A study on the Price Behavior of Base Metals traded in India

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Abstract:

This study looks into the price behavior of five base metals – aluminum, copper, zinc, lead and nickel traded on Multi Commodity Exchange (MCX), using near month futures contracts and spot contracts for the period from November 2007 to January 2013. To assess the impact of the recent Global Financial Crisis on trading of base metals, the price volatility of the base metals has been examined using GARCH models. The paper also studies the effect of implied volatility of equity market, measured by India VIX on the price volatility of the five base metals. The findings of the study suggest that there is presence of short term persistence in price volatility of the metals, and the daily price volatility of base metals is influenced by the Global Financial Crisis. The implied volatility in equity market is also found to affect the price volatility of the metals. Thus, the paper gives important evidence in support of the introduction of option contracts on base metals in Indian Commodity Markets, since option contracts are priced considering the price volatility of the underlying asset.

Keywords: Option contracts, Base metals, Volatility

JEL Codes: Q02, L61, G01

1. Introduction

The Indian Commodity Market has been growing tremendously since the operation of Commodity Futures Exchanges, both in terms of volume and value of trade. Currently, there are five national exchanges (Multi Commodity Exchange of India Limited, National Commodity & Derivatives Exchange Limited, National Multi-Commodity Exchange of India Limited, Indian Commodity Exchange Limited and ACE Derivatives and Commodity Exchange Limited) and sixteen commodity specific regional exchanges. The Indian Commodity Market allows trading of futures and spot contracts on commodities. Option contracts are not available in the Indian Commodity Market. Multi Commodity Exchange is the largest national commodity exchange in India; it began its operations in November 2003. The exchange offers many commodities in the categories of bullion, ferrous metals, non-ferrous metals, energy, and agriculture.

In this study, price behavior of five base metals (aluminum, copper, nickel, zinc and lead) which are traded on Multi Commodity Exchange is analyzed from November 2007 to January 2013. Prices of futures contracts and spot contracts of the base metals are examined. The issue of the introduction of option contracts on base metals in Indian Commodity markets has been addressed through (a) Presence of short term persistence in metal price volatility (b) Impact of recent Global Financial Crisis on daily metal price volatility (c) Impact of implied volatility of equity market, measured by India VIX[1] on weekly metal price volatilities.

The cumulative value of trade and cumulative value of trade in 'metals other than bullion' in the Indian Commodity market from 2008 till January 2013 is presented in Table 1. The table also gives value of trade in 'metals other than bullion' as a percentage of value of trade.

It is clear from the table that base metals are being widely traded in India. The share of base metals in all commodity exchanges has remained more than 10% since 2008. In the second fortnight of January 2013, total value of base metals chosen for the study as a percentage of total value of all commodities traded on MCX was 22.2%.

[1]India VIX is a volatility index based on NIFTY Index options. It is a measure of the expectation of market volatility over the near term. VIX is a trademark of Chicago Board Options Exchange; NSE has been granted a license by Incorporated ("CBOE") and Standard& Poor's, with permission from CBOE, to use such mark in the name of the India VIX.

Table 1 : Value of Trade and Value of Metals other than bullion in Indian Commodity Market (Financial Year2008 - January 2013)

Financial Year	Cumulative value of trade (Rs. Crore)	Cumulative value of trade in 'metals other than bullion' (Rs. Crore)	Value of 'metals other than bullion' as percentage of Value of trade (%)
2008	52,48,956.18	6,18,775.61	11.79
2009	77,64,754.05	18,01,636.31	23.20
2010	1,19,48,942.35	26,87,672.99	22.49
2011	`1,81,26,103.78	28,96,720.73	15.98
2012 till January 2013	1,44,17,579.08	27,08,459.64	18.79

Source: Forward Market Commission

Aluminum is the second most extensively used metal in the world, China followed by North America are the first and second largest regions involved in the production of aluminum. Usage of aluminum lies in electronics, electric cars, construction, transport, packaging, and utensils. While Chile is the largest producer of copper in the world, India is among the top twenty major producers of copper in the world. In India, the demand for copper is predominantly from the telecom sector, electrical sector, engineering, building and construction, transport and consumer durables. After aluminum and copper, lead and zinc are commonly used metals. Australia, China, and United States possess the maximum reserve of lead in the world. Lead is primarily used in the battery industry. Zinc ore is found in Australia, China and United States, and zinc production is on the rise in India. Demand of zinc emerges in construction, automobile, electrical and machinery industries, manufacture of fertilizers and galvanizing of iron and steel. Russia is the largest producer of nickel in the world, while European Nations and Japan are top two consumers of the metal. Nickel is used in the production of alloys - stainless steel used in gas turbines and chemical plants; alloy of iron and nickel used in electronics and special engineering. The metal is used in manufacture of rechargeable batteries and catalysts.

Section 2 of this paper analyses the price behavior of the five base metals traded on the Multi Commodity Exchange in India from November 2007 to January 2013. Section 3 reviews previous literature in the area, followed by Section 4 which discusses data and methodology. Section 5 elaborates on the results of the study and Section 6 presents conclusions derived from the study.

2. Price behavior of metals

2.1 Aluminum

Figure 1: Price behavior of Aluminum

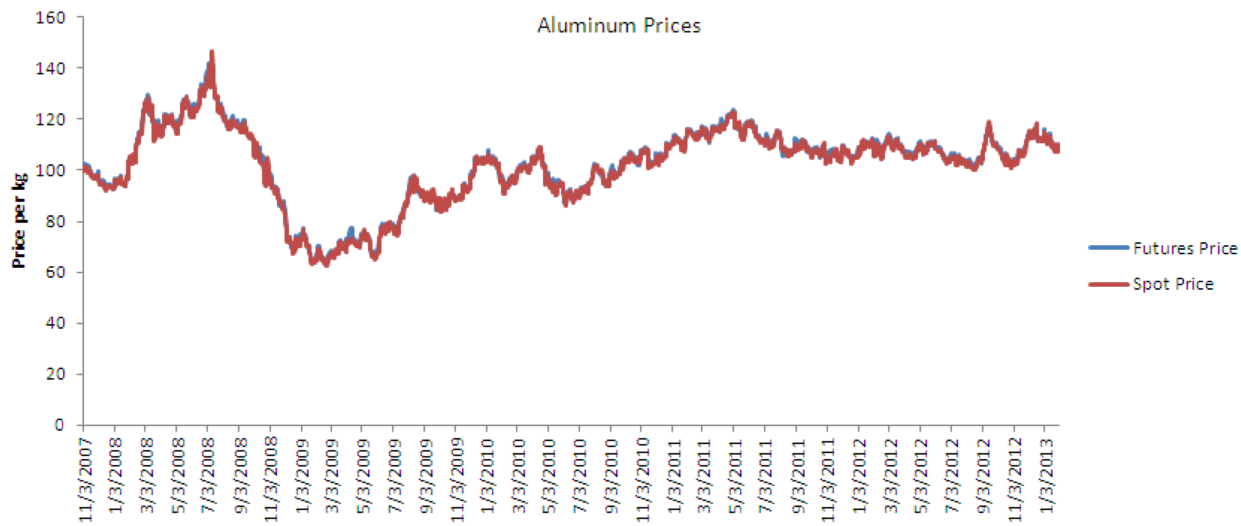

Figure 1 shows the co-movements in the spot and futures prices of Aluminum traded on MCX during the period November 3, 2007 to January 30, 2013. Aluminum experienced a sharp rise in price in the month of July 2008 when it touched a high of Rs. 146.6 per kg in the spot market and Rs. 142.25 per kg in the futures market. This could be attributed to the agreement signed between Chinese Aluminum suppliers to reduce production of the metal by 5% to 10% in July 2008 due to a production surplus in the period from January to April 2008,amounting to 458000 tons of primary aluminum. This was accompanied by the oil price hike when oil prices peaked at $147per barrel in mid-July 2008. After the oil price bubble, aluminum spot prices began to fall from a peak of Rs. 146.6 per kg (July 2008) to as low as Rs. 62.5 per kg in February 2009, as speculators started unwinding their positions. Chinese demand for aluminum reduced in the same period after the Olympics which lead to rise in inventory. A lower demand from automobiles, aviation sector and packaging sector also lead to piling up of aluminum stocks across exchanges.

