



# Dynamic linkages among oil price, gold price, exchange rate, and stock market in India



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## ABSTRACT

Governments impose taxes and levies to manage the effect of gold and crude oil imports on the exchange rate. These in return have relations with the economy of the country, best reflected in the stock market index. This study aims to explore the relation between global prices of gold, crude oil, the USD–INR exchange rate, and the stock market in India. The dynamic contemporaneous linkages have been analyzed using DCC-GARCH (standard, exponential and threshold) models and the lead lag linkages have been examined using symmetric and asymmetric Non Linear Causality tests. Empirical analyses indicate fall in gold prices and crude oil prices cause fall in the value of the Indian Rupee and the benchmark stock index i.e. Sensex. The findings of this study also support the emergence of gold as an investment asset class among the investors. More importantly, this study highlights the need for dynamic policy making in India to contain exchange rate fluctuations and stock market volatility using gold price and oil price as instruments.

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## 1. Introduction

Oil price has always been considered as a leading indicator of exchange rate movements in the world economy (Amano and van Norden, 1998). This is because international transactions of oil are done largely in US Dollars and hence higher demand for oil leads to local currency depreciation. Moreover, fluctuating international prices of oil due to variations in its demand and supply lead to fluctuations of exchange rate of an oil importing economy. Especially for oil importing countries like India, fluctuations in international oil prices lead to rupee depreciation and at the same time increase in inflation rate (Raj et al., 2008).

Recent co-movements in gold and oil prices have increased interest level of researchers in examining linkages between gold and oil as their price movements have important implications for an economy and the financial markets (Reboredo, 2013). The reason is that in an inflationary economy investors increase their

holdings of gold because it acts as hedge against inflation. Melvin and Sultan (1990), who observed that oil-exporting countries, in particular, include gold in their international reserve portfolios; when oil prices and revenues rise, they increase their investment in gold in order to maintain its share in their diversified portfolios and this increased demand for gold leads to an increase in its price that mirrors the increase in the oil price. The relation between oil price and gold price is also explained through import channel as most of the oil-importing countries pay for their supplies of oil in gold (Tiwari and Sahadudheen, 2015).

There is one more stream of literature where researchers' find that gold price and oil price are linked through the US dollar exchange rate. When the US dollar depreciates against other major currencies, investors may choose to use gold as a safe haven (Capie et al., 2005; Joy, 2011), thus pushing up gold prices (Reboredo, 2012). All these studies support the argument that gold and oil prices follow certain patterns which ultimately impact exchange rate. Therefore, examining linkages between gold price, oil price and the exchange rate of an oil importing economy could be very helpful to investors and policy makers.

Of late, commodities are emerging as investment asset classes and they are increasingly becoming part of asset portfolio

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allocations for investors and portfolio managers. It has become more evident that commodity (particularly oil and gold) traders concurrently eye both the commodities and stock market movements to determine the directions of commodities prices and stock indices (Choi and Hammoudeh, 2010). Investment in stock markets provides an alternative to commodities, since the presence of the stock markets in the economy provides a mechanism for substitution between stock and commodity classes. Since gold and other precious metals are considered to be safe assets, investors shift over to those commodities investments when economy of the country is not doing well and vice-versa.

Plethora of prior research has happened on some individual pairs of the variables under consideration using linear models. Such models might no longer be appropriate due to the increasing tendency of commodity prices to behave like financial prices. The post financial crisis period (2009–present) has seen several large swings in the prices of gold and crude oil. Emergence of ISIS and the Arab Spring led to oil price shocks, whereas price of gold surged due to it being considered a safe haven. These sharp movements might have resulted in dynamic changes in the prices of commodities and caused unexpected responses in the behavior of market participants across commodities, currencies and stock markets (Bildirici and Turkmen, 2015).

India being the fourth largest importer of oil<sup>1</sup> and the largest consumer of gold,<sup>2</sup> fluctuations in international prices of oil and gold could have significant impact on currency rate, stock market, and on other economic activities. Oil accounts for 29% of India's total energy consumption and there seems to be no possibility of scaling down on dependency in future. It is also noticed that when stock market in India is on a bull-run, foreign portfolio investment flow increases leading to an appreciation in domestic currency.

Therefore, it is very important that investors, portfolio managers, and policy makers do understand the dynamic linkages among oil price, gold price, exchange rate, and stock market. This paper aims to study the dynamic contemporaneous linkages among the above four variables by using the DCC-GARCH framework and non linear non causality tests to study the lead lag relationship amongst the four variables under examination. This paper is organized as follows. The next section presents briefly reviews the existing literature in related areas of research. Section 3 outlines the data and empirical methodologies used. Section 4 presents the results and their discussion and Section 5 concludes.

