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# Forecasting the price of gold: An error correction approach

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**Abstract** Gold prices in the Indian market may be influenced by a multitude of factors such as the value of gold in investment decisions, as an inflation hedge, and in consumption motives. We develop a model to explain and forecast gold prices in India, using a vector error correction model. We identify investment decision and inflation hedge as prime movers of the data. We also present out-of-sample forecasts of our model and the related properties.


## Introduction

India is one of the major gold consuming countries in the world and high demand from India is acknowledged to be a major factor in determining international gold prices. High import demand is also cited as the primary reason for the country's persistent current account deficit. To the best of our knowledge, there is little previous research about what determines gold prices in India. Understanding the determinants of gold price will help in developing a predictive model for forecasting future prices. This can be useful for the purpose of portfolio decision-making of investors and also as a critical input for policy making.

We submit that this paper is the first of its kind to develop a model for explaining and forecasting gold prices in India. We estimate the nature of the relationship of gold price in India with key determinants such as the stock market index, oil prices, exchange rate, interest rate, and consumer price index (CPI). We find that gold is useful as a portfolio hedge as well as a hedge against inflation. Our model is able to predict future gold prices with reasonable levels of accuracy.

## Research background

Among all precious metals, gold might be the most popular choice for investment. It has stood the test of time, and performed well during crisis situations such as market decline, currency failure, high inflation, war, and so on. It is regarded as a good hedge both against inflation as well as fall in value of other assets. The usefulness of gold as an inflation hedge would imply that when general prices are high, gold prices will also be high so that the asset can be sold in order to finance general spending activity. However the role of gold as a hedge against other assets (such as stocks, bonds, foreign currency) would mean that when the prices of other

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assets fall, the price of gold rises such that the resulting portfolio is diversified.

Many studies have looked into the pattern of gold prices (see e.g. Capie, Mills, & Wood, 2005; Worthington & Pahlavani, 2007; Baur & Lucey, 2010) to identify the factors that influence gold prices. Some of the factors that influence gold prices include inflation, exchange rate, bond prices, market performance, seasonality, income, oil prices, and business cycles. However, to the best of our knowledge, there is no work that has been done to examine gold prices in India.

We carry out an analysis to study the factors influencing gold prices in India by collecting monthly data on gold prices and other factors over a long time period. While the hedge factors are expected to work in India as in other countries, there is an additional role of gold that may not be relevant elsewhere and has been hitherto ignored in literature. Indians buy gold not just for investment but also for personal reasons, to be used as a luxury good (to wear as jewellery, to gift in weddings, for religious reasons and so on). If this reason to buy gold is significant, then higher affordability should lead to increased demand and therefore higher price for gold. We capture the wealth effect through the stock market index.

The time series variables that we study are, largely, nonstationary variables. Therefore, we need to analyse them in a cointegrating framework. We use a vector error correction approach to model and forecast the price of gold. Our benchmark estimates are for the period April 1990–August 2013.

We find that gold price has a cointegrating relationship with the stock market index, exchange rate, CPI, US bond rates, and oil price. The stock market index has a negative relationship with gold price, contradicting the argument for gold being a luxury good but supporting the role of gold as a portfolio hedge. This is consistent with Baur and McDermott (2010). The exchange rate has a negative relationship with gold price implying that a stronger rupee is associated with costlier gold. Our finding demonstrates that gold is a good hedge against the dollar from the point of view of domestic investors, which is also the case for developed countries (Reboredo, 2013a).

Oil price has a negative relationship with gold price implying that gold is a good hedge against oil as an investment, in contrast to existing evidence from developed countries (see for example, Reboredo, 2013b). The CPI has a positive relationship with gold indicating that gold is a good inflation hedge, a result that has been previously obtained for developed countries (Ghosh, Levin, Macmillan, & Wright, 2004; Worthington & Pahlavani, 2007). Finally, US bond rates are negatively related to gold price, indicating that when returns from international investments fall, investors may switch to gold.