A gradual rise in the price of the metal began around mid 2009 hovering around Rs. 95 per kg to Rs. 100 per kg in the context of production of Chinese cars, house and fixed asset investment in May 2009 and a weaker US Dollar. This was followed by minor fluctuations until a slight dip was observed when aluminum prices touched Rs. 86.45 per kg in June 2010 backed by low demand for the metal. Prices began to rise in the month of August 2010 and in April 2011 averaged around Rs. 118 per kg with closing down of smelters in China leading to a small demand-supply mismatch. Since May 2011, prices remained above Rs. 105 per kg until November - December 2011 when it touched a marginal decline which can be attributed to the Eurozone crisis and China's economic slowdown. Aluminum prices rallied in 2012 because of recovering market confidence and better than expected global growth, which was followed by a spike in September 2012 when it touched Rs. 119.15 per kg with anticipation of a pickup in economic activity beginning in the last quarter of 2012 and the impact of possible stimulus measures in China in the background. This was followed by a depression in prices till early November 2012, since then they have remained above the Rs. 105 per kg mark.

2.2 Copper

Figure 2: Price behavior of Copper

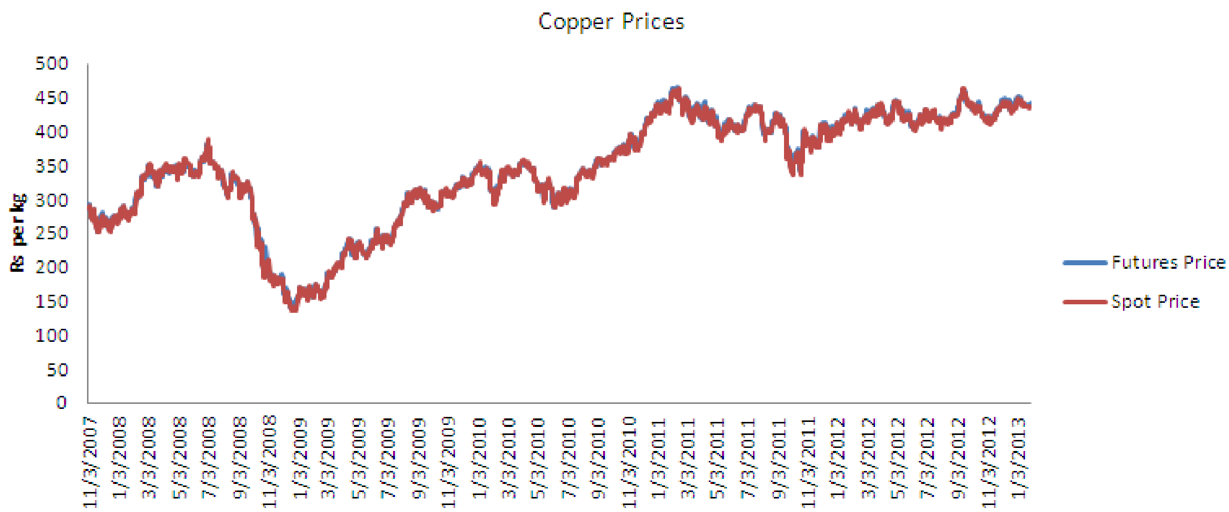

Figure 2 depicts the co-movements of futures and spot prices of copper from November 2007 to January 2013. Like aluminum, copper also faced similar movements in its price. Prices continued to stay in the range of Rs. 250-300 per kg until the second half of February 2008 touching Rs. 330 per kg due to a rise in copper prices globally amid strong Chinese demand and fall in inventories in London Metal Exchange. With the oil price hike in July 2008, copper market faced a spike, when it peaked at Rs. 388.25 per kg on July 3, 2008. This was in contrast to the slump in demand which followed the July 2008 spike, a decline in spot price continued to take place till it bottomed at Rs. 135.65 per kg on December 19, 2008 due to a substantial surplus.

Copper prices after facing a decline in demand in December 2008 recovered and rose to around Rs. 340 per kg in March 2010 with the recovery in oil price and gains in the Euro supported by fall in inventories at London Metal Exchange. A slight trough in price (Rs. 287 per kg) was observed in June 2010 which can be attributed to the decline in sale of houses and unemployment level of 10% in United States of America. The decline could also be due to monetary tightening in China and the Euro sovereign debt crisis. After a fall in inventories, copper prices began to rise and reached a record high of Rs. 460 per kg in February 2011, even higher than the rise during the oil price hike. The rise was mainly because of global price rise backed by cyclone Yasi in Australia (Australia is one of largest producers of the metal) and strong growth in manufacturing sector in US, Europe and China. Demand for copper came from firms involved in plumbing, heating, electrical and telecommunications wiring across the world. This was followed by a steady decline in the price level touching a level of Rs. 340 per kg in October 2011 and then recovering due to a decline in inventories with rise in demand from China. The prices have continued to rise above the Rs. 370 per kg mark since November 2011 and a level of Rs 462.4 per kg was reached in September 2012 faced by demand from Chinese power sector and housing sector. An announcement of investment in Indian power sector by Power Grid Corporation of approximately $18 billion to upgrade networks was received by the copper market with a rise in price.

2.3 Lead

Figure 3: Price behavior of Lead

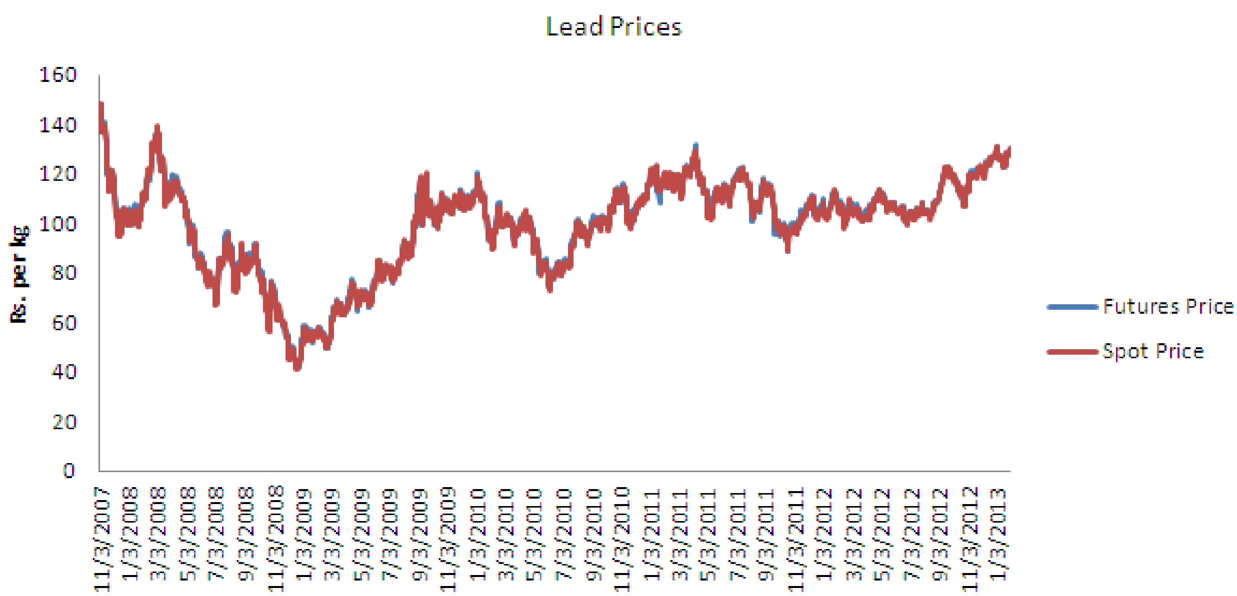

Figure 3 shows the co-movement of spot prices and futures prices of lead from November 2007 till January 2013 traded on the Multi Commodity Exchange (India). Lead prices dropped in December 2007 to Rs 94.95 per kg with slow growth of US economy and weak prospects of growth of economies across the world. Price of the metal soon took cues from the market and began to rise in first week of February 2008 and touched Rs. 139.4 on March 4, 2008. This could be attributed to the high consumption of lead for vehicle fleet expansion and production of automotive batteries, investment in infrastructure of telecom and information technology, higher demand in winters, and production deficit due to the snowstorm in China. The increase in lead prices led to a rise in price of lead batteries manufactured by Exide in India. The market soon saw a surge in prices with spot prices falling to Rs. 66.8 per kg in July 2008 with the deepening of the US financial crisis and growth in manufacturing sector coming to a standstill. The major automobile producers announced a cut in production. This led to a further fall in prices in the latter half of 2008 and plummeted to as low as Rs. 41.5 per kg on December 20, 2008 succumbing to the pressures of global financial turmoil.