## 2. Literature review

Relationships between oil price and exchange rate, oil price and gold, and exchange rate and the economy (stock market) have been researched extensively in literature. Amano and Van Norden (1998), Camarero and Tamarit (2002), Cologni and Manera (2008), Rautava (2004) and Sari et al. (2010) found a long-term correlation between oil prices and the exchange rate. Dooley et al. (1995) and Nikos (2006) indicated that exchange rate fluctuations reflect the situations of individual countries.

So far as gold price and exchange rate relationship is concerned, it has received increasing attention by both academia and industry. Sjaastad and Scacciavillani (1996) and Sjaastad (2008) studied the relationship between gold price and euro; gold price and US \$ exchange rate respectively, and argued that in the 1980s, gold price was dominated by euros but in the 1990s, US \$ gradually replaced the euro. Tully and Lucey (2007) developed an APGARCH

model to investigate the shocks of macro economy to gold spot and futures markets and found that US \$ was a major macro-economic variable to influence the gold price volatility.

On the price dynamics in crude oil market and gold market, an array of research has been reviewed and the findings suggest strong relationships (Ye, 2007; Zhang et al., 2007). Cashin et al. (1999), used the data of seven commodities and found a significant correlation between oil and gold. Hammoudeh and Yuan (2008), examined the volatility behavior of three metals: gold, silver and copper and found that oil shocks had calming effects on precious metals excluding copper. Lescaroux (2009), investigated the correlations among crude oil and precious metals and reported that they tended to move together. Soytaş et al. (2009) investigated the long run and short run impacts of gold and silver prices on oil price but found no causal relationship amongst the variables. Sari et al. (2010) studied the impact of oil price shocks over gold, silver, platinum and palladium and observed a weak asymmetric relationship among gold and oil prices.

Narayan et al. (2010) examined gold and oil spot and future markets. They concluded that gold is a hedge against inflation and oil and gold markets can be used to predict each other. Zhang and Wei (2010) tested the causality between crude oil and gold market over a period of eight years and observed a linkage between crude oil price and gold price volatility. Šimáková (2011) observed a long term relationship between oil and gold prices.

Moreover, Lee and Lin (2012) examine the nonlinear dynamic relationship among USD/Yen, gold futures, VIX, crude oil and several stock indexes. According to their findings, the role of gold is determined according to crude oil price. From this aspect; as the price of crude oil is low, gold exhibits a hedging function; when price of oil is high, gold is both a hedge and safe haven for developing countries. Chang et al. (2013) investigated the correlation among oil prices, gold prices and exchange and conclude that the variables are considerably independent. Naifar and Al Dohaiman (2013) tested the nonlinear structure of oil prices by using several econometric methods and stressed the explanatory power of linear models.

However, the dynamic linkages among any three macro-economic variables mentioned above, neither mentioned in economic theory nor studied much in empirical literature. Sari et al. (2010) examined the co-movements and information transmission among the spot prices of four precious metals, oil price, and the US dollar/euro exchange rate. They found evidence of a weak long-run equilibrium relationship but strong feedbacks in the short-run. Jain and Ghosh (2013) studied long-run relationship and causality among global oil prices, precious metals prices, and INR/USD exchange rate. They found a long run relationship among variables when exchange rate and gold price remain as dependent variables. Their Granger causality tests indicated that exchange rate causes precious metal prices and oil price in India.

After a comprehensive review of existing literature a gap was found to exist in the exploration of interaction of commodity markets, stock market and exchange rate. As the exchange rate is an important macroeconomic variable, having linkages to inflationary tendencies in an oil importing country like India, research on its interactions would provide insights for its management by the central bank. This study examines the dynamic time varying relationship among oil price, gold price, exchange rate, and stock market using DCC-GARCH framework. This study also analyzes lead-lag interaction among all the four macroeconomic variables using non-linear causality test. Evidence of non-linear causal relations has been established by Fernandez (2014) between commodity prices and price indices.

<sup>1</sup> OPEC Annual Statistical Bulletin, <http://www.opec.org/library/Annual%20Statistical%20Bulletin/interactive/current/FileZ/Main.htm>.

<sup>2</sup> Gold Demand Trends 2014, World Gold Council. [www.gold.org/download/file/3691/GDT\\_Q4\\_2014.pdf](http://www.gold.org/download/file/3691/GDT_Q4_2014.pdf).

### 3. Data description and empirical methodologies

The Bloomberg data service was utilized to collect the data. Daily data for the span of ten years, 2006–2015, was collected. The period of recession has not been separately considered in this study as one purpose of this study is to explore the dynamic conditional correlation and lead-lag relation over the entire period of study. The international gold spot price (*gold*) is measured in USD/troy ounce and Brent crude spot price (*crude*) is measured in USD/barrel. The US dollar (US \$) – Indian Rupee (INR) exchange rate has been measured as USD/INR (*inr*). BSE Sensex 30 (*sensex*) is a benchmark market index in India, maintained by the Bombay Stock Exchange (BSE). Sensex 30 in USD and on levels is used in this study for empirical analysis.

