Price, Return and Volatility Linkages of Base Metal Futures traded in India

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Abstract: In this study the price, return and volatility behaviour of base metals (aluminium, copper, nickel, lead and zinc) which are traded on Indian commodity exchange - Multi Commodity Exchange (MCX) and International commodity exchange – London Metal Exchange (LME) are analysed. The time period chosen for the study is from November 1st, 2006 to January 30th, 2013. The paper attempts to demonstrate the linkages in price, return and volatility across the two markets for the five metals through 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 findings of the paper suggest that there exists a strong linkage across the price, return and volatility of futures contracts traded on MCX and LME respectively. Given the level of linkages, the imposition of Commodity Transaction Taxes on sellers at the time of trading of these five base metals on Indian Commodity exchanges would lead to a fall in their trading volume as traders and speculators would escape the higher transaction cost of hedging by investing in International Exchanges instead of Indian Commodity exchanges. This movement from Indian to the International markets would defy the intention of imposition of the tax, as the government expects to earn revenue from the tax, and this would also defeat the very purpose of price discovery in the commodity exchanges in India.

Keywords: Futures, Commodity Transaction Tax, GARCH, Base Metals

JEL Codes: L61, Q02, G19, G13

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1. Introduction

The Union Budget 2013 has proposed to levy a commodity transaction tax of 0.01% on transactions of commodities (gold, silver, base metals, processed agricultural commodities and crude oil) traded on Indian Commodity Exchanges. 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. CTT would be levied on the seller in the trading of commodity futures.

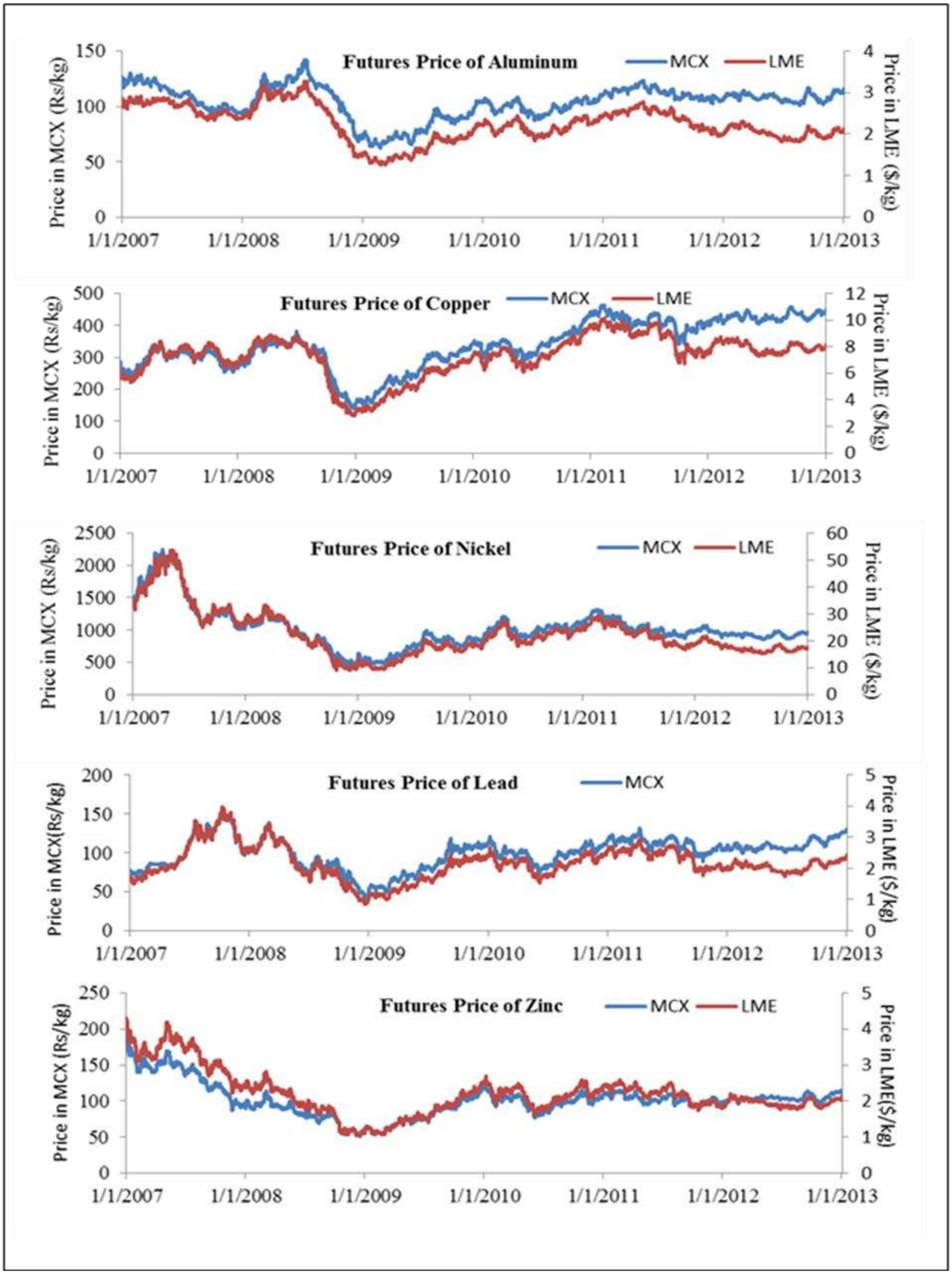
The Commodity Transaction Taxes on non-agricultural commodities (including base metals) and processed agricultural commodities traded on commodities exchanges in India will be levied from July 1, 2013. The imposition of the tax is likely to lead to movement of funds invested in Indian Commodity Exchanges 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 Markets with the International Commodity Exchanges.

The Multi Commodity Exchange offers many commodities ranging from bullion, energy, metals (ferrous as well as non ferrous metals) and agricultural commodities. The London Metal Exchange is considered to be the world's largest trading centre for industrial metals. It allows trading in non-ferrous metals (aluminium, copper, tin, nickel, lead, alloy of aluminium, NASAAC), minor metals (cobalt and molybdenum), precious metals and steel billet.

In this study, the price behaviour of base metals (aluminium, copper, nickel, lead and zinc) which are traded on Indian commodity exchange - Multi Commodity Exchange (MCX) and International commodity exchange – London Metal Exchange (LME) is analysed. The time period chosen for the study is from November 1st, 2006 to January 30th, 2013. The paper attempts to demonstrate the linkages in price, return and volatility across the two markets for the five metals 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.

Figure 1 demonstrates the co-movement in futures prices of the five base metals traded on the Multi Commodity Exchange of India and London Metal Exchange of United Kingdom. From the figure it can be observed that the futures prices of a base metal (traded on MCX and LME) move in tandem with each other. In case of aluminium and copper, price of futures contracts traded on MCX and LME faced a steep rise in the second half of 2008, a peak can be seen in other base metals too which can be attributed to the shooting up of oil prices in August 2008. A trough is noticed in the price for the five metals in the beginning of 2009 backed by fall in demand and an increase in inventories across markets of the world including India. Price for all the base metals increased after July 2010 due to rise in demand across sectors and fall in inventories. Prices have continued to remain volatile since 2011 both in the Indian and the International market.

Figure 1: Comovements in Futures Prices of Base Metals traded on MCX and LME



2. Literature Survey

A number of studies have examined the linkages in price and returns on commodities traded on commodity exchanges and securities traded on stock exchanges across the world.

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 law of one price and ran causality tests for gold and silver futures contracts traded on US and Japanese exchanges. They found results of this study similar to their previous study of platinum and palladium.

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

Copper futures markets have been studied extensively in various international studies. Li and Zhang (2009) examine the relationship between copper traded on Shanghai Futures Exchange and London Metal Exchange using co-integration and Markov Switching VECM model. They find a long run relationship between the two copper futures markets and the influence of LME is stronger is SHFE than vice versa. The same authors in an earlier piece of work, Li and Zhang (2008) investigate the time varying relationship using rolling correlations and rolling Granger Causality followed by co-integration test. The results of co-integration test show that there is a long run relationship between SHFE and LME copper prices.

The short-run return and volatility spill overs across three exchanges which allow trading for copper are examined by Lien and Yang (2009). The three exchanges included in the study are LME, NYMEX, and SHFE and a multivariate error correction dynamic conditional correlation GARCH model (DCC-MGARCH) is employed by the authors. Return spill-overs across markets are found to be bidirectional. From analysis of volatility spill-overs, they conclude that SHFE is more integrated to LME when compared to NYMEX.

The relationship between commodities including copper, aluminium, soybean and wheat across various markets of the world and China is investigated by Hua and Chen (2007). They use prices of London Metal Exchange (LME) and Shanghai Futures Exchange (SFE) for copper and aluminium, while for soybean and wheat, CBOT is used for international market. Soybean futures contracts traded on Dalian Commodity Exchange (DCE) and wheat futures contracts on the Zhengzhou Commodity Exchange (ZCE) are utilised in the study. Co-integration test of futures prices followed by representation by Error Correction Mechanism and Granger Causality tests are employed to study the linkages. A long run relationship between world markets and Chinese markets is observed in case of futures contracts of aluminium, copper and soybean. Chinese markets are found to be more responsive to changes in world markets. This was not found to be true in case of wheat futures prices.

