Relationship between Select Commodity Prices and Macroeconomic Variables in India: A VAR Analysis

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Abstract

Focusing on the recent increase in gold prices, the basic objective of the paper is to predict changes in the price of gold and to examine the relationship that exists between commodity prices and macroeconomic variables in the Indian context. The variables considered are: commodity prices as represented by gold, silver and oil; and macroeconomic variables represented by interest rates, exchange rates and stock market indices. Vector Autoregressive (VAR) Modeling has been adopted and standard VAR summary statistics such as Granger causality tests, impulse response functions, and variance decompositions are analyzed to study co-movements between the variables. Monthly data from April 2005 to December 2013 forms the sample period of our study. Primarily, the following conclusions emerge: First, the largest share of shock to price of gold is significantly explained by its own variance. Shocks in other variables explain only 10 per cent of the variation in gold prices. Interestingly, innovations in silver prices explain variations in gold prices more than it explains variations in its own price. Analysis of the impulse response functions reveals that a positive shock to oil and silver price has a favourable effect on gold price initially, though its response becomes adverse later. Further, the impact of a positive shock to Nifty on gold prices, though positive initially, dissipates thereafter. Additionally, innovations in exchange rate initially have an adverse impact on gold price, though later gold prices begin to respond favourably. Johansen's Cointegration test suggests that there is a weak long term relationship that exists among the variables analyzed in the study.

Keywords: *Gold Prices, Oil Prices, Exchange Rates, Augmented Dicky-Fuller test, Vector auto regression, Johansen's test of Cointegration, Granger Causality, Forecast Error Variance Decomposition*

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Introduction

In recent months, India has seen a huge surge in the import of gold, notwithstanding the sustained increase in its price. It is also said that India is the largest consumer of gold. Since India fulfills its almost entire requirement of gold through imports, this trend has led to worrisome levels of current account deficit (CAD). Interestingly, India's 2012 gold demand was about 11 per cent more than that of China, although China's GDP is 3.5 times that of India. Similarly, compared with the United States, which has an economy ten times the size of India, India's gold demand remains five times that of the US. As shown in Figure 1, the value of gold imports in India has surged in recent years, despite the sharp rise in gold prices, indicating that our gold imports are relatively *price inelastic*. This implies that while demand for gold may have reduced with an increase in its price, the total expenditure on gold imports has increased. Therefore, import bill on account of gold import has risen.

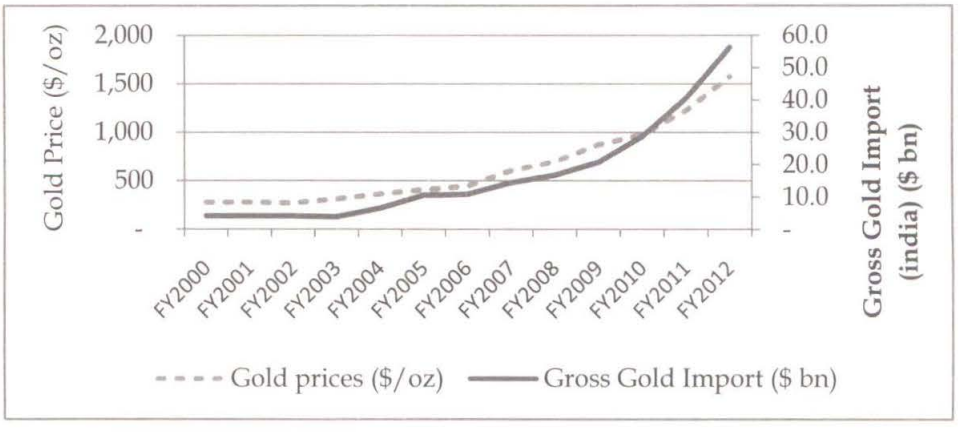


Figure 1: Gold Price and Value of Gold Imports

Source: Reserve Bank of India

The policy-makers also need to appreciate that gold demand has several drivers. Largely, demand is driven by cultural factors, tax evasion and the need to acquire a safe and liquid instrument. Further, rising inflation has made purchase of gold more of an investment decision, rather than a consumption decision. Despite price rise, it is arguable that there are some limits beyond which the consumption of gold is not likely to be substituted by other forms of consumption. Also, Indians tend to accumulate gold over a period of time, thereby giving them considerable scope to vary the rate of purchase as the prices fluctuate. In addition, rising incomes have resulted in enhanced purchases of gold. Specifically, it is estimated that for every 1 percent increase in income, gold consumption increases by 1.5 percent (implying high income elasticity).

Focusing on the recent increase in gold prices, the basic objective of the paper is to predict changes in the price of gold and to examine the relationship that exists between commodity prices and select macroeconomic variables in the Indian context.

The remainder of this paper is organized as follows: In section 2, we discuss the main factors that have led to India being a leading consumer of gold in the world. Section 3 provides a brief review of studies that have examined the determinants of the price of gold. Section 4 describes the methodology, data sources, as well as the empirical findings of the paper. Using Vector Auto-regression Modeling, the variables considered for the study are prices of gold, silver and oil; and macroeconomic variables represented by interest rates, exchange rates and stock market indices. Section 5 concludes from a broad policy perspective.

Factors contributing towards enhanced demand for gold

Gold, in general has varied uses and its demand stems primarily from household consumption, industrial consumption and investment purposes. The world consumption of new gold produced is about 50 per cent in jewellery, 40 per cent in investments, and 10 per cent in industry. However, as seen in Figure 2, the composition of gold demand, in recent years, has seen a steady movement towards the non-jewellery items. Growth in demand for gold is generally considered to be a function of economic growth, gold prices; which in turn is a function of import duty, exchange rate, inflation and interest rates, availability of alternative financial instruments; and availability of credit.

Some of the key drivers of demand for gold in India are discussed in this section.

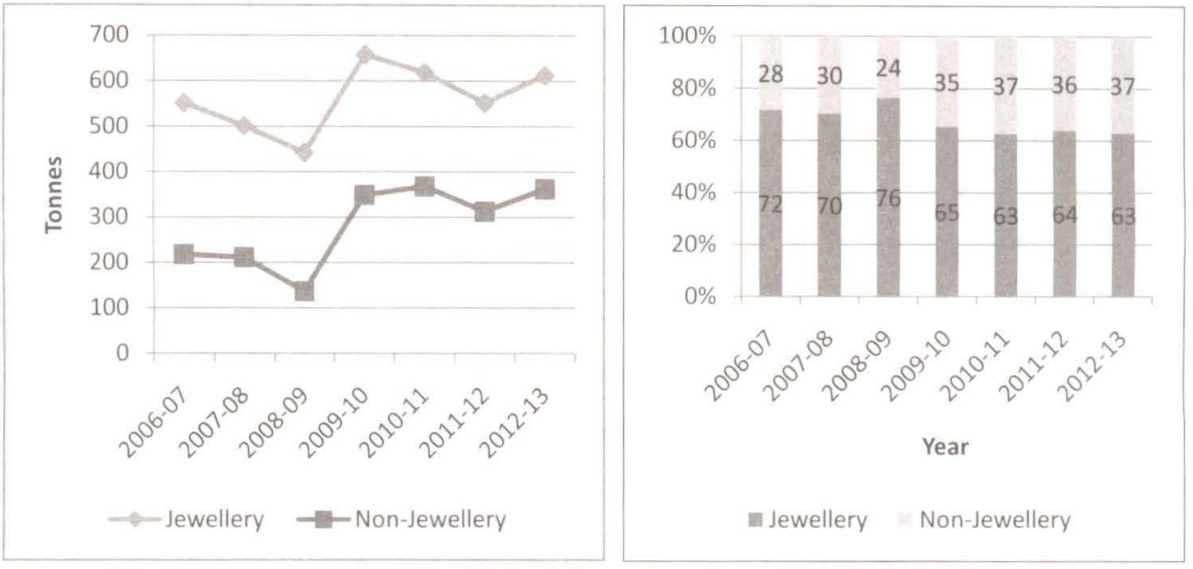


Figure 2: Gold Demand for Jewellery and Non-Jewellery Use (2006-06 to 2012-13)

Source: World Gold Council

Social and cultural factors: It is a well known fact that household demand for gold is strongly influenced by several social, economic and cultural factors. Indians are highly sentimental about gold jewellery in their possession. It is a matter of pride to invest in gold jewellery in India, hence enhanced money in the hands of the poor and middle class has historically been canalized towards purchase of gold. Indians consider it auspicious to buy/invest in gold during wedding and festival seasons. Resultantly, India witnessed a high demand for gold, inspite of an all time high price of INR 32,000 per 10 grams in 2012. It is estimated that the real purchaser of gold in India is typically a peasant. In fact 65 per cent to 70 per cent of the gold jewellery is sold in rural areas. People in rural India only know this means of investment and see it as a powerful tool to hedge against agricultural risks or urgent needs.