We tested for robustness of the results of our exercise. We have taken some commonly used transformations of the variables, for example, the logarithmic one. We have added difference polynomials of independent variables. Our findings are quite robust to these alternative specifications. The relationship established by us provides interesting insights into the role of gold in portfolio diversification and as a hedge against inflation in the Indian context. The predictive capacity of our error correction model beats alternative specifications such as the random walk, using different sub-periods, and forecasting horizons.

## Data and methodology

### Data source

The gold price data are obtained from the Reserve Bank of India's website. It is taken in real terms by deflating it, using the CPI. The CPI data we use are for urban non-manual employees and later for industrial workers maintained by the Labour Bureau, Government of India.[1] We have taken the equity market index Sensex as a proxy for the stock market. Whenever Sensex suffers a decline, the loss stricken investors may move towards gold, which increases the demand for gold, which in turn increases the price of gold. On the other hand, if Sensex represents the wealth of the people, then a higher value of the Sensex may indicate that the purchasing power of people increases, so they may be able to afford more gold, whose price increases. Sensex data are obtained from the website of the Bombay Stock Exchange.[2]

When the exchange rate increases, it makes gold imports more expensive, leading to an increase in the domestic price of gold. The US Dollar–Indian Rupee (USD–INR) exchange rate is collected from Indexmundi website[3] and Bloomberg. However if gold were a good hedge against the exchange rate then we would expect gold prices to be negatively related with the exchange rate. This would mean that a fall in the dollar value would induce investors to move towards gold thereby leading to higher gold prices.

When oil prices increase, then the cost of production increases which reduces the profits of investors who then switch to gold for safety. Therefore, oil prices are expected to have a positive effect on gold prices. But people do not buy oil simply as a factor of production; many trade it as a commodity for capital gains. So an increase in oil prices would be beneficial for such investors and they would not invest in gold. Again, this means a negative relationship between gold prices and oil prices. (Oil prices are obtained from the Indexmundi website).

The Indian bond market is still in its nascent stage. A select group of authorised domestic financial institutions are the only players in the secondary market and liquidity is limited across maturities. Therefore, the effect of the bond rates was not analysed; another reason is the lack of data on the bond market, which was available only from 2004 after the setting up of the Clearing Corporation of India Ltd (CCIL). However we used interest rates on US bonds to control for international investment prospects and the data are obtained from the US treasury website. We use monthly data on the above variables between April 1990 and August 2013.

### Data transformations

We consider real price of gold (GLP) which is free from the influence of general price movements. We have normalised gold price by dividing the nominal value by the consumer price index. For example, if the gold price in a particular month is INR 4508.91 and CPI is 2093, then GLP is calculated as INR

[1] http://labourbureau.nic.in/indexes.htm
[2] http://www.bseindia.com
[3] http://www.indexmundi.com

4508.91/2093. The Bombay Stock Exchange Sensitive Index or Sensex (SNX) is taken in a logarithmic scale to represent stock prices. Other determinants of gold price that we consider are the USD–INR exchange rate in logarithmic scale (denoted by EXR). We consider CPI in a logarithmic scale as well as the oil price (OIL). Finally we consider US bond rates (INT) to capture returns from international investments.

## Pre-testing time-series properties of the data

We start by performing unit root tests for all our time series. There are several specifications of a unit root process: random walk, random walk with drift, random walk with linear trend and drift, and so on. The cookbook procedure for carrying out unit root test is schematically shown in Fig. 1. This procedure allows one not only to test for potential non-stationarity of the process but also to categorise the extent of the random walk process. An important practical issue for the implementation of the augmented Dickey–Fuller (ADF) test is the specification of the lag length p. If p is too small then the remaining serial correlation in the errors will bias the test. If p is too large then the power of the test will suffer.

