Article

Return and Volatility Spillover among Commodity Futures, Stock Market and Exchange Rate: Evidence from India

Global Business Review
20(1) 214–237, 2019

DOI: 10.1177/0972150918803801
journals.sagepub.com/home/gbr
SAGE

Debasish Maitra[1]
Varun Dawar[2]

Abstract

This article aims to investigate return and volatility spillover among commodity, stock and exchange rate markets. The article further looks into whether there is any change in return and volatility spillover during the crisis and post-crisis periods and whether there is any in the behaviour of spillover changes between agro and non-agro based commodities. The study uses Vector Auto Regression followed along with by Granger causality are to understand the causality of returns. We have performed multivariate volatility model to study the volatility co-movement of different assets. Unidirectional return spillover from the Multi Commodity Exchange (non-agro commodity) to stock indices and exchange rates is found. Stock indices are found to influence exchange rates to return; whereas the only dollar explains the return in stock indices. Equity markets have been found to have a return spillover on NCDEX (agro commodity) during the post-crisis period. However, each asset market is found to have volatility spillover effects on the other asset market. Commodity indices have more spillover effects on stocks.

Keywords

Return, volatility, spillover, asset markets, India

Introduction

Integration of financial markets spurs complex dynamics in returns and volatilities. Spillover effects among equity, commodity and foreign exchange arise when information flow across these markets is neither instantaneous nor complete (Dean, Faff, & Loudon, 2010). This is based on the argument that all these markets follow lead–lag relationships without any instantaneous arbitraging opportunity. In the real world, neither instantaneous arbitraging nor complete transmission is observed. For example, any

[1] Assistant Professor, Department of Finance, Indian Institute of Management Indore, Indore, Madhya Pradesh, India.
[2] Assistant Professor, Department of Financial Studies, University of Delhi, New Delhi, India.

Corresponding author:
Debasish Maitra, Assistant Professor, Finance, Indian Institute of Management Indore, Indore 453556, Madhya Pradesh, India.
E-mails: deabasishm@iimidr.ac.in, debasishmaitra@gmail.com

sudden macroeconomic changes might cause an unexpected fall in one asset prices (bond prices). This may eventually influence the equity prices and cause a decline if the news is associated with the expectation of drop in corporate earnings because of the interest rate hike which might hinder the economic growth. Hence, a spillover would happen from one asset (bond) to equity markets. In another case, equity prices are falling because of the fear of higher market uncertainty where higher discount rates would be applied by investors, as a result of which the other asset (bond) price would also fall. Therefore, spillover is now from the equity market to bond market. The spillover effects are explained by the theories such as asset substitution, hedging demand shifts (Fleming, Kirby, & Ostdiek, 1998) and financial contagion (King & Wadhwani, 1990), as described by Dean et al. (2010). Asset substitution shows commodity, equity and exchange as competing assets. Information flows affect the perceived attractiveness of these assets to the investors. News that bring in a positive bounce in equity markets can influence investors to buy more equities and sell other assets; whereas, news comes with a positive sentiment in the commodity markets can motivate investors to hold more commodities than other assets. Therefore, positive shocks in one market would spillover as negative shocks to other markets. Hedging demand shifts explain that price changes in any market can lead investors to change their position in the other markets so that they can stay with the same hedge ratio. This hypothesis suggests that a good news in one market can spillover as a negative return shocks to the other market.

Contagion effects are mostly found when the news is extremely bad (Bae, Karolyi, & Stulz, 2003). This hypothesis suggests that the bad news in either of the markets is spilled over to the other markets regardless of the economic fundamentals as an overreaction to certain news arrival. Any extreme event can cause contagion effects across asset markets. This argument is in tandem with the notion of 'co-jump' (Lahaye, Laurent, & Neely, 2011) where jumps across commodities and traditional asset classes have tendency to occur concurrently right before or during any crisis (Chevallier & Ielpo, 2013).

Engle, Ito, and Lin (1990) once described the phenomena of spillovers as 'heat wave', where the market responds to the shocks originating from that markets, and as 'meteor shower', where the market responds to the shocks coming from other markets.

Similarly, a spillover can be expected between equity and commodity if the investors think that the commodities as an equity hedging alternative asset class because unlike equities the commodity price is determined by the interplay of demand and supply. It is also noted that because of the fundamental differences, the response of equity and commodity to the inflation is different. This has led the investors to consider commodity as an alternative asset class in their portfolio as an insulation against inflation (Mayer, 2009). This trend of portfolio diversification with commodities has created more integration of markets of different asset classes. One important characteristic of commodities is a negative correlation with stocks, which are because (a) the commodity gives better results (in terms of risk and returns during unexpected inflations) and (b) the commodity futures act differently from equity during various phases of the business cycle (Gorton & Rouwenhorst, 2006). Resulting commodity markets are no more delinked from other assets markets. Hence, the present development of return and volatility at commodity markets not only reflects market fundamentals of commodities but also the influence from other related markets. Moreover, the returns on commodities are having a positive skewness and are less volatile than those on equities. Hence, the downside risk is less in commodity futures. Increasingly financial investors are taking positions in commodity markets to diversify their portfolio.

It is noteworthy to mention that the Indian equity markets are greatly participated by the foreign institutional investors as a result of which foreign exchange rate also plays an important role in the Indian economy. In addition to this, transactions in commodity markets to meet export and import demand happen in the foreign currency. Investing in commodity futures contracts is also said to provide a hedge against the exchange rate. However, International Monetary Fund (IMF, 2008) discussion paper indicates that the commodity prices are generally less correlated with dollar, and the sign of correlation is negative. So, the role of exchange rate, particularly ₹/US$, cannot be discounted while examining the return and volatility spillover.

We note that when the global financial crisis has caused a decline in the equity markets in India, the same has also plunged the Multi Commodity Exchange (MCX) index by 51per cent from the level of 3,357.8 (Shunmugam & Senthivelan, 2010). This had also led to the decline of the net foreign investment from US$43.26 billion in 2007–2008 to US$5.7 billion in 2008–2009 coupled with a depreciation of dollar rate from the average of ₹40.26/USD during 2007–2008 to ₹51.23/USD in March 2009 (ESI, 2009, 2011).

In this backdrop of theory of spillover and actual market behaviour, we aim to empirically investigate the price and volatility spillover across the asset classes, namely, commodity futures, stock markets and foreign exchange as an emerging issue to understand the interrelationship not only for the investors but also to the financial institutions and policymakers. Thus, the notable gaps identified are as follows: (a) there is no evidence that has observed return and volatility spillover among equity, commodity and currency markets, with accounting for the crisis and post-crisis periods; (b) no documents is found on the spillover effects where the commodity futures markets are highly regulated and segmented like in India and (c) there are dearth of studies which can show return and volatility spillover differently for agro and non-agro commodities.

The article is organized as follows. The second section discusses various studies conducted in this realm. The third section employs econometric techniques to capture the spillover effects among the asset classes; and in the fourth section, we assess the results. The fifth section presents the summary and conclusions.

Literature Review

Integration of markets does not only take place spatially but also with different assets, which was studied by different scholars across the globe. The study in this context was first conducted by Schuh (1974) and Shei (1978) and found the impact of foreign exchange rate on agro commodity in the USA. Earlier, most of the investigations (Barnett, Bessler, & Thompson, 1983; Belongia & King, 1983; Bessler, 1984; Chambers & Just, 1982) were focused on the effect of monetary policies on commodity trade as part of the relationship between the foreign exchange and commodity markets. Lawrence and Lawrence (1981) reported that relative price of food commodities can be affected significantly by changes in the international financial variables.

Domanski and Heath (2007) examined the movement of financial investors to commodity markets and stated that investors base with the range of instruments and strategies employed in the commodity trading has broadened substantially. The liquidity in commodity markets has increased overtime indicating the positive change in heterogeneity of opinions of market participants. In continuation of this study, Mayer (2009) studied the growing interdependence between the financial and commodity markets and put forward that there is a financialization of commodity trading resulting in increased price changes that are unrelated to the market fundamentals. He examined the effect of returns, volatility and diversification motivation (such as 12-month moving average of correlation between the commodity returns and percentage change in S&P 500 index expected inflation as the difference between the nominal and real 10-year US bond and dollar–euro exchange rate) on dependent variables which are share of net long non-commercial trader positions in the total open interest and share of net long index-trader positions in the total open interest using the Auto Distributive Lag method and found that positive returns at spot markets influence the non-commercial traders; whereas, roll returns influence index traders. Inflation and dollar depreciation have a positive effect on participation of investors in the commodity markets. In describing high commodity prices, Gilbert (2009) commented that the futures market may be an important monetary spillover mechanism, but it is the commodity investors, not speculators, moved the prices up by investing in commodity as an asset class. Chong and Miffre (2009) studied the conditional return correlations to study the spillover between commodity futures and traditional assets (equities and fixed income securities). They applied Generalized Autoregressive Conditional Heteroscedasticity (GARCH) - Dynamic Conditional Correlation (DCC) model and reported that the risk reduction by including long positions in commodity futures to an equity portfolio has increased overtime. In addition to this, they also observed that the conditional correlations between the commodity futures and short-term fixed income securities fell overtime.