Sustained increase in gold prices fueling demand for gold: Another reason for the increasing imports of gold has been the sustained increase in gold prices in India. The gold prices increased markedly over the period April 2008 to March 2012. Investors reaped the benefit of attractive returns as the gold prices were increasing. This led to further investment in gold, giving impetus to further rise in gold prices. Rising prices of gold and imports of gold mutually reinforced each other. Investors seized the opportunity of investing in gold when there were

temporary falls in gold prices. Additionally, gold is considered as an investment that appreciates over years and provides a hedge against inflation. In India, price of gold (in INR per 10 gms) has grown from INR 8,910 in 2006 to INR 29,221 in 2013. This represents an average annual growth of 32 per cent. The Indian domestic gold prices have moved in tandem with the international gold prices. Constantly rising prices boosted the confidence of general public towards investment in gold. With inflation crossing a double digit mark, Indians have eventually started to see gold as a more secure means of investment, with better/higher returns vs. current deposits. As is clear from Figure 3, the cumulative rate of return in gold as an asset (over the period 2008 to 2012) has been much higher as compared to returns in alternate investments such as in the stock market or on bank deposits. Further, growth of gold prices over the period 2006 to 2011 at 33.54 per cent have been higher than the annualized inflation rate at 8.96 per cent, clearly suggesting the preference for gold purchases as an inflation hedge (the corresponding growth rates for the period 2001-02 to 2005-06 were 9.2 per cent and 4.69 per cent respectively). Additionally, no tax hassles on gold transactions in the informal market further incentivizes diverting domestic savings towards gold. Apart from these reasons, two factors specific to India, driving the demand for gold imports, need to be stressed. Firstly, India enjoys a strong position as an exporter of gems and jewellery. Thus, a significant proportion of gold imports is undertaken with a view to convert it into value added products like jewellery and export it therafter. Secondly, in recent years, utility of gold jewellery in securing credit has been reinforced to a great extent by the marketing efforts of gold loan companies. This has strengthened the liquidity motive for holding gold, which could be pledged by households as collateral, to tide over temporary mismatches in liquidity. This is discussed next.

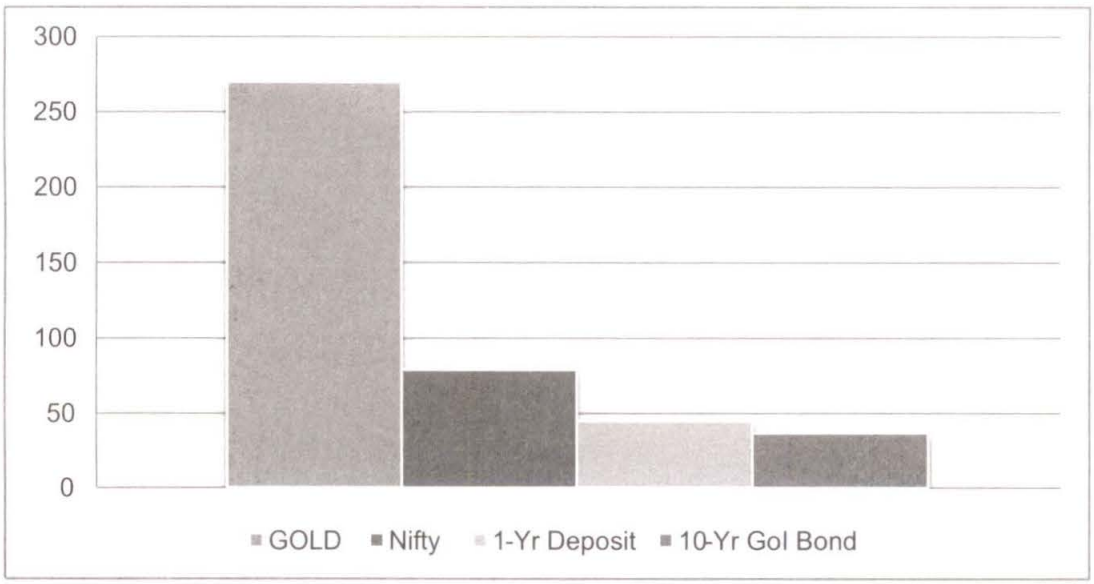


Figure 3: Cumulative Returns of Domestic Assets (January 2008 - May 2012)

Source: Reserve Bank of India (2012), Report of the Working Group to Study the Issues Related to Gold Imports and Gold Loans NBFCs in India.

Developments in gold loans market: Gold loans, in India, are traditionally provided by money lenders and local pawn brokers. This facility is availed by people from all walks of life (individuals, petty traders, borrowers in low and middle income group). While the gold imports surged, the gold loan market in India has also grown significantly and there is a decisive shift in

the players from unorganized sector to organized sector like banks and specialized Non Bank Financial Company (NBFC). In the post crisis period, personal loans have become costlier with upward revision in interest rates. Hence, a swift rise in the number of NBFC's institutions and their branch network fueled the volume of loan granted against gold. While in the organized sector, gold loans disbursed by NBFCs have witnessed rapid growth in the recent past, share of banks in total gold loans remains much higher at 72.3 per cent at the end of March 2012. However, although banks continue to retain the dominant share in the gold loan market, the share of NBFCs has been steadily increasing over the years and increased from 13. 2 per cent from March 2008 to 27.7 per cent as at the end of March 2012. Further, flexibility of loan options, liberal loan to value ratio, and easy to conform documentation, led to rapid expansion of the gold loans. Also, the average size of gold loan increased due to the rapid price increase of gold and constricted availability of retail and personal loans from banks. Since gold was now increasingly seen as a near to liquid asset, it further increased the demand for gold, leading to an increase in gold imports. Technical work undertaken by the Working Group constituted by the Reserve Bank of India (RBI, 2012) substantiated the fact that gold loans have a causal impact on the gold imports, since it encourages the liquidity motive of holding gold. An econometric analysis based on monthly data for the period 2008-09 to 2011-12 was undertaken by the group to examine the possible determinants of gold demand in India. The empirical analysis suggests that such outstanding loans have an impact on the quantum of gold imports and that there exists a positive correlation between total gold loans outstanding and the gold imports. Specifically, a 1per cent change in gold loans was estimated to lead to a 0.3 per cent change in volume of gold imports. Possible rationale for this relationship could be that when the gold prices increase, with a liberal loan to value ratio, people are generally induced to invest in gold due to the prospects of gold value appreciation and the possibility to raise a loan in case of need.

Increasing trend in the CP-DD ratio and the quantum of black money: CP-DD ratio (defined as a Ratio of Currency with Public to Demand Deposits) depicts the public preference for cash. In India, the CP-DD ratio has shown an increasing trend since 2008 and reached 1.5 per cent in 2011-12, after attaining a low of 1.1 per cent in 2007-08. This means that public preference for cash holding increased significantly during this period. Higher CP-DD ratio might be reflecting an increase in high value cash transactions, part of which, perhaps, took place for gold transactions. Gold deals in grey market are cash based, hence the possibility of large informal transactions involving huge money in recent years flowing into gold cannot be ruled out. Additionally, the gap between supply and demand of gold in India has caused spurt in gold smuggling in India.