Lead prices appeared to be on the rise since the first quarter of 2009 and continued to increase throughout 2009 reaching a maximum of Rs. 120.9 per kg on September 21, 2009. This soaring of lead prices was supported by an expected fall in world production of the metal as a result of closure of zinc mines of which lead is a by-product. The rise could also be due to seasonal demand and a reduction in capacity of Chinese smelters because of environmental concerns. Lead prices remained stable till February 2010 and became volatile in March 2010 with Rs. 91.14 per kg. There was a gradual decline in prices in the months to follow until they dropped to Rs. 73.35 per kg in June 2010. This was followed by a quick recovery, prices began rising which can be owed to reversal of LME stock build up and expectation of increase in demand of lead acid battery in the second half of 2010. Prices continued to rise in early 2011 supported by rise in Chinese imports as car sales were rising and general positive sentiments in the market. Lead prices in 2011 continued to fluctuate but remained above Rs. 90 per kg. In 2012, prices remained stable till November 2012; it peaked at Rs. 123.6 per kg. Spot prices in January 2013 averaged at Rs.126 per kg.

2.4 Zinc

Figure 4: Price behavior of Zinc

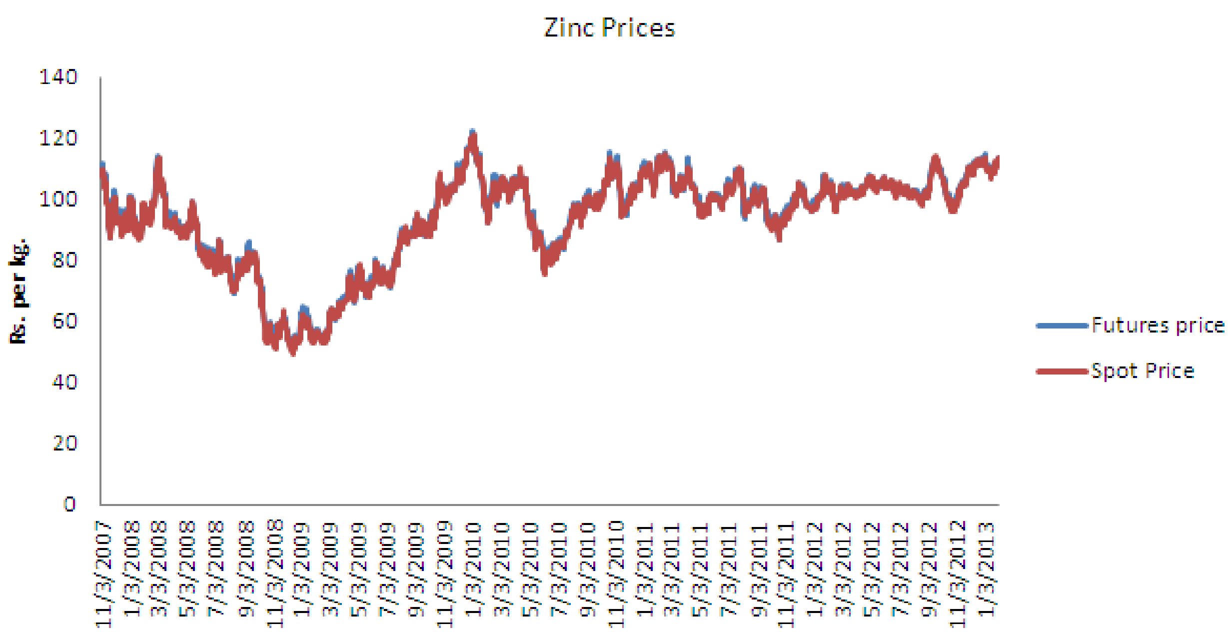

Figure 4 represents the co-movements in futures price and spot price of zinc traded on the Multi Commodity Exchange for the period between November 3, 2007 and January 30, 2013. Between

November 2007 and February 2008, spot price of zinc remained above Rs. 86 per kg, but continued to remain volatile till it peaked at Rs. 113.85 per kg on March 6, 2008. This could be as a result of strong demand from China's growing economy and infrastructure but the prices soon began to decline drastically. There was a decline of 47% till December 2008, when zinc prices dipped to as low as Rs. 49.45 per kg which was supported by weak demand and rise in inventories. The sharp fall in zinc prices lead to closure of several mines and infrastructure projects were also shelved during this phase. Spot prices continued to remain below the Rs. 62.35 per kg mark till first week of March 2009.

Prices began to move in an upward trend from March 2009 to January 2010 reaching Rs. 120.75 per kg on January 6, 2010, even higher than the 2008 level. This price recovery inspite of metal stocks in inventories and continued weak demand could be attributed to the speculative investment as overall economic conditions improved in 2009. Following this, prices continued to fluctuate below the Rs. 120 per kg and a surge was observed in the month of June 2010, when zinc prices touched Rs. 75.4 per kg due to a slowdown in manufacturing activity in China, depreciation of Euro with the sovereign debt crisis and concerns about public finances situation in Hungary. The downside in price was limited, since July 2010, zinc prices bounced back and hovered in the range of Rs. 90 per kg and Rs. 115 per kg supported by appreciation of yuan and wage hike in China. After remaining stable for a few months in 2012, prices rose in September 2012 since a recovery was expected in manufacturing industry of United States and improvement in China's slow economic growth.