The transmission of information for copper and soybean futures market between US and Chinese markets is discussed by Liu and An (2011) using multivariate GARCH framework. They find that there exists a bidirectional relationship exists with a stronger effect of US futures market on Chinese futures market in both the commodities. They also make an interesting conclusion about price discovery; they conclude that price discovery takes place in US futures market which then takes place in Chinese futures market followed by Chinese spot market. 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) study nine commodities traded in Indian commodity exchange and the rest of the world. They employ Johansen's co-integration test, error correction mechanism model, granger causality test and decomposition technique to study return spill overs of the commodities across exchanges. They also use bivariate GARCH (BEKK) model to investigate volatility spill over across commodity markets. They conclude that there is presence of co-integration and returns are affected by International markets.

Many studies have concentrated on the linkages in prices of agricultural commodities being traded in different markets of the world. In a recent paper, Han et al (2013) study the relationship between the Dalian Commodity Exchange (DCE) in China and Chicago Board of Exchange (CBOT) in US in soybean futures price discovery process using Structural Vector Autoregressive (SVAR) model to estimate the contemporaneous relationship. They also examine the long term relationship between the soybean futures across the two exchanges using Vector Error Correction (VEC) model. The analysis suggests that both the markets simultaneously affect each other in similar magnitude.

On similar lines but with different results, Booth et al (1998) study the relationship between US (Chicago Board of Trade) and Canadian (Winnipeg Commodities Exchange) wheat futures market via co-integration methodology. The results indicate an equilibrium long run relationship between prices of the two futures market. They conclude that there exists unidirectional causality from the wheat futures market of US to that of Canada due to the larger market size and volume of Chicago Board of Trade (US).

Similar methodology is employed by Fung et al (2003) to study the information flow between US and China in case of futures contracts of copper (NYMEX and Shanghai Futures Exchange, SFE), soybean (Chicago Board of Trade (CBOT) and the Dalian Commodity Exchange) and wheat (CBOT and the Zhengzhou Commodity Exchange). They use a bivariate AR-GARCH model in their analysis. They find a presence of strong effect of futures market of copper and soybean of US on China but absence of impact of US futures market on Chinese futures market in wheat.

Soybean and Corn Futures traded on US and Japan Exchanges are part of the study by Holder et al (2002). The authors use volume of contracts traded on the Chicago Board of Trade (CBOT) of US, and Tokyo Grain Exchange (TGE), and Kanmon Commodity Exchange (KCE) of Japan. To study the effect of introduction of futures contracts of US on Japan, a Generalised Linear Model and parametric t test are utilised. The study concludes that availability in US of contracts of corn does not have a major effect on volume on TGE and KCE while a higher volume is recorded of soybean in Japanese exchanges.

Price linkages between soybean and sugar futures market in Philippines (Manila International Futures Exchange, MIFE) and Japan (Tokyo Grain Exchange, TGE) are investigated by Low et al (1999). Results reveal that there is absence of arbitrage activities and co-integration of prices between MIFE and TGE. The authors attribute the lack of co-integration to variation in costs of carry and trading costs for storable commodities.

There have also been studies pertaining to crude oil and natural gas futures. The international transmission of information and market interactions in natural gas across the US and UK are dealt with by Kao and Wan (2009). They study both futures and spot prices of gas in the two countries. Co-integration analysis and GARCH is employed by the authors. They find that spot and futures contracts price series of US and UK are co-integrated in the long run and futures market of US is most efficient in processing information.

The interaction between prices of futures contracts of crude oil traded on New York Mercantile Exchange (NYMEX) and International Petroleum Exchange (IPE) is examined by Lin and Tamvakis (2001) using univariate and bivariate GARCH models. They find that NYMEX incorporates information from IPE but not vice versa. They also study spill over effects of volatility of futures return and conclude that spill over effects exist in both the directions. Granger causality tests prove that spill over effects are present from crude oil traded on previous NYMEX on the morning session prices of crude oil traded on IPE. A bivariate VAR model analyses the spill over effects from foreign market to domestic market and concludes that morning session of IPE is affected by trading of two previous days of crude oil on NYMEX.

A number of studies have been made in the area of international linkages of stock markets. To study short term information transmission between stock markets of countries, authors use intraday and overnight returns. Baur and Jung (2006) study the linkages between stock exchanges of Germany and United States using high frequency data and squared returns as a proxy for volatility of stock exchange in a GARCH framework. The study estimates the transmission across markets via a full model, a pure mean model and a pure volatility model. Their main finding is that returns of day time trading in foreign markets influence the returns of overnight trading in the domestic market.

The mean return and effects of spill over of volatility from stock exchange of US and Japan to stock markets of Hong Kong, Singapore, Taiwan and Thailand are examined by Liu and Pan (1997). They employ variants of the ARMA-GARCH model. They follow a two stage procedure for the investigation and involve un-observable innovations. The study finds that the international linkages (spill over effects) deepened after the crash in October 1987 and the US market has a stronger impact on the four Asian stock markets when analysed in comparison with Japanese stock market.

Utilising the studies of Booth et al (1998), Baur and Jung (2006) and Liu and Pan (1997) the paper tries to analyse the relationship between futures contracts traded on MCX and LME.

3. Data and Methodology

The study uses daily futures price data of base metals (aluminium, copper, nickel, lead and zinc) traded on MCX and LME for the period from November 1st, 2006 to January 30th, 2013. The near month futures contracts prices are chosen for the period of study, they are the most highly traded contracts in commodity exchanges. Data for futures prices of the base metals for both the exchanges has been extracted from Bloomberg. Exchange rate for USD-INR has been taken from Data Base for Indian Economy, RBI for the period from November 1st, 2006 to January 30th, 2013. LME futures prices are quoted in USD/tonne while MCX futures prices are quoted in Rs./kg. The LME futures price date is converted suitably into Rs./kg. Unit using exchange rates. Table 1 shows the summary statistics of the prices of futures contracts of the five base metals traded on MCX and LME in the period chosen for the study.

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

Summary Statistics	**Futures Price of Aluminium traded on LME**	**Futures Price of Aluminium traded on MCX**	**Futures Price of Copper traded on LME**	**Futures Price of Copper traded on MCX**	**Futures Price of Nickel traded on LME**	**Futures Price of Nickel traded on MCX**	**Futures Price of Lead traded on LME**	**Futures Price of Lead traded on MCX**	**Futures Price of Zinc traded on LME**	**Futures Price of Zinc traded on MCX**
Mean	104.11	104.42	337.10	338.65	1033.23	1037.18	99.25	99.46	102.79	103.26
Median	106.15	106.75	337.47	336.50	974.40	977.30	102.98	103.55	101.16	101.43
Maximum	140.71	142.25	463.17	464.90	2242.73	2240.00	156.53	152.50	206.13	205.90
Minimum	62.86	62.60	135.19	141.35	440.13	455.00	39.92	42.05	50.84	51.00
Std. Dev.	14.88	14.92	75.46	75.65	330.89	331.08	20.49	20.33	27.42	27.59
Skewness	-0.73	-0.74	-0.51	-0.45	1.31	1.32	-0.34	-0.37	1.17	1.19
Kurtosis	3.36	3.39	2.67	2.60	5.55	5.59	2.93	2.89	5.45	5.42
Jarque-Bera	180.43	187.73	94.15	78.73	1059.27	1079.44	38.34	44.93	927.05	926.91
Probability	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ADF(4,t)^	-2.192	-2.235	-2.273	-2.345	-1.743	-1.716	-2.580	-2.509	-3.129	-3.106

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

Table 1 includes the results of the unit root tests conducted on the price series of each of the five metals traded on MCX and LME respectively. The ten price series are found to be non stationary (contain a unit root) at level.

3.1 Linkages in price of metals 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 a metal traded at MCX and LME. As suggested by Hua and Chen (2007), the co-integration test is followed by modelling the relationship between futures price series into Error Correction Mechanism (ECM) model. The ECM model for the futures price series can be represented as:

$$\Delta PMCX_t = a_{10} + b_M ECM_{t-1} + \sum_{i=1}^{p} c_{1i} \Delta PMCX_{t-i} + \sum_{i=1}^{p} d_{1i} \Delta PLME_{t-i} + \epsilon_{1t} \ \dots \qquad (1)$$

$$\Delta PLME_t = a_{20} + b_L ECM_{t-1} + \sum_{i=1}^{p} c_{2i} \Delta PMCX_{t-i} + \sum_{i=1}^{p} d_{2i} \Delta PLME_{t-i} + \epsilon_{2t} \ \dots \qquad (2)$$

Where, PMCX and PLME represent the futures price series traded on MCX and LME of a metal (aluminium, copper, nickel, lead and zinc). ECM_{t-1} is the error correction term in both the equations. The coefficients of the error correction term are b_M and b_L 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 $\Delta PLME_{t-i}$ and $\Delta PMCX_{t-i}$ in Equation 1 and Equation 2 respectively, represent short run adjustments in futures price of metals.

3.2 Linkages in return on price of metals across two exchanges

For the next three sections (3.2, 3.3, 3.4) returns (calculated using futures prices) of metals are utilised. For each of the ten price series (five for MCX and five for LME), 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 metals across the two exchanges, regression is run to calculate the value of R squared for the entire period of study for each of the five metals separately. For each metal, the return on price of futures contracts traded on MCX is the dependent variable and the return on price of futures contracts traded on LME is the independent variable and vice versa to the study the opposite effect. This is followed by plotting of rolling correlation curves of returns on price of metals traded on LME and MCX.

As suggested by Li and Zhang (2008), rolling correlations 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 MCX and LME for the five base metals. 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 curves are plotted for the five metals.

3.3 Linkages in return and volatility of metals traded across exchanges

The focus of this section is to investigate the effect of returns and volatility of a metal traded in foreign market (LME/MCX) on return and volatility of metal traded in domestic market (MCX/LME). 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. 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.

