Economic Growth Centre
Working Paper Series

Oil and Gold Prices: Correlation or Causation?

by

Thai-Ha LE and Youngho CHANG

Economic Growth Centre
Division of Economics
School of Humanities and Social Sciences
Nanyang Technological University
14 Nanyang Drive
SINGAPORE 637332

Website: http://egc.hss.ntu.edu.sg

Working Paper No: 2011/02

OIL AND GOLD PRICES: CORRELATION OR CAUSATION?*

Thai-Ha Le, Youngho Chang**

Division of Economics, Nanyang Technological University

Singapore 639798, Singapore

June, 2011

Abstract

This paper uses the monthly data spanning from Jan-1986 to April-2011 to investigate the relationship between the prices of two strategic commodities: gold and oil. We examine this relationship through the inflation channel and their interaction with the index of the US dollar. We use different oil price proxies in our investigation and find that the impact of oil price on gold price is not asymmetric but non-linear. Our results show that there is a long-run relationship existing between the prices of oil and gold. Our findings imply that the oil price can be used to predict the gold price.

JEL Classification: E3.

Keywords: oil price, gold price, inflation, US dollar index, cointegration.

---

*The paper is to be presented at Vietnam Economist Annual Meeting (VEAM) 2011.
**Corresponding author. Phone: +65-822 69 879. Email: thai1@e.ntu.edu.sg.

INTRODUCTION

There is a common belief that the price of commodities tends to move in unison. It is because they are influenced by common macroeconomic factors such as interest rate, exchange rate and inflation (Hammoudeh et al, 2008). Oil and gold, among others, are the two strategic commodities which have received much attention recently, partly due to the surge in their prices and the increase in their economic uses. Crude oil is the world's most commonly traded commodity and its price is the most volatile in the commodity market. Gold is considered the leader in the market of precious metals as increases in its price seem to lead to parallel movements in the price of other precious metals (Sari et al, 2010). Gold is also an investment asset and commonly known as a "safe haven" to avoid the increasing risk in financial markets. Using gold is one of risk management tools in hedging and diversifying commodity portfolios. Investors in both advanced and emerging markets often switch between oil and gold or combine them to diversify their portfolios (Soytas et al, 2009).

The above feature descriptions of oil and gold justify the economic importance of investigating the relationship between the prices of these two commodities. Further, their special features make the prices of gold and oil not only influenced by ordinary forces of supply and demand, but also by other forces. Therefore, it is of practical significance to figure out how the oil price is related to the gold price and whether the oil price has forward influences on the gold price. Despite this fact, researches on oil price-gold price relationship are rather sparse. Therefore, it is worth our efforts to research on this area.

The goal of this paper is to examine the relationship between price returns of oil and gold. Particularly, we attempt to address following questions: Is there a causal and directional relationship between gold and oil prices? Is the relationship between their price returns weak or strong, symmetric or asymmetric, linear or nonlinear? Our paper is, to the best of our knowledge, among the very first studies concentrating on the oil price-gold price relationship. We specifically test this relationship through the inflation channel and the interaction with the US dollar index. Further, we employ several oil price proxies in our empirical examination, which have not been used before in studies on the topic, in order to explore the nonlinear and asymmetric effects of oil price changes on the gold price. Discussion of the topic is of crucial importance for investors, traders, policymakers and producers when they play catch up with each other and when they have feedback relationships with oil and exchange rate.

We discuss the oil price-gold price relationship and some of the key relevant literature in Section 1. Section 2 describes the data and methodology. Section 3 presents the empirical results. Conclusions are then set out in Section 4.

I. OIL PRICE-GOLD PRICE RELATIONS

The relationship between oil prices and gold prices is known to be positive and the two following arguments are proposed to explain this common thought.

First argument: the oil price influences the gold price

The first argument proposes a unidirectional causal relationship running from the oil price to the gold price. This implies that changes in the gold price may be monitored by observing movements in the oil price. First, high oil price is bad for the economy, which adversely affects the growth and hence pushes down share prices. Consequently, investors look for gold as one of alternative assets. We can observe such a scenario during end of the 1970s when the oil cartel reduced oil output, and hence resulted in a surge in oil price. This 1973 oil crisis shockwaves through the US and global economy and led to the long recession in the 1970s.

Second, the impact of oil prices on gold prices could be established through the export revenue channel (Melvin and Sultan, 1990). In order to disperse market risk and maintain commodity value, dominant oil exporting countries use high revenues from selling oil to invest in gold. Since several countries including oil producers keep gold as an asset of their international reserve portfolios, rising oil prices (and hence oil revenues) may have implications for the increase in gold price. This holds true as long as gold accounts for a significant part in the asset portfolio of oil exporters and oil exporters purchase gold in proportion to their rising oil revenues. Therefore, the expansion of oil revenues enhances the gold market investment and this causes price volatility of oil and gold to move in the same direction. In such a scenario, an oil price increase leads to a rise in demand (and hence the price) of gold.

Third, inflation channel seems to be the best and most common way to explain the linkage between oil and gold markets. Accordingly, a rise in crude oil prices leads to an increase in the general price level (e.g. Hunt, 2006; Hooker, 2002). When the general price level goes up, the price of gold, which is also a good, will increase. This gives rise to the role of gold as an instrument to hedge against inflation and gold is indeed renowned as an effective tool to hedge against inflation. Hence, inflation, which is strengthened by high oil prices, causes an increase in demand for gold and thus leads to a rise in the gold price (Pindyck and Rotemberg, 1990). On the other hand, when the gold price fluctuates due to changes in demand for jewelry, being hoarded as a reserve currency and/or being used as an investment asset, it is unlikely to have anything related to oil returns (Sari et al, 2010).

Several studies support for this argument. For instance, Sari et al (2010) explore directional relationships between spot price of four precious metals (gold, silver, platinum, and palladium), oil and USD/euro exchange rate and find a weak and asymmetric relationship between the price returns of oil and gold. Specifically, gold price returns do not explain much of oil price returns while oil price returns account for 1.7% of gold price returns. On examining the long-term causal and lead-and-lag relationship between oil and gold markets, Zhang et al (2010) report a significant cointegrating relationship between the prices of the two commodities. Results indicate that percentage changes of crude oil return significantly and linearly Granger cause the percentage change of gold price return. Further, at 10% level, there is no significant nonlinear Granger causality between the two markets, implying that their interactive mechanism is fairly direct.

Second argument: oil price and gold price are only correlated

This argument reminds us of a common saying in sciences and statistics that "correlation does not imply causation", which means that a similar pattern observed between movements of two variables does not necessarily imply that one causes the other. In this regard, the fact that the oil price and the gold price move in sympathy is not because one influences the other, but because they are correlated to the movement of the driving factors.

It is a common fact that both oil and gold are traded in US dollar. Therefore, volatility of the US dollar may cause fluctuations of international crude oil price and gold price to move in the same direction. For instance, the continuous depreciation of the US dollar might force the volatile boost of crude oil price and gold price. Specifically, it is argued that during expected inflation time, when the US dollar weakens against other major currencies, especially the euro, investors move from dollar-denominated soft assets to dollar-denominated physical assets (Sari et al, 2010). However, a deterioration of US dollar vis-à-vis the euro may also push up oil price as oil trade is denominated in US dollars. Zhang et al (2010) bring evidence of high correlations between the US dollar exchange rate and the prices of oil and gold and of Granger causality running from the US dollar index to the price changes of both commodities. Also, geopolitical events are another factor that may impact the prices of crude oil and gold simultaneously. In fact, both the commodity markets are very sensitive to the turmoil of international political situation. Particularly, in the worry of financial crises, investors often rush to buy gold. Consequently, the price of gold sees an ascending.