2.5 Nickel

Figure 5: Price behavior of Nickel

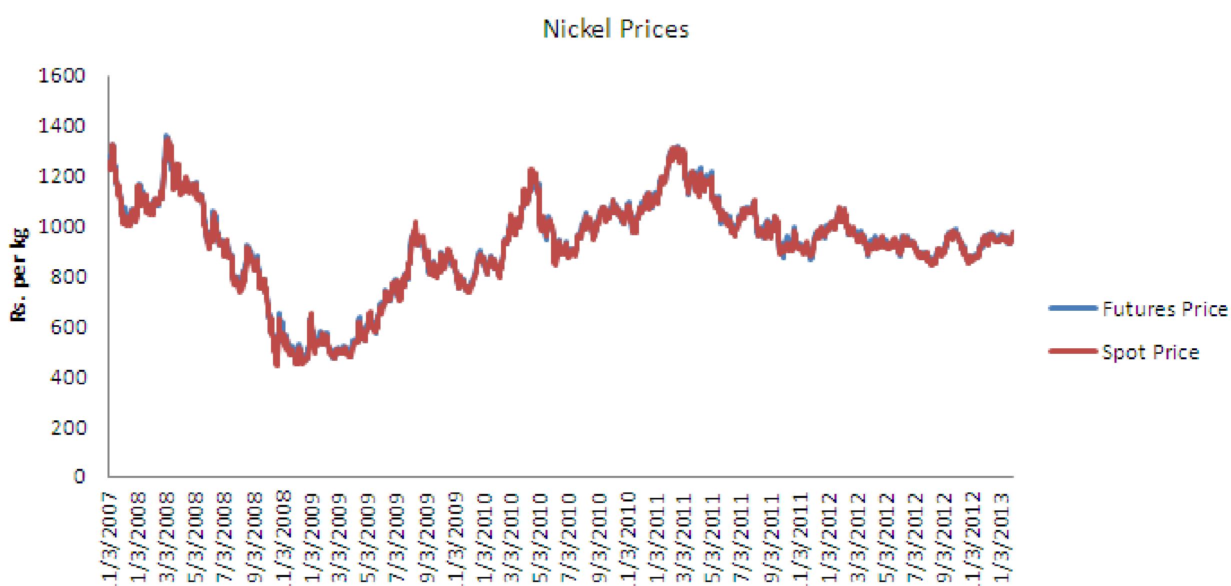

Figure 5 corresponds to the co-movements in the spot price and futures price of Nickel traded on the Multi Commodity Exchange from November 3, 2007 to January 30, 2013. During the course of the six years, the prices averaged at Rs. 924.12 per kg. It witnessed a sharp increase in the first week of March 2008 when spot price touched Rs. 1345 per kg and futures price was Rs. 1359 per kg due to falling inventories at London Metal Exchange and dampening US economy. But within the same month prices fell with the expectation of reduced demand for the metal in the slowing global economy. The price of the metal continued to fall till it reached Rs. 439.9 per kg in October 2008 as the demand weakened by the worsening of global economic situation and lead to building up of stocks. The fall in price continued to take place till May 2009. In May 2009, prices once again began to climb leading to increase in usage of Chinese nickel pig iron (a substitute of nickel).

With rising demand from stainless steel mills, a spike was observed again in April 2010, nickel spot prices soared at the Rs. 1226.8 per kg level. High volatility in prices remained throughout the period from April 2010 to February 2011. Price of nickel averaged around Rs. 1281.71 per kg in February 2011 after recovery but prices began to decline in March 2011 due to European debt situation followed by the adverse economic effect of earthquake in Japan. By October 2011, spot price had fallen to Rs. 895.5 per kg despite decline in stocks of warehouses. The prices rose from October 2011 to January 2012, and on January 28, 2012, spot price was Rs. 1075.7 per kg. This could be as a result of steady demand from alloy makers and increasing fresh long positions at the prevailing low price levels. Since then the price of nickel has been averaging around Rs 926.75 per kg, the metal remains in abundant supply globally and the presence of a substitute of the metal, nickel pig iron, has lead to decline in price level of nickel.

3. Literature Review

Brunetti and Gilbert (1995) construct long time series of non-ferrous metals (aluminum, copper, nickel, lead, zinc and tin) price quotations and measure volatility as the intra-month standard deviation of daily holding returns. They conclude that metals price volatility is stationary and observe presence of higher volatility in 1973-74 and 1987-90 which can be attributed to higher demand.

In the past, studies have considerably contributed to improving our understanding of metal price volatility and spillovers based on GARCH model and various extensions of ARCH and GARCH model. Bernard et al (2008) utilize aluminum spot and futures price series at daily, weekly and monthly frequencies. They compare stochastic models with a focus on ability to generate forecasts. Their study concludes that daily data of prices exhibit, both jump and GARCH effects whereas in monthly price data GARCH (M) effects dominate. Watkins and McAleer (2006) study futures prices of non-ferrous metals (aluminum, aluminum alloy, copper, lead, nickel, tin, and zinc) in a framework for estimating long run pricing models using co-integration.

Using the data set created by Brunetti and Gilbert (1995), McMillan and Speight (2001) analyze the daily non-ferrous metals price volatility using basic GARCH model and a variant of the

GARCH model, CGARCH Model. They report that GARCH model focuses only from medium to the long term whereas the CGARCH model decomposes metal volatility into a long-run component and a short-run transitory component. They further suggest that the volatilities of non-ferrous metal returns are linked but driven by aluminum and copper respectively.

Mckenzie et al (2001) utilize the power GARCH class of models to capture the features of volatility of metals traded on LME (aluminum, copper, nickel, lead and zinc futures). They conclude that asymmetry is absent from the futures price data of the non-ferrous metals and Taylor GARCH model is considered to be most appropriate to model the data and considered it superior to Power GARCH model. Bracker and Smith (1999) identify breakpoints in the series of copper futures prices and compare the random walk, GARCH, EGARCH, AGARCH, and the GJR model to capture the volatility of the series. They find GARCH and EGARCH to be superior to other models.

Literature suggests that extensions of GARCH model can be used to model volatility of precious metals as well as non-ferrous metals. Cochran et al (2011) study the threshold effects in returns of metals - aluminum, copper, gold, silver and platinum employing the difference in yield between 10-year treasury bonds and 90-day treasury bills as the threshold variables. They conclude that DT-FIGARCH(1, δ,1) model captures the non linearity of metal returns and their volatilities. They provide evidence to support the argument that the short memory of component of volatility process of copper, platinum and silver returns is unaffected by a change in regime whereas long memory parameters are dependent on regime.

High frequency futures price data of gold, silver and copper is used by Khalifa et al (2011) to estimate measures of volatility - absolute returns, bi-power volatility, realized volatility, integrated volatility using Fourier transformation. The authors evaluate predictive performance of GARCH (1,1) model using the four measures of volatility. They conclude from the comparison of measures of volatility that gold has highest forecast error. Empirical research has been extensively conducted for studying volatility of prices of precious metals using asymmetric Power GARCH (Tully and Lucey (2007). Akgiray et al (1991) assess the time series properties of spot prices of gold and silver by using the GARCH model. The authors split the data into similar economic periods for the analysis. The study indicates that a GARCH (1,1) model assuming a power exponential distribution is an effective model to study volatility of prices of precious metals.

GARCH and variants of GARCH are being used to model volatility of other commodities as well. Wei et al (2010) utilize daily price data of Brent and West Texas Intermediate to estimate and forecast volatility of crude oil with GARCH, IGARCH, GJR, EGARCH, and APARCH models. They demonstrate that a high degree of persistence lies in the Brent and WTI markets. They conclude that non linear GARCH models outperform the linear GARCH models in the forecasting of long run volatility of crude oil prices. Kang et al (2009) assess the persistence in volatility of crude oil prices using GARCH, IGARCH, FIGARCH and CGARCH models.

Hammoudeh and Yuan (2008) examine futures prices of oil, gold, silver and copper and utilize the GARCH, EGARCH, CGARCH model to study the impact of oil shock and interest rate on metal returns and volatilities. They conclude that conditional volatility is more persistent for gold and silver than for copper and oil volatility has a negative impact on metal volatility. Sadorsky (2006) suggests that TGARCH model fits well in volatility of heating oil and natural gas whereas GARCH model fits well in case of crude oil and unleaded gasoline volatility.

Some authors have used other variants of GARCH models, including extended GARCH model (Yang and Brorsen, 1992) to study the non-normality and the nonlinear dependence observed in price changes of commodities. Several empirical studies have illustrated the existence of strong long term dependence in agricultural commodity prices using FIGARCH models (Jin and Frechette (2004)).

Studies have used VIX as an indicator of equity market returns. Doran et al (2007) assess the effect of implied volatility levels on the returns of stock market index. They find that the returns are affected by VIX variables significantly; the relationship is stronger for portfolios with high beta value. Thus, they claim that VIX related variables have strong ability to predict. Another study with VIX as a variable is by Connolly et al (2005), they examine the relation between stock market uncertainty measured by volatility implied index and interaction between daily stock and treasury bond returns, a negative relation is observed. The authors find that stock returns tend to be low in comparison to bond returns when implied volatility increases substantially.

Copeland and Copeland (1999) found a significant relationship between movement of VIX and performance of portfolios of large capitalization stocks, thus claim that VIX can be used as leading indicator of market returns. A study by Fleming et al (1995) indicates that VIX is an appropriate proxy for expected stock market volatility as it embeds expectations from the market. In the Indian scenario, Bagchi (2012) provides evidence to support that India VIX has a positive and significant relationship with the returns of value weighted portfolios; portfolios were sorted on the basis of stock beta, market to book value of equity and market capitalization. Thus literature suggests that VIX can be used as a proxy for returns of stocks in Indian equity market.