The price movements of all four variables are plotted in Fig. 1. All price series have shown both increasing and decreasing trends over the period of study. Crude oil prices show highly fluctuating movements with sharp spikes in 2007 and 2008. Gold appreciated till 2011 and then depreciated as funds flowed in and out of its perceived safe haven. The Indian Rupee exchange rate has depreciated over the period. The BSE Sensex fell from its peaks of late 2007 along with the rest of the global indices due to the global financial crisis and is struggling to achieve those peaks again.

Table 1 highlights the descriptive statistics for the log-returns (*dl*) of all the variables under study. The means of all the returns are near zero. *crude* shows the highest volatility, as represented by standard deviation, followed by *sensex*, *gold* and *inr*. The most important inference from descriptive analysis is that the null of the Jacque Berra test is rejected by all the variables, indicating that returns are not normally distributed, which emphasizes the need of using GARCH like models in examining them.

Table 2 presents pair wise correlation coefficients (static) between variables under study. As expected, high correlation is not observed amongst the variables, except between *crude-gold* and *inr-sensex*.

These correlations are static and do not highlight the changes in correlation which happen over a period of time. Correlation analysis presents the contemporaneous relationship over a period, or at an instant, between variables and ignores the lead lag

**Table 1**  
Descriptive statistics of the variables.

	<i>dlcrude</i>	<i>dlgold</i>	<i>dlinr</i>	<i>dlsensex</i>
Mean	−0.0002	0.0002	−0.0001	0.0002
Std. Dev.	0.0213	0.01279	0.0049	0.01838
Skewness	−0.1418	−0.3366	−0.2266	0.1532
Kurtosis	7.0553	8.2401	8.5691	10.4433
Jacque Berra	1707.024 (0.00)	2883.117 (0.00)	3224.829 (0.00)	5732.39 (0.00)
Observations	2479	2479	2479	2479

Note: Figures in parenthesis indicates *p*-value.

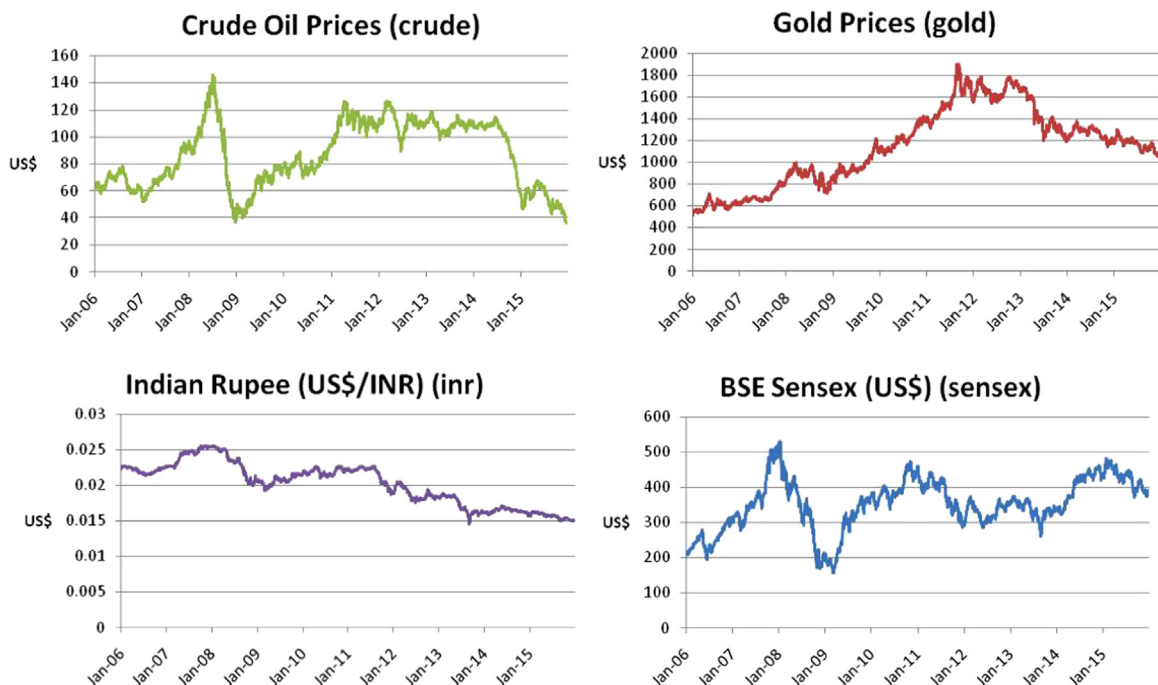
**Table 2**  
Correlation matrix.