Other notable studies which mainly looked at volatility spillovers between the stock market returns and exchange rate change are by Goldberg (1993), Darby, Hallett, Ireland, and Piscitelli (1999), Kanas (2000), Carruth, Dickerson, and Henley (2000), Servén (2003) and Chen, Naylor, and Lu (2004). Recently, Alaganar and Bhar (2007) employed Glosten, Jagannathan, and Runkle (GJR) and Generalised Autoregressive Conditional Heteroscedasticity-Mean (GARCH-M) models and found that the exchange rate volatility has lagged positive impacts on volatility of World Equity Benchmark Series. In a study by Choi, Fang, and Fu (2008) on the volatility spillover between stocks and exchange rate in New Zealand, they looked at the spillover by pre- and post-1997 crash and found that there was spillover from stocks to foreign exchange market.

Of late, Basak and Pavlova (2015) detected that the presence of institutional investors heightens the prices and volatilities of all commodity futures. By adding storage factor, they showed how financial markets transmit shocks not only to commodity futures prices but also to commodity spot prices and inventories. In order to examine the effect of speculation, Haase, Zimmermann, and Zimmermann (2016) studied the impact of financial investments on commodity markets and reinforced the argument of financialization of commodity markets. Teterin, Brooks, and Enders (2016) examined smooth volatility shifts and spillover in the US crude oil and corn futures and found that the controlling for breaks can alleviate the problem of spurious persistence, and spillover effects can be studied in short-term and long-term perspectives.

In India, recently, Mishra, Swain, and Malhotra (2007) examined the volatility spillover between the stock markets and foreign exchange market by applying AR(1)-GARCH (1,1) and AR(1,1)-EGARCH (1,1) and observed bidirectional causality between stock market and foreign exchange market except in the case of Nifty and S&P CNX 500. Recently, Adrangi, Chatrath, David-Christie, and Maitra (2014) studied the market co-movements among equity, commodity and exchange rates and found a very weak relationship between equity and commodity in India. Shiva and Sethi (2015) studied the dynamic relationship among gold prices, exchange rate and stock markets and found that gold prices unidirectional causes stock markets and exchange rates. In a study in a different context, Chakrabarty, De, and Bandyopadhyay (2015) applied wavelet based DCC-GARCH method in which they have shown that volatility spillover changes with the change of investment horizon.

It is evident that most of the studies were conducted to know the linkage between commodity and equity markets (Du, Cindy, & Hayes, 2011; Hassan & Malik, 2007; He & Chen, 2011; Kumar, Managi, & Matsuda, 2012; Lien & Yang, 2008; Malik & Ewing, 2009; Singh, Kumar, & Pandey, 2010; Yilmaz, 2010) and many studies were focused on the developed countries (Wang & Wang, 2010; Yilmaz, 2010). The spillovers across asset classes include two different kinds of phenomena (Brière, Chapelle, & Szafarz, 2012). One is directional shocks as described by Diebold and Yilmaz (2012) and, second, a contagion effect which can be defined as a significant increase in cross-market linkages after a shock

(Forbes & Rigobon, 2002). There is not much study which has looked at both the return and the volatility spillover among commodity, equity and exchange rate in India.

Objective

We find a literature gap in the Indian context where spillover effects are studied among equity, commodity and exchange rate. Therefore, being consistent with the arguments of spillover and its literature, we formulate threefold objectives: (a) to confirm whether return and volatility spillover exist among equity, commodity and exchange rates, (b) we make an attempt to observed return a volatility spillover among equity, commodity and currency markets, with accounting for the crisis and post-crisis periods and (c) we put in an effort to understand the spillover behaviour for agro and non-agro commodities.

Rationale of the Study

The debate over return and volatility spillover among equity, commodity and exchange rates raises a valid argument that the market participants with interests in physical commodities are facing challenges in estimating the risk, deciding storage and trading as the information coming from the commodity futures markets has become more complex and contaminated with the information of equity markets because of the spillover effects. The policymakers if they want to take any decision for commodity markets based on the returns and volatilities of the commodity futures markets, it could be misleading since commodity markets are being heavily influenced by equity markets which should not be the case owing to their historical weak relationship (Chong & Miffre, 2010; Dusak, 1973). This spillover has been given the reason of higher institutional participation. However, there is no such strong evidence whether the interlinkage is only because of institutional trading. Indian commodity derivatives markets are subject to strong regulations. Banks, hedge funds and pension funds are not allowed to trade in the commodity futures contracts. Hence, the commodity futures markets in India are segmented. The absence of such institutional trading cannot be considered as an only reason to decide whether cross-asset spillover exists without further examinations. The market linkage among different assets is an important concern for managers of companies who use commodities as raw materials for production. The information on the interlinkage among commodity, equity and commodity currency should be considered during the time of purchasing of commodities which will be put to use for the production and manufacturing. Besides, the understanding on cross-asset spillover would also help managers to decide on the weights that they should assign with their investments between stocks of Sensex and Nifty, and commodities of MCX and NCDEX (National Commodity & Derivatives Exchange Limited) indices (Mensi, Beljid, Boubaker, & Managi, 2013).[3]

Indian commodity futures markets are considered to be segmented as these markets are still kept away from the foreign institutional participation, index and large institutional trading. However, there is no much evidence that there is no spillover among commodity, equity and exchange markets. Therefore, it is important to examine whether return and volatility spillover effects exist among these three markets. It is equally important to look at whether the nature of commodity (agro or non-agro) differs in terms of their relationship with equity and exchange rates (Adrangi et al., 2014).

In this backdrop, the present study attempts to address the issues: is there any return and volatility spillover across asset classes? Is there any change in the nature of return and volatility spillover during the crisis and post-crisis periods? Whether return and volatility spillover effects appear different for agro and non-agro commodities?

Methodology

Data and Sample

The study is based on the daily closing returns of MCX commodity index, and NCDEX index as commodity futures index, Sensex and S&P CNX Nifty as stock market index, and dollar (USD) and Sterling as exchange rates. Commodity data has been collected from MCX (for non-agro) and NCDEX (for agro); equity data was taken from National Stock Exchange (NSE for Nifty 50) and Bombay Stock Exchange (BSE for Sensex). Exchange rate (INR/USD) was collected from RBI. The MCX index is used to represent non-agro commodity, where 40 per cent weight is given to metals, followed by 40 per cent to energy and 20 per cent to agro commodities. Contrary to this, NCDEX index represents agro commodities where 100 per cent weight is given to agro commodities. The data covering the period from 2 January 2007 to 18 August 2011 has been taken to consummate the study. The returns and volatility spillover during 2007–2008 could disentangle the contagion effect, and the same could unravel whether the directions of spillover have changed after the crisis that is during 2009–2011. In order to bridge the first gap, the sample period is segregated into two time horizons—the crisis period, 2007–2008, and the post-crisis period, 2009–2011. The returns and volatility spillover during 2007–2008 could disentangle the contagion effect, and the same could unravel whether the directions of spillover have changed after the crisis that is during 2009–2011. The previous literature has defined crisis periods in many ways. Forbes and Rigbon captured the crisis period ad hoc based on major economic and financial events. Boyer et al. (2006) employed Markov regime switching models to identify the crisis periods. Baur (2012) and Dimitriou and Kenourgios (2013) defined the length of the crisis period with the help of both based on economic event and based on statistical techniques. The crisis period that we have taken is purely based on discretion, an ad-hoc approach. This could be a limitation of this study.

Standard econometrics techniques with respect to returns and volatility spillover have been adapted. The article makes an attempt to study the interlinkage among three asset classes by examining how these three asset classes are related to each other, whether they do share any long-term relationship, what return spillover is happening from one asset to another asset, whether volatility clustering is present (as volatility may be high for certain time periods and low for other periods), although this has not much relation with volatility spillover and, finally, what volatility is being spilled over by one asset onto another. Different methodological approaches are adopted to address the aforementioned queries.

Test of Stationarity

The first step to analyse any time series starts with checking the data for stationarity. To identify whether the series is stationary or integrated, the Augmented Dickey–Fuller (ADF) test (Dickey & Fuller, 1979) and the Phillips–Perron (PP) (1988) test are employed for unit root.

Augmented Dickey-Fuller Regression

For both level and return series of P_t (= log p_t, p_t = price or index), the ADF test consists of estimating the following regressions (with constant and with constant and trend term) to ascertain whether non-stationary series is a difference stationary or trend stationary process.

$$\Delta P_t = \beta_1 + \delta P_{t-1} + \alpha_i \sum_{i=1}^{t} \Delta P_{t-i} + \varepsilon_t \tag{1}$$

$$\Delta P_t = \beta_1 + \beta_2 t + \delta P_{t-1} + \alpha_i \sum_{i=1}^{t} \Delta P_{t-i} + \varepsilon_t \quad (2)$$

where ε_t is a pure white noise, $\Delta P_t = P_t - P_{t-1}$. The null hypothesis is $\delta = 0$ against the alternative hypothesis $\delta < 0$ The rejection of null hypothesis indicates stationarity. The ADF is employed using both only the constant and the constant with trend.

