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INTERDEPENDENCE AMONG THE PRICES OF PRECIOUS METALS, THE OIL PRICE AND THE STOCK MARKET

A Thesis for the Master in Economics
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TABLE OF CONTENTS

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ABSTRACT

In this study, I examine the interdependence among the prices of precious metals, the oil price and the stock market. I provide evidence on the dynamics among the above variables for data covering April 2nd, 1990 to July 4th, 2021. The precious metals tested are the most known and used— gold, silver, platinum and palladium. As for the oil price, I gathered the prices of the West Texas Intermediate. The indexes tested are the Dow Jones Industrial Average index (DJIA), the S&P500 (SPX), the French stock market index, CAC40, the Financial Times Exchange Market 100 index (FTSE100) and the Japan stock market index, NIKKEI225. In this analysis I tested the interdependence among all the above variables. It should be mentioned that all regressions and analysis have been done on the Gretl open-source statistical package. The model used was the Vector Autoregressive Model (VAR). The variables in total were 10, therefore I run 5 VARs in order to check the influence each variable has for the other. In particular, all models consist of the WTI price, all precious metal closing prices and one index price. From VAR_1 to VAR_5 the indexes are contributed as followed, CAC40, DJIA, FTSE, NIKKEI225 and SPX. The results show that there is a degree of interdependence between the precious metals. Platinum and palladium, in particular, showcase a Granger Causality with most of the variables if not all. There is a stronger correlation among silver and gold, whereas oil exhibits various behaviors. Oil presents Granger Causality with oil itself and platinum. Furthermore, it does not influence any other of the variables in the Variance Decomposition test. To be specific, the influence is minor. As for the indexes, most of them do not show an influence by the rest of the variables.

1. Introduction

Precious metals, such as gold, silver, platinum and palladium, oil and the stock market have received much attention for many years from investors, traders, policy-makers and producers. The strong demand for oil globally, combined with the diversification of the uses of precious metals in various industries, has sparked interest in the trade of these commodities on international financial markets. Commodities matter to investors and traders, both for their size as markets and for their diversification potential in portfolio management. There is a wide literature for commodities on their diversification benefits. For financial researchers, commodities are also of interest for their potential role in asset allocation decisions. The demand for these precious metals and oil has led to price co-movements. Considering the importance of co-movements in commodity prices, portfolio diversification and market integration, it is mandatory to examine the overall dynamics of these co-movements in a multivariate setting. Economic theory has been successful, to a certain degree, in explaining the relationships among commodities and exchange rate markets. However; the empirical literature is yet to explore the dynamics of these links fully. For example, theory suggests that an increase in international oil prices could lead to inflation and exchange rate shocks. Such theories, however, fail to provide an adequate explanation concerning the direction of the causal linkages.

First and foremost, there has been a debate of whether precious metals can be viewed as a single market. Much academic and investor analysis has been done and the results have shown that gold, silver, platinum and palladium are integrated to some extent and that each metal might be a substitute for another. On the other hand, there have been research that support the opposite. Specifically, Jonathan A. Batten, Cetin Ciner and Brian M. Lucey have resulted that the market is only weakly integrated and that this degree of integration is time varying and it differs as between returns and volatility. Moreover, many researchers wonder if precious metals should be considered an asset class. To examine this statement, it is very important to take into consideration the degree of integration among the precious metals and the implications for hedging and portfolio diversification. For instance, if the correlation between the returns of some metals is low, it means there is low degree of co-movement or interdependence, whereas a high correlation translates into a high degree of integration. Furthermore, an asset class should show a high degree of integration, should have the ability to arise from common shocks and common economic fundamentals. All three of these forces work on all the assets (Greer, 1997).

Secondly, the four precious metals mentioned above have high economic value due to various factors, including their scarcity, their use in industrial processes and their role as a store of value throughout history. In the past, precious metals played a central role on the global economy because many currencies were either physically minted using precious metals or were backed by them, as in the case of the gold standard. Today, however, investors purchase precious metals mainly as a financial asset. The most popular precious metal for investment purposes is gold, followed by silver. Gold in particular, has been considered by numerous economists the leader in the market of precious metals, due to its history. Throughout the years gold has been treated as a store of value and a medium of exchange. It is held as an investment by investors, as well as governments as part of their reserves. It is a safe haven during financial crises and can be used as a hedge against inflation. Therefore, gold is the main strategic instrument for speculators and hedge funds. It is an input for industrial use and an important investment and wealth storage tool for saving holders. Therefore; because of precious metals being these multi-use tools to the economy they have high transaction volume in the markets and have high cash flow in the world.

Precious metals have ensured a very important and prominent place in the selection and design of diversified investment portfolios. They are becoming more and more important as investable assets in recent years, as the degree of uncertainty of world financial markets grows. The hedging capacity of precious metals due to their low correlations with equity markets makes them even more attractive (Hillier et al., 2006). Their resilience to financial crises has also been highlighted by academics in recent years (see, Lucey and Li, 2015; Batten et al., 2015; Baur and McDermott, 2010; Ciner et al., 2013; Agyei-Ampomah et al., 2014). Macroeconomists and financial analysts have long been concerned with the co-movement/dynamics of prices across different commodities or markets. This is because it provides information that helps investors in making investment decisions such as asset allocation, portfolio diversification, and risk management.

Oil is, as well, considered an important investment instrument for investors and its price is the most volatile in the commodity market (Regnier, 2007). It is the most traded raw material and was initially traded for its primary purposes, such as industrial use and transportation. Nowadays oil is also heavily used as a source of energy in the form of fuel. Over the course of time, it achieved a crucial position in the investment portfolio of individuals and institutional investors. There are countries that export oil, such as Canada, Mexico and Brazil but most countries in the world are net importers of oil. Some of those are the USA, Germany, the Netherlands, India etc. Oil is mostly traded in US Dollars and as a result there are serious implications on the movements of foreign exchange rates. For countries that import huge amounts of their oil consumption, an increase in the price can lead to inflation and exchange rate shocks. During these periods investors are attracted to precious metals in order to protect their portfolios against inflation and currency risk. Furthermore; that has an effect on the prices of precious metals and vice versa. The swing in oil prices is also due to certain market factors such as variation in supply, expected future production, consumption and market power

Furthermore, shocks are also a macroeconomic phenomenon that interest many economists. After the huge oil price shocks in 1970, economists have started investigating the issue a little further. Many studies have concentrated their research on oil shocks. This is probably because of the above description of oil. Gold and oil attract lots of attention due to their role in the economy, hence in most studies the main case is the impact of oil price shocks on gold returns.

Following all the above statements, I wanted to do a more precise research on the relationship of both precious metal prices and the oil price in combination of the stock market. The precious metals tested are the most known and used— gold, silver, platinum and palladium. As for the oil price, I gathered the prices of the West Texas Intermediate. The indexes tested are the Dow Jones Industrial Average index (DJIA), the S&P500 (SPX), the French stock market index CAC40, the Financial Times Exchange Market 100 index (FTSE100) and the Japan stock market index, NIKKEI225. In this analysis we tested the interdependence among all the above variables. The model used was the Vector Autoregressive Model (VAR). The variables in total were 10, which is problematic for the VAR regressions, therefore i run 5 VARs in order to check the influence each variable has for the other. In particular, all models consist of the WTI price, all precious metal prices and one index price. From VAR 1 to VAR 5 the indexes are contributes as follows, CAC40, DJIA, FTSE, NIKKEI225 and SPX. The remainder of the study is organized as follows. Section 2 covers the perspective of different studies around the same subject. Section 3 describes the data and the variables in the model. Section 4 presents the econometric methodology employed in the study. Section 5, exhibits the empirical results, in section 6 we check for the stationarity and the reliability of our VARs using the VAR inverse roots test and in section 7 I conclude. Moreover; all tables and graphs are gathered in the end of the analysis.

2. Literature Review

As stated earlier, precious metals such as gold, silver, platinum and palladium, are widely recognized as important assets for portfolio diversification, hedging and risk management (Hillier et al., 2006). Specifically gold and silver exhibit safe haven properties and hedging abilities against inflation and adverse dynamics of stocks and major exchange rate (Lucey and

Li, 2015). The empirical findings considering the relationship among the prices of all these variables are mixed and vary. The variation to the results is due to the different periods tested, as well as the different form of data. For example, Wahab et al. (1994) found a cointegration relationship between gold and silver markets using daily prices during 1982-1992. Escribano and Granger (1998) found a cointegration relationship between the monthly prices of gold and silver from 1971 to 1990, especially during the bubble and the post-bubble periods. Escribano and Granger (1998) have also concluded that the prices of gold and silver were strongly related during the bubble periods from 1979 to 1980. Fewer studies investigate the long-run relationship between gold and platinum prices. Kearney and Lombra (2008, 2009) identify a positive co-integrating relationship between gold and platinum prices using quarterly data during the 1985-1995 period, but not during the 1996-2006 period. Chevallier and Ielpo (2013) also found a co-integration relationship between daily log prices of gold and platinum prices in the presence of structural breaks using daily data during the period 2000-2011. Baur and Tran (2014) suggest that adverse financial economic forces may establish the long-run relationship between gold and silver prices over the last 40 years. The above metals are the most useful and relevant precious metals, but the literature review has many gaps when it comes to the relationship among platinum and palladium with oil. Much more work has been done considering the interdependence among gold and oil prices.

Oil is often considered the leader in the commodity markets. A change in its price affects the prices of other commodities, including that of gold. This means that changes in the gold price may be predicted if the oil price movements are monitored carefully. High oil prices are often considered bad for the economy. The reasoning is that it affects growth and it pushes down stock prices(Killian, 2009). As of the relationship between gold prices and the oil price many parameters should be considered.

First and foremost, gold and oil represent the most actively traded commodities in the world (Baruník, Kočenda, & Vácha, 2016). We should take into consideration the fact that both of these commodities are priced in US dollars. This happened in 1975, when the Organization of the Petroleum Exporting Countries (OPEC) decided to sell oil exclusively in US dollars. Therefore, the dollar volatility may have an effect to the international prices of crude oil and gold. In particular, it may cause co-movement of the prices. Evidently, it is likely that the dollar exchange rate is a co-driver of the prices of both oil and precious metals. Additionally, a deteriorating dollar has been shown to push up oil prices (Amano & van Norden, 1998), and lead to a shift towards precious metals (Baruník et al., 2016). Investors have also recently started to hold platinum as an alternative to gold (Jain & Ghosh, 2013).

Secondly, the impact of oil prices on gold prices could as well be explained by the export revenue channel (Melvin and Sultan, 1990). This implies that an increase in the price of oil may lead to an increase in the price of gold, as long as gold holds a big portion in the portfolio of the oil exporter.

Thirdly, inflation seems to be the most common channel for explaining the relationship between oil and gold. It is known that gold is used against inflation. Hunt and Hooker (2006 and 2002), have said that a rise in the crude oil price leads to an increase in the general price level. When the general price level goes up, the price of gold, which is also a good will increase. This enhances the hedge role of gold against inflation and gold is indeed renowned as an effective tool in this regard. As a result, this causes an increase in the demand for gold. Therefore, the price will increase even more (Pindyck and Rotemberg, 1990).

Lastly, interest rates play a significant role between this relationship. Low real interest rates may cause a decline in the value of the US dollar. Lets first analyze the gold price and interest rate relationship. There are many studies that support that interest rates play a significant role to the gold price (Koutsoyiannis 1983, Fortune 1987, Cai et al. 2001). During periods when nominal interest rates on short and safe financial assets are low, people tend to respond by purchasing goods such as gold, even though it has some storage cost. This obviously leads to an increase in price. As of the relationship between the oil price and the interest rate, there is a theory that increasing interest rates raises consumers' and manufactures' costs. These increases lead to a reduction to the time and money people spend to their cars, which means less demand for oil and then leads to oil prices dropping.

Besides the above statements considering the relationship among precious metal prices and the oil price, it should be noted that there is no consensus relation between those variables in the literature and the empirical studies provide mixed results. The studies focus on either the returns of the precious metals and oil, the volatility and spillovers or the movements between the variables. Sari et al (2010), has focused on the co-movements and information transitions among the closing prices of four precious metals, the oil price and the exchange rate, for the period of January 4th, 1999 till October 19th, 2007. The results showed a weak long-run equilibrium relationship with stronger feedback during the short-run. The authors also stated that an increase in the gold price leads to parallel movements with the other precious metals. For some, this statement may confirm that gold is the leading indicator of precious metals but the empirical literature and economic theory have failed to provide enough evidence regarding the interrelationships among the major precious metals, whether there is an established metal that drives or leads the pricing dynamics.

As stated by Sari et al. (2010), many economists would consider gold as the leader of the precious metal pack, but silver has more industrial uses than gold and has sometimes led gold. The importance of silver is reflected in its hourly trade since the 1930s in markets such as London, Bombay, New York and Shanghai, among others. Gold and silver have also historically been used as a store of value and medium of exchange (Jain & Ghosh, 2013; Vigne, Lucey, O'Connor, & Yarovaya, 2017). Furthermore, it is examined how the oil price is related to the prices of precious metals.

Other studies have focused on the correlation dependence among the precious metal prices. Batten et al. (2010) also analyzed the interrelationships among four precious metals using monthly data for the period from January 1986 to May 2006. The study generated conditional standard deviations and included in a VAR framework and block exogeneity causality tests, in order to establish the volatility linkages between the various macroeconomic variables and the precious metals markets. The authors resulted that there is a weak integration between gold, silver, platinum, and palladium. Ciner (2001) found evidence of the disappearance of long run relationship between gold and silver in the 1990s. This has been explained due to the increase in divergence of uses of these precious metals.

Gold, silver and platinum are metals used in the jewelry industry as well. Silver, platinum and oil are also used in the automotive and chemical industries. In addition, the relationships between these precious metals are expected and we can see co-movements in the prices of these commodities. Ciners' result has been assured by Lucey and Tully (2006) who say that this relationship strengthens and weakens over time but is prevalent over the long run. On the other hand, Shafiee and Topal (2010) present evidence for the linkages between gold prices, oil prices and inflation. Their results indicate a stable range for the ratio of gold and oil prices over a long period, indicating a stable relationship. Shafiee and Topal (2010) showed that there is a long-term relationship between oil prices and gold prices. Instead Soytas et al. (2009) concluded that precious metal prices are not statistically affected by world oil prices. Reboredo and Ugolini (2016) examine the relationship between oil prices and precious metal prices with unconditional and conditional value-at-risk methods for the period 2000 to 2015. They find that large downside and upside oil price movements have spillover effects on all metal markets and this effect is also valid before and after the global financial crisis.

Previous studies have produced mixed evidence about the long-run relationship between precious metal prices. As of the cointegrating relationship between all precious metals the results show that they are not stable over time and there are significant shifts in the price relations around business cycle peaks and during recessions. More specifically, across various econometric tests, the findings indicate that there are cointegrating relationships between weekly prices of gold and silver, and gold and platinum, over the last forty years. However, the long-run relationships are unstable, indicating a separation of precious metal prices during certain periods of time. The results further confirm several structural breaks in the cointegrating relationships during bubble periods, financial crisis, and contractions.

Additionally, the results show that the long-run relationships between precious metal prices are strongly influenced by economic conditions. These findings should contribute to the growing literature on linkages between macroeconomic fundamentals and the exact nature of the price relationships across different precious metals. On the other hand, several studies show that precious metal prices often move together and that the common variation in the metal prices relates to business cycles. Escribano and Granger (1998) demonstrate that gold and silver prices were strongly related during the bubble periods from 1979 to 1980. Baur and Tran (2014) suggest that adverse financial economic forces may establish the long-run relationship between gold and silver prices over the last 40 years. Less studies investigate the long-run relationship between gold and platinum prices. Kearney and Lombra (2008, 2009) find a positive cointegrating relationship between gold and platinum prices using quarterly data during the 1985-1995 period, but not during the 1996-2006 period. Furthermore, Chevallier and Ielpo (2013) find a cointegration relationship between daily log prices of gold and platinum prices in the presence of structural breaks using daily data during the period 2000-2011. Across various econometric tests, the findings indicate that there are cointegrating relationships between weekly prices of gold and silver, and gold and platinum, over the last forty years. However, the long-run relationships are unstable, indicating a separation of precious metal prices during certain periods of time. The results further confirm several structural breaks in the cointegrating relationships during bubble periods, financial crisis, and contractions. Analyzing the various econometric tests, the findings indicate that there are cointegrating relationships between weekly prices of gold and silver, and gold and platinum, over the last forty years. However, the long-run relationships are unstable, even indicating a separation of precious metal prices during certain periods of time. Moreover, the results confirm several structural breaks in the cointegrating relationships during bubble periods, financial crisis, and contractions.

3. Variables and Data Descriptions

My research uses the daily closing price data for five major stock markets (CAC40 index, DJIA index, FTSE index, Nikkei 225 index, S&P500 index), the prices of four precious metals (gold, silver, platinum, palladium) and as for the oil price, i used the West Texas Intermediate (WTI). The sample period spans from April 2nd, 1990, to July 30th, 2021, and consists of 7.892 observations. The data for the indexes were gathered from Yahoo Finance and the Wall Street Journal website. As for the precious metals' data, I visited the London Bullion Market Association website and the oil price data was gathered from the Federal Reserve Bank of St. Louis (FRED: https://fred.stlouisfed.org). All the prices are in U.S. currency.

3.1 The VAR model

In order to examine the interdependence among the prices of precious metals, the oil price and the stock market as well as how each of these variables behaves during shocks on each of the variables a Vector Autoregressive Model (VAR) is used. It is the ideal model to be used since it captures the relationship between multiple quantities as they change over time. The VAR model is commonly used for forecasting systems of interdependent time series and for analyzing the dynamic impact of unforeseen occurrences to the system of the variables.

The mathematical form of a VAR is

$$Y_t = A_0 + A_1 Y_{t-1} + A_2 Y_{t-2} + \ldots + A_p Y_{t-p} + e_t$$

where A_0 is a k vector of constants serving as the intercept of the model, A_i is a time-invariant $(k \times k)$-matrix and e_t is a k-vector of error terms. The variables of the form Y_{t-i} indicate that variable's value i time periods earlier and are called the "i-th lag" of Y_t. Last but not least Y_t is a k vector of endogenous variables.

3.2 Stationarity

The stationarity of the time series studied is significant to a regression analysis. Useful information and characteristics are difficult to identify in a non-stationary time series. As a result, a non stationary time series would lead to false results of the regressions. Nevertheless, most economic series are non-stationary in practice. Therefore, they should become stationary by differencing. A time series is stationary if its mean and variance are constant and do not change overtime. To test the stationarity of variables multiple unit root tests can be used, such as the Dickey-Fuller test (DF), the Augmented Dickey-Fuller test (ADF) (Dickey and Fuller, 1979) and the Phillips-Perron test (PP) (Phillips and Perron, 1988).

In particular, the ADF unit root test examines the null hypothesis of a unit root being present in a time series sample. The alternative hypothesis depends on which of the unit root test is being used, the DF or the ADF. Specifically, the ADF unit root test is used when a larger and more complicated set of time series models is tested. Moreover, the ADF statistic is a negative number that helps us reject the null hypothesis, which supports the presence of a unit root in the time series. The more negative, the stronger the rejection of the null. As for ADF, the model applied is below:

$$\Delta Y_t = \alpha + \beta t + \gamma \Delta Y_{t-1} + \delta 1 \Delta Y_{t-2} + \ldots + \delta p\text{-}1 \Delta Y_{t-p+1} + e_t$$

The tests above can be applied at the level or the first differences of the time series. Nevertheless, the first differences are preferred for 2 reasons in order to explain the impulse response function. Firstly, there is more emphasis on the increase or decrease of the trend instead of the actual change. Secondly, more information on the shocks are captured because the first difference data showcases that changes in the past two days while the level data only showcase one day. In additions, when the series is stationary on the first differences we state that the series is I(1).

4. Methodology - VARs

I. Stationarity Test

As mentioned previously in order to successfully apply the VAR model to our series, checking for the stationarity of our variables is mandatory. Firstly, all the variables are selected and the first differences are applied. Secondly, the testing covers the existence, or not, of a unit root at the first differences of each variable. The test used is the ADF unit root test, which null hypothesis' states that a unit root exists, therefore the series is not stationary. In addition, the null hypothesis should be rejected. A trend for the test is not selected, since each variable's plot shows that it is not needed (plots).

The results show that all p-values of all that variables are less than the 1% significance level. (ADF tests). This reassures that the null hypothesis can be rejected, therefore all variables are stationary, I(1), and the regressions can continue.

II. VARs

The VAR model is a statistical model used to capture the relationship between multiple quantities as they change over time. In this study there are 10 variables in total, which are too many as they lead to a big loss of degrees of freedom. Therefore, the variables were divided and 5 VARs were employed. Each VAR consists of the WTI returns, all precious metals returns and the returns of one stock index. Since there are five indexes, there are five VARs in total. The mathematical form of the VAR used is:

$$Y_t = \mathrm{A}_0 + \mathrm{A}_1 Y_{t-1} + \mathrm{A}_2 Y_{t-2} + \ldots + \mathrm{A}_6 Y_{t-p} + e_t$$

where A_0 is a 6x1 vector of constants, A_i is a 6x6 matrix of coefficients, Y_t is a 6x1 vector of endogenous variables t and e_t is a 6x1 vector of residuals.

III. Lag Selection

Another important element of the VAR model is to select the optimal lag length. Traditionally, the process of selecting the correct lag length was by repeating the VAR model and each time reducing the lag length from a large lag term until zero. Nowadays, researchers base the selection of optimal lags on different information criteria. Some of them are the Akaike information criterion (AIC), the Schwarz information criterion (SIC), the Schwarz Bayesian information criterion (BIC, Gideon E. Schwarz, 1978) and the Hannan-Quinn information criterion (HQC). Gretl uses the AIC, BIC, HQC. In this study, when testing for the lag selection, the BIC and HQC agree to one lag being selected whereas the AIC suggests a different lag each time. The BIC is best for explanation as it allows consistent estimation of the underlying data generating process. HQC is strongly consistent and is asymptotically very well-behaved. Even though two information criteria agree to using one lag that is not the optimal in this case. When daily prices are analyzed, a small number of lags should not be selected. Moreover; the above information criteria were originally developed for single equations, not VAR models. Therefore, the selection of lags is based on the Likelihood Ratio Test (LR), which is also provided by Gretl. The LR test is also used in combination with the BIC and HQC and provides more successful results for the VAR model. Concluding, the number of lags is selected based on the LR test.

