equation 4) with return on futures price of Gold traded on MCX (here domestic market is MCX) as the dependent variable. The mean equation includes lagged return on futures price of Gold traded on MCX. The variance equation in the Pure Volatility model-I includes squared return on futures prices of Gold traded on NYMEX (NYMEX is foreign market; proxy of volatility in price return of Gold futures contracts traded in foreign market).

Table 9: Results of Volatility Model (Equation 9 and Equation 4) - Impact on return of Gold traded on MCX

Return on Futures Price $(MCX)_{(t)}$ - Dependent Variable	**Gold**
Mean Equation	
Constant	**0.0007** (0.0000)
Return on Futures Price $(MCX)_{(t-1)}$	0.0036 (0.8515)
Variance equation	
Constant	**1.48E-05** (0.0000)
ARCH	0.0122 (0.2156)
GARCH	0.0187 (0.1709)
Squared Return on Futures Price$(NYMEX)_{(t)}$	**0.4854** (0.0000)
Log Likelihood	5074.13

p value is in parenthesis; Coefficients marked in bold are significant at 5% significance level

It is found from the results of mean equation that return of futures price of Gold traded on MCX are not influenced by their own lagged return. From the variance equation, the coefficient of squared returns of futures prices of Gold traded on NYMEX is found to be significant. This suggests that as per the Pure Volatility Model, there is impact of return volatility in Gold traded on NYMEX on return volatility in Gold traded on MCX.

Pure Volatility Model-II

Table 10 represents the results of the Pure Volatility model (Equation 10 and Equation 6) with return on futures price of Gold traded on NYMEX (here domestic market is NYMEX) as the dependent variable. The mean equation includes lagged return on futures price of Gold traded on NYMEX. The variance equation in the Pure Volatility model includes squared return on futures prices of Gold traded on MCX (MCX is foreign market; proxy of volatility in return of futures contracts traded in foreign market).

Table 10: Results of Volatility Model (Equation 10 and Equation 6) - Impact on return of Gold traded on NYMEX

Return on Futures Price $(NYMEX)_{(t)}$- Dependent Variable	**Gold**
Mean Equation	
Constant	**0.0008** (0.0002)
Return on Futures Price $(NYMEX)_{(t-1)}$	**-0.1551** (0.0000)
Variance Equation	
Constant	**2.87E-05** (0.0000)
ARCH	0.0187 (0.1127)
GARCH	0.0272 (0.0517)
Squared Return on Futures Price$(MCX)_{(t)}$	**1.3579** (0.0000)
Log Likelihood	4661.475

p value is in parenthesis; Coefficients marked in bold are significant at 5% significance level

It is found from the results of mean equation that return of futures price of Gold traded on NYMEX are influenced by its own lagged return. From the variance equation, the coefficient of squared returns of futures prices of Gold traded on NYMEX is found to be significant (p value for all is 0.0000, less than 0.05). This suggests that as per the Pure Volatility model, there is impact of volatility in Gold traded on MCX on return volatility in Gold traded on NYMEX, respectively.

4.4 ARMA – GARCH in mean model - Innovations Model

The results of ARMA-GARCH in mean model are described in this section.

First Stage of Model-I

Table 11 reports the results of First Stage of ARMA-GARCH in mean model (Equation 11 and Equation 12) run on the returns of Gold traded on MCX.

Table 11: First Stage (Equation 11 and Equation 12) of ARMA-GARCH in Mean Model – Gold (MCX)

Dependent Variable – Return on Futures Price of Gold traded on $MCX_{(t)}$	**Gold**
Mean Equation	
Constant	0.0003 (0.2900)
Coefficient of AR(1)	**0.9817** (0.0000)
Coefficient of MA(1)	**-0.9988** (0.0000)
Coefficient of GARCH	4.5075 (0.0530)
Variance Equation	
Constant	**1.72E-06** (0.0000)
ARCH	**0.0557** (0.0000)
GARCH	**0.9300** (0.0000)
Log Likelihood	4667.407

p value is in parenthesis; Coefficients marked in bold are significant at 5% significance level

This specification 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 Gold traded on MCX.