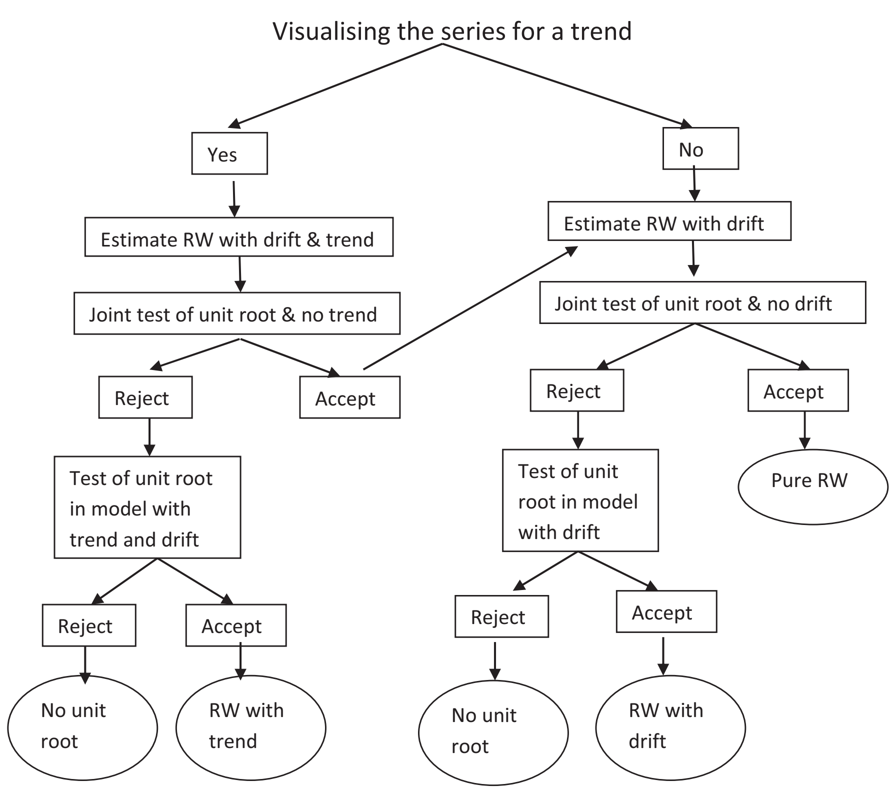
For an optimal selection of lag length, we follow the procedure suggested by Ng and Perron (1995). We set an upper bound for p and estimate the ADF test regression. If the absolute value of the t-statistic for testing the significance of the last lagged difference is not significant then we decrease p by one and repeat the same process; else we stop at that p. Schwert (1989) suggested the rule of thumb for determining the maximum lag length which is the highest integer contained in $12 \times (T/100)^{0.25}$.

Once we have found some variables as non-stationary, we can find the long run relationship between detection of cointegrating relationship. Johansen's method of vector error correction model (VECM) is appropriate in this connection.

## Econometric methodology

### Cointegration

A set of variables are cointegrated when there exists a stable long run relationship between them. While the original test of cointegration was provided by Engle and Granger (1987), due to the well-known deficiencies of this simple approach (Enders, 2004), we follow the approach subsequently provided by Johansen and Juselius (Johansen, 1988, 1991; Johansen & Juselius, 1990). Formally put, let $y_1, y_2, \ldots, y_k$ be a set of variables which we are interested in. Suppose each variable is integrated of order one, viz. I(1), there is a need for differencing in order to attain stationarity. If there exists linear combination(s) of the variables which is (are) I(0), then the variables are said to be cointegrated, i.e. they have a stable long run relationship. Then the cointegrating vector can be estimated which quantifies the relationship between the concerned variables.