IV. Estimation of VAR

The coefficients acquired from the estimation of the VAR model might not be proper to intercept directly. Therefore, both the variance decomposition and impulse response functions tests are pursued, in order to make the results more direct. Furthermore, the VAR inverse roots in relation to the unit root circle are checked.

The variance decomposition displays the percentage of the error made, forecasting a variable overtime, due to a specific shock. In other words, it shows how much of the variability in the dependent variable is explained by its “own shocks” versus the “shocks in the rest variables of the system”. In addition, the impulse response functions are used to trace out the time path (current and future values) of the variables in our model to an external change, e.g. shock in each of the variables in the system. In other words, “what is the effect of one unit shock in “X” on “Y”?”. The VAR inverse roots figures reassure that are results are stationary and correct.

5. Empirical Results

A. VAR_1

A.1 Granger-Causality Test

VAR_1 contains the WTI returns, the gold, silver, platinum and palladium returns and lastly the returns of the French market stock index, CAC40. As stated before, all variables are stationary and by following the LR test, 7 lags were selected for this VAR test. In each equation of Table 2, the p-value of all F-tests are taken into notice. They are used to show the results of the Granger-Causality test. The null hypothesis of the Granger-Causality test claims that there is no Granger causality among the variables, whereas the alternative hypothesis states that there is Granger causality among the variables tested.

In equation 1, it is tested whether their is Granger causality between the returns of WTI and the rest of the variables. By analyzing the p-values of the F-tests, we can confirm Granger causality among the returns of WTI and itself, the returns of platinum and lastly, the returns of palladium. In particular, the p-values of WTI and platinum are less than the 1% significance level, which indicates a stronger correlation among those variables and WTI. Moreover; the p-value of palladium is 0.03%, less than the 5% significance level. Moving forward, the returns of silver and gold exhibit the same results to the Granger-Causality test. Both returns appear to have Granger causality with the returns of gold, silver and the CAC40 index. All p-values are less than the 1% significance level. As of the returns of platinum, it is the only variable that shows Granger causality with all the rest of the variables. In all cases, the significance level is less than 1%, whereas the p-value of WTI is 0.06. Palladium's returns also exhibit Granger causality with all variables, on the 1% significance level, except the logs of WTI. Last but not least, in the last equation of VAR_1 the main variable is the returns of the French stock market index. CAC40 only showcases an interdependence with the variable itself. The p-values of all the other variables are pretty high, which makes us accept the null hypothesis for the Granger-Causality test.

A.2 Variance Decomposition

From the variance decomposition function, it is tested how each variable is affected by the rest of the variables in the span of ten periods time (Table 3). WTI, gold and the CAC40 index have similar results. The returns of all three of these variables, are influenced only by the variables themselves. Starting of with the oil returns, in the first period those are influenced by oil only. During the span of time, this percentage barely decreases and remains stable from day 3 and on, at the 99.8% mark. The same thing happens to the returns of gold, with the numbers being slightly different. All the remaining variables, have a minor to zero effect on gold and WTI. Thirdly, and as expected, the CAC40 index has a minor to zero influence by the other variables. Only the variable itself affects its returns to a very high level. The percentage starts at 99.97% in the first period and it exhibits approximately a 0.08 decrease in day 3. From that point and on the percentage remains stable. Platinum and palladium showcase more complex results. In the case of platinum, most of the influence is caused by the variable itself. Its percentage starts at a high mark as well (96.41%), yet there is an instant decrease noticed on day 2 (78.79%). The influence by gold and silver is small compared to the 78% mark but it is noticeable. The odd part is that both gold and silver itself barely influence silver in the beginning. Specifically, they showcase a percentage of 2.7 and 0.8 in the first period. Compared to platinum, in day 2 they exhibit and instant increase, touching 17% and 3.57% of influence respectively. The rest variables cause a minor effect on silver. As of the returns of palladium, they are influenced by platinum, gold and silver, the leader being platinum. Silver and gold present a minor influence in the first period and then a small increase in the second. Platinum, on the other hand, has a stable 25% influence on palladium. Furthermore, palladium is the main variable that influences it self, as expected, reaching a percentage of 72 at the beginning and then decreasing to 64.63% for the rest of the time span.

A.3 Impulse Response Functions

We begin the IRFs on equation 1 (Figure 1.A), testing the response of the returns of WTI to a standard deviation (SD) to each of the rest variables. Firstly, and as expected, a SD to WTI itself has a significant importance to the returns of the variable. The returns exhibit an instant steep decrease from the moment of the shock till the end of the first period. From that time and forward, the graph shows an alternation of small increases and decreases that last till the end of the 11th period tested. A SD shock to gold causes a more complex alternation of increases and decreases in the returns. It should be noted that in the short run (SR) the effect is much more noticeable, whereas from period 10-18 the graph alternates from positive to negative very close to the X axe. The time horizon needed for the shock to be absorbed is between 18-20 days. A silver shock causes a very intense response to the log of WTI. There are increases and decreases in the returns, but the decreases are steeper and more negative. It should be noted that, again, all the intense response of the returns are in the SR. From day 10 and forward the graph is very close to 0. As of a platinum shock, it instantly causes a decrease in the returns of oil. Furthermore, the response is statistically significant in the 6th period. The response is mostly negative in this whole graph, and from day 5 till day 10, a gradual decrease is noticed. From then and on, the responses are very minor, considering a gradual decrease from day 10 till day 20. The effect of a palladium shock is similar but the opposite at the same time. It starts with a steep significant increase of the returns and then alternates from positive to negative intensely till periods 7-8. From then and forward, the response is less intense and very close to zero, gradually becoming zero till the 23rd period tested. For the SD to the CAC40 index, the response is statistically insignificant, as expected, and mostly negative. Again, the shock has a much more intense effect in the SR, in contrast to the long run (LR). By days 18-22 the shock has disappeared.

Examining the response of the returns of gold (Figure 1.A), a SD to WTI and palladium is statistically insignificant. In both cases, the SD has a SR effect and from the 10th period till the 20th the shock has disappeared. The alternations from negative to positive returns are once again intense in the SR. A silver shock, causes instant positive and statistically significant returns to gold for the first period. In the second period though, we exhibit an instant and statistically significant decrease in returns. From day 10 till day 18, the results are insignificant and the effect is minor. As of a SD to gold itself, we acknowledge a steep and instant decrease in the returns. Within 13 days the shock no longer has an effect on the variable. A SD to the platinum variable reveals an instant, negative and statistically insignificant response to the returns of gold. The only significant period is through days 3-4 and it is negative. From day 8 there is a small gradual decrease in returns and until day 20 the SD has been absorbed. Lastly, increases and decreases are displayed for the CAC40 shock. The only statistically significant periods are those of day 4 and 9, where we exhibit the lowest and highest degree of returns, respectively.

Platinum was the only precious metal that exhibited a granger cause among all variables. So we expect the most significant results in the IRFs (Figure1.B). Furthermore it should be noted that the responses of platinum and palladium to SD are very similar. The graphs show minor differences only considering the days of significance. Starting of with a SD to WTI, we note that it is statistically insignificant and it takes 15 to 16 days to revert to zero. A gold shock causes a steep, significant increase to the returns of silver on day 1, which is followed by a steep, decrease on day 2. From that moment and forward, the graph shows alternations of small increases and decreases that last around 8-10 days. Continuing with the shocks on precious metals, a silver SD has the most significant effect on platinum. In the SR, we exhibit an increase in the returns, which then decrease gradually in the span of 3 days. The shock no longer has an effect from day 12 and forward. Palladium on the other hand, has only two significant effects on platinum. Specifically, they are exhibited on days 4 and 6. Very shortly the SD magnitude becomes zero. The magnitude of a SD on the index claims the most intense and positive response. For 9 days the returns of platinum are positive. From day 10 and forward we exhibit a gradual decrease that becomes zero until day 18. Lastly, a shock to platinum itself, has a significant effect in the SR, exhibiting a very steep decrease in returns, which then become negative and very close to zero.

Silver exhibits the most intense graphs of all. Considering a shock to the CAC40 index, to WTI and palladium, we exhibit very intense and steep increases and decreases in the returns for the first 10 periods. In all cases, from day 10 and forward the returns revert to zero within 8-10 days.

Ending these IRFs, with the response of the returns of the CAC40 index (Figure 1.C). From the Granger-Causality test as well as from the variance decomposition results, the index does not showcase any influence by the other variables. As a result, the response of the index to the shocks on the rest of the variables is mostly statistically insignificant. For sure we exhibit many alternations of increases and decreases in the SR for the returns but the only significant effect is that from the index itself. In particular, the graph is identical to all the graphs considering the response of the variables to a shock on themselves.

B. VAR_2

B.1 Granger-Causality Test

The returns of WTI, all precious metals and the DJIA index are included in VAR_2 (Table 4). Based again on the LR test for the lag selection, this time I selected 6 lags for this regression. The results of the Granger Causality test show some similarities with VAR_1. Firstly, the DJIA index does not exhibit any kind of relation with any other variable rather than itself. Secondly, when the returns of WTI are the main variable in the equation, Granger causality is exhibited among itself, the returns of platinum and the returns of DJIA. As for the rest of the equations, silver has no Granger causality with itself, whereas gold and the DJIA index have a strong influence to the returns of silver. Their p-value is less than the 1% significance level. It should be noted that palladium showcases Granger causality with the precious metals only. On the other hand, the returns of platinum show significant Granger causality among all precious metals and the returns of WTI on the 1% and 10% significance level, respectively.

B.2 Variance Decomposition

As of the variance decomposition test, the time span tested are ten days (Table 5). The results are very similar to the variance decomposition in VAR_1. The returns of WTI are the only returns exhibiting 100% influence from the variable itself in the first period. The returns show a slight decrease in the rest of the time span, not going below the 99.19%. The influence of the rest of the variables is very little. The DJIA index and gold are exclusively influenced by themselves, starting at the 99.9% mark. DJIA has a minor decrease reaching 99.6% of influence on day 7. From that moment and forward the percentage remains stable. It should be addressed that gold exhibits a unique fluctuation. The percentage of gold exhibits a decrease in the SR reaching its lowest mark at 99% in day 6. Then again, in day 7, it comes to a 99.94% and remains stable for the rest of the time period tested. Moving forward to the variance decompositions of silver, we see that the returns are mostly because of gold (52%). The percentage remains stable for most of the period tested. Silver's influence on itself is 47%. The most complex variance decomposition is that of platinum and palladium. Palladium's returns are a result of all 4 of the precious metals, the leader being palladium itself (64%). Platinum is responsible for 25% of the returns, whereas gold and silver have the lowest percentages of 9% and 3% respectively. Palladium's returns are a result of the influence of gold, silver and platinum.

B.3 Impulse Response Functions

Starting of with the response of the returns of the oil price to a shock in any of the rest variables (Figure 2.A). A SD to oil itself instantly causes a very steep decrease in the returns. The shock is statistically significant and from day 1until day 6, we acknowledge small increases and decreases in the returns. From that moment and forward, we can barely notice an influence. A gold shock has mostly a positive influence to the returns. In the beginning of the period tested, we exhibit a minor increase in the returns. During the 3rd-4th days the shock has a significant influence to the returns causing a very steep increasing in them. From day 7 and later the decrease is gradual and reaches the zero mark until day 12. As opposed to the graph of the gold shock, the silver shock has the exact opposite effect on the returns of oil. In the beginning, a small positive increase is exhibited, whereas the steepest reaction is negative and statistically significant. It is exhibited during that 3rd and 4th period. During the last days, the impulse responses vary between being negative and positive and revert to zero until the end of the 3rd week of the shock. A platinum shock, as well as a palladium shock, cause negative and positive responses, alternating between being significant and statistically insignificant. Furthermore, the response of WTI to a shock on palladium exhibits a more gradual decrease in the later days. In both cases the shock reverts to zero within 15 days.

As of the response of gold to shocks (Figure 2.A), we should point out that the WTI shock and the palladium shock are statistically insignificant and both need around 10-15 days in order to disappear. A gold shock is statistically significant during the first period, where we exhibit a very steep decrease in the returns. From day 2 until day 7 the shock gradually reverts to zero. The graph exhibiting the returns of gold to a silver shock is similar. During the first 2 periods the effect is statistically significant and positive. In contrast, during days 3-13 the returns are negative and statistically insignificant. In 13 days the shock has reverted to zero. Considering a

SD to the DJIA index and platinum the returns of gold are mostly negative. The significant importance of the shocks are during days 3-5 and 3-4 respectively. In both graphs, the returns gradually start to revert to zero from day 7 till 12.

The DJIA index is the only variable that does not showcase any statistically significant responses from the shocks to the rest of the variables (Figure 2.C). Specifically, the graphs of the WTI and the gold shocks are mostly negative and the graphs of the silver and palladium shock are more gradual. The returns of DJIA have a significant response to a shock in the index it self. During the first day of the shock there is a steep decrease in the returns which then become negative for the rest of the time span until the revert to zero. Lastly, the platinum shock has no significant effect to the returns and need the most days to revert to zero (around 16 days).

Silver has similar responses to gold to the different shock (Figure 2.B). A shock to oil and palladium is statistically insignificant for the returns of silver. The rest of the precious metals, have a more significant effect during some periods. For instance, a gold shock exhibits the same response as a silver shock. In the SR both decrease the returns of silver and for the rest of the time span the effects are minor, close to zero. Moreover; the shock needs 7-8 days to disappear. The returns of silver are mostly negative considering a SD in platinum. In the SR (period 0-6) the returns are low, showcasing significance of the 5% level during days 3-4. Last but not least, an index shock causes an alternation of negative and positive returns for silver in the SR. Some being statistically significant. Day 5 shows the lowest of returns and from day util day 15 we exhibit a gradual decrease of the returns that turn into zero.

Platinum has a significant influence by all shocks excluding the oil shock (Figure 2.C). The oil shock in particular, needs the most days to disappear (18 days). The unique part in the case of platinum and its returns is that the magnitude of a silver and a gold shock has positive responses in the SR. Both start with an increase in returns, which ends to the highest returns of silver. Furthermore, considering the returns of platinum after the silver shock, the decrease is more gradual than, that of the gold shock. Within 10 days the shock has reverted to zero. A shock to platinum, causes again, an instant, significant decrease in the returns during the 1st period. During the period 2-7, we exhibit negative returns and by day 10 the shock has disappeared. A palladium shock causes an insignificant increase to the returns of silver which than gradually decrease and become negative. the significant period is during days 3 and 4, where the returns are the lowest. From day 7 till 15 the returns slowly revert to zero. As of the index shock, It causes negative returns for platinum for almost the whole time span tested. The returns are the lowest during days 5-6, where the effect is also statistically significant.

Palladium reacts in a similar way to a palladium shock and a platinum shock (Figure 2.C). We exhibit a very steep decrease in returns in the first period. The returns revert to zero soon and within 6-8 days. As for the returns when a shock on gold or silver is occurred, we exhibit again similarities. The moment of the SD, the returns increase for the first period and the results are statistically significant. During the second period, we exhibit a steep decrease. The returns of palladium become zero until day 10, considering the gold shock, and for the silver shock, the returns revert to zero until day 12. the graph analyzing the response of palladium to a SD on the DJIA and WTI are more complex. In both, cases the statistically significant periods are only two. The returns of palladium on a DJIA shock are mostly negative. During days 5-6 the results are statistically significant and the returns are at their lowest point. During the periods 6-13 the returns gradually revert to zero. As of the returns when a shock on WTI occurs, they decrease slowly in the first period. In contrast to this, during the second period we exhibit a steep, decrease in returns, which is also statistically significant. In addition, in the second period we notice the lowest returns. The returns become positive during days 4-7 and from that moment and forward they revert to zero until day 14.

C. VAR_3

C.1 Granger-Causality Test

In VAR_3 the different index that we are testing, considering the variables, is FTSE (Table 6). We would expect the rest of the variables, that are the same in each VAR, to have the same results in every regression. In contrast, we exhibit different results each time. In equation 1, where the returns of WTI is the main variable, we can tell that there is Granger causality among the variable it self, platinum and palladium. The significance level for WTI and platinum is 1% and the significance of palladium is 5%. We can also acknowledge that WTI is strongly endogenous, having a p-value of 0. Moving forward to equation 2, the main variable is the returns of gold. Gold is as well strongly endogenous, and also shows a granger cause with silver and platinum only. Silver, particularly, is strongly endogenous to gold. As of the returns of platinum, they are mainly affected by a change the occurs to gold and the FTSE index. Both of these variables are strongly endogenous to platinum, having a p-value less than the 1% significance level. It should be noted that platinum is weakly endogenous, having a p-value less than the 10% significance level. Furthermore, silver has less of an influence on platinum, as its p-value is less than the 5% significance level. Platinum is the only variable that shows an influence by all the rest. It is strongly affected by a change in any of the rest of the variables, excluding the WTI. All of them are strongly endogenous. Additionally, the WTI has less of an effect, as its p-value is less than the 10% significance level. Moving forward to the last 2 equations, the main variables are palladium and the FTSE index. The results are mostly similar, considering that the main variables are affected by changes in al the rest, expect WTI again. For palladium, all variables are strongly endogenous to its returns, with the p-values practically being zero. On the other hand, the FTSE is considered strongly endogenous, whereas the rest of the variables affecting its returns are strongly exogenous. All their p-values are less than the 10% significance level.

C.2 Variance Decomposition

As for the variance decomposition analysis (Table 7) we expect similar results to the Granger-Causality tests. Starting of with the decomposition variance for the ld_WTI, we see that the results are in contrast with the VAR_3 table. The returns of oil are exclusively explained by the oil itself. During the first for days of the time span studied, there is a minor decrease in the level of the influence, starting from 100% going to 99.62%. In addition, from day 6 till day 10 the percentage is somewhat stable and still really high, 99.32%. Secondly, the gold variable is again mostly explained by itself. The influence is huge during the ten day span, covering around 99% of the returns. Silver describes a minor percentage, almost zero, of the returns of gold. Thirdly, silver's returns are highly and stably explained by gold. Gold encounters of 52.3% of the returns for most of the time tested and silver itself covers 47% of them. The rest of the variables have very small percentages, almost zero. As of the returns of platinum, they are explained by gold, silver, and the variable itself. Platinum starts with a 96% influence, which decreases steeply in the 2nd period tested, explaining 78% of its returns. Gold, on the other hand, starts with an influence of 2% and day 1, and rapidly increases its influence for the rest of the period tested, reaching 17%. Lastly, silver only occurs for the 3% of the returns. Palladium is as well influenced by the gold, silver, platinum and the variable itself. Evidently, most of its returns are based on palladium it self, covering 64% of them. Platinum has a lower percentage of 22%, whereas the influence of gold and silver is even smaller, covering 9% and 3%, respectively. Ending with the variance of decomposition for the returns of the UK index, FTSE. There is no other variable rather than itself, that explains the returns of the index. The percentage is nearly 100% and is stable overtime.

C.3 Impulse Response Functions

Beginning with the response the FTSE index to a SD on the rest of the variables in VAR_3 (Figure 3.C). It should be noted that a SD on WTI and gold have no statistically significant results on the returns of FTSE. Additionally, a gold shock causes a small decrease in the returns of FTSE during the first day tested. Furthermore, the returns exhibit an even bigger decrease during the 3rd period. The results are also negative. In the 4th period we exhibit a negative increase and from day 6 and forward the results slowly revert to zero. In total, the shock needs approximately 12 days to not have an effect to the returns of the index. As of the response to a SD to WTI, the graph is more intense, exhibiting both negative and positive returns. The decreases and increases are steeper in the SR and from the 7th day of the shock they start reverting to zero until the 13th period tested. A SD to the rest of the variables shows significance in some periods. Continuing with the silver shock, the returns are exhibited in an even steeper graph. The returns are high and significant during the 3rd period that we are testing. Furthermore, they are the highest we exhibit from any other shock. During the 4 period the influence is very small, having a small slope and immediately after that (day 6) the returns start to decrease reaching the zero mark until the 12th period. Platinum influences the returns of the index positively. From the moment the shock occurs the returns claim an increase during the SR. In addition, during the 4th day, we exhibit an instant, steep decrease in them and in day 5 we acknowledge the lowest returns of the index. From that moment and forward, the returns gradually increase and then revert to zero until the 12th day tested. The palladium shock is responsible for the lowest returns exhibited for the index. They occur on the 4th period and they are statistically significant. Last but not least, a SD to the index it self has a significant influence during the time span tested. The returns, decrease sharply during the first day of the shock and within 6 days it disappears.

Considering the responses of the gold variable in this VAR (Figure 3.A) we should note that the WTI, the palladium and the FTSE shock they are insignificant. The FTSE shock in particular, causes the most stable response to the returns of gold, which are showcased from day 3 of the shock till day 11. Furthermore, the palladium shock shows significant results only on the 3rd day of the shock, where the returns are the highest considering this shock. The platinum shock is responsible for the lowest of returns of gold. During the first 6 days of the shock the returns are negative. The lowest returns are exhibited during the 3rd period and they are statistically significant. The gold shock causes significant returns during the 1st and the last two days tested. It also needs the least days in order to revert to zero. Lastly, and more importantly, the silver shock is responsible for the highest returns of gold within the first two periods tested. Moreover; it needs approximately 10-11 days.

The returns of silver are mostly affected by the variable itself, gold, platinum and the FTSE (Figure 3.B). The WTI and palladium shocks cause insignificant results. It should be noted that a silver SD and a gold SD cause similar results to the returns of silver. In both cases, we exhibit a sharp decrease in returns during the first period and within 7 days the SDs are absorbed. The SD on FTSE and platinum showcase the opposite results. In the case of the FTSE shock, we exhibit the highest of returns during the 2nd and 3rd, whereas the SD on platinum causes the lowest of returns during the 3rd and 4th period. Both shocks need approximately 12 days to no longer affect the main variable.

The returns of platinum are, as well, mostly affected by shocks in the SR (Figure 3.B). The shocks to WTI and palladium are insignificant. Particularly, the palladium shock causes the most negative response to the returns of platinum. A FTSE shock is significant during days 1 through 3, showcasing the highest returns. Additionally, when the returns are on the peak, we notice a sharp decrease in them, touching their lowest on day 4. As of the gold, the silver and that platinum shock they are the most significant. The gold and silver SD, have similar graphs, showcasing and increase as well as a decrease in the returns during the first 3 periods tested. Although, the gold shock needs 7-8 days to disappear, the SS needs 10. Lastly, the PLS has a similar graph to all the rest that show the response of a variable to a SD to itself.