Increasing gold reserves in India: An increase in gold imports at high gold prices has led to large trade deficits and worsened India's current account deficits (CAD). In recent years, around 30 per cent of trade deficit in India has been on account of gold import. The Reserve Bank of India has developed an external vulnerability index which takes into account various measures of solvency ratios designed to reflect the vulnerability of the Indian financial system to external risks. Since gold imports contribute significantly to current account deficit, it causes the country's external vulnerability to go up. To adjust the CAD and reduce such vulnerabilities, the central bank had to buy large quantity of gold to diversify its foreign exchange reserves. As is clear from Figure 4, the gold reserves in India (in million USD and as percentage of total reserves), witnessed a huge growth, leading to further spike in gold demands in India.

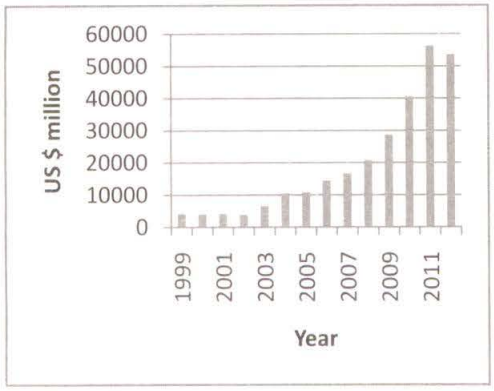


Figure 4a: Gold Import in India

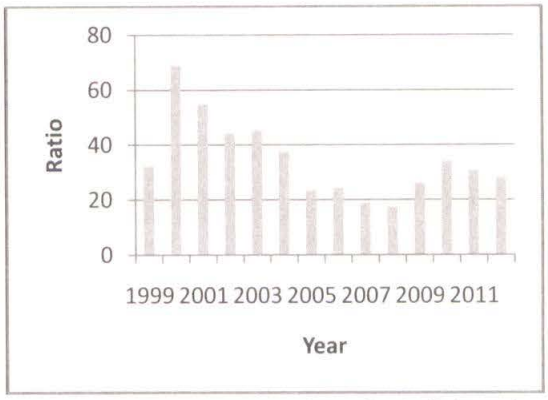


Figure 4b: Gold import / Trade deficit ratio

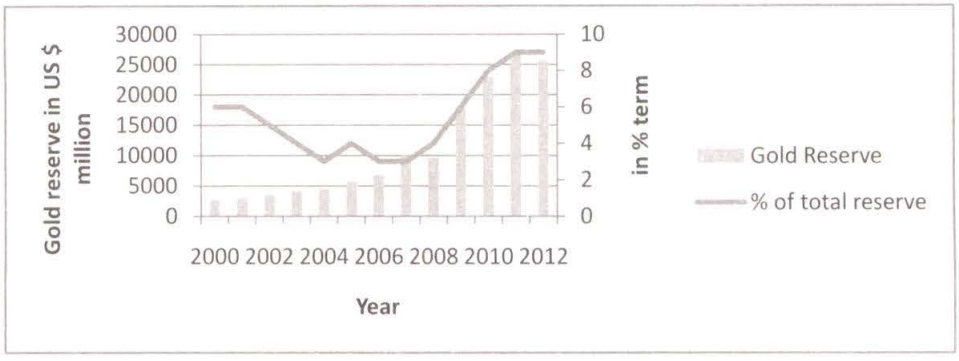


Figure 4c: Gold Reserve in India (in million USD and as percentage of total reserves)

Source: Reserve Bank of India, The Handbook of Statistics for the Indian Economy

Review of Literature

In the past, several studies have attempted to study the determinants of the price of gold. In general, this has been attempted from three major perspectives:

- Papers that analyze the price of gold in terms of macroeconomic variables. This strand of literature consists of studies which address impacts of macroeconomic variables such as exchange rates, interest rates, or output on the price of gold.
- Studies that focus on speculation and rationality of gold price movements, and
- Literature that analyzes demand for gold as a hedge against inflation

A synoptic view of these studies is provided in Table 1. Few of these papers are reviewed in this section.

Table 1

	Perspectives		Studies
First	Gold price as explained from the perspective of macroeconomic variables		Abken, 1980; Ai Han *et al.*, 2008; Ariovich, 1983; Dooley *et al.*, 1992 , 1995; Eric *et al.*, 2006; Kaufmann *et al.*, 1989; Lucey et al. (2006), Mu Lan *et al.*, 2010; Sherman, 1982, 1983, 1986; Sjaastad *et al.*, 1996, 2008; Smith, 2001, 2002; Sujit *et al.*, 2011; Toraman *et al.*, 2011; Zang *et al.*, 2010. Wang and Lee (2011)
Second	Gold prices explained from the perspective of Speculation motive		Baker *et al.*, 1985; Bialkowski *et al.*, 2011; Chua *et al.*, 1990; Diba *et al.*, 1984; Koutsoyiannis, 1983; Pindyck, 1993; Pravit, 2009
Third	Gold as a hedge against inflation		Beckmann *et al.*, 2012; Chappell *et al.*, 1997; Ghosh *et al.*, 2000, 2004; Kolluri, 1981; Laurent, 1994; Mahdavi *et al.*, 1997; Moore, 1990; Ranson, 2005 a, b; Worthington *et al.*, 2006

Source: Based on study by Sujit et.al. (2011) and updated by authors

Toraman *et al.* (2011) have estimated the factors affecting gold prices in the USA. Their study, based on monthly data between June 1992 and March 2010 included variables such as gold prices, oil prices, exchange rate, inflation rate, and real interest rate. Based on Multivariate GARCH model, they find that a high negative correlation exists between gold prices and the USA exchange rate. Further, a positive correlation has been estimated between gold prices and oil prices. Eric *et al.* (2006) estimate the determinants of gold prices in the USA, in the short run and the long-run, for the period January 1976 to August 2005. Using cointegration statistical technique, the variables included in the study are: nominal price of the gold, consumer price index (CPI), change in retail price index, volatility of the USA inflation, IMF 'World' price index, volatility of the world inflation, world income, dollar index, gold lease rate and credit risk default premium. Based on the evidence, the authors conclude that a long term relationship between the gold price and the US price level exists. Further, the study suggests a positive relationship between gold price movements and changes in US inflation rate, US inflation volatility and credit risk. The paper also reveals a negative relationship between changes in gold price, changes in the US dollar index and the gold lease rate. Dooley *et al.* (1992) investigate the relationship between price of gold and exchange rate for various countries. End of the month exchange rates between the US dollar and four other major currencies (the pound sterling, the Japanese Yen, the Deutsche Mark, and the French Franc), as well as the mark/yen exchange rate over the period January, 1976 to December, 1990 is used in the study. The general conclusion that emerges from their empirical investigations is that gold price movements have a significant explanatory power in explaining exchange rate movements, over and above the effects of movements in monetary fundamentals other than real macroeconomic variables. In addition to other techniques, the paper also applies multi variate vector auto regression and cointegration modeling techniques to test the short-run and long-run influence of the price of gold on exchange rates, conditional on other monetary and real macroeconomic variables.

Sujit *et al.* (2011) analyze the dynamic relationship between commodity prices (gold and crude oil), stock index and exchange rate for the economy of USA. Using Vector autoregressive (VAR) and co-integration techniques to explore the above relationship, they use daily data from 2 January 1998 till 5 June 2011, constituting 3485 observations. Their findings indicate that fluctuations in gold prices are largely dependent on gold itself rather than fluctuations in oil prices or stock market indices. Findings also indicate that exchange rate is highly affected by fluctuations in variables such as gold price and oil price. For one of the models, the paper estimated a weak long-term relationship among the four variables analyzed, viz. gold price, oil price, exchange rate and stock market index.