In the full model and the pure volatility model, squared returns are used in the variance equation as a measure of volatility in the foreign market (LME/MCX).

3.3.1 Full Model

This variant of the model tries to assess the impact of previous day's return of metal traded in domestic market and foreign market on today's return of metal traded in the domestic market. It also tries to capture the impact of previous day's volatility of metal traded in domestic market (GARCH effect) and foreign market on volatility of metal traded in domestic market.

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

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

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

The following two equations represent the model when we consider LME to be domestic market and MCX to be forei0000000gn market:

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

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

Where $r_{M,t}$ and $r_{L,t}$ are returns on price of a metal traded on MCX and LME respectively. $r_{M}{}^{2}{}_{,t-1}$ and $r_{L}{}^{2}{}_{,t-1}$ are lagged squared returns on price of a metal traded on MCX and LME respectively (used as proxy for volatility). The coefficients of ARCH and GARCH terms in Equation 4(variance equation) are k_5 and k_6 and 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 metal traded in domestic market and foreign market on today's return of metal traded domestic market. 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 consider MCX to be domestic market and LME to be foreign market:

Mean equation: $r_{M,t} = k_1 + k_2 r_{M,t-1} + k_3 r_{L,t-1} + \varepsilon_{M,t}$... (7)

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

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

Mean equation: $r_{L,t} = k_8 + k_9 r_{L,t-1} + k_{10} r_{M,t-1} + \varepsilon_{L,t}$... (9)

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

Where $r_{M,t}$ and $r_{L,t}$ are returns on price of a metal traded on MCX and LME respectively. k_5 and k_6 are coefficients of ARCH and GARCH terms in Equation 8(variance equation) and 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 metal traded in domestic market and foreign market on today's volatility of metal traded in the domestic market. In the mean equation, it includes the impact of yesterday's return of metal traded in domestic market on today's return and ignores the possible effect of yesterday's return in foreign market on today's return on metal traded in domestic market.The following two equations represent the model when we consider MCX to be domestic market and LME to be foreign market:

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

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

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

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

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

Where $r_{M,t}$ and $r_{L,t}$ are returns on price of a metal traded on MCX and LME respectively. $r_M{}^2{}_{,t-1}$ and $r_L{}^2{}_{,t-1}$ are lagged squared returns on price of a metal traded on MCX and LME respectively. The coefficients of ARCH and GARCH terms in Equation 12(variance equation) are k_5 and k_6 and 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 utilised to examine the linkage between returns and volatility of futures price of a base metal across two exchanges. A variant of this model is employed by Liu and Pan (1997). In the first stage, return series of futures price of a metal 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 metals traded on MCX

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

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

Where $r_{M,t}$ are returns on price of a metal traded on MCX. $r_{M,t-1}$ are lagged returns on price of a metal traded on MCX, this is the auto regressive (AR) term in Equation 15. While $\varepsilon_{M,t-1}$ 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 metals traded on LME:

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

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

where $r_{L,t}$ are returns on price of a metal traded on LME. $r_{L,t-1}$ are lagged returns on price of a metal traded on LME, this is the auto regressive (AR) term in Equation 17. While $\varepsilon_{L,t-1}$ is the moving average term in the Equations 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 metals traded on MCX. 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 metals traded on LME. 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 ten return series for five metals under consideration (five return series of metals traded on MCX and five return series of the same metals traded on LME).

The second stage of the model involves the estimation of return and volatility spill-over effects of a metal 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 metals traded on MCX (from the first stage) are used in second stage of metals traded on LME 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) point out, 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 metals traded on LME on metals traded on MCX

Mean equation: $r_{M,t} = w_1 + w_2 r_{M,t-1} + w_3 \varepsilon_{M,t-1} + w_4 h_{M,t} + w_5 e_{L,t-1} \ldots \qquad (19)$

Variance equation: $h_{M,t} = w_6 + w_7 \varepsilon^2_{M,t-1} + w_8 h_{M,t-1} + w_9 e^2_{L,t-1} \ldots \qquad (20)$

where $r_{M,t}$ are returns on price of a metal traded on MCX. $r_{M,t-1}$ are lagged returns on price of a metal traded on MCX, the auto regressive (AR) term in the equation. While $\varepsilon_{M,t-1}$ is the moving average term in Equation 19. Equation 19 and Equation 20 use the standardised residual series ($e_{L,t-1}$) and squared standardised residual series ($e^2_{L,t-1}$) respectively, obtained from the first stage of metals traded on LME. The coefficients of ARCH and GARCH terms are w_7 and w_8 in Equation 20 (variance equation).To assess the impact of metals traded on MCX on metals traded on LME

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

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

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

4. Empirical Results

4.1 Co-integration and ECM Model

The futures price series are non stationary at level and stationary at first difference, thus indicating that the futures price series of metal traded across the two exchanges (MCX and LME) follow an I(1) process. Table 2 reports the results of Johansen Co-integration Test for the five base metals.

Table 2: Results of Johansen Co-integration Tests for the five metals

Test	Metal	Lags	Ho, r is number of co-integrating relation	Trace Statistic	Critical Value at 5%	Probability	Max Eigen Statistic	Critical Value at 5%	Probability
1	**Aluminium**	4	r≤0	194.2872**	25.87211	0.0000	188.7261**	19.38704	0.0001
			r≤1	5.561122	12.51798	0.5179	5.561122	12.51798	0.5179
2	**Copper**	4	r≤0	73.46049**	25.87211	0.0000	67.55158**	19.38704	0.0000
			r≤1	5.908910	12.51798	0.4720	5.908910	12.51798	0.4720
3	**Nickel**	4	r≤0	191.3112**	25.87211	0.0000	187.6900**	19.38704	0.0001
			r≤1	3.621163	12.51798	0.7960	3.621163	12.51798	0.7960
4	**Lead**	4	r≤0	220.6526**	25.87211	0.0000	214.1363**	19.38704	0.0001
			r≤1	6.516323	12.51798	0.3977	6.516323	12.51798	0.3977
5	**Zinc**	3	r≤0	315.6759**	25.87211	0.0000	303.4237**	19.38704	0.0001
			r≤1	12.25218	12.51798	0.0554	12.25218	12.51798	0.0554

** Denotes rejection at 5% level

Both the trace statistics and max eigen statistics show that for each of the five base metals traded on MCX and LME, near month futures price series are co-integrated with one co-integrating vector. This implies that the futures prices of metals traded on MCX and LME 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 base metals traded on MCX and LME using Error Correction Mechanism with one co-integration relation (r=1) for each of the five base metals.

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 five pairs of futures price series of metals. The results of ECM model for each of the five base metals are shown from Table 3 to Table 7.

1. Aluminium - ECM Results

   Table 3 demonstrates the result of ECM for futures price of Aluminium traded on MCX and LME in the period chosen for the study from November 1st, 2006 to January 30th, 2013.

Table 3:ECM results for Aluminium

	Dependent variable - ΔPALMCX(Equation 1)		**Dependent variable – ΔPALLME (Equation 2)**	
Independent variable	**Coefficient**	**p value**	**Coefficient**	**p value**
$ECM_{(t-1)}$	-0.221378	0.0000	-0.166547	0.0033
$\Delta PALMCX_{(t-1)}$	-0.07073	0.1840	0.143302	0.0227
$\Delta PALMCX_{(t-2)}$	-0.028429	0.5759	0.106582	0.0757
$\Delta PALMCX_{(t-3)}$	-0.022304	0.6358	0.023448	0.6733
$\Delta PALMCX_{(t-4)}$	-0.00837	0.8372	-0.007679	0.8731
$\Delta PALLME_{(t-1)}$	0.054557	0.2791	-0.168432	0.0047
$\Delta PALLME_{(t-2)}$	0.046395	0.3332	-0.064788	0.2524
$\Delta PALLME_{(t-3)}$	0.016294	0.7119	-0.042004	0.4201
$\Delta PALLME_{(t-4)}$	0.002332	0.9503	-0.034431	0.4361
Constant	-0.009049	0.7588	-0.007408	0.8314
Wald Test Result for short run causality (Chi Square and p value)	1.503752 (0.8260)		6.599360 (0.1586)	

In Table 3, 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 aluminium traded on MCX and LME are used. Table 3 shows that ECM_{t-1} term is significant and negative in both the equations, ΔPALMCX equation and the ΔPALLME equation at 5% level, indicating that disequilibrium errors are an important factor for changes in the futures price of aluminium traded on MCX and in the futures price of aluminium traded on LME. When the futures price of the metals traded in the two markets 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 aluminium 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 aluminium traded on MCX and LME. The significant error correction terms also help us in asserting that long run dynamics exist in the two markets.

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 (0.8260) is more than 0.05. This suggests that there is absence of short run causality from LME aluminium futures price to MCX aluminium futures price. The Wald Test results conducted on the cross terms in Equation 2, also accept the hypothesis that the coefficients are simultaneously zero at the 5% level, the p value (0.1591) is more than 0.05. This leads to the conclusion that there is absence of short run causality from MCX aluminium futures price to LME aluminium futures price.

2. Copper – ECM Results

Table 4 demonstrates the result of ECM for futures price of copper traded on MCX and LME in the period chosen for the study from November 1st, 2006 to January 30th, 2013.