Palladium does not have a significantly influenced by a SD on WTI (Figure 3.C). We should point out though, that the WTI SD causes the lowest returns to palladium. The returns of palladium are mostly positive in this VAR. The highest returns are caused by a SD on gold in the SR. Furthermore, the most significant effect is that of FTSE, which lasts 3 whole days. The palladium and platinum shock exhibit similar results. Showing an instant decrease in returns in the first day of the shock.

The returns of WTI exhibit alternations of increases and decreases in all cases. The SD on WTI it self is the most significant. We should also note that a SD is responsible for the lowest returns of WTI. The highest returns are when a shock on platinum is occurred.

D. VAR_4

D.1 Granger-Causality Test

Starting again with equation 1 and the main variable being the returns of the WTI we can claim that platinum and the NIKKEI225 index show Granger causality (Table 8). The significance level is at 1%. Furthermore, there is a strong influence from the variable WTI on its own. Moving forward, the second equation examines the Granger causality with the main variable being gold once again. The variable itself is strongly endogenous, since its p-value is almost zero. As for the other variables, silver can be characterized as least exogenous with a p-value close to zero, whereas the rest of them accept the null hypothesis of the Granger-Causality test. Continuing with equation 3, the main variable being silver. The variable is strongly endogenous. Furthermore, the null hypothesis is rejected as for the influence of gold to the main variable. The p-value is smaller than the 1% significance level, which makes it strongly exogenous. The NIKKEI225 could be characterized as strongly exogenous, since it has a p-value of 0.005. For all rest of the variables the p-values are greater than the 10% significance level, therefore there is no Granger cause. Moreover; the results of the equations to which the main variables are the returns of platinum and palladium, are very similar. Granger causality is appeared mostly among the precious metals. More specifically, all three variables excluding the main ones in each case, are strongly endogenous. In connection, their p-values tend to be zero. Last but certainly not least, the last equation interprets the results of the Granger-Causality test with the Japanese index as the main variable. The variable could be characterized as weakly endogenous, with a p-value of 0.05. In contrast, the returns of WTI have a greater Granger cause to the main variable, since its p-value is smaller than the 1% significance level. Additionally, this makes oil a strongly exogenous variable. The remaining of the variables have no Granger cause with the returns of the index.

D.2 Variance Decomposition

The variance decomposition for the returns of the WTI price state that 99,9% of oils returns are explained by oil itself (Table 9). Considering the rest of the variables, their percentages are minor, near zero, especially for the NIKKEI225 index. As for the returns of gold, those are, again, explained mostly from gold itself. The percentage is very high during the 10 days that are tested at the 99% degree. Furthermore, there is a slight explanation of the returns coming from silver. Specifically, it only covers 0,48% of the returns. The Japanese index has similar results as oil. The variable itself causes 99% of its returns, with a slight decrease during the time tested.

As for the rest of the variables, the logarithmic differences of silver, platinum, and palladium, the results are more complex. Beginning with silver, we can acknowledge that its returns are due to gold and silver itself mostly. It should be pointed out that gold's percentage, considering the explanation of silver's returns, is higher than silver's itself. Continuing with the variance decomposition for the returns of platinum, 78% of them are explained by platinum it self. The percentage starts at 96.4% and within a day it falls to the 78% mark. Closing with palladium, its returns' are mostly covered by the variable it self. It begins with the percentage of 72% and downgrades the second day reaching 64%. Platinum explains around 25% of palladium's returns. Besides these two percentages, we also have the returns of gold and silver playing a small role. Both these variables cover a single digit explanation for the returns of palladium. In particular, they cover 9% and 3% of the returns respectively.

D.3 Impulse Response Functions

For the NIKKEI225 index (Figure 4.C), a SD in gold, WTI and the variable itself show the most significance. Starting of with a SD to the variable itself it is acknowledged that it causes an instant decrease in the returns. The significance of the shock lasts 4 days and it needs around 9 to revert to zero. Continuing with the SD in ld_WTI, the significance lasts in the SR. It causes a gradual decrease in the returns that last approximately 4 days. The SD needs 16 days to disappear. Thirdly, a SD in gold causes a significant decrease during the 7th period, where we exhibit the lowest of returns for the index. The rest of the shocks are mostly insignificant. In particular, the silver shock causes mostly negative returns, as opposed to the palladium shock. The platinum SD is significant during periods 2 and 8, where we see positive returns of the variable. In the last 4 cases the shock need around 15-18 days to disappear.

The returns of WTI decrease significantly after a SD to the variable itself. Throughout most of the period tested the SD has a significant effect to the returns. The response of the returns on SD on the rest of the variables exhibit very steep and intense graphs. Only the SD in the NIKKEI225 index seems to have a somewhat more stable effect, since the returns are mostly positive throughout the time span tested. Furthermore, the NIKKEI SD is the most significant for the WTI returns. As opposed to NIKKEI, a SD in silver, exhibits mostly negative returns reaching the lowest mark. The lowest returns are during the 7th period of the shock. As of the gold shock, the returns are mostly positive. In particular, they are significant during the 7th period of the shock. Finally, the platinum shock causes positive significant returns only during days 3-5. All the above shocks revert to zero within 15-20 days.

The returns of gold decrease instantly after a SD in the variable itself (Figure 4.A). Furthermore, the shock is significant throughout most of the time period tested, needing approximately 10 days to revert to zero. The palladium, WTI and NIKKEI225 shock show the most intense alternations of decreases and increases in the SR. Specifically, a palladium shock cause mostly negative returns. A silver shock is once again, responsible the highest returns during the first two periods. The results are significant. In contrast, from period 2 and forward, the returns are negative and the shock reverts to zero with 15 days. Finally, the platinum SD cause the most negative returns and during the 4th period we claim the lowest of returns, which are significant.

A WTI shock does not have a significant effect to the returns of silver, versus a shock in silver itself and gold. In the latter two cases we exhibit similar graphs. A SD on these two variables, cause an instant decrease in the returns of silver. From day 2 and forward, the shock have minor effects to the returns. The silver SD need approximately 10 days to revert to zero, whereas the gold SD needs 16. The effect though is unnoticeable from day 10 and on. Shocks in the stock index and palladium show alternations of increases and decreases. The palladium shock is significant during the first period, where the returns are negative, whereas the NIKKEI shock is significant during periods 4 and 6 where we exhibit positive and negative returns respectively. The index causes the lowest returns for silver. Closing the silver returns, a platinum shock is significant during periods 3-5. The returns are negative and low at that point. Furthermore, the shock has a negative effect to the variable.

A gold and silver shock have very similar effects on the return of palladium. In the SR we exhibit a significant increase and a steep decrease in returns. Furthermore, gold causes the highest returns for palladium in the first period. A platinum and palladium shock as well cause similar effects. They are mostly significant, and in the first period they both cause a very steep decrease in returns. The WTI shock cause positive and negative returns. The significant ones are negative and are during the 3rd and 7th period of the shock. Lastly, the NIKKEI225 shock causes mostly positive returns. The latter two shocks need 15-18 days to revert to zero.

Once again, for the returns of platinum (Figure 4.B), gold and silver exhibit similar effects to the returns. Moreover; we can state that the graphs are similar to those of the return of platinum. Gold causes the highest returns during the 2nd period. The palladium shock causes a gradual decrease in the returns during the periods 2-5, while on period 7 we exhibit high and significant returns. The WTI and the NIKEEI225 shocks are mostly insignificant for the returns of platinum. Finally, a shock on the main variable itself causes a significant decrease in the first period.

E. VAR_5

E.1 Granger-Causality Test

In VAR_5 the different stock index that we are testing is the S&P500 and we have selected 6 lags for this regression based on the LR test (Table 10).

Starting of with equation 1, where the main variable is the returns of WTI. The variable itself is strongly endogenous. Furthermore, we exhibit Granger Causality with platinum and palladium. The rest of the variables accept the null hypothesis of the Granger-Causality test. Platinum is strongly exogenous, whereas palladium has a p-value of 0.10, therefore it is weakly exogenous to the returns of WTI. In equation 2, we test the Granger causality among the returns of gold and the rest of the variables. The WTI price and the palladium price, seem to not influence the returns of WTI. In contrast to that, the rest of the variables, gold silver and the S&P500 index in particular, affect the returns of gold at the 1% significance level. Platinum though is weakly exogenous to the gold returns. Silver is the only precious metals that exhibits such little Granger causality with the rest of the variables. Specifically, gold and the SOX index are the only variables that affect its returns at the 1% and 5% significance level, respectively. In contrast to silver, platinum exhibits Granger causality with all the variables, excluding the index. Moreover; all precious metals are strongly endogenous to its returns, whereas WTI affects the returns at the 10% significance level. Palladium is the only variable that shows a significant Granger causality, at the 1% significance level, with the precious metals only. Lastly, The returns of the SOX index, are only influenced by the index itself and by silver.

E.2 Variance Decomposition

As of the variance decomposition test for VAR_5 the results are very similar to all others (Table 11). WTI is 100% responsible for its returns. The influence decreases slightly throughout the period tested. It should be noted that oil is the only variable, among all, that exhibits 100% responsibility for its returns, even for a day only. Secondly, gold is as well mostly responsible for its returns. The percentage starts at 99.9%, decreases slightly until day 10 reaching the lowest,98.94%. As for the returns of silver, 52% of them is again caused by gold, whereas 47% are because of silver itself. Platinum and palladium once again showcase more complex results.

The returns of platinum are due to gold, silver and platinum itself. gold starts of with a very low percentage of only 2%, which then kicks of at 17% on day 2. It remains somewhat stable for the rest of the time span. Silver's percentage is very low as well in the beginning (0.8%), which increases throughout the rest of time. In contrast to the above, platinum causes 96% of the returns. This percentage decreases over time, reaching the 78% mark. As of the returns of palladium, 9% of them are caused by gold, 3% by silver. These remains stable over time. Palladium of course is mostly responsible for its returns (64%) and platinum reaches the 23% mark.

E.3 Impulse Response Functions

Beginning with the response of the S&P500 index to SD on the rest of the variables (Figure 5.C). We expect mostly insignificant results due to the results on the Granger-Causality test. Evidently, the results are insignificant considering a SD to WTI, gold, platinum and palladium. In all cases, the shock needs 10-15 days in order to disappear. In contrast, a SD to the main variable itself is significant thought the whole period tested. The returns exhibit very steep decrease in the beginning and for the rest of the time span they are negative until days 7-8, wen they revert to zero. The silver shock, causes alternations of decreases and increases for the 8 first days. The significant effect of the shock is during days 5-8. The shock needs 3 weeks to no longer affect the returns.

Considering the response of gold to SD (Figure 5.A), we exhibit many significant periods. First and foremost, a gold SD causes a very steep decrease in returns. Throughout the rest of the period though the results are mostly insignificant and the returns revert to zero after 7-8 days. A silver shock, we indicate the highest of returns for gold. The first two periods, are significant, whereas from day 3 and further the returns are negative and insignificant. As opposed to silver, a SD on the S&P500 index is responsible for the lowest of returns of gold. The graph in this case is mostly negative, and the significant periods are days 1 and 4-5. Furthermore, negative returns are displayed considered the platinum shock. The lowest point of the graph is when the returns are significant, during days 3 and 4. Last but not least, a SD on palladium and WTI is insignificant.

The returns of silver (Figure 5.B) are insignificantly affected by a SD on WTI and palladium. In the WTI case, we exhibit alternations of small decreases and increases of the returns. A platinum shock has a similar affect to silver as it has to the returns of gold. Moreover; a gold and silver shock have identical effects to the returns of silver as well, exhibiting a very steep decrease in the returns in the first period tested. In addition, both need the least days in order to disappear. The S&P500 SD causes steeper alternations in the returns. They are mostly negative, and we should note that during the 5th period we exhibit the least returns.

The returns of platinum (Figure 5.B) are insignificantly affected by a shock on WTI. The rest of the graphs show the most unique results in all cases. A gold and silver SD, once again influence platinum's returns in a similar way. Both are more significant in the SR showing and increase and a decrease in the first 2-3 days. Particularly, a gold shock brings the highest of returns for platinum. Furthermore, in 8 days the shock reverts to zero. The S&P500 index affects negatively the returns. During the 5th period, the returns are the lowest and most significant. Lastly, a palladium shock shows a more gradual effect to the returns and once again, a SD on the variable itself causes a steep decrease returns in the SR.

In terms of the returns of palladium (Figure 5.C), we can group the results. A SD on palladium and platinum cause the same very steep decrease in returns during the 1st period. Furthermore, The shock need 8 days to disappear. A shock in silver and gold, is significant during periods 1 and 2. Both need around 10 days to disappear. In addition, a shock in gold causes the highest of returns for palladium. Lastly, the SD on WTI and the index showcase the least significant results. Furthermore, the returns are mostly negative.

Ending with the returns of WTI (Figure 5.A), affected by shocks on the rest of the variables. The graphs considering the response of ld_WTI to a shock in the index, palladium and platinum are the most intense. We exhibit the most steep alternations of increases and decreases in the returns. We should note that they are mostly negative due to the index shock, and they are the highest during the 4th period due to the platinum shock. A gold shock causes significant and high returns during the 3rd period of the shock whereas a silver shock causes negative returns on the same period. The response of WTI to a shock on itself isa similar to all other cases, where the shock occurs on the main variable.

TABLE 1 (below)

SUMMARY OF THE GRANGER CAUSALITY TEST RESULTS

GRANGER CAUSALITY TEST RESULTS			
Null Hypothesis	**F-Statistic**	**P-value**	**Decision on causality**
VAR_1			
WTI has no Granger causality with WTI	7.1718	0.0000	causality
WTI has no Granger causality with gold Gold has no Granger causality with WTI	1.4097 0.67845	0.19 0.69	no causality no causality
WTI has no Granger causality with silver Silver has no Granger causality with WTI	1.1379 0.3597	0.33 0.92	no causality no causality
WTI has no Granger causality with platinum Platinum has no Granger causality with WTI	3.9058 1.9235	0.0003 0.0617	causality causality
WTI has no Granger causality with palladium Palladium has no Granger causality with WTI	2.1544 1.4801	0.0351 0.1692	causality no causality
WTI has no Granger causality with CAC40 CAC40 has no Granger causality with WTI	1.1126 1.1381	0.35 0.3357	no causality no causality
Gold has no Granger causality with gold	8.13	0.000	causality
Gold has no Granger causality with silver Silver has no Granger causality with gold	5.47 3.18	0.000 0.0023	causality causality
Gold has no Granger causality with platinum Platinum has no Granger causality with gold	1.538 32.536	0.1493 0.0000	no causality causality
Gold has no Granger causality with palladium Palladium has no Granger causality with gold	1.4129 10.357	0.1951 0.0000	no causality causality
Gold has no Granger causality with CAC40 CAC40 has no Granger causality with gold	2.0144 1.1882	0.0496 0.3056	causality no causality
Silver has no Granger causality with silver	2.6951	0.0087	causality
Silver has no Granger causality with platinum Platinum has no Granger causality with silver	1.6014 45.803	0.12 0.0000	no causality causality
Silver has no Granger causality with palladium Palladium has no Granger causality with silver	1.2972 31.920	0.2471 0.0000	no causality causality
Silver has no Granger causality with CAC40 CAC40 has no Granger causality with silver	2.9087 1.2792	0.0049 0.2561	causality no causality
Platinum has no Granger causality with platinum	9.1803	0.0000	causality
Platinum has no Granger causality with palladium Palladium has no Granger causality with platinum	3.618 4.1587	0.0007 0.0001	causality causality
Platinum has no Granger causality with CAC40 CAC40 has no Granger causality with platinum	4.4625 0.9693	0.0001 0.4517	causality no causality
Palladium has no Granger causality with palladium	4.5379	0.0000	causality
Palladium has no Granger causality with CAC40 CAC40 has no Granger causality with palladium	4.0043 5.4785	0.0002 0.0000	causality no causality
CAC40 has no Granger causality with CAC40	5.4785	0.0000	causality

GRANGER CAUSALITY TEST RESULTS			
VAR_2			
WTI has no Granger causality with WTI	8.2341	0.0000	causality
WTI has no Granger causality with gold	1.6696	0.1241	no causality
Gold has no Granger causality with WTI	0.64372	0.6953	no causality
WTI has no Granger causality with silver	1.289	0.2584	no causality
Silver has no Granger causality with WTI	0.17316	0.9841	no causality
WTI has no Granger causality with platinum	3.9966	0.0005	causality
Platinum has no Granger causality with WTI	2.0789	0.0523	causality
WTI has no Granger causality with palladium	1.7625	0.1026	no causality
Palladium has no Granger causality with WTI	1.2783	0.2634	no causality
WTI has no Granger causality with DJIA	1.9824	0.0645	causality
DJIA has no Granger causality with WTI	1.4286	0.1993	no causality
Gold has no Granger causality with gold	8.2210	0.0000	causality
Gold has no Granger causality with silver	6.2719	0.0000	causality
Silver has no Granger causality with gold	2.9025	0.0079	causality
Gold has no Granger causality with platinum	1.8947	0.0778	causality
Platinum has no Granger causality with gold	35.697	0.0000	causality
Gold has no Granger causality with palladium	1.5267	0.1649	no causality
Palladium has no Granger causality with gold	11.073	0.0000	causality
Gold has no Granger causality with DJIA	3.3484	0.0027	causality
DJIA has no Granger causality with gold	0.77070	0.5929	no causality
Silver has no Granger causality with silver	1.5816	0.1480	no causality
Silver has no Granger causality with platinum	1.5874	0.1463	no causality
Platinum has no Granger causality with silver	55.512	0.0000	causality
Silver has no Granger causality with palladium	1.2076	0.2989	no causality
Palladium has no Granger causality with silver	39.297	0.0000	causality
Silver has no Granger causality with DJIA	3.0302	0.0058	causality
DJIA has no Granger causality with silver	0.50822	0.8026	no causality
Platinum has no Granger causality with platinum	10.594	0.0000	causality
Platinum has no Granger causality with palladium	4.1029	0.0004	causality
Palladium has no Granger causality with platinum	4.9043	0.0001	causality
Platinum has no Granger causality with DJIA	1.7593	0.1033	no causality
DJIA has no Granger causality with platinum	0.83798	0.5403	no causality
Palladium has no Granger causality with palladium	5.1665	0.0000	causality
Palladium has no Granger causality with DJIA	1.1681	0.3202	no causality
DJIA has no Granger causality with palladium	0.62696	0.7089	no causality
DJIA has no Granger causality with DJIA	12.661	0.0000	causality

GRANGER CAUSALITY TEST RESULTS			
VAR_3			
WTI has no Granger causality with WTI	8.9687	0.0000	causality
WTI has no Granger causality with gold	1.4592	0.1997	no causality
Gold has no Granger causality with WTI	0.82000	0.0000	no causality
WTI has no Granger causality with silver	1.3892	0.2248	no causality
Silver has no Granger causality with WTI	0.19074	0.9662	no causality
WTI has no Granger causality with platinum	4.849	0.0002	causality
Platinum has no Granger causality with WTI	2.2028	0.0512	causality
WTI has no Granger causality with palladium	2.254	0.0464	causality
Palladium has no Granger causality with WTI	1.4824	0.1919	no causality
WTI has no Granger causality with FTSE	1.2405	0.2871	no causality
FTSE has no Granger causality with WTI	0.64079	0.6686	no causality
Gold has no Granger causality with gold	9.5187	0.0000	causality
Gold has no Granger causality with silver	7.5232	0.0000	causality
Silver has no Granger causality with gold	3.2708	0.0059	causality
Gold has no Granger causality with platinum	2.4231	0.0333	causality
Platinum has no Granger causality with gold	44.788	0.0000	causality
Gold has no Granger causality with palladium	1.8178	0.1057	no causality
Palladium has no Granger causality with gold	14.208	0.0000	causality
Gold has no Granger causality with FTSE	0.67919	0.6392	no causality
FTSE has no Granger causality with gold	2.0173	0.0729	causality
Silver has no Granger causality with silver	2.2313	0.0485	causality
Silver has no Granger causality with platinum	2.012	0.0737	causality
Platinum has no Granger causality with silver	64.181	0.0000	causality
Silver has no Granger causality with palladium	1.3428	0.2429	no causality
Palladium has no Granger causality with silver	44.752	0.0000	causality
Silver has no Granger causality with FTSE	4.8751	0.0002	causality
FTSE has no Granger causality with silver	2.1771	0.0538	causality
Platinum has no Granger causality with platinum	12.186	0.0000	causality
Platinum has no Granger causality with palladium	3.2941	0.0057	causality
Palladium has no Granger causality with platinum	4.8925	0.0002	causality
Platinum has no Granger causality with FTSE	6.5682	0.0000	causality
FTSE has no Granger causality with platinum	2.1409	0.0577	causality
Palladium has no Granger causality with palladium	5.0517	0.0001	causality
Palladium has no Granger causality with FTSE	4.04	0.0012	causality
FTSE has no Granger causality with palladium	1.9137	0.0886	causality
FTSE has no Granger causality with FTSE	9.1903	0.0000	causality

GRANGER CAUSALITY TEST RESULTS

VAR_4			
WTI has no Granger causality with WTI	6.6924	0.0000	causality
WTI has no Granger causality with gold Gold has no Granger causality with WTI	2.4172 1.0682	0.0132 0.3822	causality no causality
WTI has no Granger causality with silver Silver has no Granger causality with WTI	1.5574 0.54958	0.1321 0.8196	no causality no causality
WTI has no Granger causality with platinum Platinum has no Granger causality with WTI	3.5135 1.8361	0.0005 0.0657	causality causality
WTI has no Granger causality with palladium Palladium has no Granger causality with WTI	2.0151 1.4100	0.0408 0.1865	causality no causality
WTI has no Granger causality with NIKKEI225 NIKKEI225 has no Granger causality with WTI	2.9116 3.5041	0.003 0.0005	causality causality
Gold has no Granger causality with gold	7.7987	0.0000	causality
Gold has no Granger causality with silver Silver has no Granger causality with gold	5.1633 3.4020	0.0000 0.0007	causality causality
Gold has no Granger causality with platinum Platinum has no Granger causality with gold	1.4106 27.783	0.1863 0.0000	no causality causality
Gold has no Granger causality with palladium Palladium has no Granger causality with gold	1.2881 8.6298	0.2445 0.0000	no causality causality
Gold has no Granger causality with NIKKEI225 NIKKEI225 has no Granger causality with gold	1.4023 1.3562	0.1898 0.2105	no causality no causality
Silver has no Granger causality with silver	3.1102	0.0016	causality
Silver has no Granger causality with platinum Platinum has no Granger causality with silver	1.3325 41.670	0.2219 0.0000	no causality causality
Silver has no Granger causality with palladium Palladium has no Granger causality with silver	1.152 29.440	0.3246 0.0000	no causality causality
Silver has no Granger causality with NIKKEI225 NIKKEI225 has no Granger causality with silver	1.8724 1.0745	0.0597 0.3776	causality no causality
Platinum has no Granger causality with platinum	8.0991	0.0000	causality
Platinum has no Granger causality with palladium Palladium has no Granger causality with platinum	3.1839 3.5859	0.0013 0.0004	causality causality
Platinum has no Granger causality with NIKKEI225 NIKKEI225 has no Granger causality with platinum	0.90481 0.97111	0.5112 0.4565	no causality no causality
Palladium has no Granger causality with palladium	4.0227	0.0001	causality
Palladium has no Granger causality with NIKKEI225 NIKKEI225 has no Granger causality with palladium	1.2792 0.79978	0.2492 0.6027	no causality no causality
NIKKEI225 has no Granger causality with NIKKEI225	1.9290	0.0514	causality