With the crisis persisting across the world financial markets, Cochran et al (2012) examine the returns and long term properties of return volatilities of metals - copper, platinum, gold and silver utilizing the FIGARCH model. They assess whether VIX is a crucial factor involved in determination of metal returns and their volatility. They document evidence for the impact of the Financial Crisis on return volatility of the metals. They conclude that changes in VIX hasa significant impact on return volatility of metals. On similar lines, Morales and Callaghan (2011) analyze the nature of volatility spillovers between returns of four precious metals - gold, silver, palladium and platinum during the Asian and the Global Financial Crisis using GARCH and EGARCH modeling. The main conclusion from their study is that there is volatility persistence between returns of precious metals during the Global Financial crisis whereas volatility persistence was weak during the Asian Crisis in the 1990s. The study shows evidence that gold dominated the precious metals market and negative news has a stronger impact in comparison to positive news on the metals market.

Arouri et al (2012) investigate the long memory properties in terms of returns and volatilities of precious metals namely: gold, silver, platinum and palladium and document evidence that there is long range dependence in the daily conditional return and volatility processes for the precious metals. They conclude that platinum isn't an appropriate hedging instrument during the periods of crisis and consider gold to serve as a better instrument. The authors ascertain that FIGARCH model is most effective in terms of predictive power for volatility and returns. Ismail et al (2012) assess the impact of the crisis on volatility of gold, silver, bronze and platinum using the GARCH model and suggest investment in gold and platinum are safer in comparison to silver and bronze.

It is observed that no study relating implied volatility in equity market (India VIX) to Indian commodity market has been done. Utilizing the studies of Cochran et al (2012), Bagchi (2012), Bernard et al (2008) and Akgiray et al (1991) this paper tries to assess the impact of the recent Global Financial Crisis on trading of base metals. The price volatility of the base metals has been examined using GARCH models. The paper also studies the effect of implied volatility of equity market, measured by India VIX on the price volatility of the five base metals, in order to study the feasibility of introduction of option contracts on base metals in the Indian Commodity Market.

4. Data and Methodology

The study comprises three parts. The first and second part of the study use daily spot price and futures prices (near month futures contract) of five metals (aluminum, copper, lead, zinc and nickel) for the period from November 3, 2007 to January 30, 2013. The closing price of near month contracts are extracted as they are generally the most liquid contracts. The third part of the study deals with weekly price series of the spot and futures of the five metals traded on Multi Commodity Exchange (MCX), India and employs India VIX closing value data[2]. The data for India VIX is available from November 5, 2007. To maintain symmetry, the period for the current study is from November 5, 2007 to January 28, 2013.

The data for metal prices has been extracted from Bloomberg and Multi Commodity Exchange website, while India VIX closing value data has been compiled from National Stock Exchange of India (NSE) website and Bloomberg.

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[2] India VIX closing values daily data is available from November 1, 2007 onwards. India VIX is reported throughout the week except Saturday and Sunday while price data for metals is reported on all days of the week excluding Sunday. To maintain symmetry weekly data for both price of metals and India VIX is employed.

4.1 Summary Statistics of Daily Price Data

Table 2 presents the summary statistics for the metal price (futures prices and spot prices) daily series for the entire period of the study. It reveals that over the time span chosen for the study among the five metals, there has been maximum fluctuation in price of nickel followed by copper and lead.

Table 2: Descriptive Statistics for Daily Price Series of Metals (in Rs/kg)

Metal	**Copper**		**Aluminum**		**Nickel**		**Zinc**		**Lead**	
Statistic	**Futures Price**	**Spot Price**	**Futures Price**	**Spot Price**	**Futures Price**	**Spot Price**	**Futures Price**	**Spot Price**	**Futures Price**	**Spot Price**
Mean	346.18	344.56	102.53	101.86	929.78	924.13	93.91	93.18	99.63	99.20
Mode	421.90	429.95	104.25	103.60	761.70	955.10	102.95	103.50	106.05	104.55
Median	347.70	348.48	105.50	104.70	945.45	941.95	98.80	98.40	104.30	103.93
Standard Dev	79.71	79.68	14.92	14.94	189.78	191.01	15.50	15.72	19.05	19.28
Minimum	141.35	135.65	62.60	62.55	455	439.90	51	49.45	42.05	41.50
Maximum	464.90	464.30	142.25	146.6	1359	1345	122.15	120.85	147.50	148.70
Skewness	-0.68	-0.71	-0.69	-0.69	-0.61	-0.63	-1.05	-1.05	-0.83	-0.80
Kurtosis	-0.35	-0.29	0.31	0.33	0.23	0.25	0.30	0.31	0.30	0.28
StDev/Mean	0.23	0.23	0.15	0.15	0.20	0.21	0.17	0.17	0.19	0.19

The first part of the study first involves computing the daily return series of the futures prices and daily return series spot prices of the metals. Return is calculated as the log difference in price.

After the calculation of daily return series, the JarqueBera test for normality is performed followed by Dickey Fuller Test and Phillips-Perron Test for stationarity. Then, regression is run to examine the relationship between return on futures price and return on spot price for each of the five base metals.

As suggested by Pindyck (2004), to understand the direction of volatility between the return on spot and futures prices for each of the metals individually, a normal GARCH(1,1) (Model–I) is run. Bollerslev (1986) proposed the standard GARCH model, which is employed in this study.

Model I

Mean equation: $h_t = j_0 + \varepsilon_t$……………………………………………………………..(Equation 1)

Variance equation: $var(\varepsilon_t | L_{t-1}) = \sigma_t^2 = s_0 + s_1(\varepsilon_{t-1})^2 + s_2\sigma_{t-1}^2$…………………………(Equation 2)

4.2 Impact of Global Financial Crisis on Price Volatility of Base Metals

To understand whether the financial crisis on September 1, 2008 (when the effects of crisis started to show up) had an impact on the daily historical volatility of base metal returns, a modified GARCH model (Model – II) is employed. The mean equation remains the same (Equation 1 as in Model-I), whereas a dummy variable (D_t) is added to the variance equation to study volatility via GARCH (Equation 3).

Model II

Mean equation: $h_t = j_0 + \varepsilon_t$……………………………………………………(same as Equation 1)

Variance equation: $var(\varepsilon_t | L_{t-1}) = \sigma_t^2 = s_0 + s_1(\varepsilon_{t-1})^2 + s_2\sigma_{t-1}^2 + s_3 D_t$……………………(Equation 3)

where D_t=0 before September 1, 2008 and D_t=1 after September 1, 2008

4.3 Impact of implied price volatility of equity market on returns and price volatility of base metals

The third part of the study uses weekly data of price series of the five metals. Weekly data is used since MCX (commodity market) operates six days a week whereas NSE (equity market) operates five days a week, thus India VIX is reported only five days a week. Hence, to maintain symmetry in data, weekly data was used for this part of the study.

The summary statistics of weekly price (spot and futures) series is presented in Table 3. Nickel has faced maximum variation in prices, relative to other base metals.

Table 3: Summary Statistics of Weekly Base Metal Prices

	Nickel Futures Price	Nickel Spot Price	Lead Futures Price	Lead Spot Price	Zinc Futures Price	Zinc Spot Price	Aluminum Futures Price	Aluminum Spot Prices	Copper Futures Price	Copper Spot Price
Mean	930.03	923.05	99.59	99.05	93.85	93.05	102.43	101.63	345.66	344.12
Median	946.70	938.10	104.35	103.40	98.70	98.05	105.60	104.70	347.90	346.05
Maximum	1340.00	1326.00	145.75	147.90	118.55	119.75	142.20	138.25	464.90	462.40
Minimum	461.80	450.20	43.25	41.60	52.00	50.95	64.00	62.55	144.65	137.60
Std. Dev.	191.28	194.31	19.09	19.47	15.54	15.78	14.97	14.95	79.94	80.12
Skewness	-0.61	-0.59	-0.82	-0.79	-1.04	-1.04	-0.68	-0.70	-0.67	-0.69
Kurtosis	3.18	3.18	3.27	3.27	3.25	3.29	3.36	3.32	2.61	2.68

The summary statistics of India VIX is demonstrated in Table 4. The implied volatility of equity market is much more than the volatility of returns of the five base metals.