RW: random walk

**Figure 1** Schematic diagram for a cookbook procedure on testing for unit root.

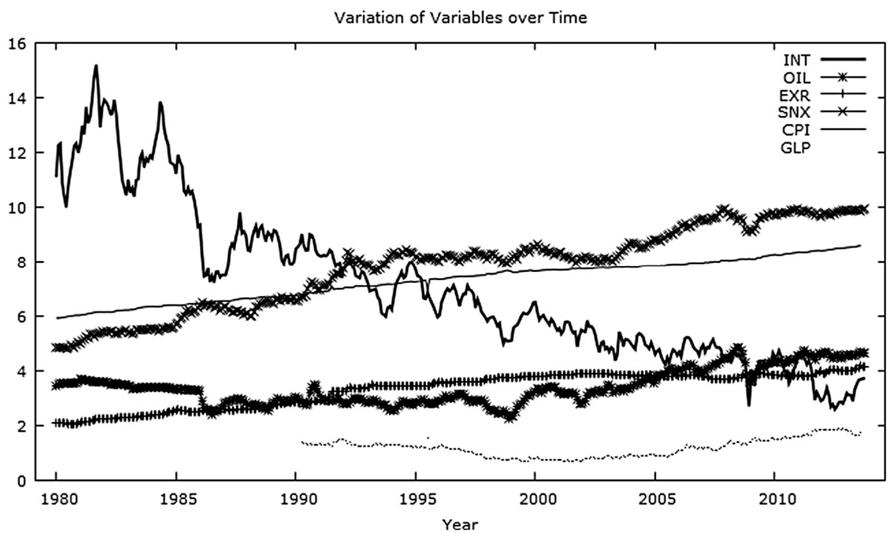



**Figure 2** Variables considered in our analysis are plotted against time. The various series from top to bottom in the legend are INT: US bond rates, OIL: oil price, EXR: USD–INR exchange rate in logarithmic scale, SNX: Sensex, CPI: Consumer price index, GLP: price of gold.

**Table 1** Unit root tests.

| | ADF test | | | | KPSS test | | | Overall |
|---|---|---|---|---|---|---|---|---|
| Variable | Lag | Trend | p-value | Verdict | Lag | Trend | Verdict | Conclusion |
| GLP | 1 | No | 0.693 | Accept | 17 | No | Reject at 1% | I(1) |
| ΔGLP | 0 | No | 0.000 | Reject | 17 | No | Accept at 1%; Reject at 5% | I(0) |
| SNX | 16 | No | 0.482 | Accept | 16 | No | Reject at 1% | I(1) |
| ΔSNX | 15 | No | 0.000 | Reject | 16 | No | Accept at 10% | I(0) |
| EXR | 7 | No | 0.843 | Accept | 7 | No | Reject at 1% | I(1) |
| ΔEXR | 1 | No | 0.000 | Reject | 1 | No | Accept at 10% | I(0) |
| INT | 15 | No | 0.739 | Accept | 15 | No | Reject at 1% | I(1) |
| ΔINT | 14 | No | 0.000 | Reject | 14 | No | Accept at 10% | I(0) |
| CPI | 15 | No | 0.861 | Accept | 15 | No | Reject at 1% | I(1) |
| ΔCPI | 14 | No | 0.000 | Reject | 14 | No | Accept at 10% | I(0) |
| OIL | 13 | No | 0.909 | Accept | 13 | No | Reject at 1% | I(1) |
| ΔOIL | 14 | No | 0.000 | Reject | 14 | No | Accept at 10% | I(0) |

ADF: augmented Dickey–Fuller; KPSS: Kwiatkowski–Phillips–Schmidt–Shin.
Variables: GLP: price of gold, SNX: Sensex, EXR: USD-INR exchange rate in logarithmic scale, INT: US bond rates, CPI: Consumer price index, OIL: oil price.

### Vector error correction model

The vector error correction model (VECM) involves expressing an nx1 vector of stationary time series (say $y_t$) in terms of a constant, lagged values of itself and an error correction term. The standard VECM (p) model can be represented as,

$$\Delta y_t = c + \varphi_1 \Delta y_{t-1} + \varphi_2 \Delta y_{t-2} + \ldots + \varphi_p \Delta y_{t-p} + ECT_t + \varepsilon_t \quad (1)$$

where ECT refers to the Error Correction Term that is a product of an adjustment factor ($\alpha$) and the cointegrating vector ($\beta$). The cointegrating vector shows the long term equilibrium relationship between the concerned variables while the adjustment factors show the speed of adjustment towards equilibrium in case there is any deviation.