GRANGER CAUSALITY TEST RESULTS			
VAR_5			
WTI has no Granger causality with WTI	8.1582	0.0000	causality
WTI has no Granger causality with gold	1.6725	0.1233	no causality
Gold has no Granger causality with WTI	0.62881	0.7074	no causality
WTI has no Granger causality with silver	1.2342	0.2851	no causality
Silver has no Granger causality with WTI	0.14796	0.9895	no causality
WTI has no Granger causality with platinum	3.8963	0.0007	causality
Platinum has no Granger causality with WTI	2.0147	0.0602	causality
WTI has no Granger causality with palladium	1.7495	0.1054	no causality
Palladium has no Granger causality with WTI	1.2226	0.2910	no causality
WTI has no Granger causality with S&P500	1.6716	0.1236	no causality
S&P500 has no Granger causality with WTI	1.0098	0.4167	no causality
Gold has no Granger causality with gold	8.2902	0.0000	causality
Gold has no Granger causality with silver	6.4348	0.0000	causality
Silver has no Granger causality with gold	2.8833	0.0083	causality
Gold has no Granger causality with platinum	1.9021	0.0766	causality
Platinum has no Granger causality with gold	35.839	0.0000	causality
Gold has no Granger causality with palladium	1.5049	0.1721	no causality
Palladium has no Granger causality with gold	11.146	0.0000	causality
Gold has no Granger causality with S&P500	3.2935	0.0031	causality
S&P500 has no Granger causality with gold	1.1502	0.3302	no causality
Silver has no Granger causality with silver	1.5793	0.1487	no causality
Silver has no Granger causality with platinum	1.6144	0.1387	no causality
Platinum has no Granger causality with silver	55.552	0.0000	causality
Silver has no Granger causality with palladium	1.2092	0.298	no causality
Palladium has no Granger causality with silver	39.473	0.0000	causality
Silver has no Granger causality with S&P500	2.7395	0.0117	causality
S&P500 has no Granger causality with silver	1.9441	0.0700	causality
Platinum has no Granger causality with platinum	10.481	0.0000	causality
Platinum has no Granger causality with palladium	4.0385	0.0005	causality
Palladium has no Granger causality with platinum	0.41550	0.8692	causality
Platinum has no Granger causality with S&P500	1.4062	0.2079	no causality
S&P500 has no Granger causality with platinum	0.41550	0.8692	no causality
Palladium has no Granger causality with palladium	0.87347	0.5134	causality
Palladium has no Granger causality with S&P500	1.3132	0.2472	no causality
S&P500 has no Granger causality with palladium	0.87347	0.5134	no causality
S&P500 has no Granger causality with S&P500	13.761	0.0000	causality

6. Inverse Roots

Ending our regressions, the VAR inverse roots test was employed in order to check the stability of the VARs (Figures 6-9). This test provides the inverse roots of the characteristic polynomials both in graph and table. In this study, I used the graph option. The estimated VARs are stationary if all roots of the VARs lay in the unit circle. As we can see from the graphs, all roots are inside the unit circle, which means that all VARs are stationary and correct. Furthermore, the IRFs are valid.

7. Comparison To Other Studies

As stated before the relationship among the oil prices, the prices of precious metals and the stock market is a subject that has concerned economists for many years and still to this day the empirical studies are not enough to interpret that relationship. Furthermore, not many studies are analyzing the same period that is covered in this study (1990-2021). Although, K.S. Sujit and B. Rajesh Kumar (2011) study the dynamic relationship among the gold price, the oil price, exchange rate and stock market returns and they cover the period from January 2nd, 1998 to June 5th, 2011. They showed that gold has a positive favorable impact to a shock in the WTI whereas all remaining impacts are minor. Similarly the WTI response to a shock in gold has a favorable effect and it lasts for more days with lots of variations. In the study presented by this paper, the results are similar. The response of gold and WTI to shocks on each other exhibit mostly positive returns, as well as variations to them during the shock. That days that that shocks last are the same with the rest of the variables though. Moreover; they particularly mention the S&P500 index and state that its response to a shock in WTI is also favorable. In contrast, this study provides the opposite results, as a SD to WTI has a negative effect for the returns of the index. Considering Sujit's and Kumar's variance decomposition tests they claim that WTI explains only 2,4% of gold's returns whereas in this study WTI explains much less of the returns of gold (maximum of 0.05%). The two studies agree that the returns of gold and WTI are mostly explained by the variables themselves, since the rest of the variables claim a percent below 1. As for the returns of the S&P500 index, the two studies agree again that most of them are caused by the variable it self.

In addition, another study that examines similar topics with this one is that of Jonathan A. Batten, Cetin Ciner and Brian M. Lucey (2015). They also confirmed that gold and silver share the closest relationship. From their variance decomposition test the resulted that gold accounts for

27.7% of silver's returns and is responsible for much less of a percentage for platinum and palladium. These results are in contrast with the results in this analysis, since gold claims 52% of silver's returns, 17.3% of platinum's and 9% for palladium's. For silver, the two studies showcase different results as well. Silver does not affect gold's returns that much whereas the percentages it claims for the returns of platinum and palladium are higher than the ones Batten, Ciner and Lucey show. Furthermore, they state that platinum and palladium are mostly insulated to each other whereas in this analysis, it is exhibited that the returns of platinum and palladium are accounted by most of the precious metals.

The study of Stavros Degiannakis, George Filis and Christos Floros examines the correlation between the stock market and oil prices. At the begging, they state that any oil price increase should be accompanied by a decrease in the stock prices, since oil price fluctuations create uncertainty to the financial world depending on the nature of the shock. Later on, on their paper they signify that it is important to examine the origin of the oil shock that is accuring. A demand-side shock in oil has a different effect to the stock markets than a supply-side shock. Lee and Chiou(2011) examined the relationship between the WTI prices and the S&P500 returns. They concluded that significant fluctuations in oil prices lead to negative impacts to the returns of the index. Moreover; Cifarelli and Paladino (2010) state that oil price shifts are negatively related to stock prices in general. Apergis and Miller (2009) on the other hand, concluded that stock markets tend to not react to oil price shocks.

8. Conclusions

The dependence of the world economy on oil has been major for many years and its behavior has attracted many economists. Oil is an irreplaceable commodity and an important factor to the economy because of its multipurpose use. Oil prices have traditionally been more volatile than other commodity prices since World War II. Throughout the years of 1990 till 2021, oil has been majorly affected by macroeconomic activities. Many Global Financial Crises (GFC) occurred during these years, etc. the 1990 crisis, the 2008 US crisis, the 2020 Covid-19 case have dramatically affected the prices of crude oil. Moreover; in 2014 an issue accused that had to do with the denial of Saudi Arabia on cutting back their production of oil. This resulted to having major supply of oil in the market with not big demand, concluding that the prices crashed. After 1986, oil price movements explain a larger fraction of the forecast error variance in real stock returns. Evidence also support that oil price volatility has asymmetric effects to the economy.

It is widely known that oil, the stock market and gold are three interconnected parameters that move the whole economy and are known for being sister markets. Anything that happens to each of these parameters affects the rest. Even though this has been happening throughout many years there has not been a single pattern of these effects because prices are non-linear structures. Moreover; there have not been enough studies evolving the relationship between oil prices, precious metals prices and the stock market. Particularly, for the years of 1990 till 2021 the studies are even less.

Due to the level of volatility in the pricing of oil, many investors turn to the precious metal market in order to protect their investments. They either want to gain more returns or just balance their loses due to oil. Particularly, gold and silver are considered safe havens when the economy is going through turmoils. As a result, the prices of these particular metals go up during these periods. Platinum and palladium play a secondary role in this case. These are metals that are mostly used in order to diversify the investors' portfolios and not as much to gain returns.

In this particular analysis the interdependence among the prices of precious metals, the oil price and the stock market is examined. The variables tested were the WTI price, the gold, silver, platinum and palladium prices as well as the CAC40, DJIA, FTSE, NIKKEI225 and the S&P500 indexes. The prices were daily and covered the years from 1990 till 2021. Granger causality tests are employed, as well as variance decompositions and impulse response functions are checked.

It is clear form the variance decomposition testing that gold and oil returns, as well as the returns of the stock indexes are largely dependent on the variables themselves. In contrast, a SD in these variables affect each other. The Granger causality tests showed that almost all stock markets indexes show Granger causality with themselves. In contrast, the FTSE index shows Granger causality with all variables except the oil price, and NIKKEI225 shows Granger causality with it self and oil. On the precious metals spectrum , gold and silver show Granger causality among each other and platinum, whereas platinum and palladium showcase Granger causality among all precious metals. Moreover; silver is the only precious metals that has Granger causality with all the indexes, particularly at the 1% significance level. Last but not least, oil has Granger causality with platinum and palladium only and DJIA and NIKKEI225. We were expecting a more significant interdependence with the rest of the indexes though.

As we can see from the impulse response functions a shock in the oil price causes low and negative returns of the indexes. Economic theory supports that in this case the economy is going through a crisis because both stocks and the oil returns are falling. Sometimes though, that can be false. Furthermore, in periods like these, people are attracted to gold in particular, or other precious metals, so higher prices in the precious metal markets might be exhibited. On the other hand, when stock markets are going through shocks we exhibit similar results in the returns of oil. Mostly the returns are low and negative. The only case, where we exhibit some positive returns of oil are those of the NIKKEI225 shock and the S&P500 shock. Concluding, it is noticed that when the stock market prices are falling the same things happen to oil prices as well.

In the case where the effect of the precious metals to the stock market is examined the results are somewhat similar. Any SD on gold, silver, platinum or palladium causes lower and negative returns to most stock market indexes. In particular, the only index that shows positive and a rise in its returns is the DJIA when a SD on silver occurs. Furthermore, the FTSE and the S&P500 indexes exhibit positive returns after some days from the shock. In general, all effects are mostly showcased in the SR in all cases.

REFERENCES

Al-Yahyaee, K. H., Mensi, W., Sensoy, A., & Kang, S. H. (2019). Energy, precious metals, and GCC stock markets: Is there any risk spillover?. Pacific-Basin Finance Journal, 56, 45-70.

Apergis, N., & Miller, S. M. (2009). Do structural oil-market shocks affect stock prices?. Energy economics, 31(4), 569-575.

Bampinas G. & Panagiotidis T., 2015. "On the relationship between oil and gold before and after financial crisis: linear, nonlinear and time-varying causality testing," Studies in Nonlinear Dynamics & Econometrics, vol. 19(5), pages 657-668, December.

Batten, J. A., Ciner, C., & Lucey, B. M. (2010). The macroeconomic determinants of volatility in precious metals markets. Resources Policy, 35(2), 65-71.

Batten, J. A., Ciner, C., & Lucey, B. M. (2015). Which precious metals spill over on which, when and why? Some evidence. Applied Economics Letters, 22(6), 466-473.

Cifarelli, G., & Paladino, G. (2010). Oil price dynamics and speculation: A multivariate financial approach. Energy economics, 32(2), 363-372.

Choi, K., & Hammoudeh, S. (2010). Volatility behavior of oil, industrial commodity and stock markets in a regime-switching environment. Energy policy, 38(8), 4388-4399.

Churchill, S. A., Inekwe, J., Ivanovski, K., & Smyth, R. (2019). Dynamics of oil price, precious metal prices and the exchange rate in the long-run. Energy Economics, 84, 104508.

Fayyad, A., & Daly, K. (2011). The impact of oil price shocks on stock market returns: comparing GCC countries with the UK and USA. Emerging Markets Review, 12(1), 61-78.

Filis, G., Degiannakis, S., & Floros, C. (2011). Dynamic correlation between stock market and oil prices: The case of oil-importing and oil-exporting countries. International review of financial analysis, 20(3), 152-164.

Gokmenoglu, K. K., & Fazlollahi, N. (2015). The interactions among gold, oil, and stock market: Evidence from S&P500. Procedia Economics and Finance, 25, 478-488.

Hatemi-J, A., & S. Hacker, R. (2009). Can the LR test be helpful in choosing the optimal lag order in the VAR model when information criteria suggest different lag orders?. Applied Economics, 41(9), 1121-1125.

Jain, A., & Ghosh, S. (2013). Dynamics of global oil prices, exchange rate and precious metal prices in India. Resources Policy, 38(1), 88-93.

Jones, C. M., & Kaul, G. (1996). Oil and the stock markets. The journal of Finance, 51(2), 463-491.

Kilian, L., & Park, C. (2009). The impact of oil price shocks on the US stock market. International Economic Review, 50(4), 1267-1287.

Kucher, O., & McCoskey, S. (2017). The long-run relationship between precious metal prices and the business cycle. The Quarterly Review of Economics and Finance, 65, 263-275.
Lee, Y-H., & Chiou, J-S. (2011). Oil sensitivity and its asymmetric impact on the stock market. Energy, 36, 168-174.

Mensi, W., Al-Yahyaee, K. H., & Kang, S. H. (2017). Time-varying volatility spillovers between stock and precious metal markets with portfolio implications. Resources Policy, 53, 88-102.

Miller, J. I., & Ratti, R. A. (2009). Crude oil and stock markets: Stability, instability, and bubbles. Energy economics, 31(4), 559-568.

Sadorsky, P. (1999). Oil price shocks and stock market activity. Energy economics, 21(5), 449-469.

Smyth, R., & Narayan, P. K. (2018). What do we know about oil prices and stock returns?. International Review of Financial Analysis, 57, 148-156.

Sukcharoen, K., Zohrabyan, T., Leatham, D., & Wu, X. (2014). Interdependence of oil prices and stock market indices: A copula approach. Energy Economics, 44, 331-339.

Sujit, K. S., & Kumar, B. R. (2011). Study on dynamic relationship among gold price, oil price, exchange rate and stock market returns. International journal of applied business and economic research, 9(2), 145-165.

Tweneboah, G., & Alagidede, P. (2018). Interdependence structure of precious metal prices: A multi-scale perspective. Resources Policy, 59, 427-434.

Yıldırım, D. Ç., Cevik, E. I., & Esen, Ö. (2020). Time-varying volatility spillovers between oil prices and precious metal prices. Resources Policy, 68, 101783.

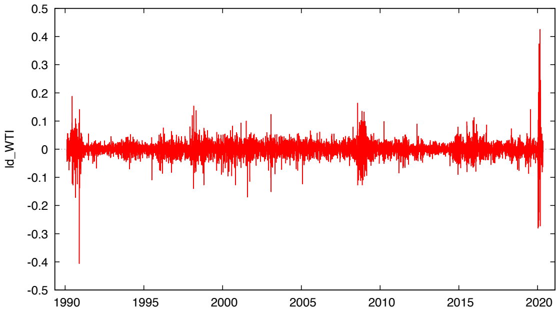
Widad, M., & Hadjer, B. (2018). Causal relationship between Islamic bonds, oil price and precious metals: evidence from Asia pacific. Al-Iqtishad Journal of Islamic Economics, 10(2), 285-298.

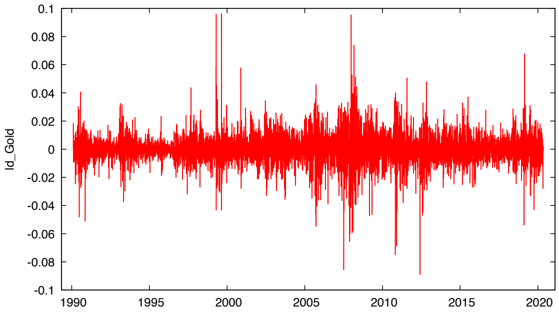
https://www.lbma.org.uk/prices-and-data/precious-metal-prices#/

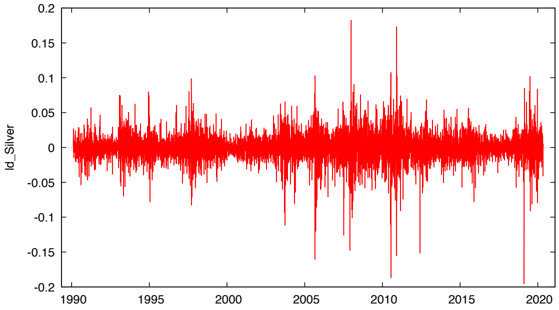
https://fred.stlouisfed.org/

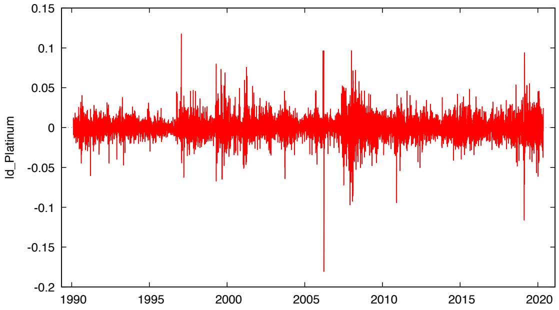
https://www.wsj.com/market-data

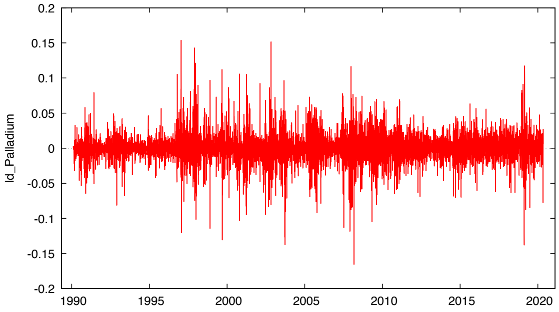
PLOTS

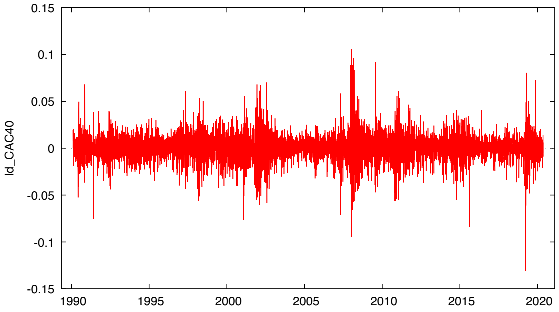

ld_WTI
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
1990
1995
2000
2005
2010
2015
2020

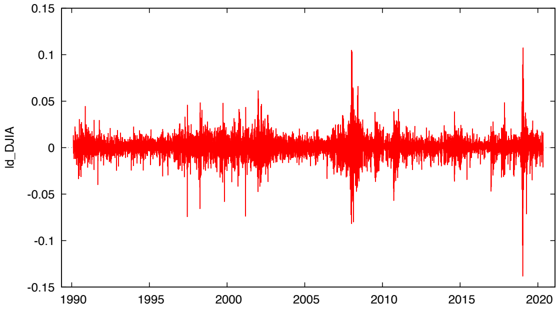

ld_Gold
0.1
0.08
0.06
0.04
0.02
0
-0.02
-0.04
-0.06
-0.08
-0.1
1990
1995
2000
2005
2010
2015
2020

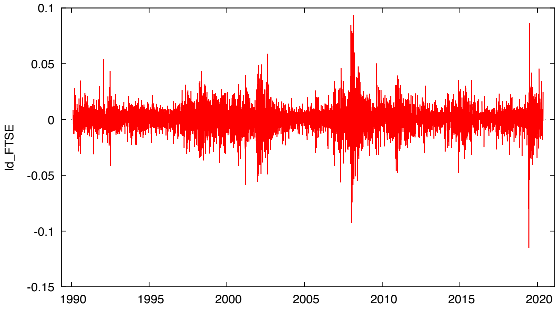

ld_Silver
0.2
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
1990
1995
2000
2005
2010
2015
2020

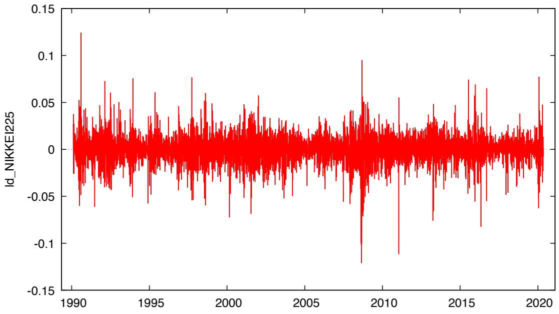

ld_Platinum
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
1990
1995
2000
2005
2010
2015
2020

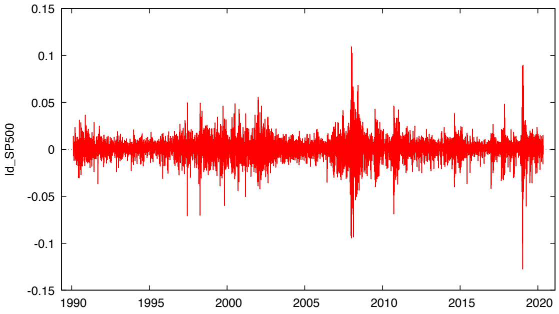

ld_Palladium
0.2
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
1990
1995
2000
2005
2010
2015
2020


ld_CAC40
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
1990
1995
2000
2005
2010
2015
2020


ld_DJIA
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
1990
1995
2000
2005
2010
2015
2020


ld_FTSE
0.1
0.05
0
-0.05
-0.1
-0.15
1990
1995
2000
2005
2010
2015
2020


ld_NIKKEI225
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
1990
1995
2000
2005
2010
2015
2020


ld_SP500
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
1990
1995
2000
2005
2010
2015
2020