Abken (1980) investigates the movement and direction in which the market responds at the time when new information arrives in the market. It is stated that owners of gold stocks have the choice of selling gold today or storing it for future sale. This decision depends on current and anticipated future prices. It is assumed that the consumer is rational. In other words, the participant in the gold market acts to maximize anticipated net revenue from the storage of gold. In the research paper, gold prices are taken as endogenous variables and interest rate and lagged values of gold prices are taken as exogenous variables in multi-regression analysis. The study uses monthly observations from January 1973 to December 1979, containing 81 observations. The author observes that gold differs only in degree from other storable commodities in the way various economic factors influence its price and concludes that the spot prices of gold (like all storable commodities) are particularly influenced by anticipations of future spot prices. In the case of gold, however, the relative insignificance of flow supply and demand compared to stocks, the relative insensitivity of flow supply and demand with respect to spot price movements, and the relative liquidity of gold, all tend to make current changes in the gold price especially sensitive to changes in its anticipated future spot price.

The study by Sjaastad (2008) has investigated the relationship between major exchange rates and

the gold prices using forecast error model. The spot gold price and forward gold price (i.e., 90-day contracts let at the beginning of each month) data were based on daily observations from January 1991 to June 2004, both in U.S. dollars. Spot and forward exchange rates between US Dollar, GB Pound, Japan Yen and Deutche Mark were also part of their study. Based on the analysis, the author observed a high positive relationship between the spot and forward gold prices. Further, real appreciations and depreciations of the Euro and the Yen against the U.S. dollar have been estimated to have profound effects on the price of gold in all other currencies. Additionally, the major gold producers of the world (Australia, South Africa, and Russia) appear to have no significant influence over the world price of gold. Also, contrary to earlier studies, Sjaastad concludes that gold no longer seems to be a store of value against "world" inflation.

Smith's (2002) paper provides empirical evidence on the relationship between the price of gold and stock price indices for countries of Europe and Japan for the period beginning in January 1991 and ending in October 2001. Three London gold prices and twenty-three stock price indices are used. All indices except the Nikkei 225 have capitalisation weights. Evidence shows that the short-run contemporaneous correlation between returns on gold and European stock price indices is generally small and negative and often insignificantly different from zero, but occasionally it is small and positive. Further, all of the gold price and stock price indices are I(1) i.e. time-series are integrated of order one I(1). Also, over the period examined, there is no cointegration involving a gold price and a stock price index. That is, there is no long-run equilibrium and the series do not share a common stochastic trend. Only weak short-run relationships are evident. Using daily time series data Mu Lan et al. (2010) explore the impact of fluctuations in gold prices, crude oil prices and exchange rates of the US dollar vs. various currencies on the stock price indices of the United States, Germany, Japan, Taiwan, and China respectively, as well as, the long and short-term correlations among these variables. The results indicate that there exist cointegrations among fluctuations in gold price, oil price and exchange rates of the dollar vs. various currencies, and the stock markets in Germany, Japan, Taiwan and China. The paper by Ai Han et al. (2008) proposes an interval method to estimate the dynamic relationship between the exchange rate of Australian dollar against the US dollar and the gold price. This study uses weekly, monthly and quarterly observations for the variables and the sample period analyzed is from January 6, 2002 to February 10, 2008. Using Interval method, interval sample data were formed to present the volatility of the variables. The Interval Least Squares approach (ILS) was extended to multi-model estimation and the computational schemes were provided. The empirical evidence suggests that the ILS estimates characterized the relationship between the exchange rate and the gold price, both in the long-run and the short-run.

In their paper Ghosh *et al* (2000), construct a theoretical model and suggest a set of conditions that would have to be satisfied for the price of gold to rise over time at the general rate of inflation. They, thus, state that if these conditions are met, then gold would be an effective long-run hedge against inflation. The authors argue that changes in factors such as the real interest rate, the covariance of returns to gold with a diversified portfolio of other assets, default risk, the convenience yield and particularly the gold lease rate can seriously disturb the equilibrium and generate considerable short-run volatility. Using monthly gold price data over the period 1976 to 1999 and adopting cointegration regression technique, their empirical analysis confirms a long-run relationship between the nominal price of gold and the USA retail price index, with an implied elasticity of one. The authors interpret this finding as gold being a long-run inflation hedge. Further, the authors conclude that short-run movements in the price of gold are driven primarily by changes in the gold lease rate, gold's beta and the USA/World exchange rate. Since movements in the nominal price of gold appear to be dominated by these short-run influences, it is concluded that the long-run relationship, although significant, is of much less importance.

Given that the gold market and the crude oil market are the main representatives of the large commodity markets, Zhang *et al.* (2010) analyze their cointegration relationship, linear and non-linear Granger causality and forecast the fluctuation of crude oil and gold prices. The authors use daily data from January 4, 2000 to March 31, 2008, with a total of 2064 observations. Their empirical analysis indicates that there are consistent trends between the crude oil price and the gold price with significant positive correlation coefficient. Additionally, their results indicate a long-term equilibrium between the two markets. Further, it is observed that crude oil price change linearly Granger causes the volatility of gold price, though the reverse does not hold true. Moreover, the two market prices do not face a significant nonlinear Granger causality, which overall suggests their fairly direct interactive mechanism.

The study by Beckmann and Czudaj (2012) analyzes whether gold provides the ability of hedging against inflation or not. The study conducts a Markov-switching vector error correction model (MS-VECM) approach for a sample period ranging from January 1970 to December 2011 using data from four major economies, viz the USA, the UK, the Euro Area, and Japan. They allow for nonlinearity and discriminate between long-run and time-varying short-run dynamics. The main findings of the study are: Firstly, gold is partially able to hedge future inflation in the long-run and this ability has been stronger for the USA and the UK, as compared to Japan and the Euro Area. Secondly, the adjustment of the general price level is characterized by regime-dependence. Based upon their findings, the authors suggest that the price for gold should be considered when aiming to appropriately forecast the inflation rate.

Objective, Methodology and Empirical Findings

Focusing on the recent increase in gold prices, the basic objective of the present study is to predict changes in the price of gold and to examine the dynamic relationship that exists between commodity prices such as gold, silver and oil; and macroeconomic variables such as interest rate, exchange rate and performance of stock market as given by movements in the stock market index. Commodity prices and macroeconomic variables are closely related. Each of them is expected to affect the demand and thereby the price of gold. Given that gold market and crude oil market are the main representatives of large commodity markets, it is of crucial practical significance to analyze their relationship. Amongst the precious metals, silver remains a close substitute as an investment alternative, and thus analyzing the relationship between silver and gold prices is important. Persisting lower/negative real interest rates is likely to result in investors diverting their saving to gold, thereby influencing demand for gold. Since most of the gold requirements in India are met through imported gold, fluctuations in the exchange rates are likely to impact demand for gold. Returns on the stock market too are expected to influence demand for gold as, in general, periods of low returns on the stock market divert savings and investments into gold. When stock prices fall, financial advisors advise investors to maintain a position in gold. Conversely during boom times, gold investments often decrease in value. While theoretically, these relationships seem simple and straightforward, in reality the interconnection between the variables remains complex. Since these macroeconomic variables witness changes over time, it is necessary to validate these relationships periodically. Therefore, in this paper we attempt to test the dynamic relationship that exists between these variables.

Methodology, Variables and Data Sources

To test the dynamic relationship, Vector Auto-regressive Modeling has been adopted and standard VAR summary statistics such as Granger causality tests, impulse response functions, and variance decompositions are analyzed to study co-movements between the variables. The paper uses monthly data over the period April 2005 to December 2013, constituting 105 observations[1]. Table A1 presents the descriptive statistics of the data in terms of levels and also in terms of percentage change.

The six variables selected for the study are briefly described as:

Gold Price (GOLD): Gold price is the monthly average price of gold (INR per 10 grams) at Mumbai. It is sourced from Handbook of Statistics on Indian Economy[2].