	<i>dlcrude</i>	<i>dlgold</i>	<i>dlinr</i>	<i>dlsensex</i>
<i>dlcrude</i>	1.0000	0.3063	0.1859	0.2549
<i>dlgold</i>	0.3063	1.0000	0.1741	0.1387
<i>dlinr</i>	0.1859	0.1741	1.0000	0.6443
<i>dlsensex</i>	0.2549	0.1387	0.6443	1.0000

structure. This study will use Dynamic Conditional Correlation (DCC GARCH) to study the time varying correlation and Non Linear Causality (Kyrtou and Labys, 2006) to study the lead lag structure between these variables.

#### 3.1. Dynamic conditional correlation – GARCH models

The DCC-GARCH model is used to examine the time varying correlations between two or more series and was developed by Engle (2009). A Vector Autoregression (VAR) model is fit to the series and its residuals are standardised by dividing them by their corresponding GARCH conditional standard deviation. Engle (2009) described this process as “De-GARCHing”. The DCC model then uses these standardised residuals to estimate the Dynamic Conditional Correlations.



**Fig. 1.** Plot of the data series.

The GARCH(p,q) model is estimated using Maximum Likelihood Estimation (MLE) methods. It can be represented by the following equations where  $y_t$  is a residual from one of the VAR equations:

$$y_t = \theta_0 + \epsilon_t \quad (1)$$

$$\epsilon_t \sim N(0, \sigma_t^2) \quad (2)$$

$$\log(\sigma_t^2) = \alpha_0 + \sum_{j=1}^p \beta_j \log(\sigma_{t-j}^2) + \sum_{i=1}^q \alpha_i \epsilon_{t-i}^2 \quad (3)$$

$\epsilon_t$  is the standardised residual from removing the mean from the VAR residual series. The log of its volatility is modeled in the last equation as a function of its own lagged values and lagged standardised residuals. The  $\beta$ 's represent the persistence of volatility and  $\alpha$ 's the GARCH effect. For the purpose of this research, GARCH (1,1) along with its extensions EGARCH (1,1) (Exponential GARCH) and TGARCH (1,1) (Threshold GARCH) have been used to standardize the residuals.

The standardised residual from all VAR equations,  $\epsilon_{i,t}$ , is further standardised with respect to its standard deviation,  $\sigma_{i,t}$  as follows:

$$s_{i,t} = \frac{\epsilon_{i,t}}{\sigma_{i,t}} \quad (4)$$

The DCC process is then defined (Engle, 2009) by  $Q_t$  as:

$$Q_t = \bar{R} + \alpha(s_{t-1}s'_{t-1} - \bar{R}) + \beta(Q_{t-1} - \bar{R}) \quad (5)$$

$$\bar{R} = \text{diag}\{Q_t\}^{-\frac{1}{2}} Q_t \text{diag}\{Q_t\}^{-\frac{1}{2}} \quad (6)$$

The model is estimated using MLE, similar to GARCH.  $R$  is the time varying correlation amongst the variables under study and can be plotted against time. The parameters  $\alpha$  and  $\beta$  are restricted to be positive and to have a total less than one. Dependence on only these parameters is one of the strengths and weaknesses of this model. Irrespective of number of variables, only these two parameters need to be estimated, making it more likely to reach the optimal solution. Contrary to this, the restriction on all the variables to be following the dynamic process defined by these two common parameters is a restrictive condition.

When the standardised residuals from two variables rise or fall together, then they will push the correlation up. This elevated level will gradually decrease back to the average level with the passage of time due to complete absorption of information. When the residuals move in different directions, they will pull the correlation down, which will move up with the passage of time. The speed of this process is controlled by the parameters  $\alpha$  and  $\beta$ .

The DCC-GARCH model will be used to study the time varying correlations amongst the four variables considered in this study. The correlations thus obtained will shed light on the time varying contemporaneous relationships amongst the variables.

### 3.2. Kyrtso-Labys non linear symmetric and asymmetric non causality test

Granger's linear test for non causality (Granger, 1969) is one of the most widely used to study lead lag relationships between variables. Hiemstra and Jones (1994) proposed a non linear version of the Granger test for non causality, but recent research by Diks and Panchenko (2005) has raised issues with the power of the test in large samples. Kyrtso and Labys (2006) and Hristu-Varsakelis and Kyrtso (2008) have proposed a non linear symmetric and asymmetric test for non causality by replacing the Vector Autoregression structure of the Granger test with a Mackey Glass model to capture the non linear relationships. This test does not suffer from power issues with large sample sizes and has been used by Muñoz and Dickey (2009), Ajmi et al. (2013) and Bildirici and Turkmen (2015) amongst many others. For a bivariate case with two variables  $X_t$  and  $Y_t$ , the model used in this study is as