Table 4: Summary Statistics of Weekly India VIX

Statistic	India VIX
Mean	28.57
Median	25.95
Maximum	85.13
Minimum	13.04
Std. Dev.	11.16
Skewness	1.43
Kurtosis	5.89

Weekly return series of the metals is computed using log difference of prices. The JarqueBera test for normality is performed followed by Dickey Fuller Test and Phillips-Perron Test for stationarity.

In this section, weekly data for metal returns on both futures and spot prices is used to analyze whether returns and conditional volatility were affected by implied volatility measured by India VIX. Modified GARCH model is employed to model this relationship. This part of the study uses two specifications (Model III and IV) in modified GARCH model. The first specification (Model-III) includes India VIX lagged variable in the mean equation (Equation 4) while there is no alteration in variance equation (same as Equation 2). This specification is used to study the impact of implied volatility in equity market on return of a metal.

Model III

Mean equation: $h_t = j_0 + j_1(IN\_VIX)_{t-1} + \varepsilon_t$……………………………….…………(Equation 4)

Variance equation: $var(\varepsilon_t|L_{t-1}) = \sigma_t^2 = s_0 + s_1(\varepsilon_{t-1})^2 + s_2\sigma_{t-1}^2$……..…………..(same as Equation 2)

The second specification (Model – IV) tries to understand the impact of implied volatility of equity market on price volatility of each of the five base metals respectively. This specification includes India VIX lagged variable in the variance equation (Equation 5).

Model IV

Mean equation: $h_t = j_0 + \varepsilon_t$………………………………………..…….(same as Equation 1)

Variance equation: $var(\varepsilon_t|L_{t-1}) = \sigma_t^2 = s_0 + s_1(\varepsilon_{t-1})^2 + s_2\sigma_{t-1}^2 + s_3(IN\_VIX)_{t-1} +$ ………...(Equation 5)

5. Empirical Results

5.1.1. Summary Statistics of Return Series of Base Metals

Table 5: Summary Statistics of Returns Series of Futures Prices and Spot Prices of Base Metals

	Nickel Futures Price	Nickel Spot Price	Lead Futures Price	Lead Spot Price	Zinc Futures Price	Zinc Spot Price	Aluminum Futures Price	Aluminum Spot Prices	Copper Futures Price	Copper Spot Price
Mean	-0.0002	-0.0002	-7.88E-05	-7.87E-05	1.72E-05	2.21E-05	4.58E-05	5.92E-05	0.0003	0.0003
Median	0.0005	0.0000	0.0008	0.0000	0.0005	0.0000	0.0005	0.0000	0.0006	0.0000
Maximum	0.128	0.177	0.101	0.179	0.093	0.094	0.067	0.075	0.079	0.100
Minimum	-0.127	-0.1239	-0.126	-0.117	-0.092	-0.090	-0.067	-0.072	-0.106	-0.115
Std. Dev.	0.021	0.023	0.022	0.024	0.019	0.020	0.013	0.015	0.017	0.020
Skewness	0.116	0.165	-0.387	0.059	-0.149	-0.218	0.038	-0.026	-0.355	-0.121
Kurtosis	8.047	10.904	6.430	7.741	5.832	5.346	5.677	6.067	7.327	6.873
J-B(p values)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
DF(0)^	-39.98	-39.12	-38.03	-39.90	-40.14	-39.76	-39.70	-41.03	-41.62	-43.72
DF(t,0)^	-39.98	-39.12	-38.06	-39.93	-40.15	-39.76	-39.69	-41.01	-41.61	-43.70
PP(0)^	-39.98	-39.12	-38.03	-39.90	-40.14	-39.76	-39.70	-41.03	-41.62	-43.72
PP(4)^	-40.01	-39.11	-38.12	-39.91	-40.15	-39.75	-39.72	-41.03	-41.60	-43.77

^Critical value at 5% level for DF(0), PP(0) and PP(4) is -2.86 and for DF(t,0) it is -3.41

Table 5 describes the summary statistics of return series of the futures and return series of spot prices of base metals. The results suggest that copper possesses the highest mean daily return while lead has poorest performance in terms of mean daily return. Returns on both spot and futures prices for nickel are positively skewed unlike zinc and copper, which are negatively skewed. A fat tailed distribution has a value of kurtosis that exceeds 3. This is true for return series of all the base metals, thus results indicate that all metal return series are leptokurtic (fat tailed). They have higher probability of securing large positive or large negative values of returns. The p value of Jarque-Bera test is zero for return series of the base metals, thus rejecting the presence of normality. Dickey Fuller Test and Phillips-Perron tests are employed to check for non-stationarity of return series. The unit root hypothesis is rejected for all the metal return series(both futures and spot price) by the tests. Thus all the base metal return series are stationary.

5.1.2 Relationship between Returns on Future Price and Spot Price

Table 6: OLS Regressions of Return on each of the Metal Futures and its respective Spot Price

	Dependent Variable: Return on Spot Price of Metal	**Constant**	**Independent variable: Coefficient of Return of Futures Price of Metal**	**R squared**
Regression 1	**Nickel Spot Price**	-3.58E-05 (9.79E-01)	0.9315 (0.0000)	0.8285
Regression 2	**Lead Spot Price**	-0.000106 (0.9432)	9.31E-01 (0.0000)	0.8190
Regression 3	**Zinc Spot Price**	4.89E-05 (0.9682)	0.90671 (0.0000)	0.8141
Regression 4	**Aluminum Spot Price**	5.33E-05 (0.9586)	0.89594 (0.0000)	0.7465
Regression 5	**Copper Spot Price**	0.000127 (0.9458)	9.07E-01 (0.0000)	0.5665

Table 6 presents the results of regressions run between return on futures prices (dependent variable) and return on spot prices (independent variable) for each of the five base metals respectively. For all the five base metals, the coefficient of return on future prices is strongly significant, signifying that return on spot prices are dependent on return on futures prices.

5.1.3 Conditional Price Volatility of metals using GARCH model

Table 7: GARCH(1,1) of Return on Metal Futures and Spot Prices using Model I

		Mean Equation	Variance Equation			
S.No.	**Return on**	**Mean Constant** (j_0)	**Variance Constant**(s_0)	**Coefficient of Error (ARCH effect)**(s_1)	**Coefficient of Variance (GARCH effect)**(s_2)	**Log Likelihood**
1	**Nickel Futures Price**	0.000140 (0.7335)	0.00000365 (0.0011)	0.069082 (0.0000)	0.923238 (0.0000)	4141.94
2	**Nickel Spot Price**	3.54E-05 (0.9373)	1.79E-06 (0.0225)	0.042211 (0.0000)	0.95454 (0.0000)	4001.942
3	**Lead Futures Price**	0.000392 (0.3501)	0.000000791 (0.1102)\	0.044123 (0.0000)	0.954893 (0.0000)	4066.502
4	**Lead Spot Price**	0.000365 (0.4481)	1.41E-06 (0.0559)	0.036881 (0.0000)	0.960841 (0.0000)	3875.208
5	**Zinc Futures Price**	0.000246 (0.4970)	2.54E-07 (0.2325)	0.028889 (0.0000)	0.969923 (0.0000)	4291.635
6	**Zinc Spot Price**	0.000237 (0.5736)	0.00000123 (0.0497)	0.033746 (0.0000)	0.963024 (0.0000)	4127.281
7	**Aluminum Futures Price**	0.000149 (0.6124)	0.00000194 (0.0003)	0.034245 (0.0000)	0.954823 (0.0000)	4754.891
8	**Aluminum Spot Price**	0.000111 (0.7335)	0.00000283 (0.0001)	0.039826 (0.0000)	0.947764 (0.0000)	4575.631
9	**Copper Futures Price**	0.000550 (0.0887)	1.60E-06 (0.0040)	0.058233 (0.0000)	0.935656 (0.0000)	4520.387
10	**Copper Spot Price**	0.000578 (0.1413)	2.78E-06 (0.0096)	0.059897 (0.0000)	0.933216 (0.0000)	4229.982

Table 7 presents the results of GARCH model which was applied on all the ten return series. Coefficients of ARCH (s_1) and GARCH (s_2) of all return series are positive and significant indicating the presence of short term persistence in volatility for all the metal return series.