Table 4:ECM results for Copper

	Dependent variable - ΔDPCUMCX		**Dependent variable - ΔDPCULME**	
Independent variable -	**Coefficient**	**p value**	**Coefficient**	**p value**
ECM(t-1)	-0.099897	0.0112	-0.055421	0.2015
ΔPCUMCX(t-1)	-0.008493	0.8818	0.446475	0.0000
ΔPCUMCX(t-2)	0.062026	0.2826	0.374902	0.0000
ΔPCUMCX(t-3)	-0.062513	0.2609	0.189218	0.0024
ΔPCUMCX(t-4)	-0.009606	0.8473	0.079691	0.1537
ΔPCULME(t-1)	-0.025639	0.6282	-0.468451	0.0000
ΔPCULME(t-2)	-0.000264	0.9961	-0.30567	0.0000
ΔPCULME(t-3)	0.040851	0.4257	-0.203094	0.0004
ΔPCULME(t-4)	-0.013925	0.7566	-0.138367	0.006
Constant	0.057214	0.6091	0.057358	0.6469
Wald Test Result for short run causality (Chi Square and p value)	1.995819 (0.7365)		56.27616 (0.0000)	

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 copper traded on MCX and LME are used. Table 4 shows that ECM_{t-1} term is significant (p value is 0.0112) and negative in the ΔPCUMCX equation (Equation 1), indicating that disequilibrium error is an important factor for the change in the futures price of copper traded on MCX. When the futures price of the metals 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 copper futures price traded on MCX will increase on an average. The error correction term in the ΔPCULME (Equation 2) is insignificant (here p value is 0.2015 which is greater than 0.05) price in LME does not adjust to equilibrium level in the copper futures market in LME in case of deviation.

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 (0.7365) is more than 0.05. This suggests that there is absence of short run causality from LME copper futures price to MCX copper futures price. The Wald Test results conducted on the cross terms in Equation 2, find that the coefficients are 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 MCX copper futures price to LME copper futures price.

3. Nickel- ECM Results

Table 5 demonstrates the result of ECM for futures price of nickel traded on MCX and LME in the period chosen for the study, from November 1st, 2006 to January 30th, 2013.

Table 5:ECM results for Nickel

	Dependent variable - ΔPNIMCX		**Dependent variable - ΔPNILME**	
Independent variable -	**Coefficient**	**p value**	**Coefficient**	**p value**
ECM(t-1)	-0.262109	0.0000	-0.078126	0.1013
ΔPNIMCX(t-1)	0.077444	0.0991	0.333782	0.0000
ΔPNIMCX(t-2)	0.004157	0.9274	0.105525	0.0501
ΔPNIMCX(t-3)	0.025251	0.5546	0.058549	0.2457
ΔPNIMCX(t-4)	-0.000837	0.9826	0.096366	0.033
ΔPNILME(t-1)	-0.04323	0.3317	-0.228338	0.7100
ΔPNILME(t-2)	0.004747	0.9113	-0.265381	0.0000
ΔPNILME(t-3)	-0.076449	0.0549	-0.088285	0.0794
ΔPNILME(t-4)	-0.025423	0.4636	-0.130407	0.0055
Constant	-0.270318	0.6034	-0.086454	0.0348
Wald Test Result for short run causality (Chi Square and p value)	6.944423 (0.1389)		40.21767 (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 nickel traded on MCX and LME are used. Table 5 shows that ECM_{t-1} term is significant (p value is 0.0000) and negative in the ΔPNIMCX equation (Equation 1), indicating that disequilibrium error is an important factor for the change in the futures price of nickel traded on MCX. When the futures price of the metals traded in MCX deviates from their equilibrium level, the error correction term, ECM_{t-1} term, price will adjust to equilibrium level. Since the error correction term is negative, the nickel futures price will increase on an average. The error correction term in the ∆PNILME (Equation 2) is insignificant, long run dynamics do not exist in the nickel futures market in LME (here p value is 0.1013 which is greater than 0.05).

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 (0.1393) is more than 0.05. This suggests that there is absence of short run causality from LME nickel futures price to MCX nickel futures price. The Wald Test results conducted on the cross terms in Equation 2, find that the coefficients are 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 MCX nickel futures price to LME nickel futures price.

4. Lead - ECM Results

Table 6 demonstrates the result of ECM for futures price of lead traded on MCX and LME in the period chosen for the study, from November 1st, 2006 to January 30th, 2013.

Table 6:ECM results for Lead

	Dependent variable - ∆PPBMCX		**Dependent variable - ∆PPBLME**	
Independent variable -	**Coefficient**	**p value**	**Coefficient**	**p value**
ECM(t-1)	-0.205956	0.0000	-0.155557	0.0019
∆PPBMCX(t-1)	-0.010061	0.8459	0.249099	0.0000
∆PPBMCX(t-2)	0.119586	0.0199	0.160849	0.0066
∆PPBMCX(t-3)	0.04343	0.3751	0.009969	0.8599
∆PPBMCX(t-4)	-0.050245	0.2451	-0.080094	0.1082
∆PPBLME(t-1)	0.053599	0.2688	-0.145701	0.0092
∆PPBLME(t-2)	-0.052906	0.2635	-0.089127	0.1025
∆PPBLME(t-3)	-0.063219	0.1582	-0.029272	0.571
∆PPBLME(t-4)	0.004122	0.9166	0.032071	0.4799
Constant	0.028464	0.5315	0.023846	0.6495
Wald Test Result for short run causality (Chi Square and p value)	8.127351 (0.0870)		24.09433 (0.0001)	

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 lead futures prices traded on MCX and LME are used. Table 6 shows that ECM_{t-1} term is significant and negative in both the equations, the ∆PPBMCX equation (p value is 0.0000) and the ∆PPBLME equation (p value is 0.0019) at 5% level, indicating that disequilibrium errors are an important factor for the changes in the futures price of lead traded on MCX and in the futures price of lead traded on LME. When the futures price of the metals 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 lead 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 lead traded on MCX and LME.

Considering the short run dynamics, from the results of Wald Test conducted on the cross terms in Equation 1, we accept that they are simultaneously zero at the 5% level since the p value (0.0870) is more than 0.05. This suggests that there is absence of short run causality from LME lead futures price to MCX lead futures price. The Wald Test results conducted on the cross terms in Equation 2, find that the coefficients are simultaneously zero at the 5% level, the p value (0.0001) is less than 0.05. This leads to the conclusion that there is presence of short run causality from MCX lead futures price to LME lead futures price.

5. Zinc – ECM Results

Table 7:ECM results for Zinc

	Dependent variable - ΔPZNMCX		**Dependent variable - ΔPZNLME**	
Independent variable -	**Coefficient**	**p value**	**Coefficient**	**p value**
ECM(t-1)	-0.144624	0.0050	-0.430231	0.0000
ΔPZNMCX(t-1)	0.027535	0.6071	0.157046	0.0189
ΔPZNMCX(t-2)	0.08976	0.0615	0.271002	0.0000
ΔPZNMCX(t-3)	0.002481	0.9522	0.046012	0.3734
ΔPZNLME(t-1)	0.007188	0.8833	-0.095616	0.1178
ΔPZNLME(t-2)	-0.053818	0.2077	-0.174958	0.0011
ΔPZNLME(t-3)	-0.0378	0.2865	-0.084501	0.0564
Constant	-0.039957	0.3464	-0.036793	0.4874
Wald Test Result for short run causality (Chi Square and p value)	3.873893 (0.2754)		21.14078 (0.0001)	

Table 7 demonstrates the result of ECM for futures price of zinc traded on MCX and LME in the period chosen for the study, November 1st, 2006 till January 30th, 2013.

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 zinc futures prices traded on MCX and LME are used. Table 7 shows that ECM_{t-1} term is significant and negative in both the equations, the ΔPZNMCX equation (p value is 0.0050) and the ΔPZNLME equation (p value is 0.0000) at 5% level, indicating that disequilibrium errors are an important factor for the changes in the futures price of zinc traded on MCX and in the futures price of zinc traded on LME. When the futures price of the metals traded in the two markets deviate from their equilibrium level, the significant error correction term, ECM_{t-1} term indicates that the price will adjust to the equilibrium level. Since the error correction term is negative, the zinc 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 zinc traded on MCX and LME.

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 (0.2754) is more than 0.05. This suggests that there is absence of short run causality from LME lead futures price to MCX zinc futures price. The Wald Test results conducted on the cross terms in Equation 2, find that the coefficients are simultaneously zero at the 5% level, the p value (0.0001) is less than 0.05. This leads to the conclusion that there is presence of short run causality from MCX zinc futures price to LME zinc futures price.

Table 8: Summary of Results of ECM

Futures price of contracts traded on MCX is dependent variable and LME is independent variable(Equation 1)		
	ECM term (LR)(Adjusts to equilibrium)	**Wald Test(SR)**
Aluminium	-0.221378 (0.0000)	1.503752 (0.8260)
Copper	-0.099897 (0.0112)	1.995819 (0.7365)
Nickel	-0.262109 (0.0000)	6.944423 (0.1389)
Lead	-0.205956 (0.0000)	8.127351 (0.0870)
Zinc	-0.144624 (0.0050)	3.873893 (0.2754)
Futures price of contracts traded on LME is dependent variable and MCX is independent variable(Equation 2)		
	ECM term (LR)(Adjusts to equilibrium)	**Wald Test(SR)**
Aluminium	-0.166547 (0.0033)	6.599360 (0.1586)
Copper	-0.055421 (0.2015)	56.27616 (0.0000)
Nickel	-0.078126 (0.1013)	40.21767 (0.0000)
Lead	-0.155557 (0.0019)	24.09433 (0.0001)
Zinc	-0.430231 (0.0000)	21.14078 (0.0001)

From the results of co-integration test, economically speaking there is a long term relationship between futures price of metals traded on MCX and LME. Summarising the results of ECM for all the base metals in Table 8. In the upper panel of Table 8, the significant error term suggests the futures price of contracts traded on MCX (aluminium, copper, nickel, lead and zinc) adjust to the equilibrium level in the long run. The insignificant result of Wald Test, suggests that there is absence of short run causality from prices of futures contract traded on LME to prices of futures contract traded on MCX (aluminium, copper, nickel, lead and zinc). Whereas in the lower panel of Table 8, the ECM term is significant in case of aluminium, lead and zinc, which indicates that price will get adjusted to the equilibrium level after deviation. In case of copper and nickel, the ECM term is not significant. The results of Wald Test of copper, nickel, lead and zinc are significant, implying that short run causality exists from futures price of contracts traded on MCX to from prices of futures contract traded on LME.