## Findings

### Summary of data

Fig. 2 plots all the relevant variables over time. The results of unit root tests are summarised in Table 1. The unit root tests clearly indicate that the relevant variables are integrated of order 1, which is indicative of the most elementary degree of non-stationarity.

### Results from modelling gold price

The results from the test of cointegration are reported in Table 2. The trace test suggests that ranks of 0 and 1 are rejected at 5% level of significance. However rank of 2 cannot

**Table 2** Johansen test of cointegration.

| Rank | Eigenvalue | Trace test statistics | Trace test p-value | Lmax test statistics | Lmax test p-value |
|---|---|---|---|---|---|
| 0 | 0.2210 | 148.4900 | 0.0000 | 67.1940 | 0.0000 |
| 1 | 0.1203 | 81.2920 | 0.0039 | 34.4680 | 0.0385 |
| 2 | 0.0944 | 46.8250 | 0.0608 | 26.6700 | 0.0626 |
| 3 | 0.0514 | 20.1550 | 0.4233 | 14.1890 | 0.3635 |
| 4 | 0.0217 | 5.9661 | 0.7024 | 5.8893 | 0.6330 |
| 5 | 0.0003 | 0.0768 | 0.7817 | 0.0768 | 0.7817 |

**Table 3** Vector error correction model (VCEM).

| Variable | β (cointegrating vectors, standard errors in parentheses) | α (adjustment vectors) |
|---|---|---|
| GLP | 1.0000 (0.0000) | 0.0002 |
| SNX | 1.9362 (0.54604) | −0.0213 |
| OIL | 0.6073 (0.6844) | 0.0007 |
| EXR | 17.3000 (2.2887) | −0.0078 |
| INT | 1.4296 (0.4751) | 0.0187 |
| CPI | −6.8974 (1.9428) | −0.0054 |

VECM system, lag order 12.
Maximum likelihood estimates, observations 1991:04–2013:08 (T = 269).
Cointegration rank = 1.
Log-likelihood = 2652.2341.
Determinant of covariance matrix = $1.0995337*10^{-16}$.
AIC = −16.4627; BIC = −10.6096; HQC = −14.1121.
Mean dependent var: 0.0017; S.D. dependent var: 0.0490.
Sum squared resid: 0.3944; S.E. of regression: 0.0443.
R-squared: 0.3860; Adjusted R-squared: 0.1813.
Durbin-Watson: 2.0063.

**Table 4** Forecast evaluation statistics.

| | |
|---|---|
| Mean error | −0.0541 |
| Mean squared error | 0.0077 |
| Root mean squared error | 0.0878 |
| Mean absolute error | 0.0582 |
| Mean percentage error | −3.2585 |
| Mean absolute percentage error | 3.4775 |
| Theil's U | 2.0555 |
| Bias proportion, UM | 0.3800 |
| Regression proportion, UR | 0.0797 |
| Disturbance proportion, UD | 0.5402 |

be rejected at the 5% level. In other words we can conclude that the variables have one cointegrating relationship among them.

Once the presence of cointegration is established we move to estimation of the cointegrating vectors and the VECM. Table 3 shows the cointegrating vector along with the standard errors of the estimates in parentheses. The coefficients suggest a relationship of the following nature:

$$GLP = -1.9362 * SNX - 17.300 * EXR - 1.4296 * INT - 0.6073 * OIL + 6.8974 * CPI \tag{2}$$

The above equation indicates that gold prices and the stock market move in the opposite direction in the long run. Unlike what is expected of a luxury good, the wealth effect does not seem to dominate in the sense that higher wealth (captured by a rise in the Sensex) does not get reflected in increased demand and price of gold. However the role of gold as a hedge clearly dominates. As gold price moves in a different direction to that of the stock market it may be inferred that the role of gold as a portfolio hedge dominates its use as a luxury good in India.