ADF TESTS

```
Augmented Dickey-Fuller test for ld_WTI
testing down from 35 lags, criterion AIC
sample size 7872
unit-root null hypothesis: a = 1

  test with constant
  including 21 lags of (1-L)ld_WTI
  model: (1-L)y = b0 + (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -0.884373
  test statistic: tau_c(1) = -16.5055
  asymptotic p-value 1.896e-39
  1st-order autocorrelation coeff. for e: -0.000
  lagged differences: F(21, 7849) = 5.749 [0.0000]
```

```
Augmented Dickey-Fuller test for ld_Silver
testing down from 35 lags, criterion AIC
sample size 7892
unit-root null hypothesis: a = 1

  test with constant
  including 0 lags of (1-L)ld_Silver
  model: (1-L)y = b0 + (a-1)*y(-1) + e
  estimated value of (a - 1): -1.06764
  test statistic: tau_c(1) = -95.0534
  p-value 0.0001
  1st-order autocorrelation coeff. for e: -0.000
```

```
Augmented Dickey-Fuller test for ld_Palladium
testing down from 35 lags, criterion AIC
sample size 7891
unit-root null hypothesis: a = 1

  test with constant
  including 2 lags of (1-L)ld_Palladium
  model: (1-L)y = b0 + (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -0.971592
  test statistic: tau_c(1) = -51.8054
  asymptotic p-value 0.0001
  1st-order autocorrelation coeff. for e: 0.000
  lagged differences: F(2, 7887) = 3.445 [0.0319]
```

```
Augmented Dickey-Fuller test for ld_DJIA
testing down from 35 lags, criterion AIC
sample size 7860
unit-root null hypothesis: a = 1

  test with constant
  including 33 lags of (1-L)ld_DJIA
  model: (1-L)y = b0 + (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -1.25726
  test statistic: tau_c(1) = -16.7505
  asymptotic p-value 4.196e-40
  1st-order autocorrelation coeff. for e: -0.000
  lagged differences: F(33, 7825) = 4.049 [0.0000]
```

```
Augmented Dickey-Fuller test for ld_NIKKEI225
testing down from 35 lags, criterion AIC
sample size 7891
unit-root null hypothesis: a = 1

  test with constant
  including 2 lags of (1-L)ld_NIKKEI225
  model: (1-L)y = b0 + (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -1.06762
  test statistic: tau_c(1) = -53.6788
  asymptotic p-value 0.0001
  1st-order autocorrelation coeff. for e: 0.000
  lagged differences: F(2, 7887) = 4.148 [0.0158]
```

```
Augmented Dickey-Fuller test for ld_Gold
testing down from 35 lags, criterion AIC
sample size 7869
unit-root null hypothesis: a = 1

  test with constant
  including 24 lags of (1-L)ld_Gold
  model: (1-L)y = b0 + (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -1.14752
  test statistic: tau_c(1) = -19.413
  asymptotic p-value 2.745e-46
  1st-order autocorrelation coeff. for e: -0.000
  lagged differences: F(24, 7843) = 2.788 [0.0000]
```

```
Augmented Dickey-Fuller test for ld_Platinum
testing down from 35 lags, criterion AIC
sample size 7870
unit-root null hypothesis: a = 1

  test with constant
  including 23 lags of (1-L)ld_Platinum
  model: (1-L)y = b0 + (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -1.03263
  test statistic: tau_c(1) = -18.757
  asymptotic p-value 6.154e-45
  1st-order autocorrelation coeff. for e: -0.000
  lagged differences: F(23, 7845) = 2.380 [0.0002]
```

```
Augmented Dickey-Fuller test for ld_CAC40
testing down from 35 lags, criterion AIC
sample size 7888
unit-root null hypothesis: a = 1

  test with constant
  including 5 lags of (1-L)ld_CAC40
  model: (1-L)y = b0 + (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -1.11495
  test statistic: tau_c(1) = -39.0331
  asymptotic p-value 2.392e-24
  1st-order autocorrelation coeff. for e: 0.000
  lagged differences: F(5, 7881) = 7.193 [0.0000]
```

```
Augmented Dickey-Fuller test for ld_FTSE
testing down from 35 lags, criterion AIC
sample size 7887
unit-root null hypothesis: a = 1

  test with constant
  including 6 lags of (1-L)ld_FTSE
  model: (1-L)y = b0 + (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -1.12334
  test statistic: tau_c(1) = -35.4052
  asymptotic p-value 8.66e-36
  1st-order autocorrelation coeff. for e: -0.000
  lagged differences: F(6, 7879) = 11.426 [0.0000]
```

```
Augmented Dickey-Fuller test for ld_SP500
testing down from 35 lags, criterion AIC
sample size 7860
unit-root null hypothesis: a = 1

  test with constant
  including 33 lags of (1-L)ld_SP500
  model: (1-L)y = b0 + (a-1)*y(-1) + ... + e
  estimated value of (a - 1): -1.22953
  test statistic: tau_c(1) = -16.1327
  asymptotic p-value 1.991e-38
  1st-order autocorrelation coeff. for e: 0.000
  lagged differences: F(33, 7825) = 3.943 [0.0000]
```

TABLE 2
GRANGER-CAUSALITY TEST VAR_1

```
VAR system, lag order 7
OLS estimates, observations 1990-02-16-2020-05-08 (T = 7886)
Log-likelihood = 133435.57
Determinant of covariance matrix = 8.0935325e-23
AIC = -33.7757
BIC = -33.5476
HQC = -33.6976
Portmanteau test: LB(48) = 2059.52, df = 1476 [0.0000]

Equation 1: ld_WTI

Mean dependent var   0.000084   S.D. dependent var   0.026237
Sum squared resid    5.348945   S.E. of regression   0.026115
R-squared            0.014532   Adjusted R-squared   0.009255
F(42, 7843)          2.753778   P-value(F)           1.00e-08
rho                  0.000692   Durbin-Watson        1.998421

F-tests of zero restrictions:

All lags of ld_WTI         F(7, 7843) =   7.1718 [0.0000]
All lags of ld_Gold        F(7, 7843) =   1.4097 [0.1964]
All lags of ld_Silver      F(7, 7843) =   1.1379 [0.3358]
All lags of ld_Platinum    F(7, 7843) =   3.9058 [0.0003]
All lags of ld_Palladium   F(7, 7843) =   2.1544 [0.0351]
All lags of ld_CAC40       F(7, 7843) =   1.1126 [0.3518]
All vars, lag 7            F(6, 7843) =  0.95378 [0.4550]

Equation 2: ld_Gold

Mean dependent var   0.000198   S.D. dependent var   0.010063
Sum squared resid    0.787293   S.E. of regression   0.010019
R-squared            0.014014   Adjusted R-squared   0.008733
F(42, 7843)          2.654053   P-value(F)           3.88e-08
rho                  0.000948   Durbin-Watson        1.998082

F-tests of zero restrictions:

All lags of ld_WTI         F(7, 7843) =  0.67845 [0.6905]
All lags of ld_Gold        F(7, 7843) =   8.1380 [0.0000]
All lags of ld_Silver      F(7, 7843) =   5.4731 [0.0000]
All lags of ld_Platinum    F(7, 7843) =   1.5380 [0.1493]
All lags of ld_Palladium   F(7, 7843) =   1.4129 [0.1951]
All lags of ld_CAC40       F(7, 7843) =   2.0144 [0.0496]
All vars, lag 7            F(6, 7843) =   2.2993 [0.0321]
```

```
Equation 3: ld_Silver
Mean dependent var   0.000208   S.D. dependent var   0.018823
Sum squared resid    2.754767   S.E. of regression   0.018741
R-squared            0.013904   Adjusted R-squared   0.008623
F(42, 7843)          2.632978   P-value(F)           5.15e-08
rho                  0.001033   Durbin-Watson        1.997914
F-tests of zero restrictions:

All lags of ld_WTI         F(7, 7843) =  0.35974 [0.9257]
All lags of ld_Gold        F(7, 7843) =   3.1825 [0.0023]
All lags of ld_Silver      F(7, 7843) =   2.6951 [0.0087]
All lags of ld_Platinum    F(7, 7843) =   1.6014 [0.1299]
All lags of ld_Palladium   F(7, 7843) =   1.2972 [0.2471]
All lags of ld_CAC40       F(7, 7843) =   2.9087 [0.0049]
All vars, lag 7            F(6, 7843) =   2.2953 [0.0324]

Equation 4: ld_Platinum
Mean dependent var   0.000104   S.D. dependent var   0.013919
Sum squared resid    1.221203   S.E. of regression   0.012478
R-squared            0.200622   Adjusted R-squared   0.196341
F(42, 7843)          46.86619   P-value(F)           0.000000
rho                  0.000148   Durbin-Watson        1.999578

F-tests of zero restrictions:

All lags of ld_WTI         F(7, 7843) =   1.9235 [0.0617]
All lags of ld_Gold        F(7, 7843) =   32.536 [0.0000]
All lags of ld_Silver      F(7, 7843) =   45.803 [0.0000]
All lags of ld_Platinum    F(7, 7843) =   9.1803 [0.0000]
All lags of ld_Palladium   F(7, 7843) =   3.6180 [0.0007]
All lags of ld_CAC40       F(7, 7843) =   4.4625 [0.0001]
All vars, lag 7            F(6, 7843) =  0.55846 [0.7637]

Equation 5: ld_Palladium
Mean dependent var   0.000384   S.D. dependent var   0.020058
Sum squared resid    2.786156   S.E. of regression   0.018848
R-squared            0.121696   Adjusted R-squared   0.116993
F(42, 7843)          25.87405   P-value(F)           1.7e-186
rho                 -0.000029   Durbin-Watson        2.000044

F-tests of zero restrictions:

All lags of ld_WTI         F(7, 7843) =   1.4801 [0.1692]
All lags of ld_Gold        F(7, 7843) =   10.357 [0.0000]
All lags of ld_Silver      F(7, 7843) =   31.920 [0.0000]
All lags of ld_Platinum    F(7, 7843) =   4.1587 [0.0001]

All lags of ld_Palladium   F(7, 7843) =   4.5379 [0.0000]
All lags of ld_CAC40       F(7, 7843) =   4.0043 [0.0002]
All vars, lag 7            F(6, 7843) =   1.0860 [0.3680]
```

```
Equation 6: ld_CAC40

Mean dependent var   0.000140   S.D. dependent var   0.013763
Sum squared resid    1.478115   S.E. of regression   0.013728
R-squared            0.010389   Adjusted R-squared   0.005089
F(42, 7843)          1.960310   P-value(F)           0.000211
rho                  0.000117   Durbin-Watson        1.999608

F-tests of zero restrictions:

All lags of ld_WTI         F(7, 7843) =   1.1381 [0.3357]
All lags of ld_Gold        F(7, 7843) =   1.1882 [0.3056]
All lags of ld_Silver      F(7, 7843) =   1.2792 [0.2561]
All lags of ld_Platinum    F(7, 7843) =  0.96933 [0.4517]
All lags of ld_Palladium   F(7, 7843) =   1.3181 [0.2370]
All lags of ld_CAC40       F(7, 7843) =   5.4785 [0.0000]
All vars, lag 7            F(6, 7843) =   1.3695 [0.2228]

For the system as a whole:

  Null hypothesis: the longest lag is 6
  Alternative hypothesis: the longest lag is 7
  Likelihood ratio test: Chi-square(36) = 63.7919 [0.0029]

  Comparison of information criteria:
  Lag order 7: AIC = -33.7757, BIC = -33.5476, HQC = -33.6976
  Lag order 6: AIC = -33.7767, BIC = -33.5804, HQC = -33.7095
```

TABLE 3
VARIANCE DECOMPOSITION VAR_1

```
Decomposition of variance for ld_WTI

period     std. error       ld_WTI     ld_Gold    ld_Silver ld_Platinum ld_Palladium     ld_CAC40

   1        0.0260439    100.0000      0.0000      0.0000      0.0000      0.0000       0.0000
   2        0.0260661     99.8752      0.0017      0.0078      0.0456      0.0681       0.0016
   3        0.0260726     99.8266      0.0021      0.0089      0.0498      0.1035       0.0092
   4        0.0261501     99.6188      0.1113      0.0088      0.0799      0.1256       0.0556
   5        0.0261826     99.4172      0.1118      0.0758      0.2100      0.1268       0.0584
   6        0.0262035     99.3498      0.1292      0.0767      0.2338      0.1521       0.0584
   7        0.0262235     99.2889      0.1423      0.0896      0.2453      0.1580       0.0759
   8        0.0262335     99.2207      0.1428      0.0953      0.2468      0.1983       0.0961
   9        0.0262342     99.2178      0.1433      0.0958      0.2472      0.1997       0.0962
  10        0.0262346     99.2166      0.1433      0.0959      0.2482      0.1998       0.0962
Decomposition of variance for ld_Gold

period     std. error       ld_WTI     ld_Gold    ld_Silver ld_Platinum ld_Palladium     ld_CAC40

   1       0.00999171      0.0009     99.9991      0.0000      0.0000      0.0000       0.0000
   2        0.0100211      0.0134     99.5137      0.4045      0.0241    0.0342       0.0101
   3         0.010025      0.0333     99.4363      0.4505      0.0287    0.0367       0.0145
   4        0.0100342      0.0499     99.2638      0.4726      0.0859    0.0863       0.0416
   5        0.0100451      0.0600     99.0484      0.4716      0.1278    0.1158       0.1764
   6        0.0100506      0.0629     99.0352      0.4711      0.1328    0.1156       0.1824
   7        0.0100535      0.0666     99.0256      0.4738      0.1350    0.1165       0.1824
   8        0.0100619      0.0686     99.0099      0.4767      0.1353    0.1268       0.1827
   9        0.0100623      0.0686     99.0077      0.4767      0.1353    0.1278       0.1840
  10        0.0100623      0.0686     99.0069      0.4767      0.1354    0.1283       0.1841
```

```
Decomposition of variance for ld_Silver

period     std. error      ld_WTI     ld_Gold    ld_Silver ld_Platinum ld_Palladium      ld_CAC40

   1        0.0186902      0.0030     52.4875     47.5096      0.0000      0.0000        0.0000
   2        0.0187502      0.0039     52.6909     47.2549      0.0060      0.0332        0.0112
   3        0.0187543      0.0115     52.6772     47.2490      0.0089      0.0363        0.0171
   4         0.018765      0.0166     52.6279     47.2289      0.0402      0.0434        0.0431
   5        0.0187767      0.0187     52.5624     47.1703      0.1181      0.0775        0.0530
   6        0.0188016      0.0188     52.4236     47.0706      0.1284      0.1001        0.2584
   7         0.018805      0.0216     52.4280     47.0540      0.1378      0.1002        0.2584
   8        0.0188205      0.0359     52.3591     47.0693      0.1401      0.1226        0.2730
   9        0.0188211      0.0362     52.3565     47.0706      0.1401      0.1226        0.2741
  10        0.0188212      0.0362     52.3565     47.0702      0.1402      0.1228        0.2741
Decomposition of variance for ld_Platinum

period     std. error      ld_WTI     ld_Gold    ld_Silver ld_Platinum ld_Palladium      ld_CAC40

   1        0.0124442      0.0002      2.6986      0.8271     96.4741      0.0000        0.0000
   2        0.0138232      0.0174     17.5448      3.6244     78.8002      0.0124        0.0008
   3        0.0138397      0.0252     17.5084      3.7881     78.6189      0.0179        0.0415
   4        0.0138486      0.0630     17.4899      3.7879     78.5621      0.0185        0.0785
   5        0.0138674      0.1266     17.4914      3.8469     78.3552      0.0918        0.0881
   6        0.0138783      0.1278     17.4693      3.8411     78.3386      0.1048        0.1184
   7        0.0139118      0.1462     17.4357      3.8556     77.9669      0.2126        0.3829
   8         0.013916      0.1663     17.4455      3.8632     77.9202      0.2212        0.3835
   9        0.0139178      0.1667     17.4529      3.8679     77.9002      0.2231        0.3892
  10        0.0139181      0.1671     17.4523      3.8682     77.8978      0.2231        0.3915

Decomposition of variance for ld_Palladium

period     std. error      ld_WTI     ld_Gold    ld_Silver ld_Platinum ld_Palladium      ld_CAC40

   1        0.0187964      0.0056      0.9553      0.6974     25.5253     72.8164        0.0000
   2        0.0199425      0.0076      9.2756      3.0708     22.7519     64.8813        0.0129
   3        0.0199686      0.0615      9.2514      3.1913     22.7084     64.7268        0.0606
   4        0.0199769      0.0680      9.2565      3.1955     22.7332     64.6814        0.0654
   5        0.0199816      0.0780      9.2522      3.2191     22.7227     64.6537        0.0744
   6        0.0199901      0.0806      9.2464      3.2313     22.7263     64.6181        0.0974
   7        0.0200451      0.0867      9.2525      3.2533     22.6077     64.3830        0.4169
   8        0.0200543      0.1255      9.2742      3.2553     22.5972     64.3312        0.4166
   9        0.0200559      0.1276      9.2752      3.2609     22.5940     64.3213        0.4211
  10        0.0200561      0.1276      9.2752      3.2610     22.5939     64.3196        0.4226
 Decomposition of variance for ld_CAC40

 period     std. error      ld_WTI     ld_Gold    ld_Silver ld_Platinum ld_Palladium      ld_CAC40

    1        0.0136907      0.0007      0.0008      0.0149      0.0062      0.0074       99.9701
    2        0.0136975      0.0316      0.0478      0.0302      0.0064      0.0106       99.8735
    3        0.0137048      0.0318      0.0486      0.0638      0.0301      0.0174       99.8082
    4        0.0137237      0.0350      0.1245      0.0935      0.0441      0.0203       99.6826
    5        0.0137274      0.0428      0.1267      0.0978      0.0443      0.0238       99.6645
    6        0.0137461      0.0617      0.1330      0.1183      0.0674      0.0447       99.5749
    7        0.0137556      0.1007      0.1464      0.1181      0.0876      0.0598       99.4874
    8         0.013762      0.1013      0.1466      0.1312      0.0879      0.1214       99.4115
    9        0.0137621      0.1017      0.1472      0.1313      0.0881      0.1216       99.4101
   10        0.0137622      0.1021      0.1473      0.1314      0.0885      0.1217       99.4091
```

FIGURE 1.A - IRF VAR_1 (WTI & GOLD RESPONSES)

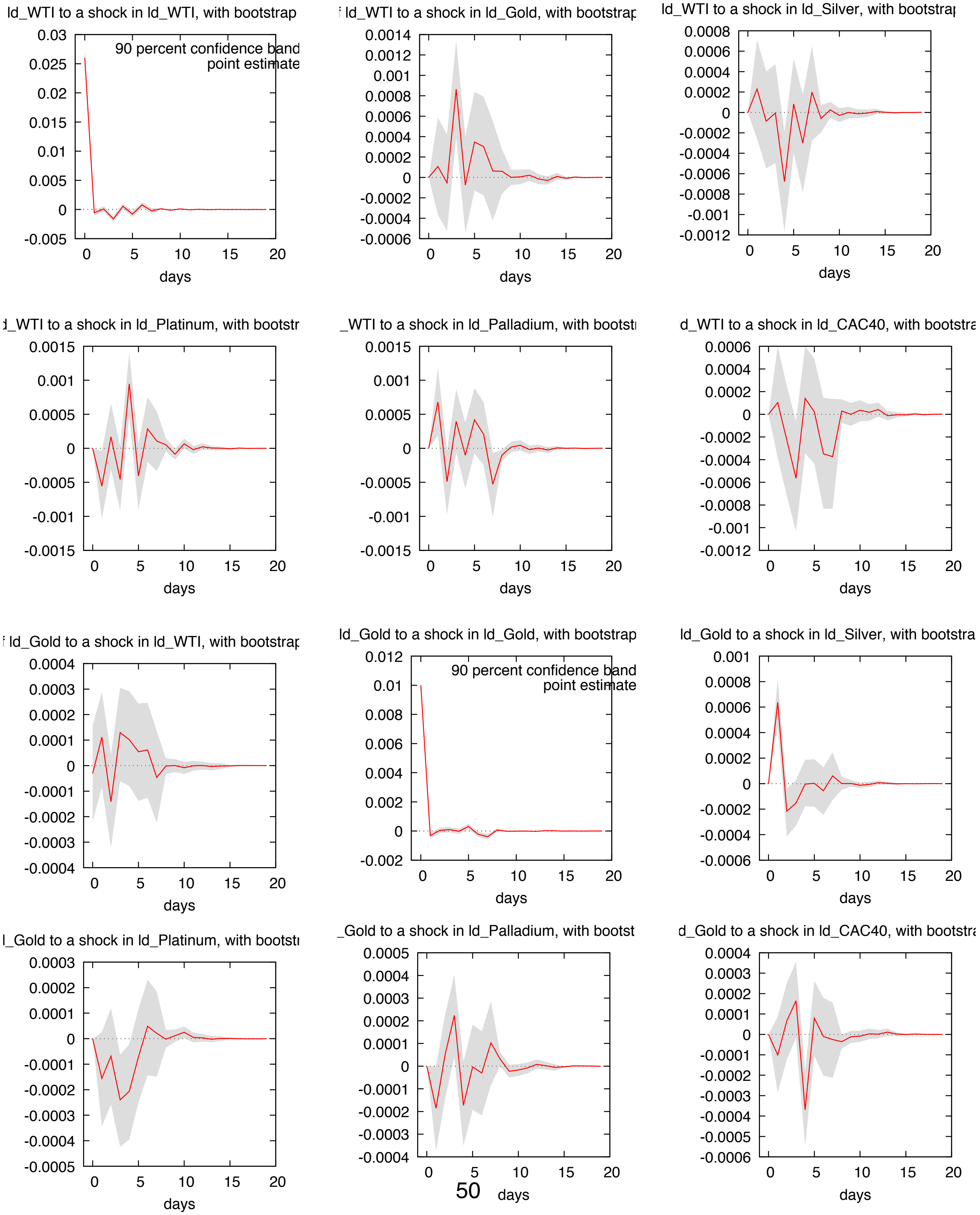


FIGURE 1.B - IRF VAR_1 (SILVER & PLATINUM RESPONSES)