4.2 Regression Analysis and Rolling Correlations of Returns

Table 9 demonstrates the summary statistics of returns on futures price of base metals traded on MCX and LME.

Table 9: Summary Statistics of Returns on Futures Contracts traded on LME and MCX

Summary Statistics of Return Series	Return on Futures Price of Aluminium traded on LME	Return on Futures Price of Aluminium traded on MCX	Return on Futures Price of Copper traded on LME	Return on Futures Price of Copper traded on MCX	Return on Futures Price of Nickel traded on LME	Return on Futures Price of Nickel traded on MCX	Return on Futures Price of Lead traded on LME	Return on Futures Price of Lead traded on MCX	Return on Futures Price of Zinc traded on LME	Return on Futures Price of Zinc traded on MCX
Mean	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Median	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Maximum	0.06	0.07	0.11	0.08	0.12	0.13	0.13	0.10	0.09	0.09
Minimum	-0.07	-0.07	-0.10	-0.11	-0.14	-0.13	-0.13	-0.13	-0.17	-0.09
Std. Dev.	0.02	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Skewness	-0.21	0.05	-0.10	-0.34	-0.12	0.10	-0.20	-0.34	-0.30	-0.19
Kurtosis	4.89	5.80	6.23	7.04	6.58	6.98	6.13	6.39	6.45	5.83
Jarque-Bera	302.37	630.70	841.74	1348.82	1017.05	1255.27	800.98	956.78	986.30	654.50
Probability	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ADF(4,t) ^	-20.446	-19.252	-19.583	-18.643	-20.424	-19.599	-19.409	-19.074	-20.379	-19.953

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

From Table 9, the mean daily returns for the five base metals traded on MCX and LME during the period from 1st November 2006 to 30th January 2013 is found to be averaging at zero. The maximum daily returns are found to be 13% in case of nickel futures contracts traded on MCX and LME. The distribution is leptokurtic for all the ten return series since value of kurtosis is found to be more than 3. The return series for all the base metals traded on MCX and LME are found to be stationary since there is absence of unit root at level.

The results of regression analysis are demonstrated in Table 10 and Table 11.

Table 10: Regression Analysis of Returns on Futures Prices of Metals

Model	Dependent Variable: Return on Futures Price of contracts traded on MCX	Independent Variable: Return on Futures Price of contracts traded on LME	Value of R^2
I	Aluminium	0.679821 (0.0000)	0.636497
II	Copper	0.745863 (0.0000)	0.746221
III	Nickel	0.714984 (0.0000)	0.665455
IV	Lead	0.673936 (0.0000)	0.628137
V	Zinc	0.693848 (0.0000)	0.702495

Table 10 reports results of regression on the return series keeping return series of futures contracts traded on MCX as dependent variable and return series of futures contracts traded on LME as independent variable. The regression analysis is performed for all the five base metals chosen. Models are run separately for each metal. The coefficient of Return on Futures Price of contracts traded on LME is more than 0.67 for the five metals, it is found to be significant at 5% level. The R squared value for all the five metal series exceeds 0.6 which suggests that there exists a strong relationship between returns of futures price of metal traded on MCX and LME.

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

Model	Dependent Variable: Return on Futures Price of contracts traded on LME	Independent Variable: Return on Futures price of contracts traded on MCX	Value of R^2
I	Aluminium	0.936271 (0.0000)	0.636497
II	Copper	1.000480 (0.0000)	0.746221
III	Nickel	0.930727 (0.0000)	0.665455
IV	Lead	0.932043 (0.0000)	0.628137
V	Zinc	1.012461 (0.00000)	0.702495

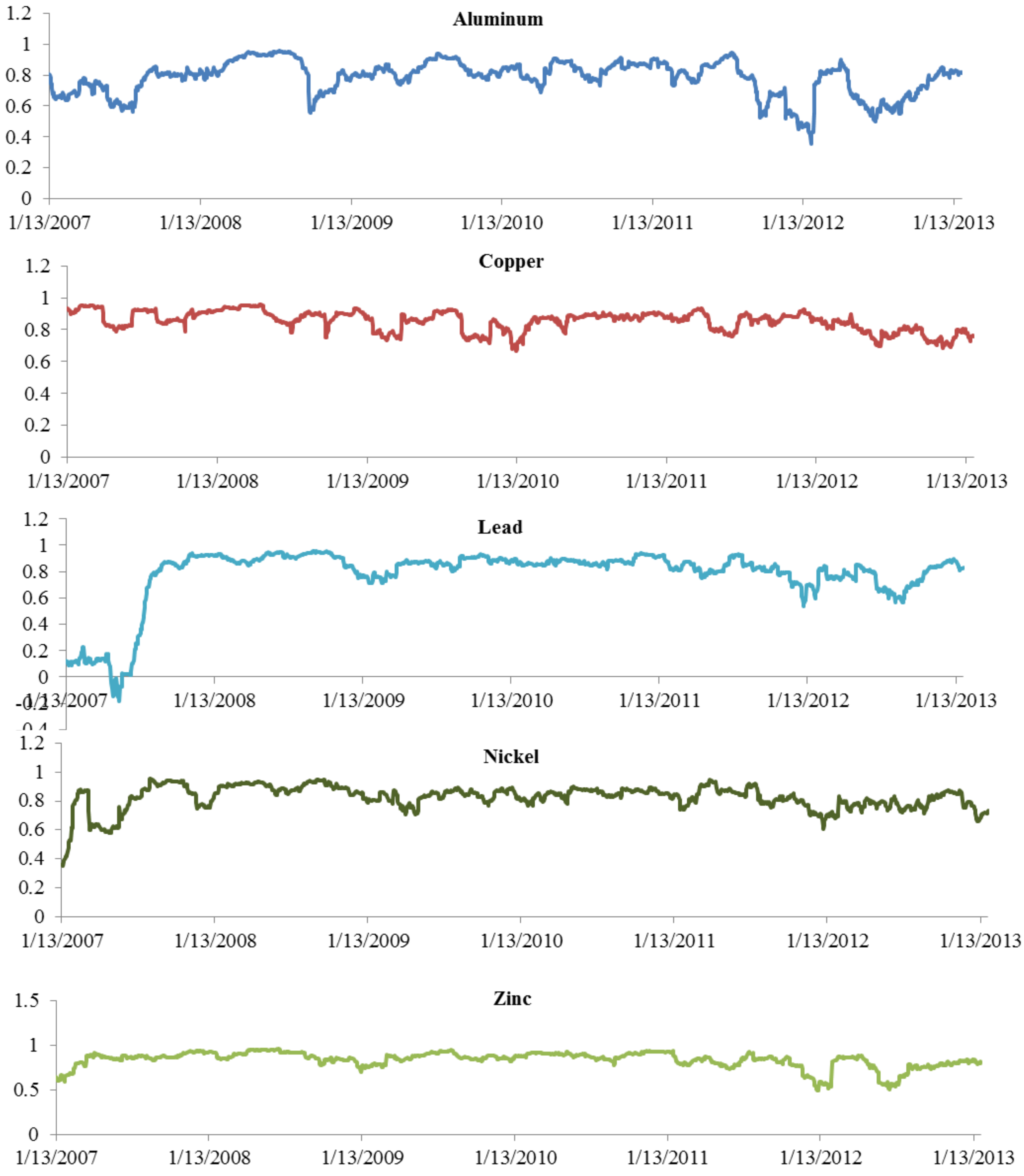
Table 11 displays results of regression when the dependent variable is return on futures price of a metal traded on LME and independent variable is return on futures price of metal traded on MCX. The coefficient of returns to futures price of all the metal traded on LME are found to be significant.

Rolling Correlations Curves

Figure 2 depicts the rolling correlation between returns on futures price of metals (aluminium, copper, nickel, lead and zinc) traded on MCX and LME.

For aluminium, the rolling correlation of returns is found to be moving in the range of 0.35 and 0.96 over the entire period. The average rolling correlation of returns for aluminium is 0.78 indicating that the returns on futures price of aluminium traded on MCX and LME move in tandem with each other. For copper, the rolling correlation of returns is seen to be moving in the range from as low as 0.67 to a maximum of 0.96. On an average the rolling correlation of returns of copper is 0.85, which is quite high. For nickel, the rolling correlation of returns reaches as low as 0.35 and attains a maximum of 0.95. The average of rolling correlation for the entire period is 0.82. For lead, the minimum value of rolling correlation for 60 day window is -0.18029, this could be because of an early stage of development of the Multi Commodity Exchange in 2007. The maximum level of rolling correlation of returns attained by lead is 0.95, while the average is 0.77. For zinc, rolling correlation of returns varies from as low as 0.49 and attains 0.96 with average hovering around 0.83. Thus comparing the averages of rolling correlation of returns, lowest correlation is in aluminium while highest is in copper.