In line with the second argument, Soytas et al. (2009) show that the world oil price has no predictive power of the prices of precious metals including those of gold in Turkey. In reality, the situation can become even more complicated, as we can observe that the oil price and gold price relationship is not stable over time. For instance, during the 1970s, the price of oil might have had a much bigger influence on that of gold than it is now.

Several studies do not support any of the two abovementioned arguments. Specifically, some papers find two-way feedback relationships between oil prices and gold prices (e.g. Wang et al., 2010). Some indicate that the price of gold, among others, is the forcing variable of the oil price, implying that when the system is hit by a common stochastic shock, the gold price moves first and the oil price follows (Hammoudeh et al, 2008). This finding does not support the common belief that oil is the leader of the price procession.

Besides the sparse number of studies focusing on oil price-gold price relationships, to the best of our knowledge, we find four major shortcomings of existing research on this area. First, existing literature has not provided much insight into the directional relationships between oil and gold prices and how they are related to each other. Second, it is the lack of statistical evidence showing long run and stable relationship between the two typical large commodity markets, given their similar price trends. Third, there are little studies on whether the oil price-gold price relationship is lead or lag, linear or nonlinear, symmetric or asymmetric. Last but not least, no study is found on the interactive mechanism of the two markets. Our study thus aims to fill these gaps.

II. DATA AND METHODOLOGY

Data

The monthly sample spans from January-1986 to April-2011 inclusive of 304 observations for each series. The West Texas Intermediate (WTI) crude oil price is chosen as the representative of the world oil price. The original WTI crude oil spot price (quoted in US dollar) is acquired from the US's Energy Information Administration (EIA). The gold price selected for evaluation is the monthly average of the London afternoon (pm) fix obtained from the World Gold Council. The monthly data on consumer price index (CPI) of the US and US dollar index are obtained from CEIC database. The US dollar index is a measure of the value of the United States dollar relative to a basket of foreign currencies, including: Euro, Japanese yen, Pound sterling, Canadian dollar, Swedish krona and Swiss franc. A rise in the index means that the value of US dollar is strengthened compared to other currencies. All the data series are seasonally adjusted to eliminate the influence of seasonal fluctuations. Monthly inflation rate is computed as the growth rate of the US CPI (2005=100). All the variables are transformed into natural logarithms to stabilize the data variability.

Non-linear transformation of oil price variables

Several previous studies have shown that oil price fluctuations have asymmetric effects on macroeconomic variables and the gold price (e.g., Wang and Lee, 2011; Sari et al, 2010; Hooker, 2002). We present seven possible proxies to oil price shocks in order to model the asymmetries between the impact of oil price increases and decreases on the gold price and inflation, as follows.

Proxy 1 is the monthly growth rate of oil prices, defined as: $\Delta op_t = lnop_t - lnop_{t-1}$.

Proxy 2 considers only increases in oil prices (Δop_t^+) and is defined as:

$$\Delta op_t^+ = \max(0, \Delta op_t).$$

Proxy 3 considers only decreases in oil prices (Δop_t^-) and is defined as:

$$\Delta op_t^- = \min(0, \Delta op_t)$$

Proxy 4 is the net oil price measure ($netop_t$), constructed as the percentage increase in the previous year's monthly high price if that is positive and zero otherwise:

$$netop_t = \max[0, op_t - \max(lnop_{t-1}, lnop_{t-2}, lnop_{t-3}, \ldots, lnop_{t-12})]$$

This proxy is proposed by Hamilton (1996) who argues that as most of the increases in oil price since 1986 have immediately followed even larger decreases; they are corrections to the previous decline rather than increases from a stable environment. Therefore, he suggests that if one wants to correctly measure the effect of oil price increases, it seems more appropriate to compare the current price of oil with where it has been over the previous year, rather than during the previous month alone. Hamilton refers to this net oil price measure as the maximum value of the oil price observed during the preceding year.

Proxy 5 is the scaled oil price ($\Delta op_t / \sigma_t$) suggested by Lee et al (1995). This transformation of oil price changes has achieved popularity in the macroeconomics literature. In order to construct this proxy, we estimate a GARCH (1,1) model with the following conditional mean equation: $\Delta op_t = \phi_0 + \sum_{i=1}^{12} \phi_1 \Delta op_{t-i} + a_t$. In which $a_t = \sigma_t \varepsilon_t$ where $\varepsilon_t \sim NID(0,1)$

And the conditional variance equation: $\sigma_t^2 = \alpha_0 + \alpha_1 a_{t-1}^2 + \beta_1 \sigma_{t-1}^2$

Note here that since we are using the monthly data, we need to include 12 lags in the conditional mean equation in order to be consistent with the measure.

The volatility-adjusted oil price (or scaled oil price) is: $sop_t = \Delta op_t / \sigma_t$

Proxy 6 is the scaled oil price increases (sop_t^+), computed as: $sop_t^+ = \max(0, sop_t)$

Proxy 7 is the scaled oil price decreases (sop_t^-), constructed as: $sop_t^- = \min(0, sop_t)$

Table 1 summarizes descriptive statistics of all the series in level and in log. The coefficient of standard deviation (indicator of variance) indicates that the gold price series has the highest volatility among the others, followed by the oil price. In log, the oil price series has the highest volatility and followed by the gold price. Further, the statistics of skewness, kurtosis and Jarque-Bera of the gold price both in level and in log all reveal that the gold price series is non-normal.

[TABLE 1 HERE]

Table 2 reports correlations among the seven oil price proxies. It shows clearly that monthly percentage changes of oil price Δop_t is highly correlated with the other five oil price proxies (above 0.8), with the only exception of $netop_t$ where the correlation is just above 0.5. Interestingly, both Δop_t^+ and Δop_t^- are highly correlated with Δop_t (0.84 and 0.83, respectively) and both sop_t^+ and sop_t^- are highly correlated with sop_t (0.85 and 0.83, respectively). Hence, it seems to be an equal dispersion between percentage increases and decreases of oil prices. Figure 1 plots the graphs of different oil price proxies. From the graph, we can see that Δop_t^- is the difference between Δop_t and Δop_t^+. Also, sop_t^- is the difference between sop_t and sop_t^+.

[TABLE 2 AND FIGURE 1 HERE]

Methodology

First, we examine the unidirectional causality running from the oil price to the gold price through the inflation channel by performing Granger causality tests on the three proposed hypotheses:

- Hypothesis a: a rise in the oil price generates inflation.
- Hypothesis b: inflation leads to a rise in the gold price.
- Hypothesis c: if the two above hypotheses are correct, a rise in the oil price leads to a rise in the gold price.

The regression equations for Granger causality analysis are as follows.