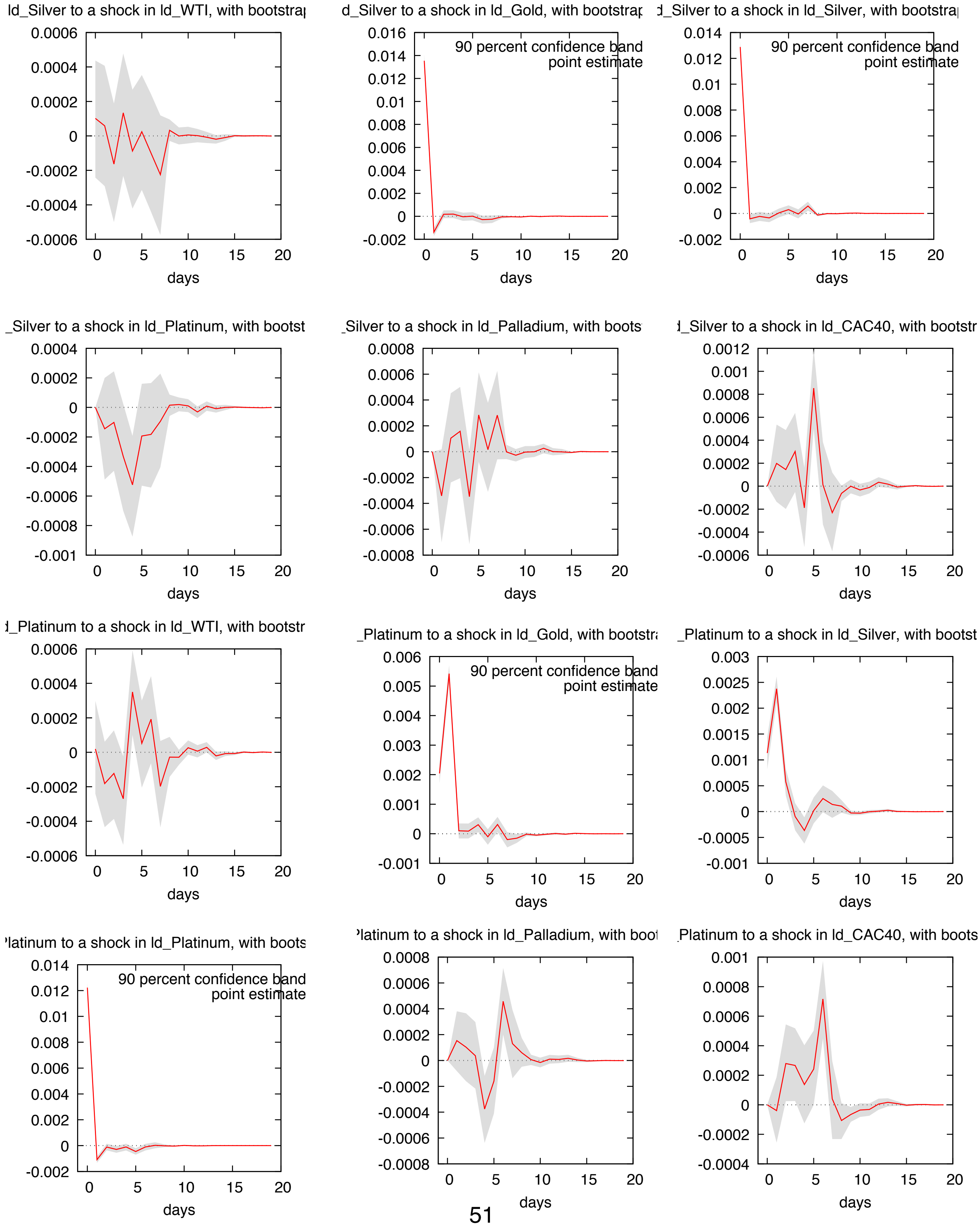


FIGURE 1.C - IRF VAR_1 (PALLADIUM & CAC40 RESPONSES)

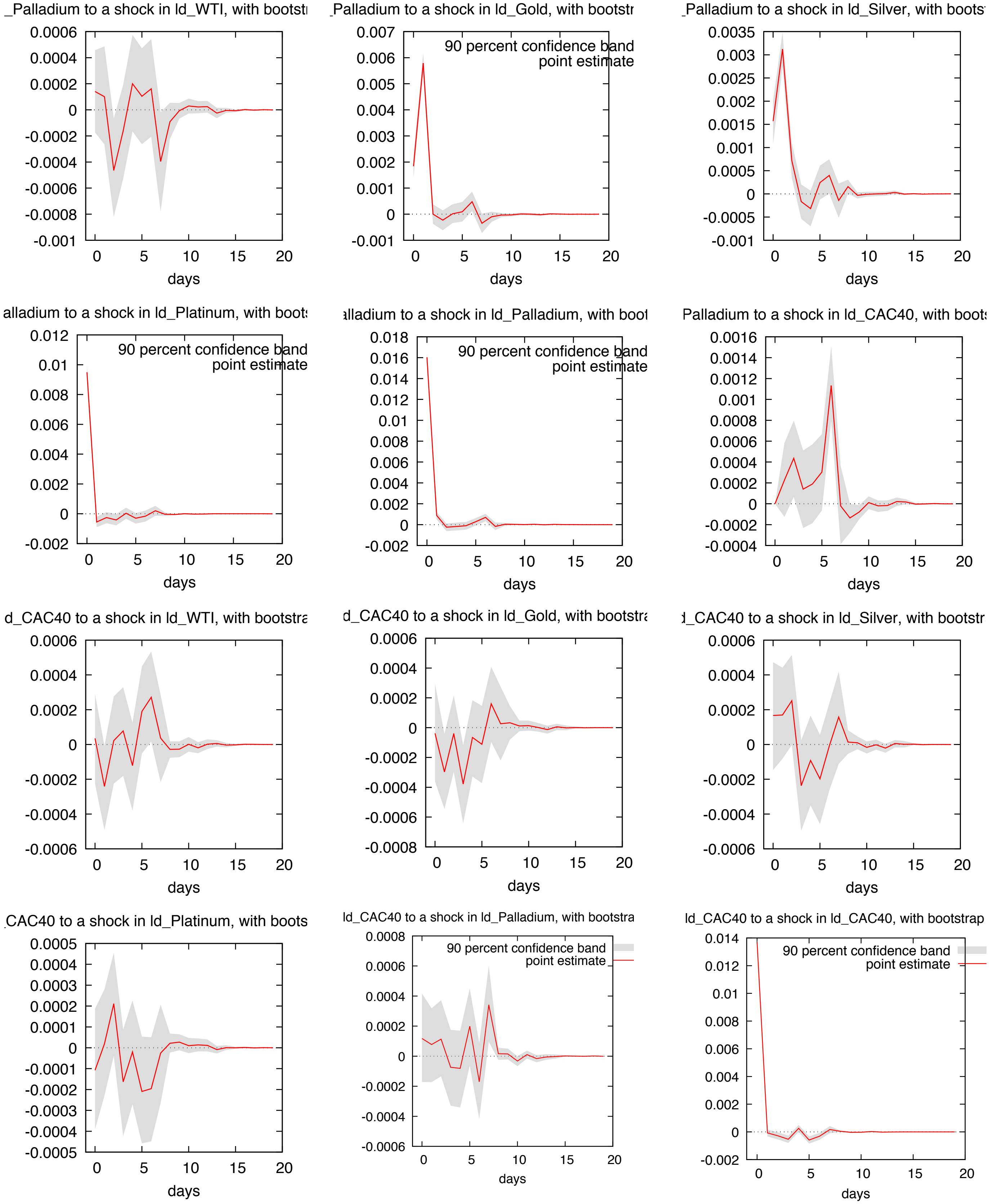


TABLE 4
GRANGER CAUSALITY TEST VAR_2

```
VAR system, lag order 6
OLS estimates, observations 1990-02-15–2020-05-08 (T = 7887)
Log-likelihood = 135103
Determinant of covariance matrix = 5.3256042e-23
AIC = -34.2034
BIC = -34.0071
HQC = -34.1361
Portmanteau test: LB(48) = 2372.52, df = 1512 [0.0000]

Equation 1: ld_WTI
Mean dependent var   0.000089   S.D. dependent var   0.026238
Sum squared resid    5.350184   S.E. of regression   0.026107
R-squared            0.014529   Adjusted R-squared   0.010009
F(36, 7850)          3.214787   P-value(F)           3.30e-10
rho                  0.000450   Durbin-Watson        1.998821

F-tests of zero restrictions:

All lags of ld_WTI         F(6, 7850) =   8.2341 [0.0000]
All lags of ld_Gold        F(6, 7850) =   1.6696 [0.1241]
All lags of ld_Silver      F(6, 7850) =   1.2890 [0.2584]
All lags of ld_Platinum    F(6, 7850) =   3.9966 [0.0005]
All lags of ld_Palladium   F(6, 7850) =   1.7625 [0.1026]
All lags of ld_DJIA        F(6, 7850) =   1.9824 [0.0645]
All vars, lag 6            F(6, 7850) =   1.3568 [0.2281]

Equation 2: ld_Gold
Mean dependent var   0.000198   S.D. dependent var   0.010063
Sum squared resid    0.788048   S.E. of regression   0.010019
R-squared            0.013082   Adjusted R-squared   0.008556
F(36, 7850)          2.890338   P-value(F)           1.84e-08
rho                 -0.000705   Durbin-Watson        2.001391

F-tests of zero restrictions:

All lags of ld_WTI         F(6, 7850) =  0.64372 [0.6953]
All lags of ld_Gold        F(6, 7850) =   8.2210 [0.0000]
All lags of ld_Silver      F(6, 7850) =   6.2719 [0.0000]
All lags of ld_Platinum    F(6, 7850) =   1.8947 [0.0778]
All lags of ld_Palladium   F(6, 7850) =   1.5267 [0.1649]
All lags of ld_DJIA        F(6, 7850) =   3.3484 [0.0027]
All vars, lag 6            F(6, 7850) =   1.0366 [0.3991]
```

```
Equation 3: ld_Silver

Mean dependent var   0.000207   S.D. dependent var   0.018822
Sum squared resid    2.760394   S.E. of regression   0.018752
R-squared            0.011903   Adjusted R-squared   0.007371
F(36, 7850)          2.626698   P-value(F)           4.19e-07
rho                 -0.000236   Durbin-Watson        2.000449

F-tests of zero restrictions:

All lags of ld_WTI         F(6, 7850) =  0.17316 [0.9841]
All lags of ld_Gold        F(6, 7850) =   2.9025 [0.0079]
All lags of ld_Silver      F(6, 7850) =   1.5816 [0.1480]
All lags of ld_Platinum    F(6, 7850) =   1.5874 [0.1463]
All lags of ld_Palladium   F(6, 7850) =   1.2076 [0.2989]
All lags of ld_DJIA        F(6, 7850) =   3.0302 [0.0058]
All vars, lag 6            F(6, 7850) =  0.21280 [0.9729]

Equation 4: ld_Platinum

Mean dependent var   0.000103   S.D. dependent var   0.013918
Sum squared resid    1.224957   S.E. of regression   0.012492
R-squared            0.198166   Adjusted R-squared   0.194489
F(36, 7850)          53.89046   P-value(F)           0.000000
rho                  0.000649   Durbin-Watson        1.998695

F-tests of zero restrictions:

All lags of ld_WTI         F(6, 7850) =   2.0789 [0.0523]
All lags of ld_Gold        F(6, 7850) =   35.697 [0.0000]
All lags of ld_Silver      F(6, 7850) =   55.512 [0.0000]
All lags of ld_Platinum    F(6, 7850) =   10.594 [0.0000]
All lags of ld_Palladium   F(6, 7850) =   4.1029 [0.0004]
All lags of ld_DJIA        F(6, 7850) =   1.7593 [0.1033]
All vars, lag 6            F(6, 7850) =   4.1181 [0.0004]

Equation 5: ld_Palladium
Mean dependent var   0.000384   S.D. dependent var   0.020056
Sum squared resid    2.795921   S.E. of regression   0.018872
R-squared            0.118618   Adjusted R-squared   0.114576
F(36, 7850)          29.34631   P-value(F)           4.0e-185
rho                  0.001300   Durbin-Watson        1.997379
F-tests of zero restrictions:

All lags of ld_WTI         F(6, 7850) =   1.2783 [0.2634]
All lags of ld_Gold        F(6, 7850) =   11.073 [0.0000]
All lags of ld_Silver      F(6, 7850) =   39.297 [0.0000]
All lags of ld_Platinum    F(6, 7850) =   4.9043 [0.0001]
All lags of ld_Palladium   F(6, 7850) =   5.1665 [0.0000]
All lags of ld_DJIA        F(6, 7850) =   1.1681 [0.3202]
All vars, lag 6            F(6, 7850) =   2.5834 [0.0168]
```

```
Equation 6: ld_DJIA
Mean dependent var   0.000323   S.D. dependent var   0.011120
Sum squared resid    0.962705   S.E. of regression   0.011074
R-squared            0.012805   Adjusted R-squared   0.008277
F(36, 7850)          2.828333   P-value(F)           3.88e-08
rho                  0.001280   Durbin-Watson        1.997433

F-tests of zero restrictions:

All lags of ld_WTI         F(6, 7850) =   1.4286 [0.1993]
All lags of ld_Gold        F(6, 7850) =  0.77070 [0.5929]
All lags of ld_Silver      F(6, 7850) =  0.50822 [0.8026]
All lags of ld_Platinum    F(6, 7850) =  0.83798 [0.5403]
All lags of ld_Palladium   F(6, 7850) =  0.62696 [0.7089]
All lags of ld_DJIA        F(6, 7850) =   12.661 [0.0000]
All vars, lag 6            F(6, 7850) =   3.2467 [0.0035]

For the system as a whole:

  Null hypothesis: the longest lag is 5
  Alternative hypothesis: the longest lag is 6
  Likelihood ratio test: Chi-square(36) = 68.0004 [0.0010]

  Comparison of information criteria:
  Lag order 6: AIC = -34.2034, BIC = -34.0071, HQC = -34.1361
  Lag order 5: AIC = -34.2039, BIC = -34.0394, HQC = -34.1476
```

TABLE 5
VARIANCE DECOMPOSITION VAR_2

```
Decomposition of variance for ld_WTI

period     std. error      ld_WTI     ld_Gold    ld_Silver ld_Platinum ld_Palladium      ld_DJIA

   1       0.0260452    100.0000      0.0000      0.0000      0.0000      0.0000      0.0000
   2       0.0260674     99.8796      0.0012      0.0046      0.0540      0.0593      0.0013
   3       0.0260816     99.7712      0.0015      0.0066      0.0579      0.0967      0.0661
   4        0.026154     99.5946      0.1103      0.0066      0.0855      0.1181      0.0850
   5       0.0261939     99.3371      0.1112      0.0709      0.2125      0.1191      0.1492
   6       0.0262159     99.2570      0.1278      0.0715      0.2381      0.1446      0.1610
   7       0.0262329     99.2138      0.1429      0.0849      0.2471      0.1491      0.1621
   8       0.0262344     99.2037      0.1444      0.0879      0.2508      0.1492      0.1640
   9       0.0262352     99.2007      0.1444      0.0885      0.2520      0.1499      0.1646
  10       0.0262358     99.1982      0.1445      0.0885      0.2539      0.1499      0.1651
Decomposition of variance for ld_Gold

period     std. error      ld_WTI     ld_Gold    ld_Silver ld_Platinum ld_Palladium      ld_DJIA

   1      0.00999587      0.0017     99.9983      0.0000      0.0000      0.0000      0.0000
   2       0.0100274      0.0119     99.4818      0.4043      0.0281      0.0324      0.0415
   3       0.0100311      0.0341     99.4097      0.4459      0.0340      0.0348      0.0415
   4       0.0100392      0.0465     99.2577      0.4722      0.0974      0.0846      0.0416
   5        0.010045      0.0542     99.1447      0.4716      0.1392      0.1131      0.0771
   6       0.0100567      0.0570     99.0036      0.4705      0.1461      0.1128      0.2098
   7       0.0100614      0.0611     98.9518      0.4717      0.1538      0.1156      0.2459
   8       0.0100617      0.0611     98.9462      0.4738      0.1544      0.1159      0.2486
   9       0.0100618      0.0613     98.9456      0.4738      0.1544      0.1161      0.2486
  10       0.0100618      0.0614     98.9452      0.4738      0.1544      0.1163      0.2488
```

```
Decomposition of variance for ld_Silver

period     std. error      ld_WTI     ld_Gold    ld_Silver ld_Platinum ld_Palladium       ld_DJIA

   1        0.0187081      0.0024     52.3129     47.6847      0.0000      0.0000         0.0000
   2        0.0187694      0.0026     52.5417     47.4105      0.0058      0.0279         0.0116
   3        0.0187741      0.0114     52.5246     47.4004      0.0086      0.0303         0.0247
   4        0.0187879      0.0131     52.4585     47.3624      0.0433      0.0394         0.0832
   5        0.0187983      0.0140     52.4021     47.3113      0.1170      0.0723         0.0832
   6        0.0188172      0.0141     52.2966     47.2398      0.1249      0.0965         0.2280
   7        0.0188198      0.0157     52.2983     47.2293      0.1303      0.0972         0.2292
   8        0.0188201      0.0160     52.2971     47.2283      0.1315      0.0973         0.2298
   9        0.0188202      0.0160     52.2970     47.2282      0.1317      0.0973         0.2299
  10        0.0188203      0.0160     52.2964     47.2276      0.1319      0.0974         0.2307
Decomposition of variance for ld_Platinum

period     std. error      ld_WTI     ld_Gold    ld_Silver ld_Platinum ld_Palladium       ld_DJIA

   1        0.0124625      0.0000      2.6835      0.8888     96.4277      0.0000         0.0000
   2        0.0138347      0.0196     17.3241      3.8002     78.8345      0.0141         0.0075
   3        0.0138517      0.0306     17.2838      3.9936     78.6473      0.0215         0.0232
   4        0.0138587      0.0785     17.2700      3.9942     78.6118      0.0220         0.0234
   5        0.0138772      0.1351     17.2718      4.0469     78.4081      0.0890         0.0491
   6        0.0138866      0.1363     17.2561      4.0420     78.4025      0.1007         0.0624
   7        0.0139164      0.1561     17.2346      4.0545     78.0728      0.2147         0.2674
   8        0.0139172      0.1562     17.2416      4.0540     78.0659      0.2149         0.2674
   9        0.0139173      0.1563     17.2415      4.0546     78.0652      0.2149         0.2674
  10        0.0139174      0.1564     17.2415      4.0548     78.0649      0.2150         0.2674
Decomposition of variance for ld_Palladium

period     std. error      ld_WTI     ld_Gold    ld_Silver ld_Platinum ld_Palladium       ld_DJIA

   1        0.0188281      0.0050      0.9386      0.7132     25.6513     72.6918         0.0000
   2         0.019977      0.0062      9.1456      3.2157     22.8618     64.7690         0.0017
   3        0.0200001      0.0645      9.1255      3.3495     22.8244     64.6343         0.0018
   4        0.0200097      0.0739      9.1283      3.3531     22.8434     64.5811         0.0203
   5        0.0200128      0.0819      9.1254      3.3731     22.8367     64.5626         0.0204
   6        0.0200214      0.0853      9.1187      3.3884     22.8430     64.5299         0.0347
   7        0.0200538      0.0913      9.1438      3.4225     22.7862     64.4279         0.1283
   8        0.0200548      0.0913      9.1516      3.4222     22.7845     64.4221         0.1283
   9        0.0200549      0.0914      9.1519      3.4228     22.7841     64.4212         0.1285
  10         0.020055      0.0914      9.1519      3.4230     22.7841     64.4210         0.1286
Decomposition of variance for ld_DJIA

period     std. error      ld_WTI     ld_Gold    ld_Silver ld_Platinum ld_Palladium       ld_DJIA

   1        0.0110482      0.0062      0.0230      0.0000      0.0019      0.0266        99.9423
   2        0.0110887      0.0131      0.0228      0.0035      0.0020      0.0492        99.9093
   3        0.0110912      0.0386      0.0249      0.0036      0.0020      0.0633        99.8675
   4        0.0110961      0.0863      0.0396      0.0039      0.0182      0.0666        99.7853
   5        0.0111028      0.0997      0.0903      0.0048      0.0292      0.0678        99.7082
   6        0.0111067      0.1013      0.1118      0.0127      0.0404      0.0688        99.6650
   7        0.0111188      0.1012      0.1168      0.0449      0.0560      0.0718        99.6092
   8        0.0111195      0.1016      0.1213      0.0459      0.0565      0.0720        99.6027
   9        0.0111195      0.1016      0.1213      0.0459      0.0566      0.0721        99.6026
  10        0.0111195      0.1018      0.1213      0.0459      0.0566      0.0721        99.6023
```

FIGURE 2.A - IRF VAR_2 (WTI & GOLD RESPONSES)