This result may also imply that gold is a safe haven asset—an asset which investors can move into in times of high volatility. The difference between a hedge and a safe haven lies in the holding of the alternative asset under extreme market conditions. Under extreme market fluctuations investors tend to hold a safe haven asset whereas a hedge is a substitute for another asset when the latter is not performing as well.

Exchange rate is negatively related to gold prices in spite of the fact that the bulk of the gold consumed in India is imported. Therefore a weaker exchange rate should translate into higher cost of imported gold, which would also make domestic price higher. However our result seems to indicate that gold is a hedge against the dollar and could also be a safe haven. US bond rates have a positive relationship with gold which suggests that when returns from investing outside the country are high, demand for gold in India may fall, and therefore its price. Oil price has a positive relationship implying that gold may act as a good hedge against prices of commodities such as oil that are held by investors in their portfolio.

## Forecasting the price of gold

To test our model's out-of-sample properties, we re-estimate our model restricting our data to August 2012. We use our model to forecast one year of data (Fig. 3) and find that the average error is about 3.47% (see Table 4). The root mean squared error of 0.11 is much less than the equivalent measure for a random walk model which is 0.75.

## Robustness exercises

We carry out a series of exercises to assess the robustness of our results. For our model to be reliable, the estimated error terms should be normally distributed without any significant autocorrelation. This can be done using the Ljung–Box test that has good small sample properties as well. The null hypothesis of this test assumes the error terms to be

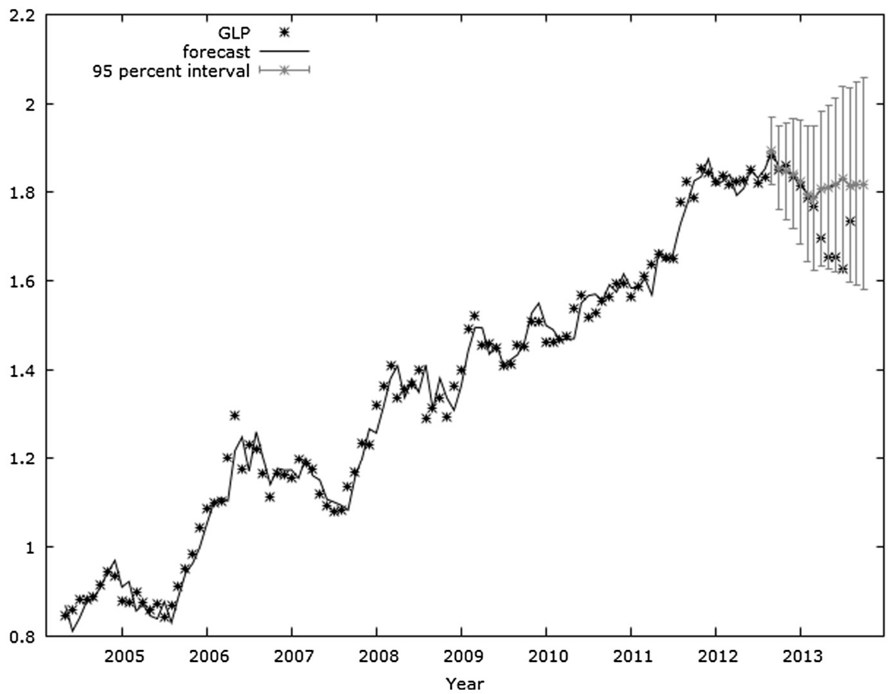
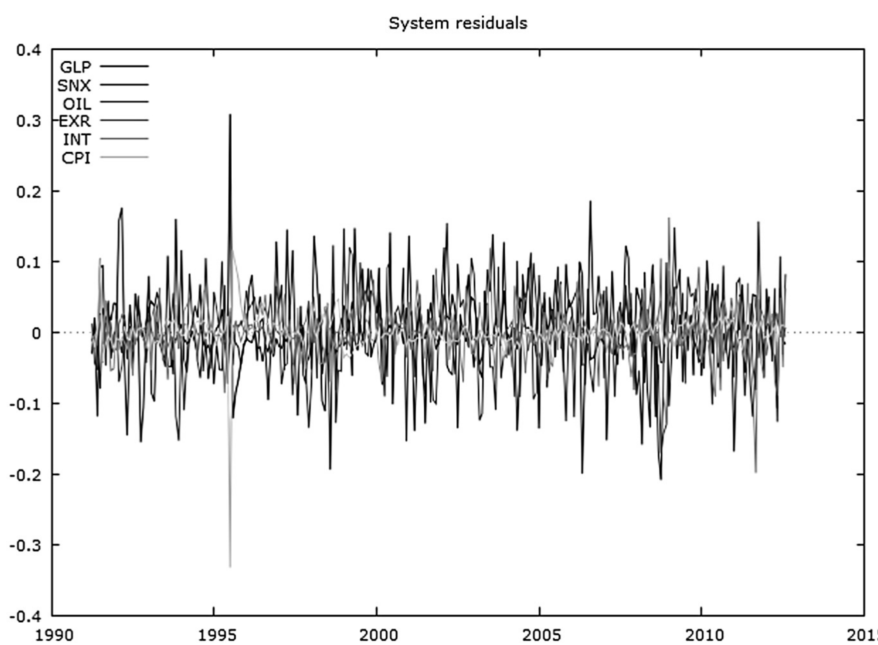