Hypothesis a:

$$\pi_t = \alpha_0 + \sum_{i=1}^{k} \alpha_{1i} . \pi_{t-i} + \sum_{i=1}^{k} \alpha_{2i} . \Delta op_{t-i} + \varepsilon_t \qquad [E.q. 1.1]$$

$$\pi_t = \alpha_0 + \sum_{i=1}^{k} \alpha_{1i} . \pi_{t-i} + \sum_{i=1}^{k} \alpha_{2i} . \Delta op_{t-i}^{+} + \varepsilon_t \qquad [E.q. 1.2]$$

$$\pi_t = \alpha_0 + \sum_{i=1}^{k} \alpha_{1i} . \pi_{t-i} + \sum_{i=1}^{k} \alpha_{2i} . \Delta op_{t-i}^{-} + \varepsilon_t \qquad [E.q. 1.3]$$

$$\pi_t = \alpha_0 + \sum_{i=1}^{k} \alpha_{1i} . \pi_{t-i} + \sum_{i=1}^{k} \alpha_{2i} . netop_{t-i} + \varepsilon_t \qquad [E.q. 1.4]$$

$$\pi_t = \alpha_0 + \sum_{i=1}^{k} \alpha_{1i} . \pi_{t-i} + \sum_{i=1}^{k} \alpha_{2i} . sop_{t-i} + \varepsilon_t \qquad [E.q. 1.5]$$

$$\pi_t = \alpha_0 + \sum_{i=1}^{k} \alpha_{1i} . \pi_{t-i} + \sum_{i=1}^{k} \alpha_{2i} . sop_{t-i}^{+} + \varepsilon_t \qquad [E.q. 1.6]$$

$$\pi_t = \alpha_0 + \sum_{i=1}^{k} \alpha_{1i} . \pi_{t-i} + \sum_{i=1}^{k} \alpha_{2i} . sop_{t-i}^{-} + \varepsilon_t \qquad [E.q. 1.7]$$

Hypothesis b:

$$\Delta lggoldp_t = \beta_0 + \sum_{i=1}^{k} \beta_{1i} . \Delta lggoldp_{t-i} + \sum_{i=1}^{k} \beta_{2i} . \pi_{t-i} + \varepsilon_t \qquad [E.q. 2]$$

Hypothesis c:

$$\Delta lggoldp_t = \gamma_0 + \sum_{i=1}^{k} \gamma_{1i} . \Delta lggoldp_{t-i} + \sum_{i=1}^{k} \gamma_{2i} . \Delta op_{t-i} + \varepsilon_t \qquad [E.q. 3.1]$$

$$\Delta lggoldp_t = \gamma_0 + \sum_{i=1}^{k} \gamma_{1i} . \Delta lggoldp_{t-i} + \sum_{i=1}^{k} \gamma_{2i} . \Delta op_{t-i}^{+} + \varepsilon_t \qquad [E.q. 3.2]$$

$$\Delta lggoldp_t = \gamma_0 + \sum_{i=1}^{k} \gamma_{1i} . \Delta lggoldp_{t-i} + \sum_{i=1}^{k} \gamma_{2i} . \Delta op_{t-i}^{-} + \varepsilon_t \qquad [E.q. 3.3]$$

$$\Delta lggoldp_t = \gamma_0 + \sum_{i=1}^{k} \gamma_{1i} . \Delta lggoldp_{t-i} + \sum_{i=1}^{k} \gamma_{2i} . netop_{t-i} + \varepsilon_t \qquad [E.q. 3.4]$$

$$\Delta lggoldp_t = \gamma_0 + \sum_{i=1}^{k} \gamma_{1i} . \Delta lggoldp_{t-i} + \sum_{i=1}^{k} \gamma_{2i} . sop_{t-i} + \varepsilon_t \qquad [E.q. 3.5]$$

$$\Delta lggoldp_t = \gamma_0 + \sum_{i=1}^{k} \gamma_{1i} . \Delta lggoldp_{t-i} + \sum_{i=1}^{k} \gamma_{2i} . sop_{t-i}^{+} + \varepsilon_t \qquad [E.q. 3.6]$$

$$\Delta lggoldp_t = \gamma_0 + \sum_{i=1}^{k} \gamma_{1i} \, \Delta lggoldp_{t-i} + \sum_{i=1}^{k} \gamma_{2i} . sop_{t-i}^{-} + \varepsilon_t \qquad [E.q. 3.7]$$

In each equation, the optimal lag is determined so as to minimize both Akaike Information Criterion (AIC) and Schwarz Criterion (SC). For instance, in the following equation:

$$\pi_t = \alpha_0 + \sum_{i=1}^{k} \alpha_{1i} . \pi_{t-i} + \sum_{i=1}^{k} \alpha_{2i} . \Delta op_{t-i} + \varepsilon_t$$

We first regress π_t only on its lagged variables of various lag length without including Δop_t and select the optimal lag length m = m* where both AIC and SC are minimized. Next we fix the value of m at m* and keep on adding the lagged variables of Δop_t until we obtain the lag length n* where AIC and SC are minimized. The overall optimal lag length in the above equation will be (m*, n*). If the value of m based on AIC is different from that based on SC, then for each of two different lags, the lagged variables of Δop_t are added and the overall optimal lag length is determined where AIC and SC are minimized. That is, if $m_1 = argminAIC(m, n = 0)$ and $m_2 = argminSC(m, n = 0)$, then (m*, n*) will be the unique solution to the following two constrained optimization problems:

$$minAIC(m, n)\ s.t. m = m_1\ or\ m_2$$

$$minSC(m, n)\ s.t. m = m_1\ or\ m_2$$

If $n_1 = argminAIC(m*, n) \neq\ n_2 = argminSC(m*, n)$ then the Granger causality test is performed for both lags $(m*, n_1)$ and $(m*, n_2)$. The same procedure is applied to the rest of equations to obtain the optimal lag lengths for each of them.

In equations [1.1] to [1.7], the null hypothesis $H_0: \alpha_{21} = \alpha_{22} = \cdots = \alpha_{2k} = 0$ means that oil price changes do not Granger cause inflation. In equation [2], the null hypothesis $H_0: \beta_{21} = \beta_{22} = \cdots = \beta_{2k} = 0$ means that inflation does not Granger cause gold price changes. In equations [3.1] to [3.7], the null hypothesis $H_0: \gamma_{21} = \gamma_{22} = \cdots = \gamma_{2k} = 0$ means that oil price changes do not Granger cause gold price changes. The tests for these hypotheses are performed by a traditional F-test resulting from an OLS regression for each equation.

The second part of our empirical analysis investigates the US dollar index as an interactive mechanism in oil price-gold price relationship. For this purpose, we model the variables into an unrestricted trivariate VAR system. Depending on whether they are stationary in level or integrated of order one, respectively, the variables are entered in level or their first differences into the VAR system of order p which has the following form:

$$Z_t = \alpha + \sum_{i=1}^{p} A_i \,. Z_{t-i} + v_t$$

Where Z_t is the (3x1) vector of endogenous variables discussed above, α is the (3x1) intercept vector, A_i is the ith (3x3) matrix of autoregressive coefficients for i=1,2…p, and v_t is a (3x1) vector of reduced form white noise residuals. Based on the unrestricted VAR model, we estimate the generalized impulse response functions (IRFs) and the generalized forecast error variance decompositions (VDCs) of Koop et al. (1996) and Pesaran and Shin (1998). The IRF and VDC analysis enables us to understand the impacts and responses of the shocks within the system. Further, the generalized approach is preferred compared to the traditional orthogonalized approach. This is because the orthogonalized approach is sensitive to the order of the variables in a VAR system which determines the outcome of the results, whereas the generalized approach is invariant to the ordering of variables in the VAR and produce one unique result.