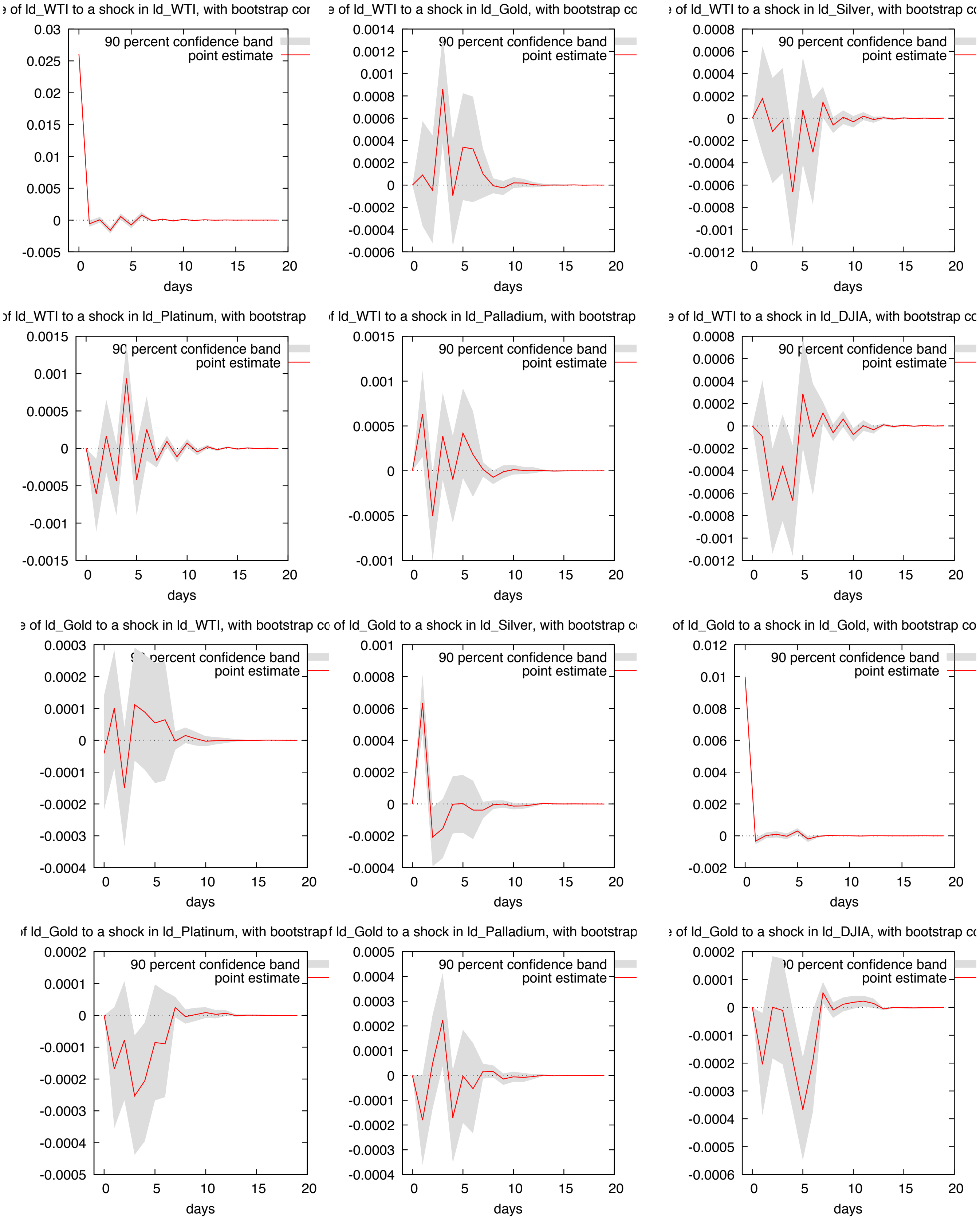


FIGURE 2.B - IRF VAR_2 (SILVER & PLATINUM RESPONSES)

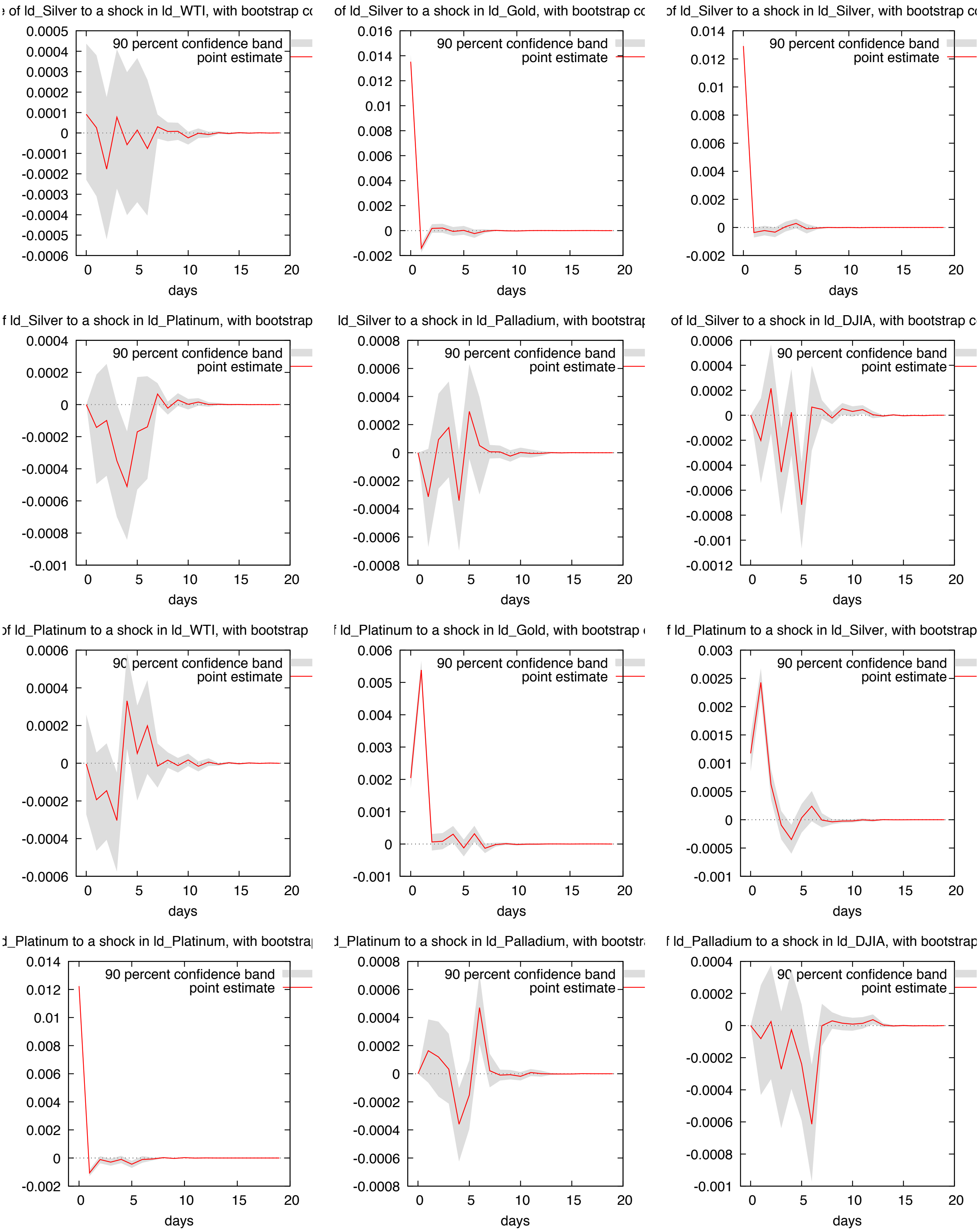


FIGURE 2.C - IRF VAR_2 (PALLADIUM & DJIA RESPONSES)

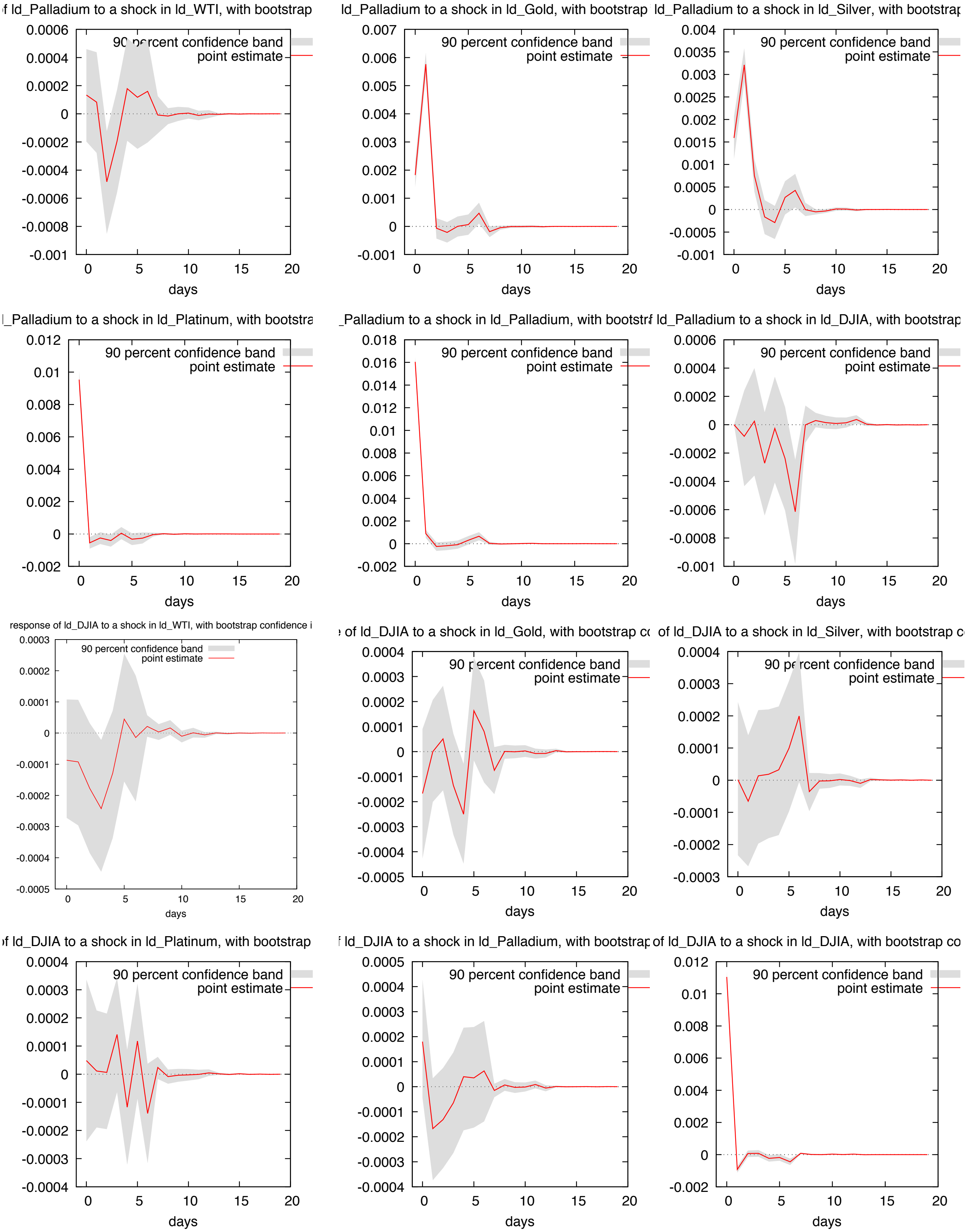


TABLE 6
GRANGER CAUSALITY TEST VAR_3

```
VAR system, lag order 5
OLS estimates, observations 1990-02-14–2020-05-08 (T = 7888)
Log-likelihood = 135108.1
Determinant of covariance matrix = 5.3418703e-23
AIC = -34.2095
BIC = -34.0450
HQC = -34.1531
Portmanteau test: LB(48) = 2187.83, df = 1548 [0.0000]

Equation 1: ld_WTI
Mean dependent var   0.000083   S.D. dependent var   0.026241
Sum squared resid    5.361889   S.E. of regression   0.026123
R-squared            0.012701   Adjusted R-squared   0.008931
F(30, 7857)          3.369059   P-value(F)           1.49e-09
rho                  0.000235   Durbin-Watson        1.999092
F-tests of zero restrictions:

All lags of ld_WTI         F(5, 7857) =   8.9687 [0.0000]
All lags of ld_Gold        F(5, 7857) =   1.4592 [0.1997]
All lags of ld_Silver      F(5, 7857) =   1.3892 [0.2248]
All lags of ld_Platinum    F(5, 7857) =   4.8490 [0.0002]
All lags of ld_Palladium   F(5, 7857) =   2.2540 [0.0464]
All lags of ld_FTSE        F(5, 7857) =   1.2405 [0.2871]
All vars, lag 5            F(6, 7857) =   1.5694 [0.1516]

Equation 2: ld_Gold
Mean dependent var   0.000196   S.D. dependent var   0.010062
Sum squared resid    0.790055   S.E. of regression   0.010028
R-squared            0.010683   Adjusted R-squared   0.006906
F(30, 7857)          2.828212   P-value(F)           4.31e-07
rho                  0.000179   Durbin-Watson        1.999523

F-tests of zero restrictions:

All lags of ld_WTI         F(5, 7857) =  0.82000 [0.5352]
All lags of ld_Gold        F(5, 7857) =   9.5187 [0.0000]
All lags of ld_Silver      F(5, 7857) =   7.5232 [0.0000]
All lags of ld_Platinum    F(5, 7857) =   2.4231 [0.0333]
All lags of ld_Palladium   F(5, 7857) =   1.8178 [0.1057]
All lags of ld_FTSE        F(5, 7857) =  0.67919 [0.6392]
All vars, lag 5            F(6, 7857) =   2.5096 [0.0199]
```

```
Equation 3: ld_Silver
Mean dependent var   0.000206   S.D. dependent var   0.018821
Sum squared resid    2.758696   S.E. of regression   0.018738
R-squared            0.012523   Adjusted R-squared   0.008752
F(30, 7857)          3.321239   P-value(F)           2.49e-09
rho                  0.000125   Durbin-Watson        1.999739

F-tests of zero restrictions:

All lags of ld_WTI         F(5, 7857) =  0.19074 [0.9662]
All lags of ld_Gold        F(5, 7857) =   3.2708 [0.0059]
All lags of ld_Silver      F(5, 7857) =   2.2313 [0.0485]
All lags of ld_Platinum    F(5, 7857) =   2.0120 [0.0737]
All lags of ld_Palladium   F(5, 7857) =   1.3428 [0.2429]
All lags of ld_FTSE        F(5, 7857) =   4.8751 [0.0002]
All vars, lag 5            F(6, 7857) =   2.1632 [0.0435]

Equation 4: ld_Platinum
Mean dependent var   0.000102   S.D. dependent var   0.013918
Sum squared resid    1.224230   S.E. of regression   0.012483
R-squared            0.198689   Adjusted R-squared   0.195630
F(30, 7857)          64.93949   P-value(F)           0.000000
rho                 -2.11e-06   Durbin-Watson        1.999939

F-tests of zero restrictions:

All lags of ld_WTI         F(5, 7857) =   2.2028 [0.0512]
All lags of ld_Gold        F(5, 7857) =   44.788 [0.0000]
All lags of ld_Silver      F(5, 7857) =   64.181 [0.0000]
All lags of ld_Platinum    F(5, 7857) =   12.186 [0.0000]
All lags of ld_Palladium   F(5, 7857) =   3.2941 [0.0057]
All lags of ld_FTSE        F(5, 7857) =   6.5682 [0.0000]
All vars, lag 5            F(6, 7857) =  0.15013 [0.9891]

Equation 5: ld_Palladium
Mean dependent var   0.000384   S.D. dependent var   0.020055
Sum squared resid    2.795730   S.E. of regression   0.018863
R-squared            0.118679   Adjusted R-squared   0.115314
F(30, 7857)          35.26770   P-value(F)           8.0e-190
rho                 -0.000842   Durbin-Watson        2.001672

F-tests of zero restrictions:

All lags of ld_WTI         F(5, 7857) =   1.4824 [0.1919]
All lags of ld_Gold        F(5, 7857) =   14.208 [0.0000]
All lags of ld_Silver      F(5, 7857) =   44.752 [0.0000]
All lags of ld_Platinum    F(5, 7857) =   4.8925 [0.0002]
All lags of ld_Palladium   F(5, 7857) =   5.0517 [0.0001]
All lags of ld_FTSE        F(5, 7857) =   4.0400 [0.0012]
All vars, lag 5            F(6, 7857) =   1.0971 [0.3613]
```

```
Equation 6: ld_FTSE

Mean dependent var   0.000141   S.D. dependent var   0.011112
Sum squared resid    0.964200   S.E. of regression   0.011078
R-squared            0.009967   Adjusted R-squared   0.006186
F(30, 7857)          2.636555   P-value(F)           2.90e-06
rho                 -0.001557   Durbin-Watson        2.003100

F-tests of zero restrictions:

All lags of ld_WTI         F(5, 7857) =  0.64079 [0.6686]
All lags of ld_Gold        F(5, 7857) =   2.0173 [0.0729]
All lags of ld_Silver      F(5, 7857) =   2.1771 [0.0538]
All lags of ld_Platinum    F(5, 7857) =   2.1409 [0.0577]
All lags of ld_Palladium   F(5, 7857) =   1.9137 [0.0886]
All lags of ld_FTSE        F(5, 7857) =   9.1903 [0.0000]
All vars, lag 5            F(6, 7857) =   1.9410 [0.0705]

For the system as a whole:

  Null hypothesis: the longest lag is 4
  Alternative hypothesis: the longest lag is 5
  Likelihood ratio test: Chi-square(36) = 65.7247 [0.0018]

  Comparison of information criteria:
  Lag order 5: AIC = -34.2095, BIC = -34.0450, HQC = -34.1531
  Lag order 4: AIC = -34.2103, BIC = -34.0777, HQC = -34.1648
```

TABLE 7
VARIANCE DECOMPOSITION VAR_3

```
Decomposition of variance for ld_WTI

period    std. error      ld_WTI     ld_Gold   ld_Silver ld_Platinum ld_Palladium     ld_FTSE

   1       0.0260721    100.0000      0.0000      0.0000      0.0000      0.0000      0.0000
   2        0.026096     99.8630      0.0023      0.0047      0.0490      0.0661      0.0149
   3       0.0261044     99.8001      0.0025      0.0068      0.0547      0.1063      0.0296
   4        0.026179     99.6253      0.1139      0.0068      0.0876      0.1277      0.0387
   5       0.0262153     99.3976      0.1149      0.0740      0.2165      0.1298      0.0672
   6       0.0262367     99.3274      0.1275      0.0747      0.2317      0.1609      0.0777
   7       0.0262376     99.3256      0.1284      0.0748      0.2325      0.1609      0.0778
   8       0.0262383     99.3221      0.1284      0.0755      0.2348      0.1610      0.0782
   9       0.0262391     99.3203      0.1284      0.0759      0.2353      0.1612      0.0789
  10       0.0262391     99.3199      0.1284      0.0759      0.2355      0.1612      0.0791

Decomposition of variance for ld_Gold

period    std. error      ld_WTI     ld_Gold   ld_Silver ld_Platinum ld_Palladium     ld_FTSE

   1       0.0100079      0.0017     99.9983      0.0000      0.0000      0.0000      0.0000
   2       0.0100386      0.0147     99.4922      0.4040      0.0256      0.0337      0.0298
   3       0.0100426      0.0328     99.4127      0.4427      0.0306      0.0359      0.0454
   4       0.0100511      0.0468     99.2545      0.4690      0.0958      0.0880      0.0459
   5       0.0100554      0.0554     99.1708      0.4687      0.1433      0.1157      0.0462
   6       0.0100611      0.0581     99.1514      0.4683      0.1600      0.1158      0.0463
   7       0.0100618      0.0581     99.1513      0.4683      0.1601      0.1158      0.0464
   8       0.0100618      0.0581     99.1505      0.4686      0.1602      0.1159      0.0466
   9       0.0100618      0.0581     99.1501      0.4686      0.1602      0.1163      0.0467
  10       0.0100618      0.0581     99.1500      0.4686      0.1602      0.1163      0.0467
```

```
Decomposition of variance for ld_Silver

period     std. error      ld_WTI     ld_Gold     ld_Silver ld_Platinum ld_Palladium       ld_FTSE

   1        0.0187012      0.0015     52.4306     47.5679      0.0000      0.0000        0.0000
   2        0.0187615      0.0033     52.6444     47.3088      0.0045      0.0304        0.0086
   3        0.0187906      0.0119     52.4911     47.1727      0.0089      0.0332        0.2822
   4        0.0188001      0.0149     52.4500     47.1641      0.0446      0.0415        0.2849
   5        0.0188105      0.0160     52.3928     47.1127      0.1217      0.0717        0.2851
   6        0.0188179      0.0161     52.3515     47.1011      0.1301      0.0944        0.3068
   7        0.0188192      0.0161     52.3550     47.0964      0.1312      0.0945        0.3068
   8        0.0188193      0.0161     52.3545     47.0960      0.1312      0.0945        0.3076
   9        0.0188193      0.0162     52.3544     47.0959      0.1312      0.0946        0.3077
  10        0.0188194      0.0162     52.3543     47.0957      0.1313      0.0946        0.3078
```

```
Decomposition of variance for ld_Platinum

period     std. error      ld_WTI     ld_Gold     ld_Silver ld_Platinum ld_Palladium       ld_FTSE

   1         0.012458      0.0000      2.6961      0.8323     96.4716      0.0000        0.0000
   2        0.0138428      0.0196     17.5561      3.6702     78.7323      0.0194        0.0023
   3        0.0138685      0.0261     17.4948      3.8527     78.4447      0.0265        0.1553
   4        0.0138906      0.0683     17.4440      3.8435     78.2400      0.0269        0.3773
   5        0.0139126      0.1279     17.4391      3.9001     77.9951      0.0996        0.4382
   6        0.0139162      0.1298     17.4364      3.8982     77.9942      0.1025        0.4388
   7        0.0139167      0.1308     17.4364      3.8985     77.9909      0.1037        0.4396
   8        0.0139169      0.1314     17.4380      3.8988     77.9882      0.1038        0.4398
   9         0.013917      0.1315     17.4376      3.8988     77.9866      0.1039        0.4417
  10        0.0139171      0.1316     17.4377      3.8988     77.9863      0.1039        0.4417
```

```
Decomposition of variance for ld_Palladium

period     std. error      ld_WTI     ld_Gold     ld_Silver ld_Platinumld_Palladium       ld_FTSE

   1        0.0188263      0.0053      0.9440      0.6976     25.6345     72.7185        0.0000
   2        0.0199791      0.0067      9.2709      3.1049     22.8444     64.7721        0.0011
   3        0.0200087      0.0591      9.2437      3.2255     22.7938     64.5955        0.0824
   4         0.020042      0.0658      9.2228      3.2211     22.7585     64.3898        0.3420
   5        0.0200457      0.0741      9.2194      3.2435     22.7519     64.3682        0.3430
   6        0.0200517      0.0785      9.2156      3.2521     22.7414     64.3676        0.3448
   7        0.0200533      0.0786      9.2193      3.2573     22.7389     64.3606        0.3454
   8        0.0200537      0.0789      9.2213      3.2576     22.7381     64.3581        0.3460
   9        0.0200538      0.0789      9.2213      3.2576     22.7380     64.3578        0.3464
  10        0.0200538      0.0789      9.2213      3.2577     22.7379     64.3578        0.3464
```

```
Decomposition of variance for ld_FTSE

period     std. error      ld_WTI     ld_Gold     ld_Silver ld_Platinum ld_Palladium       ld_FTSE

   1        0.0110561      0.0108      0.0024      0.0007      0.0002      0.0000       99.9860
   2        0.0110574      0.0129      0.0027      0.0041      0.0005      0.0063       99.9735
   3         0.011069      0.0212      0.0054      0.0809      0.0043      0.0065       99.8816
   4        0.0110888      0.0301      0.0126      0.1172      0.0106      0.0513       99.7783
   5        0.0111052      0.0373      0.0354      0.1290      0.0693      0.1132       99.6158
   6        0.0111113      0.0515      0.0451      0.1431      0.0709      0.1150       99.5744
   7        0.0111114      0.0516      0.0451      0.1431      0.0711      0.1150       99.5740
   8        0.0111114      0.0520      0.0451      0.1434      0.0711      0.1157       99.5726
   9        0.0111115      0.0521      0.0453      0.1434      0.0713      0.1163       99.5716
  10        0.0111116      0.0521      0.0454      0.1434      0.0715      0.1163       99.5712
```