Test of Co-integration

The article is making an attempt to understand the interlinkage among commodity, equity and exchange rate. This interlinkage could be short term or long term. In order to identify whether these asset classes share any long-term relationship, co-integration test is employed. In case, if co-integration is found, then it would help us build error-correction based model to know the long-run equilibrium among the asset classes.

Co-integration is employed using Johansen (1988, 1991) and Johansen and Juselius (1990) procedure, the co-integration test. It is generally used to see any long-run relationship among the non-stationary variables indicating the presence of a common stochastic trend. The variables being tested for the co-integration should be of the same order of integration. It depends on the vector autoregressive system of non-stationary variables;

$$\Delta P_t = \alpha + \Pi P_{t-1} + \sum_{i=1}^{j-1} \Gamma_i \Delta P_{t-i} + \varepsilon_t \quad (3)$$

Here, Π is an $n \times n$ matrix of parameters having rank equal to number of independent co-integrating vectors and Γ are $n \times n$ matrices of parameters. ε_t is white noise error term. If the rank of Π is equal to zero (rank of $\Pi = 0$) then all of P_t sequences are unit root process, and there is no linear combination of the Pt processes that is stationary. If Π is full rank (rank of $\Pi = n$, number of variables) then different equations are convergent, and all the variables are stationary. So, the variables to be co-integrated the rank of Π should be between 0 and n ($0 <$ rank of $\Pi < n$). There are two statistical tests (Johansen, 1988) to determine co-integration.

The first tests the null hypothesis that the number of distinct co-integrating vectors is less than or equal to r against a general alternative.

$$\lambda_{trace}(r) = -T \sum_{i=r+1}^{n} \ln(1 - \lambda\hat{}_i) \quad (4)$$

The second tests the null hypothesis that the number of co-integrating vectors is r against the alternative $r + 1$ co-integrating vectors. This maximum eigenvalue test is known as $\lambda_{max.}$

$$\lambda_{max}(r, r+1) = -T \ln(1 - \lambda\hat{}_{r+1}) \quad (5)$$

Here, T is the number of observations; $\lambda^{\wedge}_t$ is the estimated value of eigenvalue generated from the estimated Π matrix and n is the number of variables (three) being employed for the test.

The critical values to test both the hypotheses are used as given by Johansen and Juselius (1990). The lag length for co-integration is decided using the minimum Akaike information criteria (AIC).

Vector Auto Regression (VAR) and Block Causality Test

On contrary to the above argument (section 'Test of Stationarity'), there is no much evidence whether a long-term relationship among these three asset classes exists. To know how shocks to return in one asset spills over to the returns in other assets, under no con-integration, VAR model is employed. It would help know how the returns spillover is happening across asset classes, and for each VAR block causality (Granger causality) test will be able to identify the asset having impact on which other assets, even in the presence of others (Hegerty, 2013)

In this study tri-variate VAR is applied. The equations for tri-variate VAR are as follows;

$$\begin{aligned} \Delta P1_t &= \alpha_1 + \sum_{i=1}^{k} \beta_{1i}\Delta P1_{t-i} + \sum_{i=1}^{k} \gamma_{1i}\Delta P2_{t-i} + \sum_{i=1}^{k} \delta_{1i}\Delta P3_{t-i} + \varepsilon_{1t} \\ \Delta P2_t &= \alpha_2 + \sum_{i=1}^{k} \beta_{2i}\Delta P1_{t-i} + \sum_{i=1}^{k} \gamma_{2i}\Delta P2_{t-i} + \sum_{i=1}^{k} \delta_{2i}\Delta P3_{t-i} + \varepsilon_{2t} \\ \Delta P3_t &= \alpha_3 + \sum_{i=1}^{k} \beta_{3i}\Delta P1_{t-i} + \sum_{i=1}^{k} \gamma_{3i}\Delta P2_{t-i} + \sum_{i=1}^{k} \delta_{3i}\Delta P3_{t-i} + \varepsilon_{3t} \end{aligned} \tag{6}$$

Volatility Clustering

Volatility may be high for certain time periods and low for other periods. Volatility clustering is conducted by employing Autoregressive Conditional Heteroscedasticity (ARCH) test to find out the presence of volatility clustering. However, volatility clustering has no direct role to decide on spillover effects. It is only carried out to know whether the series are fit for ARCH/GARCH models. To do this, each variable is modelled with auto regression (AR) of order 1. Then residuals are squared and regressed on lag *k* to test for ARCH of order *k*. The null hypothesis is that the coefficients of every lagged autoregressive terms are zero (0) implying that there is no ARCH effect.

Volatility Spillover

To measure the spillover effect, at first, GARCH (1,1) model for three asset-returns (commodity futures, stock index and foreign exchange rate) series is estimated individually, and, then, residuals from the variance equations are extracted and squared. The squared residuals, after accounting for their GARCH effects, of one market are used in the volatility equation of another market so as to explain the volatility spillover from the former.

$$\begin{aligned} \sigma^2_{\text{t, mcx}'} &= \omega_0 + \alpha_{1,1}\varepsilon^2_{t-1} + \beta_{1,1}\sigma^2_{\text{t}-1} + \psi_1(\text{squared residual}_{\text{sensex, t}}) + \psi_2(\text{squared residual}_{\text{nifty, t}}) \\ &\quad + \psi_3(\text{squared residual}_{\text{usd, t}}) + \psi_4(\text{squared residual}_{\text{sterling, t}}) \end{aligned} \tag{7}$$

For variance equation of commodity futures, all the explanatory variables with coefficient ψ are the squared residuals of GARCH (1,1) of other asset returns such as stock index and foreign exchange rates. For variance equation of stock, all the explanatory variables with coefficient ψ are the squared residuals of GARCH (1,1) of other asset returns such as commodity index and foreign exchange rates. For variance equation of exchange rates, all the explanatory variables with coefficient ψ are the squared residuals of GARCH (1,1) of other asset returns such as stock index and commodity index.

Multivariate GARCH

Multivariate GARCH (MGARCH) models are also employed because it is recognized that returns in various markets or returns of various scripts do not move in isolation of other markets or other financial instruments. It has been shown that they co-move, and modelling such temporal dependence of asset returns also is paramount in understanding the volatility pattern. This gave rise to an extension of the scalar ARCH/GARCH models, and they came to be called the MGARCH models. Most obvious application of the MGARCH models relates to understanding the relations between volatilities and volatility spillover of several markets.

Baba, Engle, Kraft and Kroner-GARCH

The Baba, Engle, Kraft and Kroner (BEKK) model is an MGARCH model which captures better dynamics. It is given by:

$$H_t = C_0 C_0^T + \sum_{k=1}^{k} \sum_{i=1}^{p} A^T k_i \varepsilon_{t-i} \, \varepsilon^T{}_{t-i} A_{ki} + \sum_{k=1}^{k} \sum_{j=1}^{p} B^T{}_{kj} H_{t-j} B_{kj} \quad (8)$$

where A_{ki} and B_{ki} are 3 × 3 matrices of parameters and W is a lower triangular matrix. The BEKK ensures that the H is always positive definite. The positive definiteness of the covariance matrix is ensured owing to the quadratic nature of the terms on the equation's right-hand side.

Analysis

Descriptive Statistics

The indices and exchange rates are transformed into returns by taking the first difference of the log prices or indices that is $r_t = \ln(P_t/P_{t-1})$. Figures 1–3 display movements of indices of commodity futures, stock indices and exchange rates.

Tables 1 and 2 provide the descriptive statistics of returns for the periods 2007–2008 and 2009–2011, respectively. Mean returns are mostly during the crisis period, 2007–2008. The kurtosis, a measure of peakedness, is high implying a fat tail, not modestly sized deviations. High leptokurtic also signifies

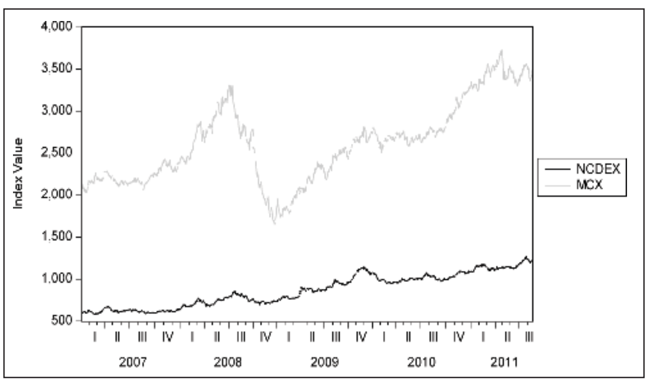

Figure 1. Movement of INDEX and MCX

Source: The authors.

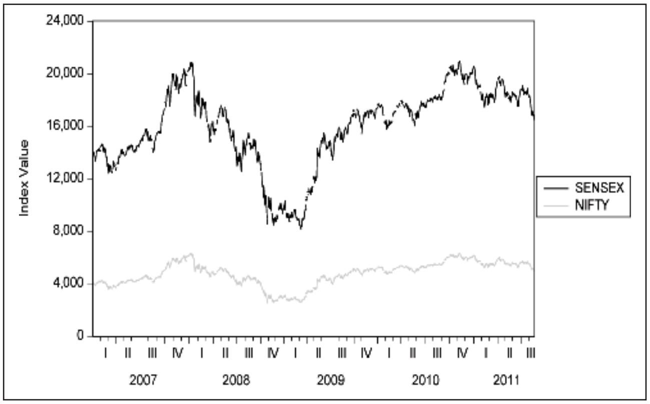

Figure 2. Movement of Sensex and Nifty

Source: The authors.