Oil Price (OIL): Oil price is the crude oil price (US dollar per barrel) of Indian Basket. Indian Basket of crude oil price is declared by the Indian Oil Corporation Limited[3]. It is sourced from the Indian Oil Corporation Limited[4].

Silver Price (SILVER): Silver price is the monthly average price of silver (INR per kilogram) at Mumbai. It is sourced from Handbook of Statistics on Indian Economy[5].

Interest Rate (INTT): The interest rate considered here is the monthly average of Mumbai Inter-Bank Offer Rate (MIBOR) on a one month basis. Since changes in rate of interest induce an investor to make portfolio adjustments, the same has been incorporated in the model. It is sourced from the National Stock Exchange of India[6].

Stock Market Index (NIFTY): Stock market index is considered on the basis of monthly average of CNX NIFTY. The CNX Nifty is National Stock Exchange of India's benchmark index for Indian equity market. CNX Nifty has shaped up as the largest single financial product in India, with an ecosystem comprising of exchange traded funds (onshore and offshore), exchange-traded futures and options, other index funds and OTC derivatives (mostly offshore). Thus, CNX NIFTY is a well-diversified stock index, accounting for major sectors of the Indian economy. It is sourced from the National Stock Exchange of India[7].

Exchange Rate (EXCHRATE): Exchange rate is the price of one country's currency expressed in another country's currency. The exchange rate considered here is Reserve Bank of India's (RBI) reference rate on monthly average basis expressed in Indian Rupees (INR) per United States Dollar ($). Since most of gold requirements in India are met through imported gold, the exchange rate is likely to have an important effect in influencing demand for gold. It is sourced from the Reserve Bank of India[8].

In order to examine the relationship between gold price, oil price, silver price, interest rate, share market index, and exchange rate, the paper adopts the Vector Autoregressive (VAR) technique and Johansen's Cointegration test. In this model, all variables are assumed to be endogenous and each variable is explained by its lagged values and lagged values of other endogenous variables included in the system. In our study, there are no exogenous variables.

In general, the mathematical formulation of a VAR Model can be represented by:

$$y_t = A_1 y_{t-1} + \cdots + A_p y_{t-p} + B x_t + \epsilon_t$$

where,

y_t represents a k vector of endogenous variables,

x_t represents a d vector of exogenous variables,

$A_1, \ldots, A_p$ and B represents matrices of coefficients that are to be estimated, and

ϵ_t represents a vector of error terms.

As stated, our study focuses on six variables each of them assumed to be endogenous. Specifically, the VAR model is represented by the following six equations:

$$GOLD_t = \alpha_{10} + \sum_{j=1}^{p} \beta_{1j}\, \mathrm{GOLD}_{t-p} + \sum_{j=1}^{p} \gamma_{1j}\, \mathrm{OIL}_{t-p} + \sum_{j=1}^{p} \delta_{1j}\, \mathrm{SILVER}_{t-p} + \sum_{j=1}^{p} \eta_{1j}\, \mathrm{INTT}_{t-p} + \sum_{j=1}^{p} \theta_{1j}\, \mathrm{NIFTY}_{t-p} + \sum_{j=1}^{p} \lambda_{1j}\, \mathrm{EXCHRATE}_{t-p} + \epsilon_{1t} \quad \ldots\ldots 1$$

$$OIL_t = \alpha_{20} + \sum_{j=1}^{p} \beta_{2j}\, \mathrm{GOLD}_{t-p} + \sum_{j=1}^{p} \gamma_{2j}\, \mathrm{OIL}_{t-p} + \sum_{j=1}^{p} \delta_{2j}\, \mathrm{SILVER}_{t-p} + \sum_{j=1}^{p} \eta_{2j}\, \mathrm{INTT}_{t-p} + \sum_{j=1}^{p} \theta_{2j}\, \mathrm{NIFTY}_{t-p} + \sum_{j=1}^{p} \lambda_{2j}\, \mathrm{EXCHRATE}_{t-p} + \epsilon_{2t} \quad \ldots\ldots 2$$

$$SILVER_t = \alpha_{30} + \sum_{j=1}^{p} \beta_{3j} GOLD_{t-p} + \sum_{j=1}^{p} \gamma_{3j} OIL_{t-p} + \sum_{j=1}^{p} \delta_{3j} SILVER_{t-p} + \sum_{j=1}^{p} \eta_{3j} INTT_{t-p} + \sum_{j=1}^{p} \theta_{3j} NIFTY_{t-p} + \sum_{j=1}^{p} \lambda_{3j} EXCHRATE_{t-p} + \epsilon_{3t} \quad \ldots\ldots 3$$

$$INTT_t = \alpha_{40} + \sum_{j=1}^{p} \beta_{4j} GOLD_{t-p} + \sum_{j=1}^{p} \gamma_{4j} OIL_{t-p} + \sum_{j=1}^{p} \delta_{4j} SILVER_{t-p} + \sum_{j=1}^{p} \eta_{4j} INTT_{t-p} + \sum_{j=1}^{p} \theta_{4j} NIFTY_{t-p} + \sum_{j=1}^{p} \lambda_{4j} EXCHRATE_{t-p} + \epsilon_{4t} \quad \ldots\ldots 4$$

$$NIFTY_t = \alpha_{50} + \sum_{j=1}^{p} \beta_{5j} GOLD_{t-p} + \sum_{j=1}^{p} \gamma_{5j} OIL_{t-p} + \sum_{j=1}^{p} \delta_{5j} SILVER_{t-p} + \sum_{j=1}^{p} \eta_{5j} INTT_{t-p} + \sum_{j=1}^{p} \theta_{5j} NIFTY_{t-p} + \sum_{j=1}^{p} \lambda_{5j} EXCHRATE_{t-p} + \epsilon_{5t} \quad \ldots\ldots 5$$

$$EXCHRATE_t = \alpha_{60} + \sum_{j=1}^{p} \beta_{6j} GOLD_{t-p} + \sum_{j=1}^{p} \gamma_{6j} OIL_{t-p} + \sum_{j=1}^{p} \delta_{6j} SILVER_{t-p} + \sum_{j=1}^{p} \eta_{6j} INTT_{t-p} + \sum_{j=1}^{p} \theta_{6j} NIFTY_{t-p} + \sum_{j=1}^{p} \lambda_{6j} EXCHRATE_{t-p} + \epsilon_{6t} \quad \ldots\ldots 6$$

Where, GOLD, OIL, SILVER, INTT, NIFTY, and EXCHRATE represent gold price, oil price, silver price, interest rate, stock market index, and exchange rate respectively; p represents lag length; and ϵ_{it} (i = 1 to 6) represents the white noise errors.

Stationarity of Variables: For the VAR estimation all the variables included in the model should be stationary. A stationary time series is significant to a regression analysis since analyzing useful characteristics are difficult in a non-stationary time series. However, most economic time series are non-stationary in practice. Therefore, the first step in time series modelling is to check each relevant series for stationarity. A time series is said to be stationary if its mean and variance are constant and, the covariances depend on the distance of two time periods (i.e. the auto covariance function between Xt_1 and Xt_2 depends only on the interval t^1 and t_2.). Tests for stationarity check whether one can reject the null hypothesis of unit roots. The Dicky-Fuller unit root test (DF), augmented Dicky-Fuller unit root test (ADF) (Dicky and Fuller, 1979) and the Phillips-Perron unit root test (PP) (Phillips and Perron, 1988) are often used to test for stationarity.

The results of stationarity based on Augmented Dickey-Fuller Test are reported in Table 2. Analysis of the table clearly indicates that the series is non-stationary at level, while the same becomes stationary when the variables are converted into their first difference . Since the variables are non-stationary at level, cointegration may exist among the variables used in the model. Thus, as a next step, we test for cointegration. Specifically, Johansen's test of cointegration is estimated to check whether long term equilibrium relation exists between the variables under study or not. The test is based on trace test statistic . The result of Johansen cointegration test shows that no or very weak cointegration exists among variables. The results are placed in annexure as Table A2.