III. RESULTS AND INTERPRETATIONS

Testing for the significance of oil-gold relationship via the inflation channel

Stationarity tests

Granger causality test is relevant only when the variables involved are either stationary or nonstationary but cointegrated. For the purpose of examining the order of integration of the variables, we perform several unit root tests, namely ADF (Dickey and Fuller, 1981), PP (Phillips and Perron, 1988), KPSS (Kwiatkowski et al, 1992) – with constant and trend, and without trend – on levels and first differences of all the logged series: gold prices, US CPI, US dollar index, and the seven oil price proxies. Table 3a and b report the results. Considering the fact that the three unit root tests do not account for a structural break, the Zivot-Andrews (Zivot and Andrews, 1992) test is employed with results reported in Table 4a and b. All the tests have a common suggestion that, at conventional levels, all the logged series are non-stationary while their first differences and the oil price proxies are stationary.

[TABLE 3A,B AND 4A,B HERE]

Cointegration tests

Since all the series are nonstationary in level and integrated of the same order, I(1), this suggests a possibility of the presence of cointegrating relationship among variables. In order to explore such a possibility, Johansen cointegration tests (Johansen, 1988 and Johansen and Juselius, 1990) are performed to test for the existence of cointegrating relationships between each pair: the oil price and inflation, inflation and the gold price, and the gold price and the oil price. As pre-test of the testing procedure, logged variables are entered as levels into VAR models with different lag lengths and F-tests are used to select the optimal number of lag lengths needed in the cointegration analysis. Three criterions, the AIC, SC and the likelihood ratio (LR) test are applied to determine the optimal lag length. Since the tests are very common and standardized, we will not report the results of this procedure here in order to conserve space. Table 5 presents the results of Johansen multivariate cointegration tests, which overall show that each pairs of variables under our examination are co-integrated at 5% significance level. This implies that there exist long-run relationships between the oil price and inflation, between the gold price and inflation, and between the prices of oil and gold.

[TABLE 5 HERE]

Granger causality analysis

Since the variables are stationary in first differences and co-integrated of order 1, next we perform the Granger causality analysis. The optimal lag lengths selected for each regression equation based on the procedure described in the previous section are reported in Table 6.

[TABLE 6 HERE]

F-test in Table 7 reports the null hypothesis that all determined lags of oil price measures can be excluded. All the F-statistics are significant with the use of different oil price proxies, suggesting that no non-linear relationship existing between the oil price and inflation. The signs of impact are identical and the same as expected for all the seven oil price proxies. F-test in Table 8 reports the null hypothesis that all determined lags of inflation can be excluded. The results indicate that, at 5% level, we cannot reject the null hypothesis with lag 1 month of inflation variable but we can reject it with lag 2 months of inflation. Further, the impact of inflation on the gold price has the same sign as expected, indicating that a rise in inflation will increase the gold price immediately. F-test in Table 9 reports the null hypothesis that all determined lags of oil price measures can be excluded. The results show that non-linear relationships might exist between the price changes of oil and gold. Specifically, when monthly changes in the oil price and positive oil price changes are used as proxies of oil price changes, the evidence of causality is much clearer. With the use of the volatility-adjusted oil price and negative oil price changes, the evidence is relatively weaker. The signs of impact are identical for all cases and the same as expected in our hypothesis.

[TABLE 7, 8, 9 HERE]

Testing for asymmetries

According to Lee et al. (1995), Hamilton (1996, 2000), oil prices may have asymmetric effects on macroeconomic variables such as inflation and possibly on the gold price. For the purpose of testing the asymmetries, oil price increases and decreases are entered as separated variables in bivariate estimation equations for the gold price changes as follows:

$$\Delta lggoldp_t = \varphi_0 + \sum_{i=1}^{k} \varphi_{1i} . \Delta lggoldp_{t-i} + \sum_{i=1}^{k} \varphi_{2i} . \Delta op_{t-i}^{+} + \sum_{i=1}^{k} \varphi_{3i} . \Delta op_{t-i}^{-} + \varepsilon_t \qquad [E.q. 4.1]$$

$$\Delta lggoldp_t = \varphi_0 + \sum_{i=1}^{k} \varphi_{1i} . \Delta lggoldp_{t-i} + \sum_{i=1}^{k} \varphi_{2i} . sop_{t-i}^{+} + \sum_{i=1}^{k} \varphi_{3i} . sop_{t-i}^{-} + \varepsilon_t \qquad [E.q. 4.2]$$

We construct a Wald coefficient test to examine whether the coefficients of positive and negative oil price shocks in the VAR are significant different. The null hypothesis is $H_0: \sum_{i=1}^{k} \varphi_{2i} = \sum_{i=1}^{k} \varphi_{3i}$. F-statistic for Equation 4.1 is F(1,298) = 1.726 (p-value = 0.1899) and F-statistic for Equation 4.2 is F(1,286) = 0.045 (p-value = 0.8320). The results indicate that oil price changes have no asymmetric effects on the growth rate of gold prices.

Trivariate relationship

A trivariate model is estimated to test whether the impact of the oil price on the gold price is only through the inflation channel or through additional mechanisms. For this purpose, the generalized impulse response function is estimated based on the following model:

$$\Delta lggoldp_t = \mu_0 + \sum_{i=1}^{k} \mu_{1i} . \Delta lggoldp_{t-i} + \sum_{i=1}^{k} \mu_{2i} . \pi_{t-i} + \sum_{i=1}^{k} \mu_{3i} . \Delta op_{t-i}^{+} + \varepsilon_t \quad [E.q. 4.3]$$

We use the proxy Δop_t^{+} for oil price shocks since its impact on gold price changes is highest among those of the other oil price proxies. The results in Figure 2 shows that a one standard deviation shock of Δop_t^{+} has a significant and positive impact on growth rate of gold price even when inflation is included in the regression equation. This implies that the relationship between oil prices and gold prices cannot be solely explained by the effect of oil price changes on inflation. Thus in the next section we will include the US dollar index as an interactive mechanism for examining the oil price-gold price relationship.

The generalized VAR approach to model relationships between the prices of oil and gold and the US dollar index

As we conclude from the previous section that inflation is not the only mechanism that explains the linkage between the price of oil and gold. Therefore, in this section, we will allow for the interaction of the two variables (the oil price and the gold price) with another factor which is the value index of the US dollar. From Table 3a, b and 4a, b we know that all the three variables: gold prices, oil prices and US dollar indices are nonstationary in levels (natural log forms) and stationary in first differences. Therefore, all variables are entered in first differences into the VAR system of order p as described above.

Table 10 reports the results of Johansen cointegration tests. Given the first test assumption of only intercepts in cointegrating equations, both the maximum eigenvalues and Trace statistics show two cointegrating vectors among the three variables. This result indicates that there is a long-run relationship existing among the prices of oil and gold and US dollar value and this relationship is driven by two forces. However the results are robust to test assumptions. For example, when allowing for a linear trend in cointegrating equations, we have different results. Specifically, the Trace test suggests one cointegrating relationship while the maximum eigenvalue indicates no cointegrating relationship among the variables. Since scholars generally prefer the maximum eigenvalue test over the Trace test, we may conclude that, given this test assumption, no cointegrating relationship exists among the variables.