Figure 3. Movement of USD and Sterling

Source: The authors.

Table 1. Descriptive Statistics of Returns on Commodity Index, Stock Index and Exchange Rate during 2007–2008

	MCX	NCDEX	Nifty	Sensex	Sterling	USD
Mean	−0.000324	0.000430	−0.000628	−0.000762	−0.000447	0.000190
SD	0.013524	0.010237	0.023081	0.023178	0.008025	0.005543
Skewness	−0.529324	−0.468895	−0.431603	−0.233335	−0.917723	−0.010684
Kurtosis	5.666178	4.181006	5.822863	5.005953	8.621731	7.079793
Jarque–Bera	165.6135	45.76879	175.3628	85.36271	703.8259	334.9840
Probability	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000

Source: The authors.

Table 2. Descriptive Statistics of Returns on Commodity Index, Stock Index and Exchange Rate during 2009–2011

	MCX	NCDEX	Nifty	Sensex	Sterling	USD
Mean	0.000981	0.000949	0.000585	0.000617	0.000197	0.000123
SD	0.010712	0.008590	0.015938	0.016118	0.007226	0.005475
Skewness	−0.214534	0.240084	1.430649	1.325214	−0.270501	−0.100983
Kurtosis	5.207449	4.404976	18.24871	16.95052	5.574465	5.461053
Jarque–Bera	151.9187	66.22747	7231.337	6057.658	207.9049	183.1812
Probability	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000

Source: The authors.

non-normality of both the series. Skewness and kurtosis are greater in stock indices suggesting that the stock market may be more volatile than others. All returns are negatively skewed during the 2007–2008 period while the same is positively skewed during the post-crisis period, 2009–2011. This result is further bolstered by Jarque–Bera (JB) test for normality which comes very significant and rejects the null hypothesis of normality at 5 per cent level of significance.

Unit Root Test for Stationarity

Unit root tests including both ADF and PP are conducted to test the stationarity of each time series. The tests are carried out with both level data and return series for both the crisis and post-crisis periods. The ADF tests are performed with constant and constant and trend, and it is found that each series consists of unit root at level and becomes stationary when taken as returns (Table 3).

1.1. Long-Run Dependence

Johansen co-integration test is employed to investigate the presence of any stochastic trend among three assets (commodity futures, stock index and exchange rate), and the result is presented in Tables 4 and 5. Lag length criteria is decided based on the minimum Schwarz information criteria. It is found that there is no co-integration among three asset classes. The results are presented in Tables 4 and 5 using intercept but no trend in CE (cointegrating equation) and VAR. No combination of three assets (commodity futures, stock index and exchange rate) is found having a common stochastic trend. So, the assumption of any long-run relationship is rejected during both the crisis and the post-crisis periods. Therefore, any spillover, if exists, among three different assets is of short-term only.

Estimation of Return Spillover Using Tri-variate Vector Auto Regression

The VAR model is estimated to see the magnitude and sign of relation between endogenous and lagged exogenous variables. The tri-variate VAR is estimated using the commodity futures index, stock index and exchange rates. Three variables representing three different assets returns are analysed by VAR for both the crisis and the post-crisis periods. The results are presented in Tables 6 and 7.

Return spillover is also analysed during the crisis period (2007–2008) and the post-crisis period (2009–2011) to examine any significant change in the direction and degree of return spillover across different assets over these two time periods. During 2007–2008, commodity market, MCX, does not get

Table 3. Test of Stationarity of Indices and Exchange Rate for the Periods 2007–2008 and 2009–2011

	2007–2008		2009–2011	
	ADF		ADF	
Index/Exchange Rate	Constant	Constant and Trend	Constant	Constant and Trend
		Level Data		
MCX	−0.333	0.477	−1.399	−2.739
NCDEX	−1.290	−1.851	−0.842	−2.019
Sensex	−0.398	−0.927	−2.416	−1.287
Nifty	−0.557	−0.962	−2.390	−1.271
USD	0.117	−1.127	−0.507	0.037
Sterling	−0.863	−1.452	−1.384	−1.406
		Return Series		
MCX	−19.951*	−20.126*	−25.612*	−25.608*
NCDEX	−21.397*	−21.379*	−25.507*	−25.489*
SENSEX	−20.043*	−20.125*	−25.304*	−25.446*
NIFTY	−20.221*	−20.305*	−25.738*	−25.879*
USD	−20.843*	−21.114*	−27.221*	−27.359*
Sterling	−22.806*	−22.811*	−25.785*	−25.785*

Source: The authors.
Notes: * and ** indicate the level significance at 5% and 10% level, respectively.
Critical values:
ADF (constant, constant and trend)
5% = −2.863, −3.413
10% = 2.568, −3.129

any return spillover from equity and exchange rates, while NCDEX index receives spillover from Sensex, but not from Nifty. Sensex is not influenced by the commodity markets. The exchange rate is affected by the equity markets and the MCX index (Table 6).

These findings become little different during the 2009–2011 period. Commodity market, only NCDEX, gets return spillover from the equity markets; whereas, the equity markets receive return spillover only from MCX (Table 7).

Block Causality Test

The results obtained using the block causality test which is a generalized Granger causality test is presented in Table 8. Causality test is performed over two sample periods, 2007–2008 and 2009–2011. It is evident that there is no significant difference between these two sample periods. The MCX returns do Granger cause Nifty returns and exchange rate returns. There is a return spillover observed from equity markets to agro-based commodity markets (NCDEX) and from MCX index to only Sensex markets during the post-crisis period (Table 8).

Volatility Clustering

The presence of the volatility clustering is tested using ARCH-LM test after modelling with which implies that there is a serial autocorrelation in squared residuals. From Table 9, it is ostensible that every series has volatility clustering showing autoregressive conditional heteroscedasticity.

Table 4. Johansen Multivariate Co-integration Test for the Period 2007–2008

	No. of CE = 0			No. of CE = At Most 1			No. of CE = At Most 2		
Index/Exchange Rate	Eigenvalue	λ_{trace}	λ_{max}	Eigenvalue	λ_{trace}	λ_{max}	Eigenvalue	λ_{trace}	λ_{max}
MCX-Sensex-USD	0.028	27.492	14.098	0.023	13.39	11.244	0.004	2.149	2.149
MCX-Sensex-Sterling	0.028	19.733	13.688	0.012	6.044	6.033	0.00002	0.011	0.011
MCX-Nifty-USD	0.029	26.376	14.541	0.021	11.834	10.062	0.003	1.771	1.771
MCX-Nifty-Sterling	0.025	18.125	11.977	0.012	6.147	6.09	0.0001	0.05	0.05
NCDEX-Sensex-USD	0.033	22.984	16.55	0.010	6.434	5.087	0.002	1.346	1.346
NCDEX-Sensex-Sterling	0.019	15.988	9.685	0.012	6.302	6.244	0.0002	0.057	0.057
NCDEX-Nifty-USD	0.033	22.244	16.06	0.010	6.182	4.88	0.003	1.299	1.299
NCDEX-Nifty-Sterling	0.018	15.111	8.816	0.0129	6.294	6.261	0.00006	0.032	0.032

Source: The authors.
Note: *Indicates the significance at 5% (if any is present).
Critical value at 5% CE = 0: 29.797 (λ_{trace}), 21.132 (λ_{max}), CE = at most 1: 15.495 (λ_{trace}), 14.264 (λ_{max}), CE = at most 2: 3.841 (λ_{trace}), 3.841 (λ_{max}).

Table 5. Johansen Multivariate Co-integration Test for the Period 2009–2011

	No. of CE = 0			No. of CE = At most 1			No. of CE = At most 2		
Index/Exchange Rate	Eigenvalue	λ_{trace}	λ_{max}	Eigenvalue	λ_{trace}	λ_{max}	Eigenvalue	λ_{trace}	λ_{max}
MCX-Sensex-USD	0.0141	18.372	10.21	0.011	8.153	8.152	0.000001	0.001	0.001
MCX-Sensex-Sterling	0.008	11.558	6.476	0.006	5.082	4.828	0.0003	0.253	0.253
MCX-Nifty-USD	0.014	18.577	10.222	0.011	8.354	8.33	0.00002	0.018	0.018
MCX-Nifty-Sterling	0.09	11.739	6.715	0.006	5.024	4.785	0.0003	0.238	0.238
NCDEX-Sensex-USD	0.015	21.091	10.987	0.0138	10.10	9.998	0.0001	0.104	0.104
NCDEX-Sensex-Sterling	0.009	12.26	6.69	0.007	5.468	5.382	0.0001	0.086	0.086
NCDEX-Nifty-USD	0.0154	21.14	11.13	0.0136	10.01	9.85	0.0002	0.151	0.151
NCDEX-Nifty-Sterling	0.009	12.23	6.795	0.007	5.43	5.347	0.0001	0.0886	0.0886

Source: The authors.
Notes: *Indicates the significance at 5% (if any is present).
Critical value at 5% CE = 0: 29.797 (λ_{trace}), 21.132 (λ_{max}), CE = at most 1: 15.495 (λ_{trace}), 14.264 (λ_{max}), CE = at most 2: 3.841 (λ_{trace}), 3.841 (λ_{max}).