follows:

$$X_t = \alpha_{11} \frac{X_{t-\tau_1}}{1 + X_{t-\tau_1}^{c_1}} - \delta_{11} X_{t-1} + \alpha_{12} \frac{Y_{t-\tau_2}}{1 + Y_{t-\tau_2}^{c_2}} - \delta_{12} Y_{t-1} + \epsilon_t \quad (7)$$

$$Y_t = \alpha_{21} \frac{X_{t-\tau_1}}{1 + X_{t-\tau_1}^{c_1}} - \delta_{21} X_{t-1} + \alpha_{22} \frac{Y_{t-\tau_2}}{1 + Y_{t-\tau_2}^{c_2}} - \delta_{22} Y_{t-1} + \mu_t \quad (8)$$

where,  $\alpha_{ij}$  and  $\delta_{ij}$  are the parameters to be estimated and the residuals are normally distributed.  $\tau_i$  are integer delays and  $c_i$  are constants to be determined prior to estimation by maximizing the likelihood of the model. For the purpose of this study, delays of one to five and constant exponents of one to two were tested for each model fitted with a pair of variables. Most models had maximum likelihood using a delay of one and constant exponent of two.

The test is carried out in two steps. In the first step, the unconstrained model is estimated using OLS. To test for  $Y$  causing  $X$ , in the second step a constrained model with " $\alpha_{12}=0$ " is estimated. The Kyrtso-Labys test statistic can be derived from the SSRs of the constrained and unconstrained models and it follows an  $F$  distribution. If the test statistic is higher than the critical value, then we can reject the null hypothesis of  $Y$  not causing  $X$ . The test statistic is as follows:

$$S_F = \frac{(S_C - S_U)/n_{restr}}{S_U/(N - n_{free} - 1)} \sim F_{n_{restr}, N - n_{free} - 1}$$

where,  $n_{free}$  is the number of free parameters in the model and  $n_{restr} - 1$  is the number of parameters set to zero while testing the constrained model.

This study explores the symmetric as well as the asymmetric causal relationship. The symmetric causal relationship indicates the direction of causality amongst the variables but does not indicate the type or size of effect. For the purpose of this study, the asymmetric test is defined to test the effect of positive or negative changes in the causal variable on the dependant variable. An increase (or decrease) in the causal variable might cause increase or decrease in the dependent variable, which the Asymmetric test will help us ascertain. To test whether nonnegative returns in the series  $Y$  cause the series  $X$ , an observation  $(X_i, Y_i)$  is included for regression only if  $Y(t-\tau_2) \geq 0$ . The test is then run in similar way as defined before. Testing the reverse causality employs the same method with the order of series reversed.

Hristu-Varsakelis and Kyrtso (2008) highlight that asymmetric causality testing "sharpens" the common symmetric causality test. It yields further insights into the impact of the causal variable on the dependant variable.

## 4. Results and discussion

As the first step, all the variables are transformed into log price series for further econometric analysis. Augmented Dickey Fuller (Dickey and Fuller, 1979), PPP (Phillips and Perron, 1988) and KPSS (Kwiatkowski et al. 1992) unit root tests are conducted on the levels of all series with a trend and intercept term. Lag length for unit root tests are chosen by Schwarz Information Criteria (SIC). All the series on levels indicated presence of a unit root and are tested again after first differencing for presence of unit roots. Differenced variables are denoted by adding "d" to the level variable name. All the differenced series indicate absence of a unit root and hence stationary in nature.<sup>3</sup> These differenced variables are then fitted to a Vector Autoregression (VAR) model. The optimal lag length is estimated using the AIC criterion and is found to be six. The

<sup>3</sup> Results of the unit root tests are available with the author and can be shared on request.



**Table 3**  
DCC parameters from GARCH, EGARCH and TGARCH models.

Parameter	Coefficients from GARCH family of models		
	GARCH	EGARCH	TGARCH
$\alpha$	0.0248 [7.4909]***	0.0224 [4.9319]***	0.0215 [4.7704]***
$\beta$	0.9487 [85.1083]***	0.9541 [71.4951]***	0.9562 [72.9881]***
Akaike Information Criterion (AIC)	–25.604	–25.625	–25.625
Hannan Quinn Information Criterion (HQIC)	–25.580	–25.597	–25.598

Note: Numbers in parenthesis indicate the t-stat of the coefficient. \*\*\*, \*\*, and \* denote significance at the 10%, 5% and 1% level of significance respectively.

residuals of the VAR models are De-GARCHed using standard GARCH, EGARCH and TGARCH model. A DCC model is fit on the standardized residuals from each of these three GARCH like models. The following table highlights the model parameters from the various GARCH models tested (Table 3).