Table 2: Augmented Dickey-Fuller Test

	Lag length	Exogenous	t-statistic	p-value*
Data in level				
GOLD	0	C	-0.18330	0.9360
OIL	1	C	-2.61516	0.0932
SILVER	0	C	-1.16203	0.6885
INTT	1	C	-2.41378	0.1405
NIFTY	1	C	-2.08202	0.2524

EXCHRATE	1	C	-0.38521	0.9066
Data in % change				
PC_GOLD	0	C	-10.09064	0.0000
PC_OIL	0	C	-6.23947	0.0000
PC_SILVER	1	C	-7.44842	0.0000
PC_INTT	0	C	-7.60398	0.0000
PC_NIFTY	0	C	-7.38598	0.0000
PC_EXCHRATE	0	C	-7.16744	0.0000

*Note: * represents MacKinnon (1996) one-sided p-values.*

Selection of optimal lag: An important aspect of VAR model is to select the optimal lag length. While too short a lag length may not capture the dynamic behavior of the variables (Chen and Patel, 1998), too long a lag length is likely to distort the data and lead to a decrease in the power of the model (DeJong et al., 1992). In this study, following five criteria for choosing the optimal lag length have been adpoted:

- LR: Sequential modified LR test statistics
- FPE: Final Prediction Error
- AIC: Akaike information criterion
- SC: Schwarz criterion, and
- HQ: Hannan-Quinn information criterion

The results of lag length selection by different criteria are placed in Table 3. Of the five criteria, three of the criteria propose an optimal lag length of 2 periods, while the remaining two propose an optimal lag length of 1 period. For the purpose of our study, we have considered a lag length of 2 to be appropriate and optimal.

Table 3: Lag Length Selection by Different Criteria

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-3536.92	NA	2.14E+24	73.0499	73.20916	73.1143
1	-2831.789	1308.49	2.18E+18	59.25339	60.36821*	59.70417*
2	-2786.815	77.89338*	1.83e+18*	59.06835*	61.13874	59.90552
3	-2756.342	49.00871	2.09E+18	59.18231	62.20825	60.40585
4	-2724.654	47.04201	2.38E+18	59.27121	63.25272	60.88114
5	-2687.423	50.66429	2.49E+18	59.24584	64.18291	61.24215
6	-2646.953	50.06603	2.52E+18	59.15367	65.04631	61.53637
7	-2619.617	30.43561	3.51E+18	59.33232	66.18052	62.1014
8	-2581.81	37.41745	4.19E+18	59.29506	67.09882	62.45052

*Note: * indicates lag order selected by the criterion; LR: sequential modified LR test statistic (each test at 5% level); FPE: Final prediction error; AIC: Akaike information criterion; SC: Schwarz information criterion; HQ: Hannan-Quinn information criterion.*

Ordering of the variables: Ordering of variables remains critical in estimation of VAR models. Ideally, theory should suggest an ordering, i.e. movements in some variables are likely to follow, rather than precede others. It is also worth noting that the more highly correlated the residuals are from an estimated equation, the more the variable ordering will be important. But when the residuals are almost uncorrelated, the ordering of the variables will make little difference. Proper ordering shows that current innovations in the variable that is placed first, affects the rest of the variables. At the same time, the current innovations in variables placed towards the end

are not expected to affect the variables in the beginning of the order. The study selected the ordering of the variables by conducting pair-wise Granger causality tests with the optimal lag length (i.e., 2) selected by the criteria. The result of pair-wise Granger causality is placed in Table 4. The following order was selected for this study after considering multiple overlapping results from pair wise Granger causality.

Order of study: GOLD, OIL, SILVER, INTT, NIFTY, EXCHRATE

Table 4: Pair-wise Granger Causality Tests

Null Hypothesis	F-Statistic	Probability
EXCHRATE does not Granger Cause INTT	0.21129	0.8099
INTT does not Granger Cause OIL	0.22076	0.8023
GOLD does not Granger Cause INTT	0.37501	0.6883
SILVER does not Granger Cause GOLD	0.46397	0.6302
OIL does not Granger Cause GOLD	0.49026	0.6140
SILVER does not Granger Cause NIFTY	0.49740	0.6096
EXCHRATE does not Granger Cause GOLD	0.53496	0.5874
INTT does not Granger Cause GOLD	0.58673	0.5581
EXCHRATE does not Granger Cause OIL	0.68544	0.5063
NIFTY does not Granger Cause SILVER	0.77168	0.4650
NIFTY does not Granger Cause GOLD	0.79174	0.4559
EXCHRATE does not Granger Cause SILVER	0.80390	0.4505
GOLD does not Granger Cause SILVER	0.83586	0.4366
SILVER does not Granger Cause INTT	1.19825	0.3061
NIFTY does not Granger Cause EXCHRATE	1.23500	0.2953
INTT does not Granger Cause NIFTY	1.24314	0.2930
OIL does not Granger Cause NIFTY	1.24812	0.2916
INTT does not Granger Cause SILVER	1.59603	0.2079
GOLD does not Granger Cause NIFTY	1.72424	0.1837
GOLD does not Granger Cause EXCHRATE	2.15888	0.1209
OIL does not Granger Cause SILVER	2.34932	0.1008
INTT does not Granger Cause EXCHRATE	2.52974	0.0849***
SILVER does not Granger Cause EXCHRATE	2.86450	0.0618***
NIFTY does not Granger Cause INTT	2.88278	0.0607***
EXCHRATE does not Granger Cause NIFTY	2.99216	0.0548***
GOLD does not Granger Cause OIL	3.72619	0.0276**
NIFTY does not Granger Cause OIL	4.26121	0.0168**

OIL does not Granger Cause EXCHRATE	4.66856	0.0116**
SILVER does not Granger Cause OIL	5.05843	0.0081*
OIL does not Granger Cause INTT	5.42144	0.0058*
*(Note: *, **, *** represents 1%, 5%, 10% significance levels respectively.)*		

Estimation of VAR

Because VARs involve current and lagged values of multiple time series, they capture co-movements that cannot be detected in univariate or bivariate models. Standard VAR summary statistics such as Granger causality tests, impulse response functions, and variance decompositions are well accepted and widely used methods for portraying these co-movements. These summary statistics are useful because they provide targets for theoretical macroeconomic models. Further, since coefficients obtained from the estimation of the VAR model are not interpreted directly, interpretation of VAR statistics such as Granger causality tests, impulse response functions, and variance decompositions are often more useful. Block F-tests and an examination of causality in a VAR will suggest which of the variables in the model have statistically significant impacts on the future values of each of the variables in the system. But F-test results, by construction, will not be able to explain the sign of the relationship or how long these effects require to take place. That is, F-test results will not reveal whether changes in the value of a given variable have a positive or negative effect on other variables in the system, or how long it would take for the effect of that variable to work through the system. Such information will, however, be given by an examination of the VAR's impulse responses and variance decompositions.

Impulse responses trace out the responsiveness of the dependent variables in the VAR to shocks or innovations to each of the variables. So, for each variable from each equation separately, a unit shock is applied to the error, and the effects upon the VAR system over time are noted. Provided that the system is stable; the shock gradually dies away. Impulse Response Functions (IRFs) are used to trace out the dynamic interaction among variables. In other words, it focuses more on the increase or decrease in trend rather than the actual value of the variable. On the other hand, variance decompositions offer a slightly different method for examining VAR system dynamics. They give the proportion of the movements in the dependent variables that are due to their 'own' shocks, versus shocks to the other variables. A shock to the ith variable will directly affect that variable offcourse, but it will also be transmitted to all of the other variables in the system through the dynamic structure of the VAR. Variance decompositions determine how much of the s-step-ahead forecast error variance of a given variable is explained by innovations to each explanatory variable for s = 1, 2, ... In practice, it is usually observed that own series shocks explain most of the (forecast) error variance of the series in a VAR. Thus variance decomposition is used to detect the causal relationships among the variables, and shows the extent to which a variable is explained by the innovations or shocks in all the variables in the system.