Table 6. Tri-variate VAR for the Period 2007–2008

Dependent variable	Constant	Return MCX (−1)	Return MCX (−2)	Return NCDEX (−1)	Return Sensex (−1)	Return Sensex (−2)	Return Nifty (−1)	Return Nifty (−2)	Return USD (−1)	Return USD (−2)	Return Sterling (−1)	Return Sterling (−2)
				Return MCX-Return Sensex-Return USD								
MCX	−0.0002	0.0819**	0.072	–	0.009	−0.013	–	–	−0.019	0.096	–	–
Sensex	−0.0006	0.0374	−0.001	–	0.0619	−0.900**	–	–	−0.331	−0.0398*	–	–
USD	0.0001	−0.017	0.057*	–	−0.067*	−0.01	–	–	−0.036	−0.065	–	–
				Return MCX-Return Sensex-Return Sterling								
MCX	−0.0001	0.078**	0.0668	–	0.009	−0.017	–	–	–	–	0.027	0.066
Sensex	−0.0006	0.023	−0.021	–	0.091*	−0.035	–	–	–	–	0.061	0.124
Sterling	−0.0005	0.113*	0.108*	–	−0.049*	−0.019	–	–	–	–	−0.107*	−0.124*
				Return MCX Return Nifty-Return USD								
MCX	−0.0002	0.083**	0.0728	–	–	–	0.008	−0.017	−0.024	0.092	–	–
Nifty	−0.0004	0.056	0.014	–	–	–	0.048	−0.079	−0.345**	−0.395*	–	–
USD	−0.0002	−0.016	−0.059*	–	–	–	−0.067*	−0.011	−0.035	−0.066	–	–
				Return MCX-Return Nifty-Return Sterling								
MCX	−0.0001	0.0788**	0.0675	–	–	–	0.009	−0.020	–	–	0.0257	0.067
Nifty	−0.0005	0.043	−0.005	–	–	–	0.079**	−0.027	–	–	0.021	0.173
Sterling	−0.0005	0.112*	0.108*	–	–	–	−0.047*	−0.015	–	–	−0.103*	−0.124*
				Return NCDEX-Return Sensex-Return USD								
NCDEX	0.0004	–	–	0.019	0.008	–	–	–	−0.051	–	–	–
Sensex	−0.0007	–	–	0.126	0.061	–	–	–	−0.243	–	–	–
USD	0.0001	–	–	−0.005	−0.066*	–	–	–	−0.036	–	–	–
				Return NCDEX-Return Sensex-Return Sterling								
NCDEX	0.0004	–	–	0.014	0.014	–	–	–	–	–	0.075	–
Sensex	−0.0007	–	–	0.119	0.0802**	–	–	–	–	–	0.052	–
Sterling	−0.0005	–	–	0.0205	−0.0426*	–	–	–	–	–	−0.0477	–
				Return NCDEX-Return Nifty-Return USD								
NCDEX	0.0004	–	–	0.020	–	–	0.006	–	−0.0546	–		–
Nifty	−0.0006	–	–	0.156	–	–	0.047	–	−0.269	–		–
USD	0.0001	–	–	−0.004	–	–	−0.066*	–	−0.034	–		–
				Return NCDEX-Return Nifty-Return Sterling								
NCDEX	0.0004	–	–	0.015	–	–	0.011	–	–	–	0.074	–
Nifty	−0.0006	–	–	0.153	–	–	0.067	–	–	–	0.012	–
Sterling	−0.0005	–	–	0.019	–	–	−0.038*	–	–	–	−0.0005	–

Source: The authors.
Note: *Indicates significance at 5% level.

Table 7. Tri-variate VAR for the Period 2009–2011

Dependent variable	Constant	Return MCX (−1)	Return MCX (−2)	Return NCDEX (−1)	Return Sensex (−1)	Return Sensex (−2)	Return Nifty (−1)	Return Nifty (−2)	Return USD (−1)	Return USD (−2)	Return Sterling (−1)	Return Sterling (−2)
				Return MCX-Return Sensex-Return USD								
MCX	0.0009*	0.0489	–	–	0.0184	–	–	–	0.0111	–	–	–
Sensex	0.0003	0.244*	–	–	0.024	–	–	–	−0.027	–	–	–
USD	0.0002	−0.054*	–	–	−0.0957*	–	–	–	−0.137*	–	–	–
				Return MCX-Return Sensex-Return Sterling								
MCX	0.00009*	0.041	−0.035	–	0.011	−0.007	–	–	–	–	0.093	−0.029
Sensex	0.0002	0.246*	0.098**	–	0.0153	−0.053	–	–	–	–	−0.095	0.0168
Sterling	0.0001	0.0312	0.066*	–	−0.041*	0.0002	–	–	–	–	0.034	−0.108*
				Return MCX Return Nifty-Return USD								
MCX	0.0009*	0.0482	–	–	–	–	0.022	–	0.115	–	–	–
Nifty	0.0003	0.227*	–	–	–	–	0.007	–	−0.028	–	–	–
USD	0.0002	−0.053*	–	–	–	–	−0.10*	–	−0.143*	–	–	–
				Return MCX-Return Nifty-Return Sterling								
MCX	0.0009*	0.039	−0.037	–	–	–	0.014	−0.001	–	–	0.094**	−0.028
Nifty	0.0002	0.229*	0.116*	–	–	–	−0.002	−0.043	–	–	−0.087	0.003
Sterling	0.0001	0.0322	0.068*	–	–	–	−0.043*	−0.004	–	–	0.032	−0.011*
				Return NCDEX-Return Sensex-Return USD								
NCDEX	0.0009*	–	–	0.067**	−0.056*	–	–	–	−0.018	–	–	–
Sensex	0.0005	–	–	−0.003	0.047	–	–	–	−0.080	–	–	–
USD	0.0001	–	–	0.031	−0.104*	–	–	–	−0.128*	–	–	–
				Return NCDEX-Return Sensex-Return Sterling								
NCDEX	0.0009*	–	–	0.0657**	−0.053*	–	–	–	–	–	0.026	–
Sensex	0.0005	–	–	−0.002	0.055	–	–	–	–	–	0.029	–
Sterling	0.0001	–	–	0.053	−0.0345*	–	–	–	–	–	0.029	–
				Return NCDEX-Return Nifty-Return USD								
NCDEX	0.0009*	–	–	0.0683**	–	–	−0.060*	–	−0.022	–	–	–
Nifty	0.0005	–	–	0.0177	–	–	0.0283	–	−0.077	–	–	–
USD	0.0001	–	–	0.0320	–	–	−0.108*	–	−0.134*	–	–	–
				Return NCDEX-Return Nifty-Return Sterling								
NCDEX	0.0009*	–	–	0.066**	–	–	−0.055*	–	–	–	0.025	–
Nifty	0.0005	–	–	0.0185	–	–	0.0362	–	–	–	−0.054	–
Sterling	0.0001	–	–	0.054**	–	–	−0.037*	–	–	–	0.028	–

Source: The authors.
Note: *Indicates significance at 5% level.

Table 8. Block Causality during 2007–2008 (2009–2011)

Dependent Variable	Return MCX	Return NCDEX	Return SENSEX	Return NIFTY	Return USD	Return Sterling
Return MCX	–	–	No	No	No	No
Return NCDEX	–	–	No (Yes)	No (Yes)	No	No
Return SENSEX	No (Yes)	No	–	–	Yes	No
Return NIFTY	Yes	No	–	–	Yes	No
Return USD	Yes	No	Yes	Yes	–	–
Return Sterling	Yes	No	Yes	Yes	–	–

Source: The authors.
Note: The values in parentheses suggest the findings during 2009–2011.

Table 9. ARCH-LM Test for Volatility Clustering

							Q-stat		ARCH-LM	
Return	Constant	AR(1)	AR(2)	MA(1)	MA(2)	MA(3)	Q (6)	Q(12)	*F*-stat	Chi-square
MCX	0.0004	0.073*	–	–	–	–	9.17	16.86	11.21*	43.31*
							(0.10)	(0.11)	(0.00)	(0.00)
NCDEX	0.0006*	0.027	–	–	–	–	7.18	15.82	11.05*	42.68*
							(0.49)	(0.15)	(0.00)	(0.00)
SENSEX	0.0001	0.076*	–	–	–	–	7.10	14.05	21.71*	80.92*
							(0.21)	(0.23)	(0.00)	(0.00)
NIFTY	0.0002	0.063*	–	–	–	–	5.55	12.80	17.07*	64.61*
							(0.35)	(0.31)	(0.00)	(0.00)
USD	0.0000	−0.43*	−0.75*	0.42*	0.68*	–	4.28	13.83	24.10*	89.09*
							(0.12)	(0.09)	(0.00)	(0.00)
Sterling	−0.0001	1.22*	−0.85*	−1.22*	0.77*	0.05	7.47$	10.29	20.45*	76.52*
							(0.11)	(0.17)	(0.00)	(0.00)

Source: The authors.
Notes: *Indicates significance at 5% level, $denotes Q-stat at lag 9 due to ARIMA adjustment up to lag 5. AR and MA signify Auto Regression and Moving Average, respectively. Q-stat implies Ljung-Box Q statistic.