5.2 Impact of Global Financial Crisis on Price Volatility of Base Metals

This part of the study deals with the impact of the financial crisis which began in September 2008. Table 8 presents the results from modified GARCH model(Model-II) which is employed on returns of daily price of base metals data. The variance equation contains the dummy variable term (Equation 3). It can be observed from the sixth column of Table 8 that the coefficient of the dummy variable, s_3, is significant for all the returns of base metals (both futures and spot prices) even though the value of the coefficient is small. This implies metal price volatility is influenced by the crisis.

Table 8: Modified GARCH(1,1) of Return on Metal Futures and Spot Prices (Model II)

		Mean Equation	Variance Equation				
S.No.	**Return on**	**Mean Constant** (j_0)	**Variance Constant** (s_0)	**Coefficient of Error (ARCH effect)** (s_1)	**Coefficient of Variance (GARCH effect)** (s_2)	**Dummy Variable Coefficient** (s_3)	**Log Likelihood**
1	**Nickel Futures Price**	8.73E-05 (0.8258)	1.19E-05 (0.0002)	0.071972 (0.0000)	0.915593 (0.0000)	-7.79E-06 (0.0033)	4145.478
2	**Nickel Spot Price**	1.84E-05 (0.9675)	6.95E-06 (0.0049)	0.03858 (0.0000)	0.955976 (0.0000)	-5.06E-06 (0.0216)	4004.608
3	**Lead Futures Price**	0.000388 (0.3560)	1.12E-05 (0.0069)	0.055477 (0.0000)	0.939549 (0.0000)	-9.34E-06 (0.0151)	4065.488
4	**Lead Spot Price**	0.000471 (0.2876)	4.70E-05 (0.0000)	0.083355 (0.0000)	0.858372 (0.0000)	-2.73E-05 (0.0002)	3847.666
5	**Zinc Futures Price**	0.000389 (0.2693)	5.56E-05 (0.0000)	0.139602 (0.0000)	0.798724 (0.0000)	-4.12E-05 (0.0000)	4247.155
6	**Zinc Spot Price**	0.000397 (0.3437)	9.90E-05 (0.0000)	0.130659 (0.0000)	0.715495 (0.0000)	-5.01E-05 (0.0006)	4080.239
7	**Aluminum Futures Price**	0.000107 (0.7142)	2.06E-06 (0.0000)	0.01851 (0.0000)	0.976697 (0.0000)	-0.00000142 (0.0000)	4756.408
8	**Aluminum Spot Price**	0.000104 (0.7500)	3.28E-06 (0.0001)	0.029963 (0.0000)	0.961885 (0.0000)	-1.65E-06 (0.0064)	4575.143
9	**Copper Futures Price**	0.000557 (0.0878)	4.63E-06 (0.0067)	0.05806 (0.0000)	0.933223 (0.0000)	-2.84E-06 (0.0442)	4521.973
10	**Copper Spot Price**	0.000741 (0.0443)	3.21E-05 (0.0000)	0.11742 (0.0000)	0.799951 (0.0000)	-1.07E-05 (0.0098)	4193.439

5.3 Impact of implied volatility of equity market on returns and price volatility of base metals

In this section, weekly data for metal returns on both futures and spot prices is used to analyze the impact of implied volatility of Indian equity market on the returns and conditional price volatility of base metals. Table 9 shows the summary statistics of metal returns on weekly basis for the period between November 5, 2007 to January 28, 2013.

Table 9: Summary Statistics of Weekly Returns of Base Metal Prices

	Nickel Futures Price	Nickel Spot Price	Lead Futures Price	Lead Spot Price	Zinc Futures Price	Zinc Spot Price	Aluminum Futures Price	Aluminum Spot Prices	Copper Futures Price	Copper Spot Price
Mean	-0.001	-0.001	0.000	-0.001	0.000	0.000	0.000	0.000	0.002	0.002
Median	0.001	-0.001	0.002	0.000	0.000	0.000	0.001	0.000	0.003	0.002
Maximum	0.269	0.232	0.203	0.211	0.156	0.123	0.097	0.106	0.105	0.135
Minimum	-0.177	-0.198	-0.164	-0.176	-0.176	-0.185	-0.158	-0.160	-0.134	-0.231
Std. Dev.	0.053	0.054	0.056	0.058	0.046	0.047	0.032	0.033	0.039	0.047
Skewness	0.277	-0.091	-0.077	0.027	-0.262	-0.252	-0.218	-0.220	-0.346	-0.975
Kurtosis	5.833	5.019	4.190	4.014	4.596	3.948	5.069	4.948	3.830	6.994
J-B(p values)	0.000	0.000	0.000	0.003	0.000	0.001	0.000	0.000	0.001	0.000
DF(0)^	-17.84	-17.04	-15.89	-16.48	-17.29	-17.42	-14.61	-15.12	-14.91	-18.51
DF(t,0)^	-17.86	-17.05	-15.94	-16.53	-17.30	-17.43	-14.58	-15.09	-14.88	-18.48
PP(0)^	-17.84	-17.04	-15.89	-16.48	-17.29	-17.42	-14.61	-15.12	-14.91	-18.51
PP(4)^	-17.80	-17.03	-15.89	-16.51	-17.36	-17.46	-14.57	-15.11	-14.94	-18.38

^Critical value at 5% level for DF(0), PP(0) and PP(4) is -2.8723 and for DF(t,0) it is -3.4277

From Table 9, it is revealed that copper possess highest mean weekly return (both in terms of futures prices and spot prices) while nickel possess lowest mean weekly returns. On risk adjustment basis (comparing standard deviation divided by mean) zinc is found to be performing better than other metals. When unconditional volatility of returns is analyzed on the basis of standard deviation of returns, lead has the highest while aluminum has the lowest standard deviation. With the exception of returns of nickel futures prices and lead spot prices, all other prices are negatively skewed for the time period in consideration. This implies, there lies a substantial probability of return being negative in case of spot contracts of nickel, zinc, aluminum and copper and futures contracts of lead, zinc, aluminum and copper. The value of kurtosis for all series is higher than 3, indicating a heavy tailed leptokurtic distribution. The probability of Jarque-Bera shows that the null hypothesis of joint normality of return series can be rejected. On running the stationarity tests, Dickey Fuller Test and Phillips Perron test for the weekly return series, it is observed that all the ten weekly return series (spot and futures prices) are stationary.

Table 10 reports the results of modified GARCH(1,1) (Model-III) estimation results for the ten weekly return series.