[TABLE 10 HERE]

We use the first differences of the logged oil price, logged gold price and logged US dollar index data series in the unrestricted VAR to estimate the generalized IRFs and the generalized forecast error VDCs. The IRF illustrates the impact of a unit shock to the error of each equation of the VAR. The results in Table 11 suggest that gold price is immediately responsive to innovations in oil price. The response is persistently positive and dies out quickly in 2-3 months after the oil price shock. As for fluctuations in the US dollar index, the gold price also reacts instantaneously and persistently negative. The response also dies out after 2-3 months of the shock. Thus, the sign of the gold price's responses to innovation in the oil price and the US dollar index are the same as expected in theory.

[TABLE 11 AND FIGURE 3 HERE]

The forecast error VDC analysis provides a tool of analysis to determine the relative importance of oil price shocks in explaining the volatility of the gold price. Due to its dynamic nature, VDC accounts for the share of variations in the endogenous variables resulting from the endogenous variables and the transmission to all other variables in the system (Brooks, 2008). The results reported in Table 12 indicate that most of variations in each of the three series are due to its own innovation. The oil price is shown to have significant contribution to explaining variations in the gold price. Specifically, the oil price percentage change accounts for about 4.04% of the variation in the gold price. Compared to that of the oil price, the US dollar index appears to have more significantly role in explaining volatilities in the gold price when accounting for 15.84% of the variation in the gold price. Further, for both the oil price and the US dollar index, the contributions to variations in gold prices are increasing overtime and become stable after 3-4 months of the innovations.

[TABLE 12 HERE]

As a final step, the VAR for generalized IRFs and VDCs is checked for stability. The results indicate that the VAR system is stable in that all inverse roots of AR characteristic polynomial are within the unit circle.

IV. CONCLUSION

This paper investigates the relationship between the oil price and the gold price by studying the indirect impact of the oil price on the gold price through the inflation channel and their interactions with the US dollar index. Besides adding to the sparse literature on oil price-gold price relationships, the contribution of this study is the use of different oil price proxies in order to consider the asymmetric and non-linear effect of oil price changes on inflation and the gold price. Our principal findings are as follows.

First, we find co-integrating (long-run) relationships between the oil price and inflation, inflation and the gold price, and the price of oil and gold. This finding suggests that pairwise relationships among the variables are not only limited to the short-run. The results from Granger causality analysis support our proposed hypothesis on oil price-gold price relationship through inflation channel. It means that, in the long-run, rising oil price generates higher inflation which strengthens the demand for gold and hence pushes up the gold price. Moreover, the short optimal lag lengths in the regression equations (i.e. 1-2 months) imply that the relationships between each pair of the three variables are insignificantly lead-and-lag. Second, when different oil price proxies are used, we show that the impacts of the oil price fluctuations on inflation and on the gold price are symmetric and non-linear. Specifically, the significance of the proxy measuring percentage increase in oil prices indicates that oil price increases appear to have greater impact on the gold price when they follow a period of lower price increases. However, we do not find enough evidence to assume that the oil price has asymmetric effect on the gold price.

Third, we study the trivariate relationship among the oil price, the gold price and the US dollar index. The results show that there is a long-run relationship among the prices of oil and gold and the US dollar index. The conclusions are, however, robust to other specifications of the cointegration tests. In generalized IRF analysis, we find positive and negative responses of the gold price to the oil price and the US dollar index, respectively, which are the same as expected in theory. We also observe that the responses of the gold price to innovations in the oil price and the US dollar index are instantaneous and dying out quickly. This confirms the fact that the oil price-gold price relationship does not lag long. In reality, as information on the oil price and the US dollar index has been readily available, other relevant markets including the gold market appear to respond quickly to movements in the two variables. The generalized forecast error VDCs indicate that variation in the gold price is better explained by fluctuations of the US dollar index, compared to that of the oil price.

Our findings have several implications. First, the role of gold as a hedge against inflation is strengthened. Second, the implication for those investors who include US dollar denominated assets in their portfolios is that oil and gold could be close substitutes as safe havens from fluctuations in the US dollar's value. Third, the oil price does nonlinearly cause the gold price and can be used to predict the gold price. This would significantly help monetary authorities and policy makers in monitoring the price of major commodities in markets. Since the number of studies on oil price-gold price relationships is very limited, it gives rise to many opportunities for further studies on the area. For instance, future work can focus on the dynamic and time-varying interaction between the oil price and the gold price. Further researches can also be conducted on evaluating the volatility, risk and spillover effects between the two markets and/or other markets such as those of other precious metals.

REFERENCE

BAUR, D.G. and MCDERMOTT, T.K. (2010). Is gold a safe haven? International evidence. *Journal of Banking and Finance*, Elsevier, 34, 1886-1898.

BROOK, C. (2008). *Introductory Econometrics for Finance*. Cambridge University Press.

CUNADO, J. and GRACIA F.P. (2003). Do oil price shocks matter? Evidence for some European countries. *Energy Economics*, Elsevier, 25 (2), 137-154.

DICKEY, D.A. and FULLER, W.A. (1981). Likelihood ratio statistics for autoregressive time series with a unit root. *Econometrica*, 49 (4), 1057–1072.

HAMILTON, J.D. (1996). This is what happened to the oil price-macroeconomy relationship. *Journal of Monetary Economics*, Elsevier, 38 (2), 215-220.

HAMILTON, J.D. (2000). What is an oil shock? *Journal of Econometrics*, Elsevier, 113 (2), 363-398.

HAMMOUDEH, S., SARI R. and EWING B.T. (2008). Relationships among strategic commodities and with financial variables: A new look. *Contemporary Economic Policy*, 27 (2), 251-264.

HOOKER, M.A. (2002). Are oil shocks inflationary? Asymmetric and nonlinear specifications versus changes in regime. *Journal of Money, Credit and Banking*, 34, 540-561.

HUNT, B. (2006). Oil price shocks and the U.S. stagflation of the 1970s: Some insights from GEM. *Energy Journal*, 27, 61-80.

KOOP, G., PESARAN, M.H. and POTTER, S.M. (1996). Impulse response analysis in non-linear multivariate models. *Journal of Econometrics*, 74 (1), 119–147.

KWIATKOWSKI, D., PHILLIPS P.C.B., SCHMIDT P., and SHIN, Y. (1992). Testing the Null Hypothesis of Stationarity against the Alternative of a Unit Root. *Journal of Econometrics*, 54, 159–178.

LEE, K., NI, S. and RATTI, R. (1995). Oil Shocks and the Macroeconomy: the Role of Price Variability. *Energy Journal*, 16, 39-56.

MELVIN, M. and SULTAN, J. (1990). South African political unrest, oil prices, and the time varying risk premium in the fold futures market. *Journal of Futures Markets*, 10, 103-111.

PESARAN, M.H. and SHIN, Y. (1998). Generalized Impulse Response Analysis in Linear Multivariate Models. *Economics Letters*, 58, 17-29.