Volatility Spillover Using GARCH (1,1) Model

Volatility spillover is modelled using GARCH (1,1) model. At first, every series is fitted with GARCH (1,1) and checked for the further presence of any volatility clustering, and found that GARCH (1,1) fits well and leaves no ARCH effect in residuals. For variance equation of one asset return, the independent variables used are the squared residuals extracted from the variance equations of another asset returns and presented in the Table 8. It is found that there are volatility spillover effects from the stock indices (Sensex and Nifty) and exchange rates (USD and Sterling) to the MCX commodity futures index while there are no spillover effects from the exchange rates to the NCDEX futures index.

However, it is worthy to note that there are volatility spillover effects from the commodity futures and exchange rates to stock markets as well as from the commodity futures and stock indices to exchange rates.

Table 10. Volatility Spillover

Dependent variable (Conditional Variance of returns)	Constant	ARCH (−1)	GARCH (−1)	Squared Residuals After Univariate GARCH Model MCX	NCDEX	SENSEX	NIFTY	USD	Sterling
MCX	$1.7 \times 10^{-6*}$	0.019*	0.951*	–	–	0.0325*	−0.024*	−0.020*	−0.002
NCDEX	$5.3 \times 10^{-6*}$	0.061*	0.859*	–	–	0.036*	−0.0289*	−0.006	−0.0181
SENSEX	-3.1×10^{-6}	0.145*	0.739*	0.104*	0.115*	–	–	0.235*	0.272*
NIFTY	-3.4×10^{-6}	0.152*	0.717*	0.0974*	0.147*	–	–	0.284*	0.3217*
USD	$-1.3 \times 10^{-6*}$*	0.241*	0.651*	0.006*	−0.007*	0.0073*	−0.004	–	–
Sterling	7.3×10^{-7}	0.036*	0.928*	0.005*	−0.0062*	0.009*	−0.006*	–	–

Source: The authors.
Note: * and ** indicate the significance at 5% and 10% level, respectively.

It is also found that the volatility negatively spills from Nifty, USD and Sterling to both commodity futures index. It shows that when there is more volatility in these markets there is a chance of lesser volatility in commodity futures markets. But when the volatility increases in commodity futures markets it causes positive changes in volatility in stock markets. It indicates that investors try to diversify their risk in the stock markets and exchange rates by diversifying their investment to commodity futures markets.

Estimates of Tri-variate GARCH Model

The estimates of tri-variate BEKK-GARCH for crisis and post-crisis periods are estimated and presented in Tables 11 and 12. It is performed to examine the volatility spillover across different assets. The elements of A matrix and B matrix are called ARCH and GARCH coefficients, respectively. It is observed that some of the covariances of ARCH terms are positive (negative) and significant suggesting that the two shocks of same sign affect conditional covariances between corresponding assets positively (negatively). The stronger ARCH effect is found during the crisis period, i.e. 2007–2008 in exchange rate while highest ARCH effect in equity markets is evident during post-crisis period. The spillover of persistent volatility that is GARCH is indicated by $B(1,2)$, $B(2,1)$, $B(1,3)$, $B(3,1)$ and $B(2,3)$, $B(3,2)$ for the commodity futures stock index, commodity futures exchange rate and stock index exchange rate, respectively.

It is found that during 2007–2008, volatility spillover direction mostly exists from equity to commodity markets. There is almost no or negligible spillover from commodity markets to equity while equity markets spill over to the MCX index, which are mostly metals, bullion and energy-based commodities. During the post-crisis period, 2009–2011, volatility spillover exists in both ways from commodity to equity and vice versa. Volatility spillover is found the highest from MCX commodity index to equity markets. There is very little or no evidence of spillover across commodity and exchange markets. The linkage is found a little bit higher during 2009–2011 between commodity and equity markets.

Interpretation of Results

Empirical examinations of the article indicate that the impact of return and volatility spillover of one market on the markets is present. It is very much evident that the return spillover exists from both the commodity markets to equity markets and exchange rates. However, such spillover effects from only

Table 11. Tri-variate BEKK-GARCH for Period 2007–2008

Dependent variable	A(1,1)	A(1,2)	A(1,3)	A(2,1)	A(2,2)	A(2,3)	A(3,1)	A(3,2)	A(3,3)	B(1,1)	B(1,2)	B(1,3)
MCX-SENSEX-USD	−0.185*	−0.116	−0.007	0.038*	0.356*	−0.027*	0.144	0.166	0.509*	0.986*	0.004	0.0005
MCX-SENSEX-Sterling	−0.044	0.065	−0.107*	−0.051	0.308	0.007	0.178	−0.236	−0.061	0.905*	−0.357*	−0.035*
MCX-NIFTY-USD	−0.181*	−0.124	−0.012	0.038*	0.358*	−0.023*	0.104	0.161	0.526*	0.987*	0.011	−0.000
MCX-NIFTY-Sterling	−0.119*	−0.080	−0.114*	0.005	0.355*	−0.004	0.167*	0.181	0.201*	0.949*	−0.167*	0.172*
NCDEX-SENSEX-USD	−0.082	0.063	0.010	0.124*	0.361*	−0.038*	0.147	0.106	0.557*	0.931*	−0.000	0.044*
NCDEX-SENSEX-Sterling	0.257*	0.138	−0.019	−0.048*	0.253*	−0.042*	0.072	0.194	0.249*	0.904*	0.087	0.006
NCDEX-NIFTY-USD	−0.068	0.092	0.012	0.109	0.361*	−0.036*	0.144	0.166	0.567*	0.948*	−0.006	0.038*
NCDEX-NIFTY-Sterling	0.241	0.157*	−0.044	−0.040*	0.256*	−0.023	0.084	0.142	0.284*	0.906*	0.022	0.023

Dependent variable	B(2,1)	B(2,2)	B(2,3)	B(3,1)	B(3,2)	B(3,3)	$Q^2(4)$	$Q^2(8)$	LL
MCX-SENSEX-USD	−0.014*	0.913*	0.017*	−0.047	−0.128	0.859*	1.96, 11.01, 1.40	2.54, 11.53, 3.48	4633.19
MCX-SENSEX-Sterling	0.175*	0.872*	0.098*	−0.059	−0.836*	0.962*	3.64, 22.41*, 3.20	4.63, 24.03*, 10.67	4408.13
MCX-NIFTY-USD	−0.016*	0.912*	0.013*	−0.025	−0.096	0.856*	1.98, 10.75, 1.70	2.50, 11.11, 3.67	4627.38
MCX-NIFTY-Sterling	0.044*	0.923*	0.020*	−0.598*	−0.219*	0.887*	3.537, 7.564, 5.626`	4.120, 8.06, 23.18*	4402.71
NCDEX-SENSEX-USD	−0.044*	0.921*	0.011*	−0.033	−0.052	0.797*	5.798, 9.280, 1.426	16.12*, 10.24, 4.77	4721.04
NCDEX-SENSEX-Sterling	0.004	0.862*	0.114*	−0.119*	−1.044*	0.924*	3.178, 18.58*, 3.28	9.07, 20.42*, 23.83*	4474.44
NCDEX-NIFTY-USD	−0.041*	0.916*	0.012	−0.052	−0.089	0.799*	5.265, 8.149, 1.688	14.65, 9.22, 4.83	4716.55
NCDEX-NIFTY-Sterling	0.006	0.870*	0.111*	−0.133*	−1.04*	0.915*	3.17, 18.52, 2.30	9.66, 18.87*, 24.85*	4470.03

Source: The authors.

Notes: *Indicates the significance at 5% level. The values 1, 2 and 3 in parentheses represent the commodity, equity and exchange rate, respectively, A and B terms are ARCH and GARCH terms, (1,1), (2,2) and (3,3) terms indicate variances, (1,2), (2,1), (1,3), (3,1), (2,3) and (3,2) imply spillover effects (from 1 to 2), (from 2 to 1), (from 1 to 3), (from 3 to 1), (from 2 to 3) and (from 3 to 2), respectively. LL implies Log-Likelihood.