Impulse response function: The impulse responses estimated in our study show the response to one standard deviation shock in the error terms of other variables. The X axis represents the time period, while the Y axis represents the shock in the movement trend. It is pertinent to keep in mind that an upward direction of the IRF does not mean an increase in variable. Rather, it signifies that the 'increase in trend' is strengthened. Based on the impulse response functions shown in Figure 5(a and b), few observations are listed:

- A positive shock to oil price has a favourable effect on gold price until the 2nd month. Thereafter, its response becomes adverse and remains so until the end of the 4th month. Similar trends are observed when innovations are given to silver price. A positive shock to Nifty has no impact on the IRF of gold until the first month and a

half. However, soon thereafter, the impact becomes highly pronounced in the upward direction though it dissipates equally fast to become zero by the end of the fourth period. A positive shock to exchange rate initially has an adverse impact on gold price, though by the beginning of the 2nd month, gold prices begin to respond favourably to a one standard deviation shock in exchange rate. Lastly, a positive shock to gold price has a large favourable effect on its own price. The favorable effect remains strong for the initial month. However, within a month and a half the impact dissipates.

Figure 5a: Impulse Response Functions-Response of GOLD to Gold, Oil, Silver, Interest, Nifty and Exchange Rate

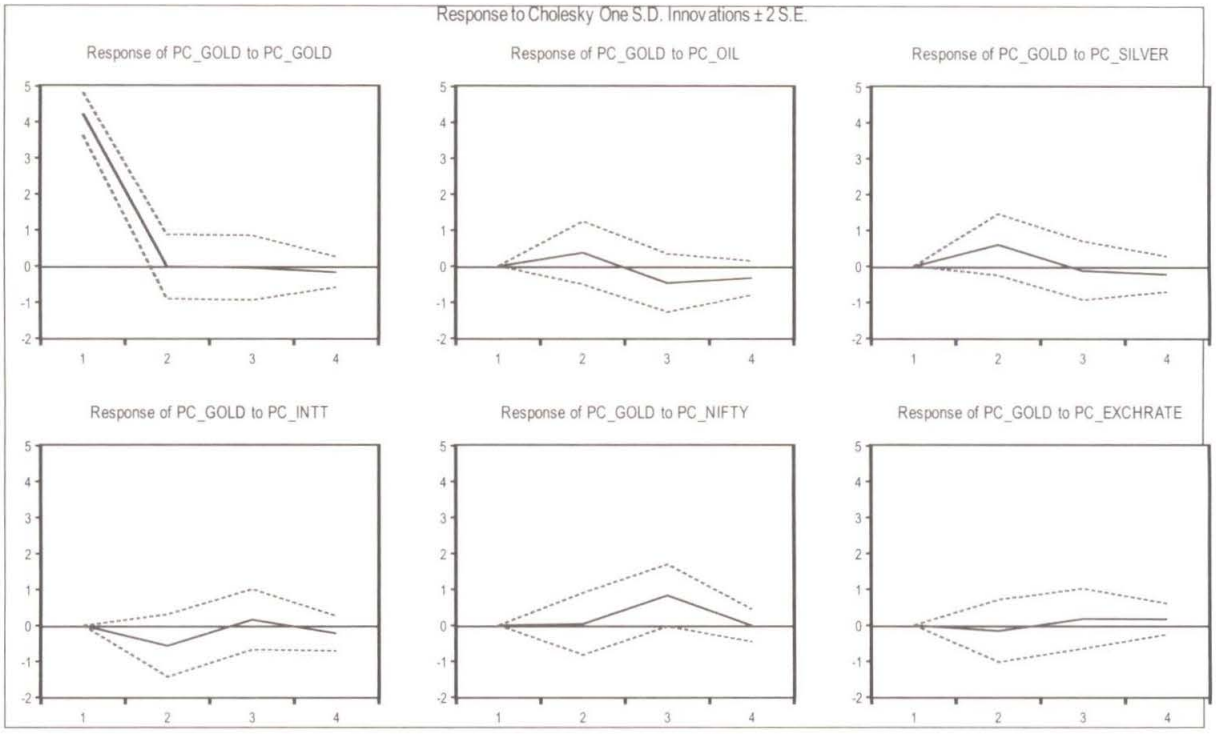
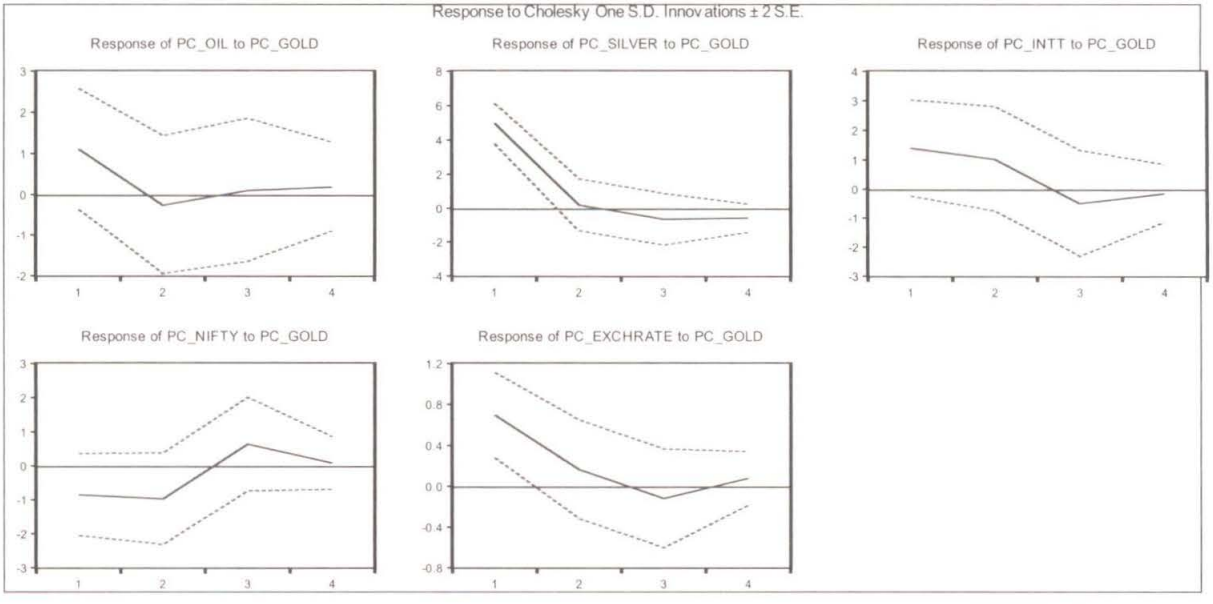


Figure 8b: Impulse Response Functions-Response of Oil, Silver, Interest, Nifty and Exchange Rate to GOLD



Analysis of the variance decomposition of NIFTY shows that apart from its own shock contribution of 75% in the 1st year period, oil price changes account for the largest share of shock to NIFTY, amounting to about 15% in the 1st year period and stagnating at around 16% thereafter. Further, innovations in NIFTY explain less than 2% variations in price of gold in the 1st period. Though increasing, this remains less than 5% by the end of 4th period.

Interestingly, innovations in silver explain more than 52% variations in price of gold in the 1st year and stabilize to around 43% in the next 3 periods under study. In fact, shocks in silver prices explain variations in gold prices more than it explains variations in own shock contribution. Further, innovations in silver prices explain between 11% and 14% variations in price of oil between the 1st and 4th period.

The variance decomposition of exchange rate is significantly explained by itself (56%), followed by price of oil (14.5%), NIFTY (11%), and price of gold (9.3%) in the 4th period. Price of silver and interest rate together contribute less than 10% to the variance decomposition.