It can be seen that both  $\alpha$  and  $\beta$  are highly significant across all the GARCH models, indicating that all the models are good fit. The low values of “ $\alpha$ ” and the high values of “ $\beta$ ” indicate that the correlation process is resistant to shocks and reverts to the mean quickly. This indicates that the correlations amongst the variables should be stable without many outliers. Since values of AIC and HQIC information criteria are not notably different for above three models, we have used standard GARCH model to estimate the time varying correlation using DCC.<sup>4</sup>

The time varying correlations amongst the variables are plotted in Fig. 2.

As shown in Fig. 2, the dynamic correlations amongst the variables are stable with few outliers. The dynamic conditional correlations between *crude-gold* and *inr-sensex* are always in the positive zone, going to maximums of up to 0.54 and 0.84 respectively. *crude-inr* and *crude-sensex* correlation can be seen to higher in the 2008–2013 period, indicating higher correlations during the financial crisis and beyond period. As the crisis has led to a slowdown across the world, increase in crude demand and hence its prices, is viewed as an indicator for economic growth. As the Indian economy is dependent on its exports to provide for its crude imports, such improvements in growth expectations cause its stock index to rise and currency to appreciate. *gold-inr* and *gold-sensex* display short periods of negative correlation, which might be indicative of investors shifting away from risky assets to the perceived safe haven of gold.

The *inr-sensex* correlation remains stable within a band of 0.5–0.8. This indicates the co-dependency of both the main stock market index and the exchange rate. Foreign Institutional Investor (FII) fund flows into the Indian stock market will lift the market index and cause the exchange rate to appreciate, whereas outflows will lead to a fall in the market index and depreciate the currency. This relation can explain the high correlation observed in this variable pair.

The DCC GARCH model is used to investigate the time varying contemporaneous correlation amongst the variables. However, it does not shed light on the lead lag structure or the causal structure amongst the variables. To investigate the same, Kyrtsou–Labys non-linear causality tests were conducted. The results from both Symmetric and Asymmetric models are presented below in Table 4.

The Symmetric case tests for the presence of directional causality amongst the pair of variables, ignoring the effect of positive or negative changes in the causal variable on the dependant variable. The Asymmetric case tests causality for a positive change and negative change series separately. This along with the coefficient of the causal variable allow us to examine the effect of a positive or negative change in the causal variable on the dependent variable.

From Table 4, it appears that in the symmetric case, *gold* causes *inr* and *inr* causes *sensex*. In both cases the relation is due to the causality from the negative case. On observing the sign of the coefficients from the model, it can be inferred that fall in gold prices causes depreciation of the Indian Rupee exchange rate and depreciation of the Indian Rupee causes fall in Sensex. Fall in global gold prices would cause an increase in demand for gold in India, hence raising its imports and causing depreciation of the currency. Gold imports of India are a major source of headache for the government as it forms a huge portion of the current account deficit. Depreciation of the Indian Rupee makes the benchmark Sensex look weaker from the perspective of FIIs, who would then proceed to sell portions of their portfolios and pull out funds from the market leading to a fall in Sensex.

Fall in crude prices is seen to cause both the Indian Rupee exchange rate and the Sensex index. Examination of the coefficients from the model seem to indicate that fall in crude prices cause a depreciation of the currency and trigger a fall in the sensex. This has been discussed before in the context of crude prices becoming an international barometer for growth expectations. Fall in crude prices indicate an upcoming global slowdown, causing the Indian Rupee to depreciate and Sensex to fall.

Negative changes in Gold prices and Sensex are observed to cause each other. The model coefficients seem to indicate that a fall in gold prices causes a fall in Sensex, but a fall in Sensex causes gold prices to gain. In times of crisis, investors shift from risky assets such as the stock market into safer ones such as gold. The process of shifting would cause a sell off in the stock market, making the index plunge while simultaneously causing gold prices to rise on enhanced demand. Reboredo (2013) found similar results while exploring the safe haven nature of gold.

The results from the Krystou–Labys Non Linear Causality tests provide further insights into the lead lag relations amongst these variables from macroeconomic perspective. The symmetric test provides us information about the direction of causality and the asymmetric test provides information about the positive or negative impact of causality. In the symmetric case, it was observed that gold price causes the exchange rate in India and subsequently the exchange rate causes stock market behavior. However, it is difficult to comment on exact nature of this unidirectional causality from symmetric test results. Further examination using the asymmetric test reveals that fall in gold prices is found causing depreciation of the Indian Rupee and depreciation of the Indian Rupee causing a fall in the stock market in India. This directional relationship highlights the important role the government in managing demand for gold and crude oil.