Table 12. Tri-variate BEKK-GARCH for Period 2009–2011

Dependent variable	A(1,1)	A(1,2)	A(1,3)	A(2,1)	A(2,2)	A(2,3)	A(3,1)	A(3,2)	A(3,3)	B(1,1)	B(1,2)	B(1,3)
MCX-SENSEX-USD	0.154*	−0.572*	−0.007	0.124*	0.605*	0.026	−0.115	0.069	0.328	0.711*	0.682*	0.059
MCX-SENSEX-Sterling	0.312*	−0.032*	−0.041	0.137*	0.174*	−0.062*	0.209*	0.284*	0.084*	0.554*	0.033	0.048
MCX-NIFTY-USD	0.154*	−0.571*	−0.007	0.124*	0.605*	0.026	−0.115	0.069	0.328*	0.711*	0.682*	0.059
MCX-NIFTY-Sterling	0.291*	0.039*	−0.092*	0.157*	0.185*	−0.008	0.166*	0.192*	0.132*	0.455*	0.026	0.048
NCDEX-SENSEX-USD	0.102	0.180	0.577*	−0.211*	0.269*	−0.091*	−0.464*	0.186	0.249*	−0.145*	0.191*	−0.208*
NCDEX-SENSEX-Sterling	0.087	0.155*	−0.057*	−0.149*	0.172*	−0.054*	−0.115	0.185*	0.188*	−0.099	0.071	−0.100*
NCDEX-NIFTY-USD	0.081*	0.042*	0.030	0.090*	0.094*	0.031*	0.094*	−0.231*	0.454*	0.963*	0.058*	−0.035*
NCDEX-NIFTY-Sterling	0.230*	0.195*	0.004	0.031	0.611	−0.024	0.133*	0.065	0.203*	0.768*	0.085	0.009

Dependent variable	B(2,1)	B(2,2)	B(2,3)	B(3,1)	B(3,2)	B(3,3)	$Q^2(4)$	$Q^2(8)$	LL
MCX-SENSEX-USD	−0.095*	0.222*	0.018	−0.147	−1.006*	0.972*	6.62, 2.38, 7.10	10.48, 13.99, 10.78	7128.99
MCX-SENSEX-Sterling	0.000	0.893*	0.138*	0.068	−0.667*	0.950*	4.25, 0.811, 5.120	8.018, 2.74, 15.13	6900.38
MCX-NIFTY-USD	−0.095*	0.222*	0.019	−0.146	−1.005*	0.972*	6.628, 2.383, 7.101	10.479, 13.998, 10.787	7128.99
MCX-NIFTY-Sterling	−0.003	0.971*	0.000	0.085	0.042*	0.975*	4.587, 0.501, 6.019	8.438, 1.547, 11.322	6907.54
NCDEX-SENSEX-USD	0.172*	0.942*	0.033*	−0.048	0.013	0.877	6.263, 1.893, 4.940	14.363, 3.102, 6.413	7308.81
NCDEX-SENSEX-Sterling	0.144*	0.965*	0.021*	0.085	−0.025	0.968*	10.33, 1.45, 6.45	15.95*, 3.914, 10.58	7051.78
NCDEX-NIFTY-USD	−0.017*	0.992*	−0.007	−0.028	0.115*	0.866*	3.381, 1.057,1.458	10.52, 3.12, 2.78	7316.38
NCDEX-NIFTY-Sterling	0.015	0.975*	−0.015*	−0.003	0.054	0.969*	3.53, 0.976, 5.42	10.00 5.25, 8.62	7048.02

Source: The authors.

Notes: *Indicates the significance at 5% level. The values 1, 2 and 3 in parentheses represent the commodity, equity and exchange rate, respectively, A and B terms are ARCH and GARCH terms, (1,1), (2,2) and (3,3) terms indicate variances and (1,2), (2,1), (1,3), (3,1), (2,3) and (3,2) imply spillover effects (from 1 to 2), (from 2 to 1), (from 1 to 3), (from 3 to 1), (from 2 to 3) and (from 3 to 2), respectively. LL implies Log-Likelihood.

equity markets to agro-based commodity markets are noted during the 2009–2011 period. The return spillover from commodity market (MCX) positively impacts the return of equity markets during the post-crisis period. Thus, any news causing higher returns in commodity markets also increases return in equity markets. There is no return spillover observed from equity markets to commodity markets during the crisis period. The findings suggest more linkage of return spillover between commodity and equity markets during 2009–2011.

In relation to volatility spillover, both Sensex and Nifty have spillover effects on the commodity markets. Spillover effects from the commodity markets to equity markets are higher than otherwise. The negative volatility spillover from MCX to Sensex and Sensex to NCDEX are observed during 2009–2011. This can be explained by asset substitution or hedging demand. Thus, any news increases risk in one market would cause a negative risk to the other market. This also gives the opportunity to the investors to diversify their portfolio risk.

The return and volatility spillover effect among these three asset classes is complex in nature. Spillover linkage is very short term in nature without having any long-run relationship. A little bit higher return and volatility linkages are found between commodity and equity during 2009–2011, which could be due to the fact that after the crisis, the investors became extra cautious and started reacting more to news coming in any markets. However, the results obtained differ from what have been observed in the developed countries as there are more linkages found in the developed countries. The Indian commodity markets are not like global commodity markets because it is still segmented and kept away from investments from financial institutions and banks.

Conclusion

The present study not only focuses on return but also highlights volatility spillover across different asset classes. It is found that three assets (commodity futures, stock index and exchange rate) do not have any long-term relationship as they are devoid of any common stochastic trend. However, it is observed that there is return spillover from MCX to equity markets in 2009–2011. Unidirectional return spillover is observed from MCX to both stock indices (Sensex and Nifty) and exchange rates. Exchange rate, only USD influences Sensex and Nifty, but both stock indices are found to have effects on the exchange rates. It is apparent that NCDEX is influenced unidirectionally by the conditional returns of equity markets only during the post-crisis period. This suggests that investors have become more sensitive to information flow in any of the markets during the post-crisis period.

Managerial/Policy Implications

This study would also help investors and policymakers understand that the investment outlook has changed a little bit after the crisis. Returns in the commodity markets in India are not highly linked with other asset markets, thus, a portfolio diversification opportunity exists. In terms of policy implications, the results of volatility spillover are interesting as more number of interlinkages between asset markets is found. The results indicate that though the return spillover is not statistically significant between some asset markets, the volatility spillover is found significant almost among all asset markets, which are more apparent during the post-crisis phase. Therefore, it is ostensible that the market participants have begun to take risk more seriously, with an objective of risk minimization rather than return maximization and returns during the post-crisis period because of their experience regarding risk during the crisis period.

Thus, returns of one asset market might not give spillovers to others, but risk spillover remains pervasive from moving across the asset markets. Moreover, the difference in findings between return spillover and volatility spillover is also because of the fact that (a) volatility cannot be observed directly in the market and (b) volatility spillover captures non-linearity which is not uncovered by return spillover through VAR modelling. The positive or negative volatility spillovers from one to another could lower the risk-adjusted returns (Chevallier & Ielpo, 2013). The study is, therefore, helpful to policymakers to understand the nature of return and risk spillover better. This also enables them to take a different view in terms of policy measures as there is a disconnect of the market behaviour of emerging markets like India from other developed markets where return and volatility spillover across assets is more.

Acknowledgement

Authors are highly indebted to the insightful comments given by the anonymous referees. The literature referred by the reviewers has changed the shape of the article.

Declaration of Conflicting Interests

The author declared no potential conflicts of interest with respect to the research, authorship and/or publication of this article.

Funding

The author received no financial support for the research, authorship and/or publication of this article.

Note

1. $$W_t^{Com} = \frac{h_t^{equity} - h_t^{com\&equity}}{h_t^{Com} - 2h_t^{com\&equity} + h_t^{equity}},$$

$$W_t^{com} = 0, \text{if } w_t^{com} < 0$$

$$W_t^{com}, \text{if } 0 \le \mathrm{w}_t^{com} \le 1$$

$$1, \text{if } w_t^{com} > 1$$

where W_t^{Com} is the weight of commodities in ₹1 of two assets, h_t^{equity} and h_t^{com} is conditional variance of Sensex or Nifty and MCX and NCDEX returns at time *t*, respectively. The $h_t^{\mathrm{com\ \&\ equity}}$ is the conditional covariance between MCX/NCDEX and Sensex/Nifty returns. If the interlinkage is more, as can be identified by covariance between two assets, then the weights would be different.

References

Adrangi, B., Chatrath, A., David-Christie, R., & Maitra, D. (2014). Market comovements, regulation, and financial crisis: Evidence from Indian markets. *Review of Futures Markets*, *22*(2), 21–47.

Alaganar, V. T., & Bhar, R. (2007). Empirical properties of currency risk in country index portfolios. *The Quarterly Review of Economics and Finance*, *47*(1), 159–174.

Bae, K. H., Karolyi, G. A., & Stulz, R. M. (2003). A new approach to measuring financial contagion. *Review of Financial studies*, *16*(3), 717–763.

Barnett, R. C., Bessler, D. A., & Thompson, R. L. (1983). The money supply and nominal agricultural prices. *American Journal of Agricultural Economics*, *65*(2), 303–307.

Basak, S., & Pavlova, A. (2016). A model of financialization of commodities. *The Journal of Finance*, *71*(4), 1511–1556.

Baur, D. G. (2012). Financial contagion and the real economy. *Journal of Banking and Finance*, *36*(10), 2680–2692.

Belongia, M., & King, R. A. (1983). A monetary analysis of food price determination. *American Journal of Agricultural Economics*, *65*(1), 131–135.

Bessler, D. A. (1984). Relative prices and money: A vector autoregression on Brazilian data. *American Journal of Agricultural Economics*, *66*(1), 25–30.

Brière, M., Chapelle, A., & Szafarz, A. (2012). No contagion, only globalization and flight to quality. *Journal of International Money and Finance*, *31*(6), 1729–1744.

Boyer, B. H., Kumagai, T., & Yuan, K. (2006). How do crises spread? Evidence from accessible and inaccessible stock indices. *The Journal of Finance*, *61*(2), 957–1003.