Table 10: Modified GARCH(1,1) of Return on Weekly Metal Futures and Spot Prices(I) – Model III

		Mean Equation		Variance Equation			
S.No.	**Return on**	**Mean Constant** (j_0)	**Coefficient of lagged India VIX** (j_1)	**Variance Constant** (s_0)	**Coefficient of Error (ARCH effect)** (s_1)	**Coefficient of Variance (GARCH effect)** (s_2)	**Log Likelihood**
1	**Nickel Futures Price**	1.87E-03	-8.38E-05	-1.14E-05	-0.01671	1.013471	442.3923
		(0.8138)	(0.7861)	(0.1960)	(0.0524)	(0.0000)	
2	**Nickel Spot Price**	-1.33E-03	2.97E-05	1.74E-07	0.046914	0.947556	439.6721
		(0.8517)	(0.9139)	(0.9883)	(0.0116)	(0.0000)	
3	**Lead Futures Price**	0.010206	-0.000403	-1.06E-05	-0.018263	1.013876	432.2693
		(0.0000)	(0.0001)	(0.2277)	(0.1563)	(0.0000)	
4	**Lead Spot Price**	0.008722	-0.000262	-1.51E-05	-0.013319	1.011071	429.6344
		(0.2282	(0.3411)	(0.0321)	(0.4057)	(0.0000)	
5	**Zinc Futures Price**	0.001039	-6.01E-05	4.83E-06	-0.029512	1.016408	481.3058
		(0.5640)	(0.0068)	(0.2291)	(0.0000)	(0.0000)	
6	**Zinc Spot Price**	-0.00137	1.02E-04	-8.39E-06	-0.016055	1.015002	478.4784
		(0.3608)	(0.0000)	(0.0745)	(0.2222)	(0.0000)	
7	**Aluminum Futures Price**	-0.000951	8.67E-05	4.02E-05	1.32E-01	8.38E-01	562.9049
		(0.7985)	(0.4580)	(0.0795)	(0.0069)	(0.0000)	
8	**Aluminum Spot Price**	0.004877	-0.00017	5.19E-05	0.058247	0.89935	545.2381
		(0.3572)	(0.3186)	(0.0264)	(0.0211)	(0.0000)	
9	**Copper Futures Price**	2.35E-05	0.000101	7.45E-05	0.133563	0.810277	522.5444
		(0.9970)	(0.6589)	(0.1490)	(0.0055)	(0.0000)	
10	**Copper Spot Price**	0.000195	0.00013	1.04E-04	0.133015	0.807661	485.1777
		(0.9809)	(0.6632)	(0.0903)	(0.0003)	(0.0000)	

Under the first specification of modified GARCH(1,1) model(Model-III) the mean equation includes a variable namely India VIX lagged apart from the constant (Equation 4) . In Table 10, for the return series of lead futures prices, zinc futures prices, and zinc spot prices, the coefficient of India VIX lagged (j_1) in the mean equation is significant while for the remaining seven return series the coefficient of India VIX lagged (j_1) is insignificant. Thus it can be inferred that only weekly returns of lead futures prices, zinc futures prices and zinc spot prices are influenced by implied volatility of equity market.

In the variance equation (of Model-III), the coefficient of the GARCH term (s_2) for all the metals return series is positive and highly significant, which implies that there exists short term persistence in volatility.

Table 11 contains results of second specification of modified GARCH(1,1) model(Model IV) for the ten metal return series.

Table 11: Modified GARCH(1,1) (Model IV) of Return on Weekly Metal Futures and Spot Prices

		Mean Equation	Variance Equation				
S.No.	**Return on**	**Mean Constant** (j_0)	**Variance Constant** (s_0)	**Coefficient of Error (ARCH effect)** (s_1)	**Coefficient of Variance (GARCH effect)** (s_2)	**Coefficient of lagged IndiaVIX** (s_3)	**Log Likelihood**
1	**Nickel Futures Price**	4.06E-04	-7.74E-04	0.052739	0.569526	6.46E-05	437.9606
		(0.8786)	(0.1836)	(0.3011)	(0.0255)	(0.1609)	
2	**Nickel Spot Price**	-1.53E-03	-4.13E-05	-0.02194	1.015668	1.60E-06	446.9217
		(0.5379)	(0.0010)	(0.0000)	(0.0000)	(0.0004)	
3	**Lead Futures Price**	0.001085	-2.55E-03	-0.028554	-0.177878	0.000223	424.9225
		(0.7083)	(0.0030)	(0.5649)	(0.4948)	(0.0002)	
4	**Lead Spot Price**	0.00233	-7.02E-04	0.090324	0.600867	5.91E-05	421.2425
		(0.4140)	(0.1133)	(0.2013)	(0.0010)	(0.0914)	
5	**Zinc Futures Price**	0.000126	2.43E-05	0.001407	1.000169	-1.66E-06	475.7107
		(0.9551)	(0.1028)	(0.0018	(0.0000)	(0.0351)	
6	**Zinc Spot Price**	9.05E-05	-1.30E-03	-0.02034	-0.223356	0.000142	466.5157
		(0.9710)	(0.0205)	(0.6896	(0.4641)	(0.0006)	
7	**Aluminum Futures Price**	0.000699	-4.02E-05	7.77E-02	7.93E-01	6.00E-06	568.0738
		(0.6886	(0.2086)	(0.1174	(0.0000)	(0.0341)	
8	**Aluminum Spot Price**	0.001491	-8.08E-05	-0.076556	1.019851	5.12E-06	558.5232
		(0.2231)	(0.0000)	(0.0000	(0.0000)	(0.0000)	
9	**Copper Futures Price**	1.63E-03	-6.82E-04	0.03814	0.290574	5.84E-05	528.6493
		(0.393	(0.0923)	(0.5801	(0.4661)	(0.0820)	
10	**Copper Spot Price**	0.002447	-4.85E-04	0.090853	0.616354	3.70E-05	494.7925
		(0.2368)	(0.0240)	(0.0353	(0.0001)	(0.0235)	

In the second specification (Model IV), only the variance equation contains an additional variable India VIX lagged variable besides ARCH and GARCH terms (Equation 5). From the coefficient of India VIX lagged (s_3) in the variance equation it is observed that implied volatility in equity market does not affect volatility of spot return series of lead but it affects spot return of copper, aluminum, zinc and nickel. In case of volatility of futures returns, implied volatility in equity market affects price volatility of futures on aluminum, zinc and lead but does not affect price volatility of futures on copper and nickel. This suggests that traders from equity market would not find it beneficial to switch trading from equity market to trading in the base metals in Indian commodity market.

The GARCH term (s_2) is significant for all metal return series except in case of returns on lead futures prices, zinc spot prices and copper futures prices. Thus for all except lead futures prices, zinc spot prices and copper futures prices, it can be can be advanced that there is presence of short term persistence in volatility.

Similar to the results obtained in literature, this study provides evidence for existence of short term persistence in volatility of weekly return series. But some of the results discussed in this section are contrary to earlier studies by Cochran et al (2012) in which FIGARCH methodology leads to a conclusion that a statistically significant relationship exists between daily metal returns (copper, gold, silver, and platinum) and implied volatility of equity market. Their study also argues that there lies a significant relationship between the metal price volatilities and lagged implied volatility of equity market. This argument is true only for a few metal return series when seen in the Indian context, as inferred from discussion of coefficients of variables in the second specification of modified GARCH(1,1) model.

6.Conclusion

Results indicate that returns on future prices and returns on spot prices of base metals are linearly related, and there is presence of persistence in metal price volatility as estimated by GARCH (1,1) model. Financial crisis has a significant impact on daily price volatilities of metals. The estimates of modified GARCH model on weekly returns indicate that implied volatility of equity market influence weekly metal returns for lead futures, zinc futures and zinc spot contracts. Implied volatility of equity market significantly influences weekly price volatility of spot contract of copper, aluminum, nickel and zinc and it does not influence the weekly price volatility of spot contract of lead. Implied volatility of equity market significantly influences weekly price volatility of futures contract of aluminum, zinc and lead and it does not influence the weekly price volatility of futures contract of copper and nickel.

Though, the volatility in commodity market is lower than volatility in equity market but the price volatility of these metals have been significantly affected by the volatility of the equity market. Since the pricing of futures contract does not consider the volatility of the underlying asset, therefore to mitigate the risk of price volatility in the base metals, it is suggested to introduce option contracts in the Indian Commodity market on these base metals. Option contracts are priced taking into consideration the price volatility of the underlying base metal. Thus introduction of option contracts would benefit the producers and consumers of the metals in the commodity market. It will provide them an opportunity to construct a hedge to reduce the particular risk they face in the underlying assets.

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