First Stage of Model-II

Similarly, Table 12 reports the results of First Stage of ARMA-GARCH in mean model (Equation 13 and Equation 14) run on the return of Gold traded on NYMEX. This is run to estimate the standardised residual which is used in the second stage of the model.

Table 12: Results of First Stage of ARMA GARCH in Mean Model (Equation 13 and Equation 14) – Gold (NYMEX)

Dependent Variable – Return on Futures Price of Gold traded on NYMEX	**Gold**
Mean Equation	
Constant	-0.0004 (0.4623)
Coefficient of AR(1)	0.3401 (0.0429)
Coefficient of MA(1)	**-0.4609** (0.0033)
Coefficient of GARCH	**6.7012** (0.0429)
Variance Equation	
Constant	**2.52E-06** (0.0008)
ARCH	**0.0472** (0.0000)
GARCH	**0.9387** (0.0000)
Log Likelihood	4294.824

p value is in parenthesis; Coefficients marked in bold are significant at 5% significance level

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 model. Standardised residuals and squared standardised residuals are a proxy for un-observed innovation in foreign market.

Second Stage of Model – I

Table 13 represents the results of the second stage of ARMA-GARCH in mean model (Equation 15 and Equation 16) with return of Gold traded on MCX (here domestic market is MCX) as the dependent variable. The mean equation includes AR term, MA term and GARCH term. The mean equation of the model also includes standardised residual (standardised residuals derived from ARMA-GARCH in mean model of metals traded on NYMEX, Table 12– First stage) .The variance equation in the model includes ARCH and GARCH term. The variance equation of the model also contains squared standardised residual. These residuals are included to assess the impact of innovation in foreign market on domestic market.

Table 13: Second Stage - ARMA GARCH in Mean Model (Equation 15 and Equation 16) –Gold

Dependent Variable - Return on Futures Price of Gold traded on $MCX_{(t)}$	**Gold**
Mean Equation	
Constant	**0.0004** (0.0446)
AR(1)	**0.3342** (0.0036)
MA(1)	**-0.5090** (0.0000)
GARCH	**6.6371** (0.0069)
Residual of $NYMEX_{(t)}$	**0.0026** (0.0000)
Variance Equation	
Constant	-2.93E-06 (0.0000)
ARCH	**0.0956** (0.0000)
GARCH	**0.7153** (0.0000)
Square of Residual of $NYMEX_{(t)}$	**2.18E-05** (0.0000)
Log Likelihood	4823.345

p value is in parenthesis; Coefficients marked in bold are significant at 5% significance level

It is found from the results of mean equation that the standardised residual of Gold futures traded on NYMEX influence returns of Gold traded on MCX, thus suggesting that Gold traded on NYMEX has return spillover effects of innovation on return of Gold traded on MCX.

From the variance equation, ARCH and GARCH effects are found to be significant. The coefficient of squared standardised residual for Gold is found to be significant in the variance equation, implying that Gold traded on NYMEX has volatility spillover effects of innovation on Gold traded on MCX.

Second Stage of Model – II

Table 14 represents the results of the second stage of ARMA-GARCH in mean model (Equation 17 and Equation 18) with return on futures price of Gold traded on NYMEX (here domestic market is NYMEX) as the dependent variable. The mean equation includes AR term, MA term and GARCH term, respectively. The mean equation of the model also includes standardised residual (standardised residuals derived from ARMA-GARCH in mean model of Gold futures traded on MCX-Table 11). The variance equation in the model includes ARCH and GARCH term. The variance equation of full model also contains squared standardised residual. These residuals are included to assess the impact of innovation in foreign market on domestic market.

Table 14: Second Stage: ARMA-GARCH in Mean Model (Equation 17 and Equation 18) – Gold

Dependent Variable - Return on Futures Price of Gold traded on NYMEX	**Gold**
Mean Equation	
Constant	0.0003 (0.4330)
AR(1)	0.0275 (0.8109)
MA(1)	**-0.2714** (0.0148)
GARCH	0.9001 (0.7384)

Residual of MCX $_{(t)}$	**0.0020** (0.0000)
Variance Equation	
Constant	**-3.54E-06** (0.0054)
ARCH	**0.0671** (0.0000)
GARCH	**0.8427** (0.0000)
Square of Residual of MCX$_{(t)}$	**1.81E-05** (0.0000)
Log Likelihood	4378.793

p value is in parenthesis; Coefficients marked in bold are significant at 5% significance level

It is found from the results of mean equation that the standardised residual of Gold traded on MCX influence returns of Gold traded on NYMEX respectively (p value of all is 0.0000), thus suggesting that Gold futures traded on MCX have a return spill-over effects of innovation on return of Gold traded on NYMEX.