PHILLIPS, P.C.B. and PERRON, P. (1988). Testing for a unit root in time series regression. *Biometrika*, 75 (2), 335–346.

PINDYCK, R. and ROTEMBERG, J. (1990). The excess co-movement of commodity prices. *Economic Journal*, 100, 1173-1189.

SARI, R., HAMMOUDEH, S., and SOYTAS, U. (2010). Dynamics of oil price, precious metal prices, and exchange rate. *Energy Economics*, 32, 351-362.

SOYTAS, U., SARI R., HAMMOUDEH, S., and HACIHASANOGLU E. (2009). World Oil Prices, Precious Metal Prices and Macroeconomy in Turkey. *Energy Policy*, 37, 5557-5566.

WANG, K.M. and LEE, Y.M. (2011). The yen for gold. *Resources Policy*, 36 (1), 39-48.

WANG, M.L., WANG, C.P. and HUANG, T.Y. (2010). Relationships among oil price, gold price, exchange rate and international stock markets. *International Research Journal of Finance and Economics*, 47, 82-91.

ZHANG, Y.J. and WEI, Y.M. (2010). The crude oil market and the gold market: Evidence for cointegration, causality and price discovery. *Resources Policy*, 35, 168-177.

ZIVOT, E. and ANDREWS, D. (1992). Further evidence of great crash, the oil price shock and unit root hypothesis. *Journal of Business and Economic Statistics*, 10, 251-270.

Table 1: Descriptive statistics

	Gold price	Oil price	US CPI	USD index
Level				
Mean	475.8516	35.20132	84.75586	92.89587
Std. dev.	256.2063	25.43289	16.90498	10.79047
Skewness	2.033076	1.550841	0.032031	0.628330
Kurtosis	6.417506	4.521876	1.926191	3.022601
Jarque-Bera	357.3639	151.1961	14.65748	20.00958
Probability	0.000000	0.000000	0.000656	0.000045
Observations	304	304	304	304
Log				
Mean	6.065196	3.360899	4.419231	4.524958
Std. dev.	0.410795	0.596610	0.205182	0.113658
Skewness	1.331069	0.806669	-0.259014	0.350805
Kurtosis	3.936264	2.447558	2.038137	2.766382
Jarque-Bera	100.8718	36.83532	15.11809	6.926563
Probability	0.000000	0.000000	0.000521	0.031327
Observations	304	304	304	304

Table 2: Correlation of monthly oil prices Δop_t with alternative oil price proxies

	Δop_t	Δop_t^+	Δop_t^-	$netop_t$	sop_t	sop_t^+	sop_t^-
Δop_t	1.000000						
Δop_t^+	0.842014	1.000000					
Δop_t^-	0.825356	0.390378	1.000000				
$netop_t$	0.544202	0.655285	0.242912	1.000000			
sop_t	0.980087	0.830057	0.803886	0.536376	1.000000		
sop_t^+	0.832834	0.976077	0.399749	0.639998	0.850282	1.000000	
sop_t^-	0.816035	0.406115	0.967623	0.252283	0.832028	0.415798	1.000000

Table 3a: Results of Unit root tests without a structural break (in log level)

	ADF	PP	KPSS
Intercept			
Oil price	-0.894536	-0.206335	1.691717
Gold price	2.327841	2.409120	0.964025
CPI	-2.567288	-2.011489	2.092665
US dollar index	-2.240482	-2.425294	0.494023
Intercept and trend			
Oil price	-2.596944	-2.749776	0.397149
Gold price	0.789024	0.886082	0.463509
CPI	-2.147472	-1.586051	0.359187
US dollar index	-2.367781	-2.471507	0.252689

Without trend, critical values for ADF, PP and KPSS tests are respectively: at 1% = -3.45, -3.45, and 0.74; at 5% = -2.87, -2.87, and 0.46; at 10% = -2.57, -2.5, and 0.35. With trend, critical values for ADF, PP, and KPSS tests are respectively: at 1% = -3.99, -3.99, and 0.22; at 5% = -3.42, -3.43, and 0.15; at 10% = -3.14, -3.14, and 0.12.

Table 3b: Results of Unit root tests without a structural break

	ADF	PP	KPSS
Intercept			
Δop_t	-14.01946	-13.90614	0.154060
Δop_t^+	-14.30261	-14.30520	0.246141
Δop_t^-	-13.66706	-13.64151	0.065943
$netop_t$	-11.42817	-11.50797	0.177725
sop_t	-13.87254	-13.81695	0.162335
sop_t^+	-14.49507	-14.49507	0.392448
sop_t^-	-14.57387	-14.53521	0.027254
$\Delta goldp_t$	-15.80148	-15.80832	1.079552
π_t	-10.92531	-10.51219	0.395637
$\Delta USDI_t$	-13.25183	-13.18147	0.131982
Intercept and trend			
Δop_t	-14.00981	-13.89219	0.023728
Δop_t^+	-14.35683	-14.35048	0.062959
Δop_t^-	-13.63016	-13.60234	0.053400
$netop_t$	-11.47095	-11.53910	0.041338
sop_t	-13.92271	-13.81315	0.024548
sop_t^+	-14.63809	-14.67736	0.037260
sop_t^-	-14.55242	-14.51191	0.022283
$\Delta goldp_t$	-16.22625	-16.18656	0.207229
π_t	-11.24674	-10.53118	0.070765
$\Delta USDI_t$	-13.22840	-13.15770	0.130336

Without trend, critical values for ADF, PP and KPSS tests are respectively: at 1% = -3.45, -3.45, and 0.74; at 5% = -2.87, -2.87, and 0.46; at 10% = -2.57, -2.5, and 0.35. With trend, critical values for ADF, PP, and KPSS tests are respectively: at 1% = -3.99, -3.99, and 0.22; at 5% = -3.42, -3.43, and 0.15; at 10% = -3.14, -3.14, and 0.12.

Table 4a: Results of Zivot-Andrews unit root test (in log level)

	[k]	t-statistics	Break point
Oil price	1	-4.675187	1997M02
Gold price	2	-4.215443	2000M03
CPI	3	-4.257470	1990M01
US dollar index	2	-3.978297	1999M02

The critical values for Zivot and Andrews test are -5.57,-5.30, -5.08 and -4.82 at 1%, 2.5%, 5% and10% levels of significance respectively.

Table 4b: Results of Zivot-Andrews unit root test

	[k]	t-statistics	Break point
$\Delta \boldsymbol{op_t}$	4	-8.380363	1999M01
$\Delta \boldsymbol{op_t^+}$	0	-14.73982	1990M10
$\Delta \boldsymbol{op_t^-}$	4	-7.804398	1991M07
$\boldsymbol{netop_t}$	0	-11.79658	1990M11
$\boldsymbol{sop_t}$	0	-14.08059	1999M01
$\boldsymbol{sop_t^+}$	0	-15.07534	1990M10
$\boldsymbol{sop_t^-}$	1	-10.04956	1991M03
$\Delta \boldsymbol{goldp_t}$	1	-14.00649	2001M05
$\boldsymbol{\pi_t}$	2	-9.206813	1990M11
$\Delta \boldsymbol{USDI_t}$	1	-12.14658	2002M02

The critical values for Zivot and Andrews test are -5.57,-5.30, -5.08 and -4.82 at 1%, 2.5%, 5% and10% levels of significance respectively.