Figure 2: Results of rolling correlations of returns of futures prices of base metal traded on MCX and LME



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 metal traded on MCX

Return on Futures Price (MCX) - Dependent Variable	**Aluminium (i)**	**Copper (ii)**	**Nickel (iii)**	**Lead (iv)**	**Zinc (v)**
Mean Equation					
Mean Constant	-6.42E-05 (0.8092)	0.000504 (0.0924)	0.000107 (0.7882)	0.000596 (0.1240)	5.24E-06 (0.9879)
Return on Futures Price (MCX)(t-1)	-0.128119 (0.0000)	-0.046455 (0.2718)	-0.049475 (0.1733)	-0.067931 (0.0248)	-0.053164 (0.1292)
Return on Futures Price (LME)(t-1)	0.151095 (0.0000)	0.018229 (0.6184)	0.098679 (0.0009)	0.147648 (0.0000)	0.085036 (0.0039)
Variance Equation					
Variance constant	1.03E-06 (0.0043)	0.00000174 (0.0009)	1.78E-06 (0.0181)	1.72E-06 (0.0224)	2.12E-07 (0.3025)
ARCH	0.027367 (0.0000)	0.064141 (0.0000)	0.041625 (0.0000)	0.05613 (0.0000)	0.027211 (0.0000)
GARCH	0.963915 (0.0000)	0.940324 (0.0000)	0.950296 (0.0000)	0.939211 (0.0000)	0.972995 (0.0000)
Squared Return on Futures Price(LME)(t-1)	0.001515 (0.4489)	-0.007897 (0.0553)	0.003163 (0.4935)	0.001983 (0.3397)	-0.000446 (0.6946)
Log Likelihood	5765.927	5414.055	4780.815	4909.836	5121.006

Table 12 demonstrates the results of the Full model (Equation 3 and Equation 4) with return on futures price of metals traded on MCX (here domestic market is MCX) as the dependent variable. The mean equation includes lagged return on futures price traded of metals traded on MCX and a term of lagged return on futures price of metals traded on LME(here foreign market is LME). The variance equation in the full model includes lagged squared return on futures prices of metals traded on LME (considered to be a proxy of volatility in price return of futures contracts traded in foreign market). The model is run separately for each metal.

It is found from the results of mean equation that return of futures price of aluminium and lead traded on MCX are influenced by their own lagged return respectively. While the return on futures prices of aluminium, nickel, lead and zinc traded on MCX are affected by lagged return of futures price of aluminium, nickel, lead and zinc traded on LME respectively. Return on futures price of copper traded on MCX remains unaffected by both lagged return on futures price of copper traded on MCX and lagged return on futures price of copper traded on LME.

From the variance equation, for all the five return series, ARCH and GARCH effects are found to be significant. The coefficient of lagged squared returns of futures prices of metals traded on LME is found to be insignificant (p value more than 0.05 for all). This suggests that as per the full model, there is absence of impact of volatility of metals traded on LME on volatility of futures price of metals traded on MCX respectively.

4.3.1 – Full Model – II

Table 13: Results of Full Model (Equation 5 and 6) - Impact on price return of metal traded on LME

Return on Futures Price (LME) - Dependent Variable	Aluminium (i)	Copper (ii)	Nickel (iii)	Lead (iv)	Zinc (v)
Mean Equation					
Mean Constant	-3.06E-06 (0.9923)	0.000159 (0.6538)	0.0000713 (0.8798)	0.000424 (0.3731)	-0.000141 (0.7330)
Return on Futures Price (LME)(t-1)	-0.223444 (0.0000)	-0.325356 (0.0000)	-0.281748 (0.0000)	-0.197437 (0.0000)	-0.245649 (0.0000)
Return on Futures Price (MCX)(t-1)	0.191672 (0.0000)	0.300207 (0.0000)	0.359836 (0.0000)	0.287519 (0.0000)	0.258324 (0.0000)
Variance Equation					
Variance constant	2.71E-06 (0.0007)	2.17E-06 (0.0057)	4.71E-06 (0.0003)	1.20E-06 (0.0526)	6.77E-07 (0.0415)
ARCH	0.006324 (0.1809)	0.013839 (0.0875)	0.006619 (0.2981)	0.009741 (0.0052)	0.006059 (0.0162)
GARCH	0.959469 (0.0000)	0.941575 (0.0000)	0.944896 (0.0000)	0.972645 (0.0000)	0.976929 (0.0000)
Squared Return on Futures Price(MCX)(t-1)	0.028855 (0.0001)	0.048965 (0.0000)	0.052077 (0.0000)	0.020616 (0.00000)	0.02072 (0.0000)
Log Likelihood	5440.894	5162.32	4525.553	4540.236	4752.815

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

It is found from the results of mean equation that return of futures price of aluminium, copper, nickel, lead and zinc traded on LME are influenced by their own lagged return. While the return on futures prices of aluminium, copper, nickel, lead and zinc are affected by lagged return of futures price of aluminium, copper, nickel, lead and zinc traded on LME respectively.

From the variance equation, for all the five return series, ARCH and GARCH effects are found to be significant. The coefficient of lagged squared returns of futures prices of metals 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 metals traded on MCX on return and volatility of futures price of metals traded on LME respectively.

4.3.2 Mean Model - I

Table 14: Results of Mean Model (Equation 7 and 8) - Impact on price return of metal traded on MCX

Return on Futures Price (MCX) - Dependent Variable	**Aluminium (i)**	**Copper (ii)**	**Nickel (iii)**	**Lead (iv)**	**Zinc (v)**
Mean Equation					
Mean Constant	-6.05E-05 (0.8197)	0.00044 (0.1455)	9.93E-05 (0.8020)	0.000591 (0.1259)	6.98E-06 (0.9839)
Return on Futures Price (MCX)(t-1)	-0.129134 (0.0000)	-0.047119 (0.2708)	-0.050172 (0.1590)	-0.065758 (0.0256)	-0.052644 (0.1183)
Return on Futures Price (LME)(t-1)	0.152336 (0.0000)	0.019252 (0.6075)	0.09765 (0.0007)	0.145521 (0.0000)	0.084606 (0.0033)
Variance equation					
Variance constant	1.02E-06 (0.0025)	1.83E-06 (0.0013)	1.77E-06 (0.0091)	2.04E-06 (0.0010)	1.97E-07 (0.3315)
ARCH	0.02776 (0.0000)	0.057412 (0.0000)	0.043306 (0.0000)	0.058812	0.026758 (0.0000)
GARCH	0.965691 (0.0000)	0.936105 (0.0000)	0.952797 (0.0000)	0.938601 (0.0000)	0.972839 (0.0000)
Log Likelihood	5765.826	5413.29	4780.639	4909.603	5120.966

Table 14 represents the results of the Pure Mean model (Equation 7 and Equation 8) with return on futures price of metals traded on MCX (here domestic market is MCX) as the dependent variable. The mean equation includes lagged return on futures price of metals traded on MCX and a term of lagged return on futures price of metals traded on LME(here foreign market is LME). The variance equation contains only ARCH and GARCH terms. The model is run separately for each metal.

It is found from the results of mean equation that return of futures price of aluminium and lead traded on MCX are influenced by their own lagged return. While the return on futures prices of aluminium, nickel, lead and zinc are affected by lagged return of futures price of aluminium, nickel, lead and zinc traded on LME respectively. Return on futures price of copper traded on MCX remains unaffected by both lagged return on futures price of copper traded on MCX and lagged return on futures price of copper traded on LME.

From the variance equation, for all the five 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 aluminium, nickel, lead and zinc traded on LME on return of futures price of aluminium, nickel, lead and zinc traded on MCX respectively.

4.3.2 Mean Model - II

Table 15: Results of Mean Model (Equation 9 and 10) - Impact on price return of metal traded on LME

Return on Futures Price (LME) - Dependent Variable	**Aluminium (i)**	**Copper (ii)**	**Nickel (iii)**	**Lead (iv)**	**Zinc (v)**
Mean Equation					
Mean Constant	-4.39E-05 (0.8903)	0.000412 (0.2498)	0.000127 (0.7775)	0.000433 (0.3613)	-1.01E-05 (0.9805)
Return on Futures Price (LME)(t-1)	-0.223215 (0.0000)	-0.343767 (0.0000)	-0.269593 (0.0000)	-0.208347 (0.0000)	-0.263677 (0.0000)
Return on Futures Price (MCX)(t-1)	0.191394 (0.0000)	0.314851 (0.0000)	0.337671 (0.0000)	0.29924 (0.0000)	0.280442 (0.0000)
Variance Equation					
Variance constant	2.33E-06 (0.0014)	2.88E-06 (0.0023)	3.37E-06 (0.0040)	7.72E-07 (0.2151)	4.38E-07 (0.2423)
ARCH	0.027388 (0.0000)	0.056252 (0.0000)	0.045515 (0.0000)	0.025725 (0.0000)	0.022963 (0.0000)
GARCH	0.961464 (0.0000)	0.934889 (0.0000)	0.949539 (0.0000)	0.972619 (0.0000)	0.975371 (0.0000)
Log Likelihood	5432.605	5153.448	4509.736	4530.436	4743.089

Table 15 shows the results of the Pure Mean model (Equation 9 and Equation 10) with return on futures price of metals traded on LME (here domestic market is LME) as the dependent variable. The mean equation includes lagged return on futures price of metals traded on LME and a term of lagged return on futures price of metals traded on MCX (here foreign market is MCX). The variance equation contains only ARCH and GARCH terms. The model is run separately for each metal.