For the oil price variance decomposition, apart from its own shock, which amounts to about 97.7% in the first period and 91% in the 4th period, no other source of shock is large. The next largest is close to 2.5% and this is for innovations in interest and NIFTY. The contribution of shocks in silver and exchange rate to oil price changes remain less than 1% until the 4th period.

The variance decomposition analysis of interest rates shows that apart from the contribution of its own shock, which accounts for the largest portion of the shocks throughout the 4 year period under consideration (from as high as 96.8% in the 1st period to a gradual decline to 84.3% in the 4th period), it is also observed that NIFTY (4.9%), followed by gold and silver (3.9% and 3.8% respectively) account for a significant part of the variance. Meanwhile, the other variable which also picks up a small part of the variance is oil (2.8%). Incidentally, the contribution of the exchange rate to the variance in interest rates in the model is rather small and remains negligible over the period of study at less than 0.15%.

Conclusion and Policy Recommendations

Gold as an asset has a hybrid nature: not only is it used as a commodity in many industries, but historically it has been a medium of exchange and acted as a store of value, which makes it akin to money. For its unique properties, demand for gold has remained high and recent years have witnessed a sharp surge in its price; both globally and domestically.

Focusing on the recent increase in gold prices, the basic objective of the paper has been to predict changes in the price of gold and to examine the dynamic relationship between commodity prices such as gold, silver and oil; and macroeconomic variables such as interest rate, exchange rate and performance of stock market. Adopting Vector Autoregressive Modeling, standard VAR summary statistics such as Granger causality tests, impulse response functions, and variance decompositions are analyzed to study co-movements between variables. Monthly data from April 2005 to December 2013 forms the sample period of our study. Primarily the following conclusions emerge:

- Stationarity tests estimate the series to be non-stationary at level, and stationary at first difference.
- Johansen's cointegration test suggests a weak long-term relationship between variables analyzed in the study.
- The gold price variance decomposition analysis reveals that the largest share of shock to price of gold is significantly explained by its own variance, which accounts for 100 % in the 1st year period and about 90% in the 4th period. Shocks in other variables explain a very small variance in the price of gold. Specifically, shocks in the stock market index account for about 3.5% of the variance. Prices of oil and silver explain a little over 2% of the variance in the price of gold. Meanwhile, the contributions of exchange rate shocks remain at less than half a per cent through the 4 period forecasting.

- Over time, there is an increasing trend of the contributions of all variables (other than price of gold) in explaining variance in the price of gold.
- Based on the impulse response functions we conclude the following:
  - A positive shock to oil price has a favourable effect on gold price initially, i.e. until the 2nd month. Thereafter, its response becomes adverse and remains so until the end of the 4th month. Similar trends are observed when innovations are given to silver price.
  - Initially, a positive shock to Nifty has no impact on the impulse response functions of gold, though by the middle of the second month the impact becomes highly pronounced in the upward direction. However, it dissipates equally fast and becomes zero by the end of the fourth period.
  - A positive shock to exchange rate initially has an adverse impact on gold price, though by the beginning of the 2nd month, gold prices begin to respond favourably to shocks in exchange rate.

Despite an increase in gold price, demand for gold in India has remained high. Gold demand in India has several drivers. Largely, demand is driven by cultural factors, tax evasion and the need to acquire a safe and liquid instrument. Further, rising inflation has made purchase of gold more of an investment decision, rather than a consumption decision. Despite price rise, it is arguable that there are some limits beyond which the consumption of gold is not likely to be substituted by other forms of consumption. Also, Indians tend to accumulate gold over a period of time, thereby giving them considerable scope to vary the rate of purchase as the prices fluctuate. In addition, rising incomes have resulted in enhanced purchases of gold. Specifically, it is estimated that for every 1 per cent increase in income, gold consumption increases by 1.5 per cent (implying high income elasticity). With a combination of price inelasticity and income elasticity, curbing gold imports through duty hikes remains questionable. In order to curtail the growing demand for gold, it is prudent to design innovative financial instruments that provide high real returns, such as products analogous to inflation indexed bonds. 'Purchase transactions' in gold-backed financial products to reduce demand for physical gold also need to be encouraged. Additionally, few supply related measures could also be adopted, such as, recycling of domestic gold, and introducing tax incentives on instruments which utilize idle gold.

End Notes

[1]Where required, missing data have been interpolated /extrapolated using linear regressions.

[2]http://rbidocs.rbi.org.in/rdocs/Publications/DOCs/171T_BST130913.xls

[3]It may be mentioned that most of oil requirements in India are met through imports.

[4]https://iocl.com/Products/CrudeOilPrices.aspx

[5]http://rbidocs.rbi.org.in/rdocs/Publications/DOCs/171T_BST130913.xls

[6]http://www.nseindia.com/content/debt/1month.zip

[7]http://www.nseindia.com/products/content/equities/indices/historical_index_data

[8]http://www.rbi.org.in/scripts/ReferenceRateArchive.aspx

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Annexures

Table A1: Descriptive Statistics

Descriptive Statistics						
In level	*GOLD*	*OIL*	*SILVER*	*INTT*	*NIFTY*	*EXCHRATE*
Mean	17327.71	83.90333	32487.86	7.6	4587.728	47.5623
Median	15232.2	78.02	25608.48	8.04	4966.507	45.963
Maximum	31672.83	132.47	65269.35	11.73	6246.869	63.75214
Minimum	6030.38	40.61	10639.81	3.71	1987.095	39.37478
Std. Dev.	8363.879	23.76445	16994.04	1.958454	1169.622	5.631074
Skewness	0.386836	0.051291	0.495024	-0.358348	-0.606578	1.018024
Kurtosis	1.703612	1.732861	1.691739	2.382821	2.195192	3.663148
Jarque-Bera	9.97145	7.070716	11.77637	3.913715	9.272653	20.0605
Probability	0.006835	0.029148	0.002772	0.141302	0.009693	0.000044
Observations	105	105	105	105	105	105
In % change	*PC_GOLD*	*PC_OIL*	*PC_SILVER*	*PC_INTT*	*PC_NIFTY*	*PC_ EXCHRATE*
Mean	1.520627	0.757902	1.368548	0.462378	1.101353	0.334035
Median	1.244253	2.05032	1.396473	0.951283	2.19708	0.10518
Maximum	13.42285	17.54011	28.67922	26.57772	18.14595	6.537395
Minimum	-10.76514	-33.69062	-19.32796	-22.60891	-27.03348	-4.350942
Std. Dev.	4.186503	8.263031	7.1388	8.570368	6.405383	2.22686
Skewness	0.065558	-1.499642	0.291207	-0.3192	-0.902066	0.54942
Kurtosis	3.670499	6.825917	4.739681	4.066037	6.31264	3.564013
Jarque-Bera	2.02263	102.4112	14.58468	6.690616	61.65673	6.61076
Probability	0.36374	0	0.000681	0.035249	0	0.036685
Observations	104	104	104	104	104	104

Table A2: Johansen's Co-integration Test

	Eigen value	Null Hypothesis	Trace Statistic	Critical value (5%)
With linear deterministic	0.319782	r=0	90.17960	95.75366
trend in data	0.224783	r≤1	50.87470	69.81889
	0.139936	r≤2	24.90426	47.85613
	0.058628	r≤3	9.527930	29.79707
	0.025733	r≤4	3.365382	15.49471
	0.006900	r≤5	0.706271	3.841466
No deterministic	0.306016	r=0	90.94598*	83.93712
trend in data	0.218706	r≤1	53.68468	60.06141
	0.130037	r≤2	28.51074	40.17493
	0.075793	r≤3	14.30169	24.27596
	0.040132	r≤4	6.262088	12.32090
	0.020226	r≤5	2.084189	4.129906

*Note: Trace test indicates no cointegration under linear deterministic trend, and 1 cointegrating equation under no deterministic trend; and * denotes rejection of the hypothesis at the 0.05 level.*

Figure A1: Impulse Response Functions

Response to Cholesky One S.D. Innovations ± 2 S.E.