Table 5: Johansen-Juselius multivariate cointegration test results

Test assumption: the level data have linear deterministic trends but the cointegrating equations have only intercepts					
r	n-r	λ_{max}	95%	Tr	95%
Oil price and inflation (Lag = 6)					
$\boldsymbol{r = 0}$*	$r = 1$	31.67878	14.26460	31.82087	15.49471
$\boldsymbol{r \leq 1}$	$r = 2$	0.142084	3.841466	0.142084	3.841466
Gold price and inflation (Lag = 1)					
$\boldsymbol{r = 0}$*	$r = 1$	102.1102	14.26460	107.3183	15.49471
$\boldsymbol{r \leq 1}$*	$r = 2$	5.208106	3.841466	5.208106	3.841466
Gold price and oil price (Lag = 3)					
$\boldsymbol{r = 0} *$	$r = 1$	16.51619	14.26460	17.54749	15.49471
$\boldsymbol{r \leq 1}$	$r = 2$	1.031299	3.841466	1.031299	3.841466

Note: r = number of cointegrating vectors, n-r = number of common trends, λ_{max} = maximum eigenvalue statistic, Tr = trace statistic. * denote rejection of the hypothesis at the 0.05 level.

Table 6: Optimal lags for Granger causality testing regression equations

Equation	Optimal lags	
	m*	n*
$\boldsymbol{E.q.1.1}$	3	1
$\boldsymbol{E.q.1.2}$	3	1
$\boldsymbol{E.q.1.3}$	3	1 and 2
$\boldsymbol{E.q.1.4}$	3	1
$\boldsymbol{E.q.1.5}$	3	1
$\boldsymbol{E.q.1.6}$	3	1
$\boldsymbol{E.q.1.7}$	3	1
$\boldsymbol{E.q.2}$	1	1 and 2
$\boldsymbol{E.q.3.1}$	1	1 and 2
$\boldsymbol{E.q.3.2}$	1	1
$\boldsymbol{E.q.3.3}$	1	1 and 2
$\boldsymbol{E.q.3.4}$	1	1
$\boldsymbol{E.q.3.5}$	1	1
$\boldsymbol{E.q.3.6}$	1	1
$\boldsymbol{E.q.3.7}$	1	1

Table 7: Test of causality of inflation with different oil price proxies

	$\Delta \boldsymbol{op_t}$	$\Delta \boldsymbol{op_t^+}$	$\Delta \boldsymbol{op_t^-}$	$\boldsymbol{netop_t}$	$\boldsymbol{sop_t}$	$\boldsymbol{sop_t^+}$	$\boldsymbol{sop_t^-}$
$\boldsymbol{\alpha_{20}}$	0.014652	0.015522	0.024443	0.029380	0.001002	0.001178	0.001684
[t-value]	[9.14125]	[5.36754]	[9.34625]	[6.90467]	[7.89682]	[5.37814]	[7.65134]
n*	1	1	1 and 2	1	1	1	1
F-test op	**37.94782**	**15.06456**	**35.42905**	**4.081762**	**41.67078**	**16.25538**	**40.43426**
[p-value]	[0.0000]	[0.0001]	[0.0000]	[0.0443]	[0.0000]	[0.0001]	[0.0000]
			19.75048				
			[0.0000]				

Figures in bold are statistically significant at 5% level.

Table 8: Test of causality of gold oil price changes

	$\boldsymbol{\pi_t}$
$\boldsymbol{\beta_{20}}$	2.777745
[t-value]	[0.0002]
n*	1 and 2
F-test op	1.706981
[p-value]	[0.1924]
	3.804235
	[0.0234]

Figure in bold is statistically significant at 5% level.

Table 9: Test of predictability of gold price changes with different oil price proxies

	Δop_t	Δop_t^+	Δop_t^-	$netop_t$	sop_t	sop_t^+	sop_t^-
γ_{20}	0.088458	0.149494	0.093844	0.119741	0.006981	0.009780	0.010072
[t-value]	[0.0002]	[0.0001]	[0.0160]	[0.0448]	[0.0001]	[0.0009]	[0.0011]
n*	1 and 2	1	1 and 2	1	1	1	1
F-test	2.065760	**3.751519**	0.207718	0.014191	2.569695	2.135153	1.435315
op [p-value]	[0.1517]	[0.0537]	[0.6489]	[0.9053]	[0.1100]	[0.1451]	[0.2319]
	2.615704		2.143240				
	[0.0748]		[0.1191]				

Figures in bold are statistically significant at 10% level.

Table 10: Johansen-Juselius multivariate cointegration test results for oil price, gold price and US dollar value relationships

r	n-r	λ_{max}	95%	Tr	95%
1st assumption: the level data have linear deterministic trends but the cointegrating equations have only intercepts (Lag = 3)					
$r = 0$*	$r = 1$	21.35604	21.13162	38.18378	29.79707
$r \leq 1$*	$r = 2$	16.50032	14.26460	16.82775	15.49471
$r \leq 2$	$r = 3$	0.327429	3.841466	0.327429	3.841466
2nd assumption: The level data and the cointegrating equations have linear trends (Lag = 3)					
$r = 0$	$r = 1$	22.83168	25.82321	47.43282*	42.91525
$r \leq 1$	$r = 2$	17.18933	19.38704	24.60113	25.87211
$r \leq 2$	$r = 3$	7.411799	12.51798	7.411799	12.51798

Note: r = number of cointegrating vectors, n-r = number of common trends, λ_{max} = maximum eigenvalue statistic, Tr = trace statistic. * denote rejection of the hypothesis at the 0.05 level.

Table 11: Generalized impulse responses of growth rate of gold price to one SE shock

Unrestricted VAR (lag = 1)			
Period	Gold price	Oil price	USD index
1	0.033684	0.006773	-0.013406
2	0.002853	0.003163	-0.003394
3	0.000680	0.001006	-0.001113
4	0.000208	0.000317	-0.000368
5	6.59E-05	0.000101	-0.000121
6	2.11E-05	3.24E-05	-3.94E-05
7	6.79E-06	1.04E-05	-1.28E-05
8	2.19E-06	3.37E-06	-4.16E-06
9	7.08E-07	1.09E-06	-1.35E-06
10	2.29E-07	3.53E-07	-4.37E-07

Note: Generalized impulse response functions are performed on the first differences of logged variables.