Carruth, A., Dickerson, A., & Henley, A. (2000). What do we know about investment under uncertainty? *Journal of Economic Surveys*, *14*(2), 119–154.

Chakrabarty, A., De, A., & Bandyopadhyay, G. (2015). A Wavelet-based MRA-EDCC-GARCH methodology for the detection of news and volatility spillover across sectoral indices—Evidence from the Indian Financial Market. *Global Business Review*, *16*(1), 35–49.

Chambers, R. G. (1984). Agricultural and financial market interdependence in the short run. *American Journal of Agricultural Economics*, *66*(1), 12–24.

Chambers, R. G., & Just, R. E. (1982). An investigation of the effect of monetary factors on agriculture. *Journal of Monetary Economics*, *9*(2), 235–247.

Chen, J., Naylor, M., & Lu, X. (2004). Some insights into the foreign exchange pricing puzzle: Evidence from a small open economy. *Pacific-Basin Finance Journal*, *12*(1), 41–64.

Chevallier, J., & Ielpo, F. (2013). Volatility spillovers in commodity markets. *Applied Economics Letters*, *20*(13), 1211–1227.

Choi, D. F. S., Fang, V., & Fu, T. Y. (2008). Volatility spillovers between stock market returns and exchange rate changes: The New Zealand case. *International Journal of Modern Economics*, *2*(1), 64–83.

Chong, J., & Miffre, J. (2006). Conditional correlation and volatility in commodity futures and traditional asset markets. *Journal of Alternative Investments*.

———. (2010). Conditional correlation and volatility in commodity futures and traditional asset markets. *Journal of Alternative Investment*s, *12*(3), 61–75.

Chong, J., Miffre, J., & Stevenson, S. (2009). Conditional correlations and real estate investment trusts. *Journal of Real Estate Portfolio*, *15*(2), 173–184.

Darby, J., Hallett, A. H., Ireland, J., & Piscitelli, L. (1999). The impact of exchange rate uncertainty on the level of investment. *The Economic Journal*, *109*(454), 55–67.

Dean, W. G., Faff, R. W., & Loudon, G. F. (2010). Asymmetry in return and volatility spillover between equity and bond markets in Australia. *Pacific-Basin Finance Journal*, *18*(3), 272–289.

Dickey, D. A., & Fuller, W. A. (1979). Distribution of the estimators for autoregressive time series with a unit root. *Journal of the American Statistical Association*, *74*(366a), 427–431.

Diebold, F. X., & Yilmaz, K. (2012). Better to give than to receive: Predictive directional measurement of volatility spillovers. *International Journal of Forecasting*, *28*(1), 57–66.

Dimitriou, D., & Kenourgios, D. (2013). Financial crises and dynamic linkages among international currencies. *Journal of International Financial Markets, Institutions and Money*, *26*(C), 319–332.

Domanski, D., & Heath, A. (2007). Financial investors and commodity markets. *BIS Quarterly Review*, *3*, 53–67.

Du, X., Cindy, L. Y., & Hayes, D. J. (2011). Speculation and volatility spillover in the crude oil and agricultural commodity markets: A Bayesian analysis. *Energy Economics*, *33*(3), 497–503.

Dusak, K. (1973). Futures trading and investor returns: An investigation of commodity market risk premiums. *Journal of Political Economy*, *81*(6), 1387–1406.

Engle, R. F., Ito, T., & Lin, W. L. (1990). Meteor showers or heat waves? Heteroskedastic intra-daily volatility in the foreign exchange market. *Econometrica*, *58*(3), 525–542.

ESI. (2009). *Economic survey of India.* New Delhi: Oxford University Press.

———. (2011). *Economic survey of India.* New Delhi: Oxford University Press.

Fleming, J., Kirby, C., & Ostdiek, B. (1998). Information and volatility linkages in the stock, bond, and money markets. *Journal of Financial Economics*, *49*(1), 111–137.

Forbes, K. J., & Rigobon, R. (2002). No contagion, only interdependence: Measuring stock market comovements. *The Journal of Finance*, *57*(5), 2223–2261.

Gilbert, C. L. (2010). How to understand high food prices. *Journal of Agricultural Economics*, *61*(2), 398–425.

Goldberg, L. S. (1993). Exchange rates and investment in United States industry. *The Review of Economics and Statistics*, *75*(4), 575–588.

Gorton, G., & Rouwenhorst, K. G. (2006). Facts and fantasies about commodity futures. *Financial Analysts Journal*, *62*(2), 47–68.

Haase, M., Zimmermann, Y. S., & Zimmermann, H. (2016). The impact of speculation on commodity futures markets—A review of the findings of 100 empirical studies. *Journal of Commodity Markets*, *3*(1), 1–15.

Hassan, S. A., & Malik, F. (2007). Multivariate GARCH modeling of sector volatility transmission. *The Quarterly Review of Economics and Finance*, *47*(3), 470–480.

He, L. Y., & Chen, S. P. (2011). Nonlinear bivariate dependency of price–volume relationships in agricultural commodity futures markets: A perspective from multifractal detrended cross-correlation analysis. *Physica A: Statistical Mechanics and Its Applications*, *390*(2), 297–308.

Hegerty, S. W. (2013). Exchange market pressure, stock prices, and commodity prices in West Africa. *International Review of Applied Economics*, *27*(6), 750–765.

International Monetary Fund (IMF). (2008). *Global and financial stability report*. Washington, DC: IMF.

Johansen, S. (1988). Statistical analysis of cointegration vectors. *Journal of Economic Dynamics and Control*, *12*(2), 231–254.

———. (1991). Estimation and hypothesis testing of cointegration vectors in Gaussian vector autoregressive models. *Econometrica: Journal of the Econometric Society*, *59*(6), 1551–1580.

Johansen, S., & Juselius, K. (1990). Maximum likelihood estimation and inference on cointegration—With applications to the demand for money. *Oxford Bulletin of Economics and Statistics*, *52*(2), 169–210.

Kanas, A. (2000). Volatility spillovers between stock returns and exchange rate changes: International evidence. *Journal of Business Finance & Accounting*, *27*(3–4), 447–467.

King, M. A., & Wadhwani, S. (1990). Transmission of volatility between stock markets. *Review of Financial Studies*, *3*(1), 5–33.

Kumar, S., Managi, S., & Matsuda, A. (2012). Stock prices of clean energy firms, oil and carbon markets: A vector autoregressive analysis. *Energy Economics*, *34*(1), 215–226.

Lahaye, J., Laurent, S., & Neely, C. J. (2011). Jumps, cojumps and macro announcements. *Journal of Applied Econometrics*, *26*(6), 893–921.

Lawrence, C., & Lawrence, R. Z. (1981, December). Global commodity prices and financial markets: Theory and evidence. In *AEA Meeting*. Washington DC.

Lien, D., & Yang, L. (2008). Asymmetric effect of basis on dynamic futures hedging: Empirical evidence from commodity markets. *Journal of Banking & Finance*, *32*(2), 187–198.

Malik, F., & Ewing, B. T. (2009). Volatility transmission between oil prices and equity sector returns. *International Review of Financial Analysis*, *18*(3), 95–100.

Mayer, J. (2009). The growing interdependence between financial and commodity markets (No. 195). Geneva: United Nations Conference on Trade and Development.

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

Mishra, A. K., Swain, N., & Malhotra, D. K. (2007). Volatility spillover between stock and foreign exchange markets: Indian evidence. *International Journal of Business*, *12*(3), 343.

Phillips, P. C., & Perron, P. (1988). Testing for a unit root in time series regression. *Biometrika*, *75*(2), 335–346.

Schuh, G. E. (1974). The exchange rate and US agriculture. *American Journal of Agricultural Economics*, *56*(1), 1–13.

Servén, L. (2003). Real-exchange-rate uncertainty and private investment in LDCs. *Review of Economics and Statistics*, *85*(1), 212–218.

Shei, S.-Y. (1978). *The exchange rate and United States agricultural product market: A general equilibrium approach.* Taipei, Taiwan: Institute of Economics, Academia Sinica.

Shiva, A., & Sethi, M. (2015). Understanding dynamic relationship among gold price, exchange rate and stock markets: Evidence in Indian context. *Global Business Review, 16*(5), 93–111.

Shunmugam, V., & Senthilvelan, T. G. (2010). Commodity markets-road map to 2020. In P. S. Velmurugan, P. Palanichamy & V. Shunmugam (Eds.), *Indian commodity markets* (pp. 33–49). New Delhi: Serial Publication.

Singh, P., Kumar, B., & Pandey, A. (2010). Price and volatility spillovers across North American, European and Asian stock markets. *International Review of Financial Analysis*, *19*(1), 55–64.

Teterin, P., Brooks, R., & Enders, W. (2016). Smooth volatility shifts and spillovers in US crude oil and corn futures markets. *Journal of Empirical Finance*, *38*, 22–36.

Wang, P., & Wang, P. (2010). Price and volatility spillovers between the greater China markets and the developed markets of US and Japan. *Global Finance Journal*, *21*(3), 304–317.

Yilmaz, K. (2010). Return and volatility spillovers among the East Asian equity markets. *Journal of Asian Economics*, *21*(3), 304–313.