No non linear causal relations are observed between crude oil prices and gold prices. This is supported by the results of Zhang and Wei (2010). However, this no non-linear causal relation between oil price and gold price is contrary to the findings of presence linear causality by Narayan et. al (2010) and Jain and Ghosh (2013).

## 5. Conclusion

This study examines the dynamic relationship between international gold and crude prices, the US Dollar – Indian Rupee

<sup>4</sup> Time varying correlations from other models have also been estimated but not presented due to them being similar to the ones obtained from the GARCH model and are available with the authors on request.

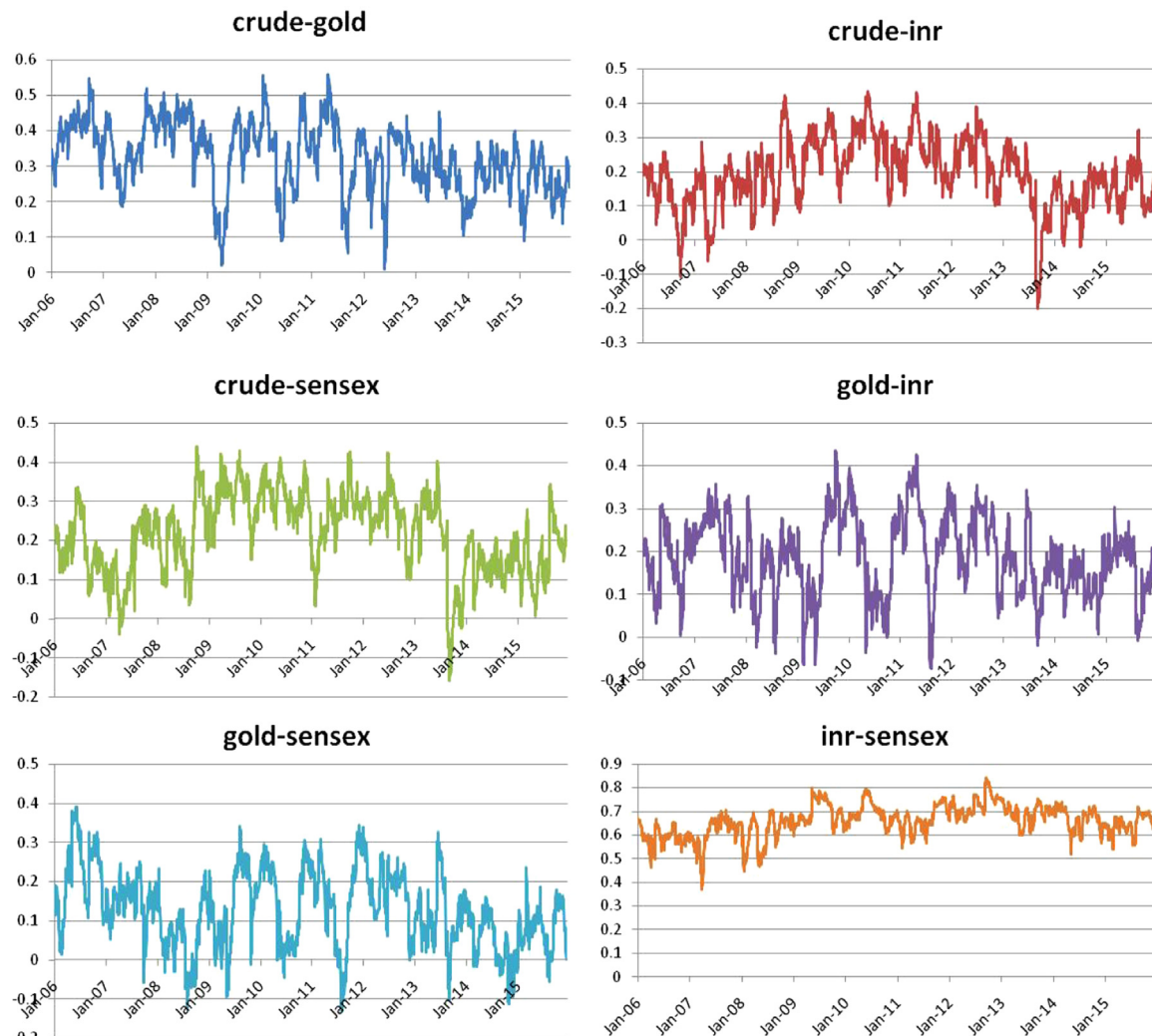


Fig. 2. Dynamic conditional correlations amongst variables.