**Figure 3** Forecast values: The magnitude of error. GLP: price of gold.




INT: US bond rates, OIL: oil price, EXR: USD-INR exchange rate in logarithmic scale, SNX: Sensex, CPI: Consumer price index, GLP: price of gold.

**Figure 4** Forecast values: The magnitude of error.

normally distributed and independent. Hence an acceptance of the null would imply that our estimates are robust. We carry out the test for the estimated error term from all the equations of the VECM. For all the equations the p-values of the test statistics are actually very high (>0.90) which we interpret as non-existence of serial autocorrelation. The combined residual plots (Fig. 4) bear testimony to our analysis. Furthermore we tried out the above exercise with alternative lag orders from 9 to 15 (benchmark model presented is for lag order 12) but the results thus obtained are qualitatively not different from the benchmark model.

## Conclusion

We have modelled gold prices in India and shown it to have a long term relationship with the stock market index, exchange rate, US bond rates, oil prices and the consumer price index. We found evidence that the role of gold as a portfolio hedge dominates its use as a luxury good in India. Gold prices are negatively related with oil prices, further indicating the role of gold as a hedge. Gold prices go up when the rupee is weaker implying that gold is a good hedge against the dollar. When returns from investing outside the country are high, gold price in India is low. Finally, gold acts as a good inflation hedge as it moves in the same direction as CPI. We found evidence that the above variables are able to forecast gold over a 12-month horizon better than a random walk model.

One implication of our results is that since gold seems to be a useful portfolio hedge as well as inflation hedge, government policies to curb the import of gold may be futile. Yet the large amounts of gold imports are a cause for concern as they have kept India's current account deficit high leading to pressure on the rupee. Our research suggests that policies that directly address the causes of inflation and provide alternative investment opportunities for retail investors may better serve the objective of bringing down gold imports.

Future work in this area can proceed in several directions. In terms of methodology, alternative approaches such as copula, artificial neural networks, Fourier transformation and wavelet analysis can be employed to assess the scope for improvement in the forecasting power. Other research approaches such as behavioural finance models can be tested using micro data on investors' personal choices to study their influence on gold prices. Studies can compare the gold holding decisions of households and corporate houses to evaluate the consumption vis-à-vis investment motives behind gold purchase.

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