It is found from the results of mean equation that return of futures price of aluminium, copper, nickel, lead and zinc traded on LME are influenced by their own lagged return. While the return on futures prices of aluminium, copper, nickel, lead and zinc are affected by lagged return of futures price of aluminium, copper, nickel, lead and zinc traded on MCX respectively.

From the variance equation, for all the five 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 aluminium, copper, nickel, lead and zinc traded on MCX on return of futures price of aluminium, nickel, lead and zinc traded on LME respectively.

4.3.3. Pure Volatility Model -I

Table 16: Results of Volatility Model (Equation 11 and 12) - Impact on price return of metal traded on MCX

Return on Futures Price (MCX) - Dependent Variable	**Aluminium (i)**	**Copper (ii)**	**Nickel (iii)**	**Lead (iv)**	**Zinc (v)**
			Mean Equation		
Mean Constant	-4.59E-05 (0.8628)	0.000504 (0.0921)	0.000105 (0.7928)	0.000606 (0.1175)	1.12E-05 (0.9741)
Return on Futures Price (MCX)(t-1)	0.012871 (0.5704)	-0.028243 (0.2345)	0.04429 (0.0565)	0.065853 (0.0054)	0.033289 (0.1439)
			Variance equation		
Variance constant	1.07E-06 (0.0041)	1.73E-06 (0.0009)	1.60E-06 (0.0217)	1.89E-06 (0.0094)	1.99E-07 (0.3135)
ARCH	0.025855 (0.0000)	0.064077 (0.0000)	0.039844 (0.0000)	0.056401 (0.0000)	0.026438 (0.0000)
GARCH	0.962084 (0.0000)	0.940459 (0.0000)	0.95302 (0.0000)	0.939462 (0.0000)	0.973491 (0.0000)
Squared Return on Futures Price(LME)(t-1)	0.003871 (0.0132)	-0.007909 (0.0535)	0.002751 (0.5055)	0.001325 (0.4824)	-0.000246 (0.8190)
Log Likelihood	5753.539	5413.937	4776.639	4894.573	5117.465

Table 16 represents the results of the Pure Volatility model (Equation 11 and Equation 12) with return on futures price of metals traded on MCX (here domestic market is MCX) as the dependent variable. The mean equation includes lagged return on futures price of metals traded on MCX. The variance equation in the Pure Volatility model includes lagged squared return on futures prices of metals traded on LME (LME is foreign market; proxy of volatility in price return of futures contracts traded in foreign market). The model is run separately for each metal.

It is found from the results of mean equation that return of futures price of lead traded on MCX are influenced by their own lagged return. The return of futures price of aluminium, copper, nickel and zinc are not influenced by their own lagged return.

From the variance equation, for all the five return series, ARCH and GARCH effects are found to be significant. The coefficient of lagged squared returns of futures prices of aluminium traded on LME is found to be significant (p value is 0.0132, less than 0.05). This suggests that as per the Pure Volatility Model, there is impact of lagged price return volatility in aluminium traded on LME on price return volatility in aluminium traded on MCX.

4.3.3. Pure Volatility Model -II

Table 17: Results of Volatility Model (Equation 13 and 14) - Impact on price return of metal traded on LME

Return on Futures Price (LME) - Dependent Variable	Aluminium (i)	Copper (ii)	Nickel (iii)	Lead (iv)	Zinc (v)
Mean Equation					
Mean Constant	-0.0000147 (0.9634)	0.000158 (0.6581)	7.57E-05 (0.8746)	0.000466 (0.3348)	-0.000159 (0.7024)
Return on Futures Price (LME)(t-1)	-0.099511 (0.0000)	-0.108427 (0.0000)	-0.034416 (0.1295)	-0.011506 (0.6219)	-0.068437 (0.0022)
Variance Equation					
Variance constant	2.49E-06 (0.0009)	2.06E-06 (0.0078)	5.27E-06 (0.0001)	1.34E-06 (0.0365)	7.57E-07 (0.0273)
ARCH	0.005942 (0.1814)	0.010974 (0.1571)	0.012178 (0.0551)	0.009004 (0.0043)	0.005131 (0.0357)
GARCH	0.961574 (0.0000)	0.941774 (0.0000)	0.94153 (0.0000)	0.972526 (0.0000)	0.976636 (0.0000)
Squared Return on Futures Price(MCX)(t-1)	0.028376 (0.0000)	0.054244 (0.0000)	0.049758 (0.0000)	0.022036 (0.0000)	0.022481 (0.0000)
Log Likelihood	5431.704	5145.63	4495.922	4519.495	4740.062

Table 17 represents the results of the Pure Volatility model (Equation 13 and Equation 14) with return on futures price of metals traded on LME (here domestic market is LME) as the dependent variable. The mean equation includes lagged return on futures price of metals traded on LME. The variance equation in the Pure Volatility model includes lagged squared return on futures prices of metals traded on MCX (MCX is foreign market; proxy of volatility in price return of futures contracts traded in foreign market). The model is run separately for each metal. It is found from the results of mean equation that return of futures price of aluminium, copper, and zinc traded on LME are influenced by their own lagged return. The return of futures price of nickel and lead are not influenced by their own return.

From the variance equation, for all the five return series, ARCH and GARCH effects are found to be significant. The coefficient of lagged squared returns of futures prices of aluminium, copper, nickel, lead and zinc traded on LME 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 lagged price return volatility in aluminium, copper, nickel, lead and zinc traded on MCX on price return volatility in aluminium, copper, nickel, lead and zinc traded on LME.

Table 18 gives a summary of results of modified GARCH model, it is suggested that the results obtained from Pure Mean Model and Pure Volatility Model are found to be consistent with the results obtained from Full Model except in case of Aluminium traded on MCX (volatility of aluminium returns on futures traded on MCX is not affected by aluminium returns on futures traded on LME in full model whereas volatility of aluminium returns on futures traded on MCX is not affected by aluminium returns on futures traded on LME in volatility model).

Table 18: Summary of Results of Modified GARCH Model

Returns of Futures contracts traded on MCX is dependent variable				
	Full Model		**Pure Mean Model– Impact on Mean**	**Pure Volatility Model– Impact on Volatility**
	Mean Return	**Volatility**		
Aluminium	0.151095 (0.0000)	0.001515 (0.4489)	0.152336 (0.0000)	0.003871 (0.0132)
Copper	0.018229 (0.6184)	-0.007897 (0.0553)	0.019252 (0.6075)	-0.007909 (0.0535)
Nickel	0.098679 (0.0009)	0.003163 (0.4935)	0.09765 (0.0007)	0.002751 (0.5055)
Lead	0.147648 (0.0000)	0.001983 (0.3397)	0.145521 (0.0000)	0.001325 (0.4824)
Zinc	0.085036 (0.0039)	-0.000446 (0.6946)	0.084606 (0.0033)	-0.000246 (0.8190)
Returns of Futures contracts traded on LME is dependent variable				
	Full Model		**Pure Mean Model – Impact on Mean**	**Pure Volatility Model – Impact on Volatility**
	Mean Return	**Volatility**		
Aluminium	0.191672 (0.0000)	0.028855 (0.0001)	0.191394 (0.0000)	0.028376 (0.0000)
Copper	0.300207 (0.0000)	0.048965 (0.0000)	0.314851 (0.0000)	0.054244 (0.0000)
Nickel	0.359836 (0.0000)	0.052077 (0.0000)	0.337671 (0.0000)	0.049758 (0.0000)
Lead	0.287519 (0.0000)	0.020616 (0.00000)	0.29924 (0.0000)	0.022036 (0.0000)
Zinc	0.258324 (0.0000)	0.02072 (0.0000)	0.280442 (0.0000)	0.022481 (0.0000)

4.4 ARMA – GARCM in mean model – The Innovation Model Results

4.4.1 First Stage of Model-I

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

Dependent Variable – Return on Futures Price of metal traded on MCX	Aluminum (i)	Copper (ii)	Nickel (iii)	Lead (iv)	Zinc (v)
Mean Equation					
Mean constant	0.000223 (0.8147)	0.000985 (0.1052)	0.001076 (0.2258)	-0.000304 (0.7553)	-0.001091 (0.1765)
Coefficient of AR(1)	-0.178779 (0.4492)	-0.233891 (0.2118)	-0.683209 (0.0001)	0.028682 (0.9914)	-0.428437 (0.0722)
Coefficient of MA(1)	0.083666 (0.7260)	0.123043 (0.5188)	0.650732 (0.0003)	-0.037033 (0.9889)	0.360895 (0.1421)
Coefficient of GARCH	-1.359304 (0.7631)	-2.414804 (0.2344)	-2.048915 (0.2192)	1.670968 (0.3531)	2.924416 (0.1117)
Variance Equation					
Mean constant	2.29E-06 (0.0015)	3.07E-06 (0.0017)	4.36E-06 (0.0008)	7.45E-07 (0.2020)	5.52E-07 (0.1681)
ARCH	0.027302 (0.0000)	0.055686 (0.0000)	0.048543 (0.0000)	0.023811 (0.0000)	0.022884 (0.0000)
GARCH	0.961908 (0.0000)	0.934764 (0.0000)	0.945111 (0.0000)	0.974582 (0.0000)	0.975111 (0.0000)
Log Likelihood	5423.57	5132.693	4483.564	4507.863	4726.533

Table 19 reports the results of First Stage of ARMA-GARCH in mean model (Equation 15 and Equation 16) run on the returns of metals traded on MCX. 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 five metals traded on MCX.

4.4.1 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 metals traded on LME. This is run to estimate the standardised residual which is used in the second stage of the model.