**Table 4**  
Kyrtsoú–Labys causality test results.

Relation	Symmetric case	Asymmetric case		Coefficient of asymmetric causal variable	
		P case	N case	P case	N case
$\Delta crude \rightarrow \Delta gold$	0.7372	0.1866	3.2434	0.0121	−0.0435
$\Delta gold \rightarrow \Delta crude$	1.6052	3.3908	0.0962	−0.0231	0.0591
$\Delta crude \rightarrow \Delta inr$	1.2706	1.5037	10.6264*	0.002	0.0248*
$\Delta inr \rightarrow \Delta crude$	0.8890	0.5230	0.9601	0.213	0.2545
$\Delta crude \rightarrow \Delta sensex$	3.2456	0.9818	18.5131*	0.0365	0.0731*
$\Delta sensex \rightarrow \Delta crude$	0.1948	0.0006	1.3707	0.0806	0.0493
$\Delta gold \rightarrow \Delta inr$	10.8503*	2.0914	32.6936*	0.0331	0.0797*
$\Delta inr \rightarrow \Delta gold$	0.0009	2.2297	1.1652	0.0752	−0.0927
$\Delta gold \rightarrow \Delta sensex$	3.3734	0.3833	10.7152*	0.0678	0.1357*
$\Delta sensex \rightarrow \Delta gold$	1.0920	0.5976	7.6049*	0.0089	−0.0173*
$\Delta inr \rightarrow \Delta sensex$	6.9649*	1.9234	15.7589*	0.0587	0.3021*
$\Delta sensex \rightarrow \Delta inr$	1.8193	0.4863	0.2585	0.0149	0.0196

Note: Values in columns 2, 3 and 4 are F statistics for the corresponding causality tests. Asymmetric (P) and (N) indicate causality tests for positive and negative changes in the causing variable, respectively. Asterisk indicates rejection of the null hypothesis (no causality) at the 5% level of significance. Values in columns 5 and 6 are the coefficients of the causal variable from the test.

Exchange rate and the BSE Sensex 30 (benchmark index of Indian stock market, indicator of economic activity in India) using a decade long data set (2006–2015). The dynamic contemporaneous relation is examined using a DCC-GARCH model and Non Linear Causality test by [Krystou and Labys \(2006\)](#) is used to examine lead lag structure among the above variables.

Time varying correlations from the DCC-GARCH model suggested that during the 2008–2013, the correlation between crude prices and Indian exchange rate was higher than the rest of the period. Similar observation can be made for crude oil prices – stock market index. As crude prices are increasingly being considered a determinant for future growth of an economy, its significant

relation with the exchange rate and benchmark index is well expected. Short periods of negative correlation between gold price and the exchange rate and between gold price and stock market is also observed. This might be indicative of investors shifting from risky assets like the stock market to the perceived safe haven like gold. The time varying correlations also indicate mean reverting correlations amongst the variables moving within defined bands.

The results from the Krystou–Labys Non Linear Causality tests provide further insights into the lead lag relations amongst these variables. The symmetric test provides us information about the direction of causality and the asymmetric test provides information about the positive or negative impact of causality. In the symmetric case, it was observed that gold price causes the exchange rate in India and subsequently the exchange rate causes stock market behavior. However, it is difficult to comment on exact nature of this unidirectional causality from symmetric test results. Upon further examination using the asymmetric test, it is observed that fall in gold prices is found causing depreciation of the Indian Rupee and depreciation of the Indian Rupee causing a fall in the stock index.

Moreover, asymmetric causality test also demonstrated causality between crude oil and INR; crude oil and Sensex; gold price and Sensex; and Sensex and gold price. For instance, a fall in crude prices causes both depreciation of the Indian Rupee and a fall in stock market in India. The stock index and gold also have a bi-directional relationship, with fall in gold prices causing a fall in the Sensex as well as a fall in the Sensex causing gold prices to gain. This can be explained from the perspective of investors shifting between asset classes to optimize their risk-return behavior.

The results of this study have significant implications for academia, practitioners, and policy makers. The dynamic relationships between oil price - exchange rate and oil price - stock market shed some light on the need for dynamic policy changes by Reserve Bank and Government of India. The fact that India imports three quarters of its oil requirements and is the number one consumer of gold in world, our findings of dynamic linkages will be immensely helpful for policy makers. In fact, Government of India has tried different regulations in past to manage exchange rate and stock market behavior using gold price and oil price as policy instruments. For instance Government of India quadrupled customs duty on gold import in 2012 to stabilize exchange rate through reducing gold import though think-tanks in India and abroad were highly critical of this policy. It is also noticed that to manage exchange rate through oil prices, the government has tried to negotiate directly with oil exporting countries to accept Indian Rupee instead of the US Dollar. More so the government owned oil companies have been directed to approach the Indian central bank directly for foreign currency instead of purchasing from the open markets. Additionally, Government of India is promoting Gold Monetization Scheme (GMS) launched in 2015 to successfully contain fluctuations in the exchange rate and volatility in stock market.

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