From the variance equation, ARCH and GARCH effects are found to be significant. The coefficient of squared standardised residual for Gold is found to be significant in the variance equation. This implies that Gold futures traded on MCX exhibit volatility spillover effects of innovation on Gold traded on NYMEX.

5 Concluding Remarks

The findings of the models discussed in the study can be summarised as follows. The price series of the precious metal, Gold traded on MCX and NYMEX are found to be co-integrated implying that there exists a long run relationship between futures contracts of Gold traded on MCX and NYMEX respectively. In terms of causality, it is found that the causality in price runs in one direction from Gold futures contracts traded on MCX to Gold futures contracts on NYMEX, but not in the opposite direction, that is, from NYMEX to MCX.

Using the three variants of modified GARCH model, it is found that the returns on futures prices for Gold traded on MCX are influenced by return and volatility of Gold traded on NYMEX. It is also found that the returns and volatility on futures price of Gold traded on NYMEX are affected by futures contracts traded on MCX.

The results of the ARMA-GARCH in mean model, the innovations model, indicate that there is return and volatility spillover effect of innovation from Gold futures contracts traded on NYMEX towards the Gold futures contracts traded on MCX when standardised residuals are included in the mean equation. It is also seen that there is return and volatility spillover effect of innovation from Gold futures contracts traded on MCX towards the Gold futures contracts traded on NYMEX.

Thus, given the level of integration of prices, return and volatility in Gold futures contracts traded on MCX and NYMEX. Any increase in transaction cost (through the imposition of commodities transaction taxes levied by the government or higher transaction charges levied by the commodity exchange) on trading of Gold futures contracts can lead to a fall in their trading volume as traders would escape by investing in International Markets instead of Indian Markets. This movement from Indian to the International markets would defy the intention of imposition of the charge/tax, as the exchange/government expects to earn handsome revenue from the charge/tax, and this would also defeat the very purpose of price discovery in the commodity exchanges in India.

6 References

1. Aruga, K., & Managi, S. (2011a).Testing the International linkage in the platinum-group metal futures markets. *Resources Policy*, 36(4), 339-345.

2. Aruga, K., & Managi, S. (2011b).Tests on price linkage between the US and Japanese gold and silver futures markets. *Economics Bulletin*, 31(2), 1038-1046.

3. Dhillon, U. S., Lasser, D. J., & Watanabe, T. (1997). Volatility, information, and double versus Walrasian auction pricing in US and Japanese futures markets. *Journal of Banking & Finance*, 21(7), 1045-1061.

4. Fung, H.G., Leung, W K., & Xu, X. E. (2003). Information flows between the U.S. and China Commodity Futures Trading. *Review of Quantitative Finance and Accounting,* 21(3), 267–285.

5. Kumar, B., & Pandey, A. (2011). International linkages of the Indian commodity futures markets. *Modern Economy*, 2(3), 213-227.

6. Mensi, W., Beljid, M., Boubaker, A., & Managi, S. (2013). Correlations and volatility spillovers across commodity and stock markets: Linking energies, food, and gold. *Economic Modelling*, *32*, 15-22.

7. Sahoo, P., & Kumar, R. (2008). Impact of Proposed Commodity Transaction Tax on Futures Trading in India.Working paper no. 216. *Indian Council for International Economic Relations*. New Delhi. India.

8. Xu, X.E., & Fung, H. (2005). Cross-market linkages between US and Japanese precious metals futures trading. *Journal of International Financial Markets, Institutions and Money*, 15(2), 107-124.

9. Zhang, Y. J., & Wei, Y. M. (2010). The crude oil market and the gold market: Evidence for cointegration, causality and price discovery. *Resources Policy*, 35(3), 168-177.