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

Dependent Variable – Return on Futures Price of metal traded on LME	**Aluminium (i)**	**Copper (ii)**	**Nickel (iii)**	**Lead (iv)**	**Zinc (v)**
Mean Equation					
Mean constant	0.000157 (0.8105)	0.000795 (0.1173)	0.000126 (0.8554)	0.001070 (0.0943)	0.000294 (0.6120)
Coefficient of AR(1)	0.483915 (0.6130)	-0.616073 (0.0202)	0.403172 (0.3017)	0.553852 (0.0037)	0.117665 (0.8519)
Coefficient of MA(1)	-0.466411 (0.6291)	0.576943 (0.0359)	-0.355318 (0.3740)	-0.477627 (0.0177)	-0.081394 (0.8978)
Coefficient of GARCH	-1.394824 (0.7481)	-2.074563 (0.3784)	-0.064109 (0.9715)	-1.639240 (0.3619)	-1.291303 (0.5372)
Variance Equation					
Mean constant	1.03E-06 (0.0019)	1.87E-06 (0.0012)	1.60E-06 (0.0123)	2.09E-06 (0.0008)	2.07E-07 (0.2960)
ARCH	0.026823 (0.0000)	0.057595 (0.0000)	0.04121 (0.0000)	0.057738 (0.0000)	0.026965 (0.0000)
GARCH	0.966618 (0.0000)	0.935625 (0.0000)	0.95522 (0.0000)	0.93939 (0.0000)	0.972619 (0.0000)
Log Likelihood	5753.086	5414.146	4777.304	4898.049	5117.614

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.

4.4.2.1 Second Stage Stage of Model - I

To assess the Impact of LME on MCX

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

Dependent Variable - Return on Futures Price of metal traded on MCX	Aluminium (i)	Copper (ii)	Nickel (iii)	Lead (iv)	Zinc (v)
Mean Equation					
Mean constant	0.000105 (0.8620)	0.000988 (0.1125)	0.000622 (0.3400)	0.000624 (0.3157)	-0.000274 (0.9336)
Coefficient of AR(1)	-0.032596 (0.8025)	0.051414 (0.8947)	-0.367129 (0.0612)	-0.47007 (0.0142)	0.041357 (0.9353)
Coefficient of MA(1)	-0.156162 (0.2282)	-0.111305 (0.7763)	0.289735 (0.1687)	0.382574 (0.0659)	-0.118487 (0.8181)
Coefficient of GARCH	-1.153877 (0.7758)	-3.008961 (0.2288)	-1.575138 (0.3574)	-0.136995 (0.9379)	-0.275264 (0.9601)
Residual of LME (t-1)	0.002850 (0.0000)	0.001186 (0.0471)	0.002564 (0.0000)	0.003267 (0.0000)	0.003434 (0.0048)
Variance Equation					
Mean constant	6.60E-07 (0.2366)	5.72E-05 (0.0000)	-5.41E-07 (0.7734)	2.09E-06 (0.1505)	0.000225 (0.0061)
ARCH	0.027818 (0.0000)	0.248191 (0.0000)	0.036163 (0.0000)	0.057379 (0.0000)	0.161772 (0.0010)
GARCH	0.96262 (0.0000)	0.626581 (0.0000)	0.957922 (0.0000)	0.940539 (0.0000)	0.567692 (0.0002)
Square of Residual of LME(t-1)	8.00E-07 (0.1648)	-2.05E-05 (0.0000)	3.05E-06 (0.1919)	-3.65E-07 (0.8214)	-1.90E-05 (0.0000)
Log Likelihood	5765.225	5354.454	4780.616	4906.505	4842.398

Table 21 represents the results of the second stage of ARMA-GARCH in mean model (Equation 19 and Equation 20) with return on futures price of metals 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 lagged standardised residual (standardised residuals derived from ARMA-GARCH in mean model of metals traded on LME-

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. These residuals are included to assess the impact of innovation in foreign market on domestic market.

It is found from the results of mean equation that the lagged standardised residual of the five metals traded on LME influence returns of all the metals traded on MCX respectively, thus suggesting that metals traded on LME have mean spill-over effects of innovation on return of metals traded on MCX.

From the variance equation, for all the five metal price return series, ARCH and GARCH effects are found to be significant. Whereas, the coefficient of lagged squared standardised residual for copper and zinc is found to be significant in the variance equation, implying that copper and zinc traded on LME have volatility spill over effects of innovation on metals traded on MCX.

4.4.2.1 Second Stage of Model - II

To assess the Impact of MCX on LME

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

Dependent Variable - Return on Futures Price of metal traded on LME	Aluminium (i)	Copper (ii)	Nickel (iii)	Lead (iv)	Zinc (v)
Mean Equation					
Mean constant	0.000332 (0.7050)	0.001861 (0.0002)	0.001078 (0.1556)	-0.000619 (0.5001)	-0.001574 (0.0368)
Coefficient of AR(1)	-0.033617 (0.7558)	-0.046314 (0.5376)	0.110883 (0.1565)	-0.086533 (0.5200)	-0.069626 (0.4799)
Coefficient of MA(1)	-0.191697 (0.0906)	-0.284965 (0.0002)	-0.41637 (0.0000)	-0.09559 (0.5007)	-0.167173 (0.1141)
Coefficient of GARCH	-1.721989 (0.6790)	-5.836503 (0.0004)	-2.072169 (0.1567)	2.292223 (0.1827)	4.145823 (0.0193)
Residual of MCX (t-1)	0.002271 (0.0000)	0.004046 (0.0000)	0.006889 (0.0000)	0.004684 (0.0000)	0.003895 (0.0000)
Variance Equation					
Mean constant	2.60E-07 (0.7754)	-3.38E-06 (0.0014)	-1.04E-06 (0.6282)	-5.72E-06 (0.0000)	-2.00E-06 (0.0563)
Coefficient of ARCH	0.017888 (0.0006)	0.025103 (0.0000)	0.035008 (0.0000)	0.014731 (0.0000)	0.01878 (0.0000)
Coefficient of GARCH	0.967031 (0.0000)	0.962106 (0.0000)	0.9576 (0.0000)	0.978488 (0.0000)	0.977564 (0.0000)
Square of Residual of MCX (t-1)	2.88E-06 (0.0024)	0.00000696 (0.0000)	5.39E-06 (0.0227)	0.00000904 (0.0000)	3.17E-06 (0.0087)
Log Likelihood	5429.571	5148.177	4508.427	4530.679	4741.391

Table 22 represents the results of the second stage of ARMA-GARCH in mean model (Equation 21 and Equation 22) with return on futures price of metals traded on LME (here domestic market is LME) 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 derived from ARMA-GARCH in mean model of metals traded on MCX-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 (standardised residuals derived from ARMA-GARCH in mean model of metals traded on MCX -Table 19). These residuals are included to assess the impact of innovation in foreign market on domestic market.

It is found from the results of mean equation that the lagged standardised residual of aluminium, copper, nickel, lead and zinc traded on MCX influence returns of aluminium, copper, nickel, lead and zinc traded on LME respectively (p value of all is 0.0000), thus suggesting that a metal traded on MCX has mean spill-over effects of innovation on return of metal traded on LME.

From the variance equation, for all the five metal price return series, ARCH and GARCH effects are found to be significant. The coefficient of lagged squared standardised residual for aluminium, copper, nickel, lead and zinc is found to be significant in the variance equation. This implies that a metal traded on MCX has volatility spill over effects of innovation on a metal traded on LME.

5. Conclusion

The findings of the three models discussed in the study can be summarised as follows. The price series of each of five pairs of metals (aluminium, copper, nickel, lead and zinc) traded on MCX and LME are found to be co-integrated implying that there exists a long run relationship between futures contracts of aluminium, copper, nickel, lead and zinc traded on MCX and LME respectively.

A deviation of futures price from its equilibrium long run level is corrected in case of aluminium, lead and zinc futures contracts traded on MCX and LME. Whereas in case of copper and nickel, deviation from equilibrium is corrected in case of futures contracts traded on MCX and not in case of futures contracts traded on LME.

For copper, nickel, lead and zinc, causality in price runs in one direction, from futures contracts traded on MCX to futures contracts on LME but not in the opposite direction that is from LME to MCX. Short term causality in futures price of aluminium is not observed to run in either direction.

Using the three variants of modified GARCH model, it is found from that the returns on futures prices for aluminium, nickel, lead and zinc traded on MCX are influenced by contracts traded on LME while their volatility in returns remains unaffected by contracts traded on LME. The returns and volatility on futures price of aluminium, copper, nickel, lead and zinc traded on LME are affected by futures contracts traded on MCX respectively.

The results of the ARMA-GARCH in mean model indicate that there is mean spill over effect of innovation from futures contracts traded on LME towards the futures contracts traded on MCX for all the metals when lagged standardised residuals are included in the mean equation. Even though a volatility spill over effect of innovation from futures contracts traded on LME is only significant in case of copper and zinc when lagged squared standardised residuals are included in the variance equation. In case of futures contracts traded on LME, there is presence of mean and volatility spill over effect of innovation on the five base metals traded on LME.

Thus, given the level of integration of prices, return and volatility in futures contracts of base metals traded on MCX and LME. The imposition of Commodity Transaction Taxes on sellers of 0.01 per cent on transaction value on the five base metals traded on commodity exchanges would lead to a fall in their trading volume as traders and speculators would escape the higher transaction cost by investing in International Markets (e.g. LME) instead of Indian Markets (e.g. MCX). This movement from Indian to the International markets would defy the intention of imposition of the tax, as the government expects to earn handsome revenue from the tax, and this would also defeat the very purpose of price discovery in the commodity exchanges in India.

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