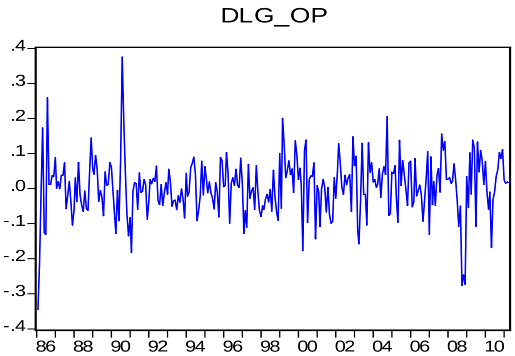
Table 12: Generalized variance decomposition for growth rate of gold price

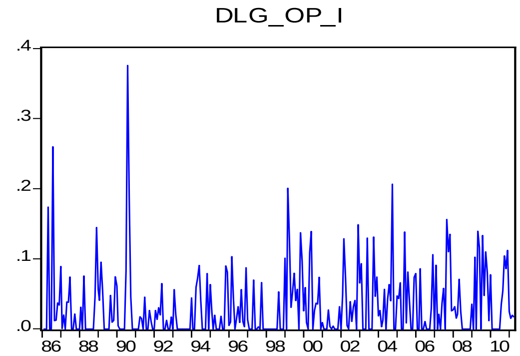
Unrestricted VAR (lag = 1)			
Period	Gold price	Oil price	USD index
1	1.00000	.040430	.15840
2	.98932	.048375	.16557
3	.98801	.049166	.16635
4	.98786	.049245	.16644
5	.98785	.049253	.16645
6	.98785	.049253	.16645
7	.98785	.049253	.16645
8	.98785	.049253	.16645
9	.98785	.049253	.16645
10	.98785	.049253	.16645

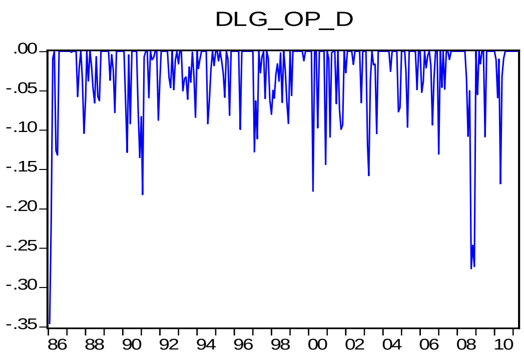
Note: Generalized forecast error variance decompositions are performed on the first differences of logged variables.

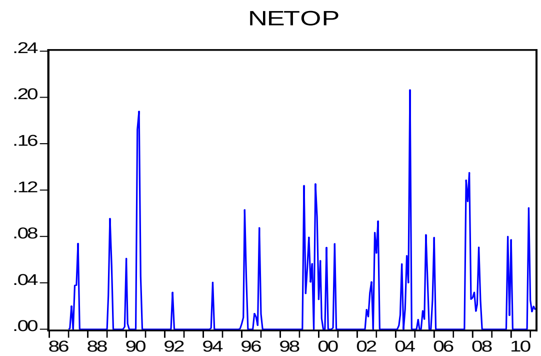
Figure 1: Different oil price measures

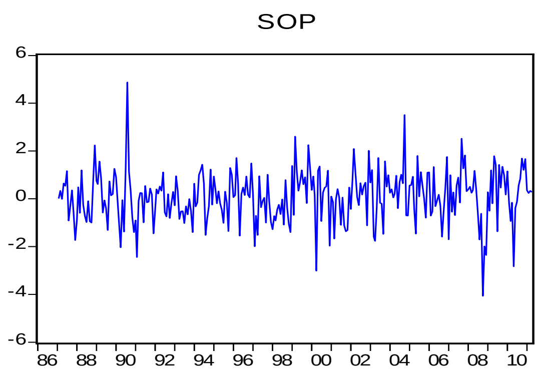
Note: The figures present the graphs of the seven oil price proxies, respectively: $\Delta op_t, \Delta op_t^+, \Delta op_t^-, netop_t, sop_t, sop_t^+$ and sop_t^-.

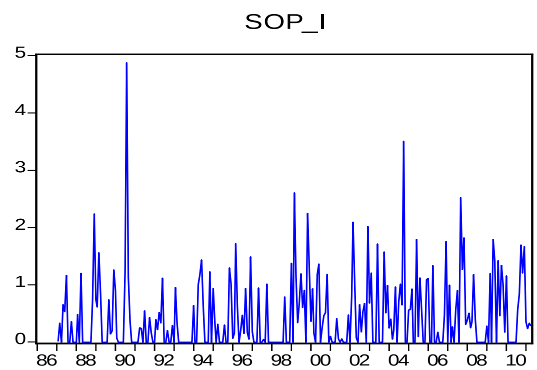

DLG_OP
.4
.3
.2
.1
.0
-.1
-.2
-.3
-.4
86 88 90 92 94 96 98 00 02 04 06 08 10


DLG_OP_I
.4
.3
.2
.1
.0
86 88 90 92 94 96 98 00 02 04 06 08 10


DLG_OP_D
.00
-.05
-.10
-.15
-.20
-.25
-.30
-.35
86 88 90 92 94 96 98 00 02 04 06 08 10


NETOP
.24
.20
.16
.12
.08
.04
.00
86 88 90 92 94 96 98 00 02 04 06 08 10


SOP
6
4
2
0
-2
-4
-6
86 88 90 92 94 96 98 00 02 04 06 08 10


SOP_I
5
4
3
2
1
0
86 88 90 92 94 96 98 00 02 04 06 08 10

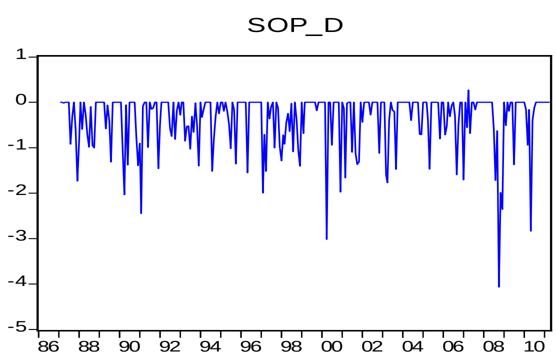
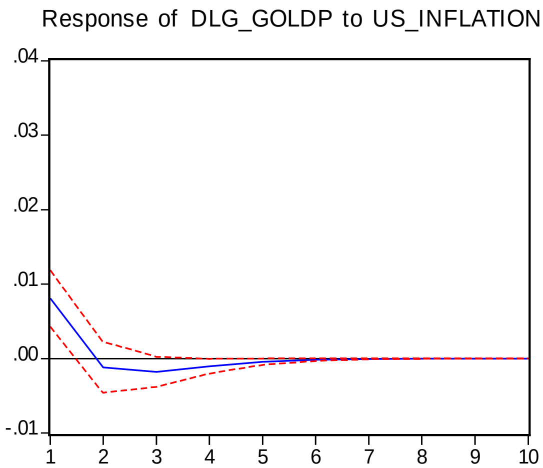

SOP_D
1
0
-1
-2
-3
-4
-5
86 88 90 92 94 96 98 00 02 04 06 08 10

Figure 2: Impulse response of gold prices to US inflation and Δop_t^+



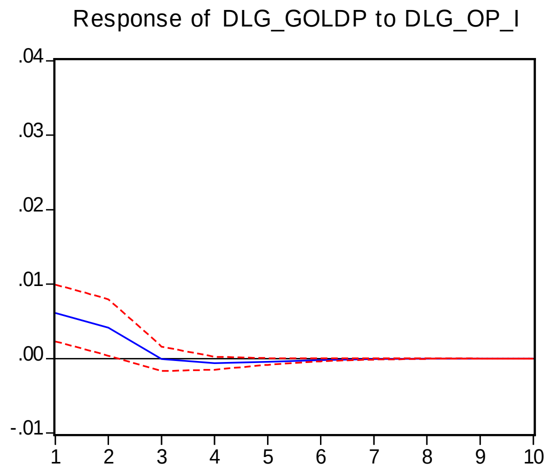


Figure 3: Generalized impulse responses of gold prices to one SE shock in oil prices in the trivariate VAR model