FIGURE 3.A - IRF VAR_3 (WTI & GOLD RESPONSES)

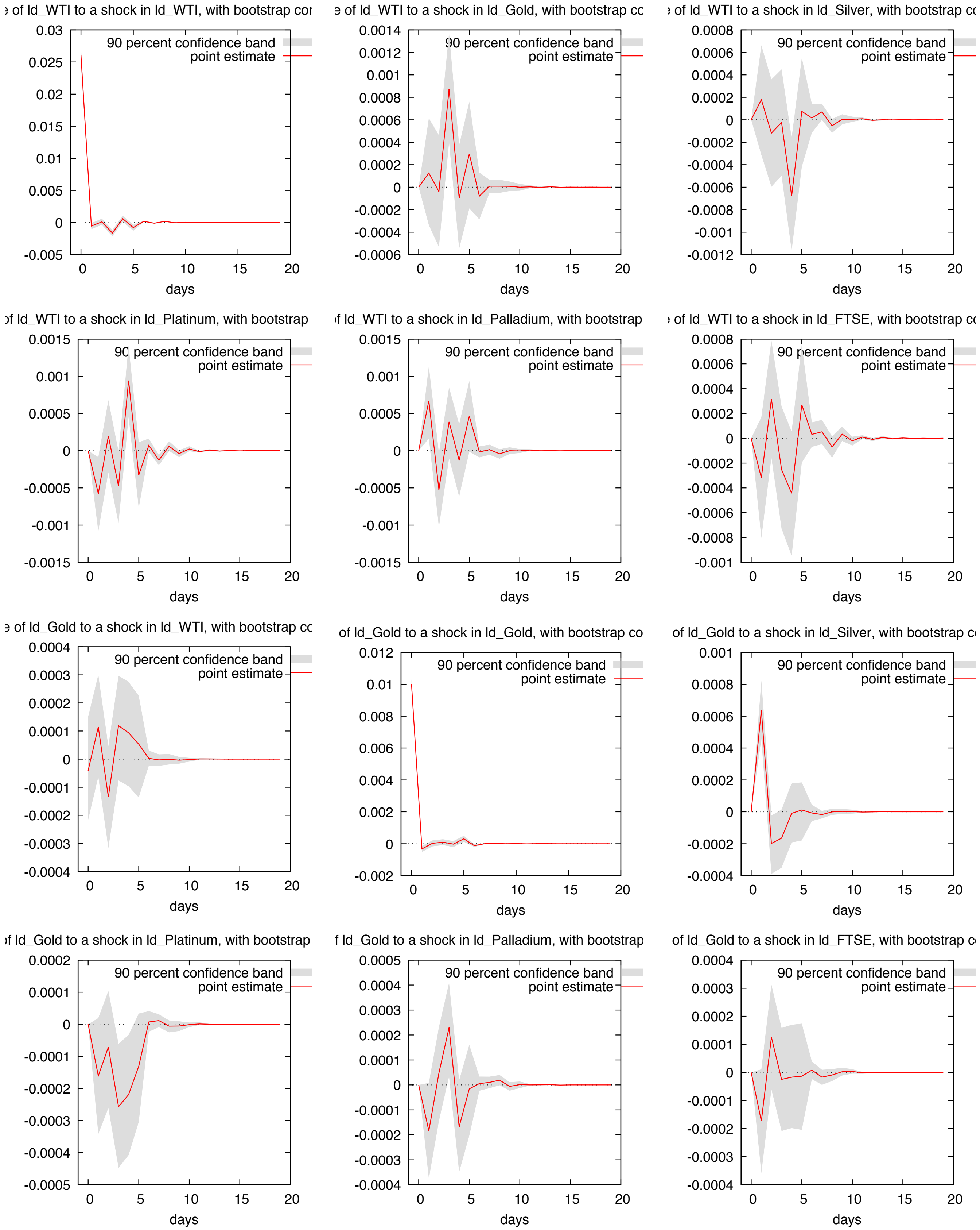
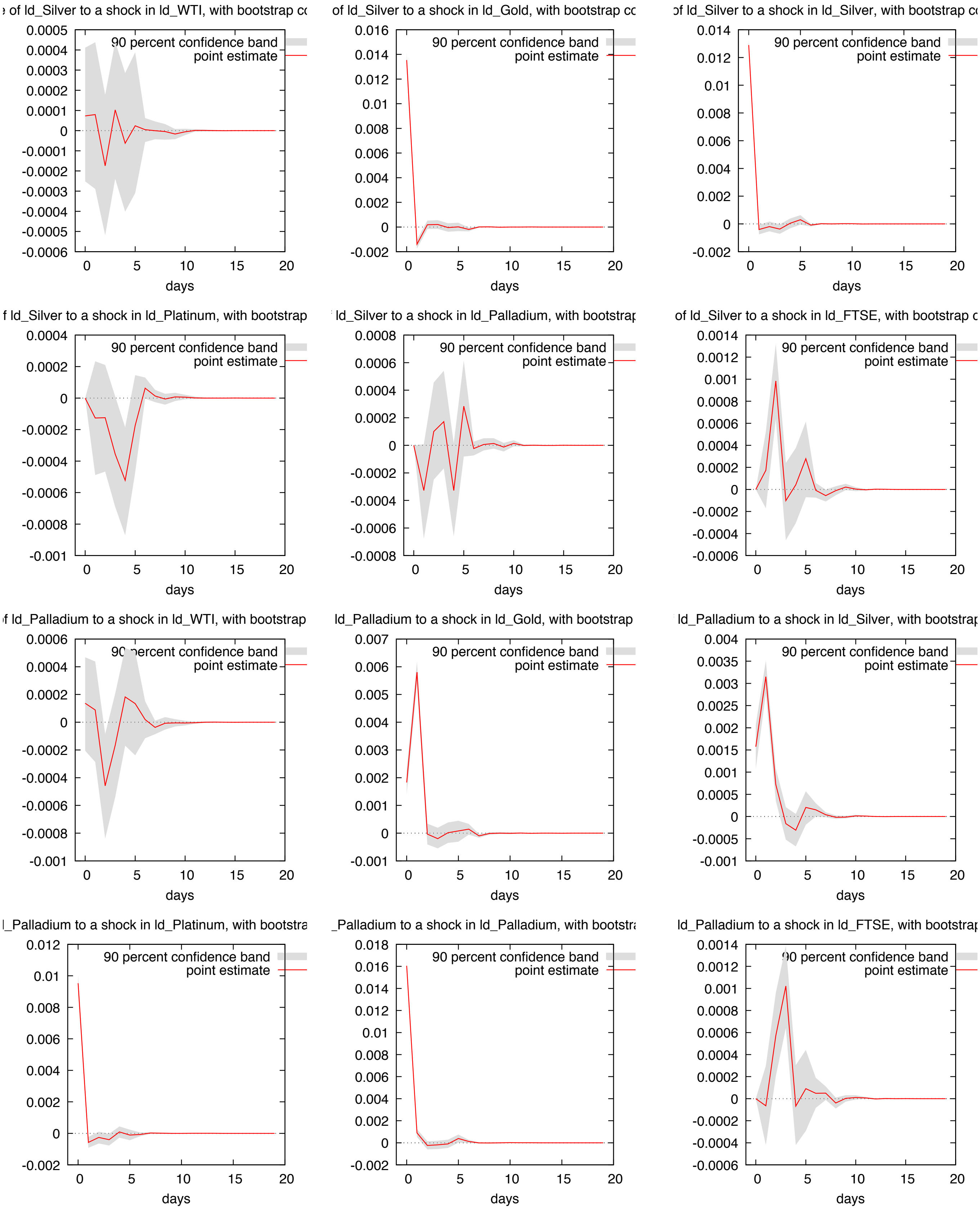


FIGURE 3.B - IRF VAR_3 (SILVER & PLATINUM RESPONSES)



of ld_Silver to a shock in ld_WTI, with bootstrap c

of ld_Silver to a shock in ld_Gold, with bootstrap cc

of ld_Silver to a shock in ld_Silver, with bootstrap c

f ld_Silver to a shock in ld_Platinum, with bootstrap

ld_Silver to a shock in ld_Palladium, with bootstrap

of ld_Silver to a shock in ld_FTSE, with bootstrap c

f ld_Palladium to a shock in ld_WTI, with bootstrap

ld_Palladium to a shock in ld_Gold, with bootstrap

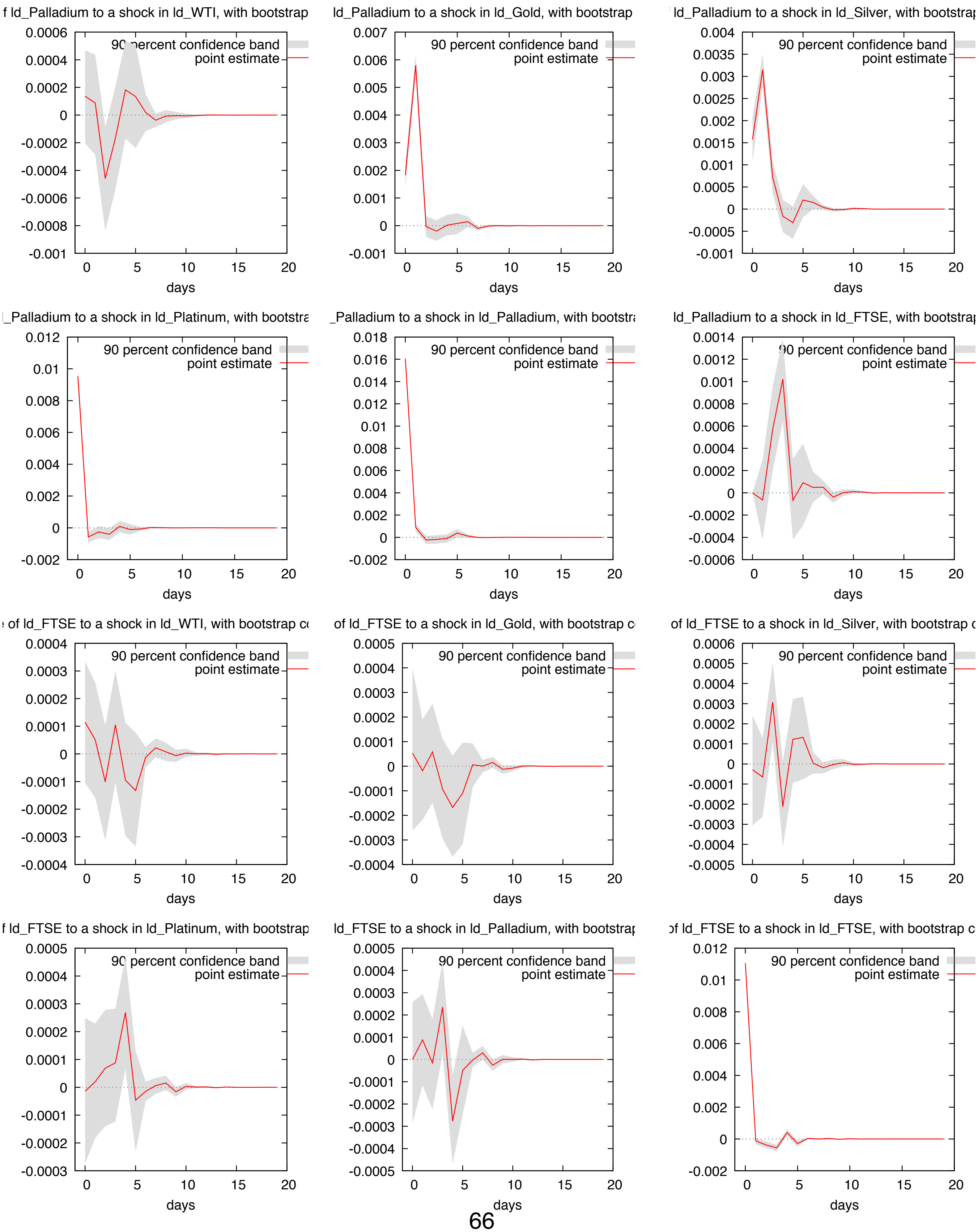
ld_Palladium to a shock in ld_Silver, with bootstrap

_Palladium to a shock in ld_Platinum, with bootstra

_Palladium to a shock in ld_Palladium, with bootstra

ld_Palladium to a shock in ld_FTSE, with bootstrap

FIGURE 3.C - IRF VAR_2 (PALLADIUM & FTSE RESPONSES)



f ld_Palladium to a shock in ld_WTI, with bootstrap

ld_Palladium to a shock in ld_Gold, with bootstrap

ld_Palladium to a shock in ld_Silver, with bootstraj

_Palladium to a shock in ld_Platinum, with bootstra

_Palladium to a shock in ld_Palladium, with bootstra

ld_Palladium to a shock in ld_FTSE, with bootstraj

of ld_FTSE to a shock in ld_WTI, with bootstrap c

of ld_FTSE to a shock in ld_Gold, with bootstrap c

of ld_FTSE to a shock in ld_Silver, with bootstrap c

f ld_FTSE to a shock in ld_Platinum, with bootstrap

ld_FTSE to a shock in ld_Palladium, with bootstrap

of ld_FTSE to a shock in ld_FTSE, with bootstrap c

TABLE 8
GRANGER CAUSALITY TEST VAR_4

```
VAR system, lag order 8
OLS estimates, observations 1990-02-19-2020-05-08 (T = 7885)
Log-likelihood = 133326.55
Determinant of covariance matrix = 8.2848331e-23
AIC = -33.7432
BIC = -33.4832
HQC = -33.6541
Portmanteau test: LB(48) = 1829.16, df = 1440 [0.0000]

Equation 1: ld_WTI
Mean dependent var   0.000087   S.D. dependent var   0.026237
Sum squared resid    5.329826   S.E. of regression   0.026080
R-squared            0.017951   Adjusted R-squared   0.011935
F(48, 7836)          2.984013   P-value(F)           2.79e-11
rho                  0.000814   Durbin-Watson        1.998265

F-tests of zero restrictions:

All lags of ld_WTI         F(8, 7836) =   6.6924 [0.0000]
All lags of ld_Gold        F(8, 7836) =   2.4172 [0.0132]
All lags of ld_Silver      F(8, 7836) =   1.5574 [0.1321]
All lags of ld_Platinum    F(8, 7836) =   3.5135 [0.0005]
All lags of ld_Palladium   F(8, 7836) =   2.0151 [0.0408]
All lags of ld_NIKKEI225   F(8, 7836) =   2.9116 [0.0030]
All vars, lag 8            F(6, 7836) =   3.0425 [0.0057]

Equation 2: ld_Gold
Mean dependent var   0.000198   S.D. dependent var   0.010064
Sum squared resid    0.786538   S.E. of regression   0.010019
R-squared            0.014948   Adjusted R-squared   0.008914
F(48, 7836)          2.477354   P-value(F)           7.11e-08
rho                  0.000065   Durbin-Watson        1.999835

F-tests of zero restrictions:

All lags of ld_WTI         F(8, 7836) =   1.0682 [0.3822]
All lags of ld_Gold        F(8, 7836) =   7.7987 [0.0000]
All lags of ld_Silver      F(8, 7836) =   5.1633 [0.0000]
All lags of ld_Platinum    F(8, 7836) =   1.4106 [0.1863]
All lags of ld_Palladium   F(8, 7836) =   1.2881 [0.2445]
All lags of ld_NIKKEI225   F(8, 7836) =   1.4023 [0.1898]
All vars, lag 8            F(6, 7836) =   2.4510 [0.0228]
```

```
Equation 3: ld_Silver
Mean dependent var   0.000207   S.D. dependent var   0.018824
Sum squared resid    2.753964   S.E. of regression   0.018747
R-squared            0.014168   Adjusted R-squared   0.008129
F(48, 7836)          2.346092   P-value(F)           4.77e-07
rho                  0.000077   Durbin-Watson        1.999747

F-tests of zero restrictions:

All lags of ld_WTI         F(8, 7836) =  0.54958 [0.8196]
All lags of ld_Gold        F(8, 7836) =   3.4020 [0.0007]
All lags of ld_Silver      F(8, 7836) =   3.1102 [0.0016]
All lags of ld_Platinum    F(8, 7836) =   1.3325 [0.2219]
All lags of ld_Palladium   F(8, 7836) =   1.1520 [0.3246]
All lags of ld_NIKKEI225   F(8, 7836) =   1.8724 [0.0597]
All vars, lag 8            F(6, 7836) =   1.2912 [0.2574]

Equation 4: ld_Platinum
Mean dependent var   0.000102   S.D. dependent var   0.013920
Sum squared resid    1.223818   S.E. of regression   0.012497
R-squared            0.198856   Adjusted R-squared   0.193949
F(48, 7836)          40.52122   P-value(F)           0.000000
rho                  0.000923   Durbin-Watson        1.998101

F-tests of zero restrictions:

All lags of ld_WTI         F(8, 7836) =   1.8361 [0.0657]
All lags of ld_Gold        F(8, 7836) =   27.783 [0.0000]
All lags of ld_Silver      F(8, 7836) =   41.670 [0.0000]
All lags of ld_Platinum    F(8, 7836) =   8.0991 [0.0000]
All lags of ld_Palladium   F(8, 7836) =   3.1839 [0.0013]
All lags of ld_NIKKEI225   F(8, 7836) =  0.90481 [0.5112]
All vars, lag 8            F(6, 7836) =  0.98536 [0.4332]

Equation 5: ld_Palladium
Mean dependent var   0.000384   S.D. dependent var   0.020059
Sum squared resid    2.791449   S.E. of regression   0.018874
R-squared            0.120026   Adjusted R-squared   0.114636
F(48, 7836)          22.26687   P-value(F)           3.4e-179
rho                  0.000272   Durbin-Watson        1.999442

F-tests of zero restrictions:

All lags of ld_WTI         F(8, 7836) =   1.4100 [0.1865]
All lags of ld_Gold        F(8, 7836) =   8.6298 [0.0000]
All lags of ld_Silver      F(8, 7836) =   29.440 [0.0000]
All lags of ld_Platinum    F(8, 7836) =   3.5859 [0.0004]
All lags of ld_Palladium   F(8, 7836) =   4.0227 [0.0001]
All lags of ld_NIKKEI225   F(8, 7836) =   1.2792 [0.2492]
All vars, lag 8            F(6, 7836) =  0.60299 [0.7282]
```

```
Equation 6: ld_NIKKEI225
Mean dependent var  -0.000135   S.D. dependent var   0.013937
Sum squared resid    1.513985   S.E. of regression   0.013900
R-squared            0.011429   Adjusted R-squared   0.005373
F(48, 7836)          1.887327   P-value(F)           0.000211
rho                 -0.000014   Durbin-Watson        1.999906

F-tests of zero restrictions:

All lags of ld_WTI         F(8, 7836) =   3.5041 [0.0005]
All lags of ld_Gold        F(8, 7836) =   1.3562 [0.2105]
All lags of ld_Silver      F(8, 7836) =   1.0745 [0.3776]
All lags of ld_Platinum    F(8, 7836) =  0.97111 [0.4565]
All lags of ld_Palladium   F(8, 7836) =  0.79978 [0.6027]
All lags of ld_NIKKEI225   F(8, 7836) =   1.9290 [0.0514]
All vars, lag 8            F(6, 7836) =   2.7094 [0.0125]

For the system as a whole:

  Null hypothesis: the longest lag is 7
  Alternative hypothesis: the longest lag is 8
  Likelihood ratio test: Chi-square(36) = 67.1802 [0.0012]

  Comparison of information criteria:
  Lag order 8: AIC = -33.7432, BIC = -33.4832, HQC = -33.6541
  Lag order 7: AIC = -33.7438, BIC = -33.5157, HQC = -33.6657
```

TABLE 9
VARIANCE DECOMPOSITION VAR_4

```
Decomposition of variance for ld_WTI

period     std. error      ld_WTI     ld_Gold   ld_Silver ld_Platinum ld_Palladium ld_NIKKEI225

   1       0.0259989    100.0000      0.0000      0.0000      0.0000      0.0000       0.0000
   2       0.0260208     99.8770      0.0022      0.0046      0.0533      0.0627       0.0000
   3       0.0260278     99.8233      0.0023      0.0070      0.0560      0.1036       0.0078
   4       0.0261134     99.5655      0.1052      0.0070      0.0873      0.1251       0.1099
   5       0.0261447     99.3715      0.1064      0.0792      0.2066      0.1266       0.1096
   6       0.0261753     99.2383      0.1211      0.0797      0.2306      0.1507       0.1796
   7        0.026195     99.1829      0.1329      0.0943      0.2409      0.1570       0.1918
   8       0.0262052     99.1143      0.1351      0.0987      0.2408      0.1993       0.2118
   9       0.0262339     98.9149      0.1810      0.1771      0.2504      0.2067       0.2698
  10       0.0262344     98.9115      0.1828      0.1777      0.2508      0.2068       0.2703

Decomposition of variance for ld_Gold

period     std. error      ld_WTI     ld_Gold   ld_Silver ld_Platinum ld_Palladium ld_NIKKEI225

   1      0.00998755      0.0020     99.9980      0.0000      0.0000      0.0000       0.0000
   2       0.0100169      0.0151     99.5097      0.4194      0.0239        0.0315       0.0003
   3       0.0100208      0.0368     99.4344      0.4597      0.0307        0.0336       0.0049
   4       0.0100292      0.0547     99.2775      0.4825      0.0856        0.0831       0.0165
   5       0.0100346      0.0633     99.1704      0.4820      0.1330        0.1103       0.0409
   6       0.0100397      0.0666     99.1622      0.4815      0.1372        0.1102       0.0423
   7       0.0100447      0.0699     99.1129      0.4846      0.1394        0.1109       0.0823
   8       0.0100525      0.0710     99.0993      0.4864      0.1392        0.1214       0.0826
   9       0.0100625      0.1205     98.9470      0.5218      0.1393        0.1286       0.1428
  10       0.0100626      0.1205     98.9466      0.5219      0.1395        0.1286       0.1429
```

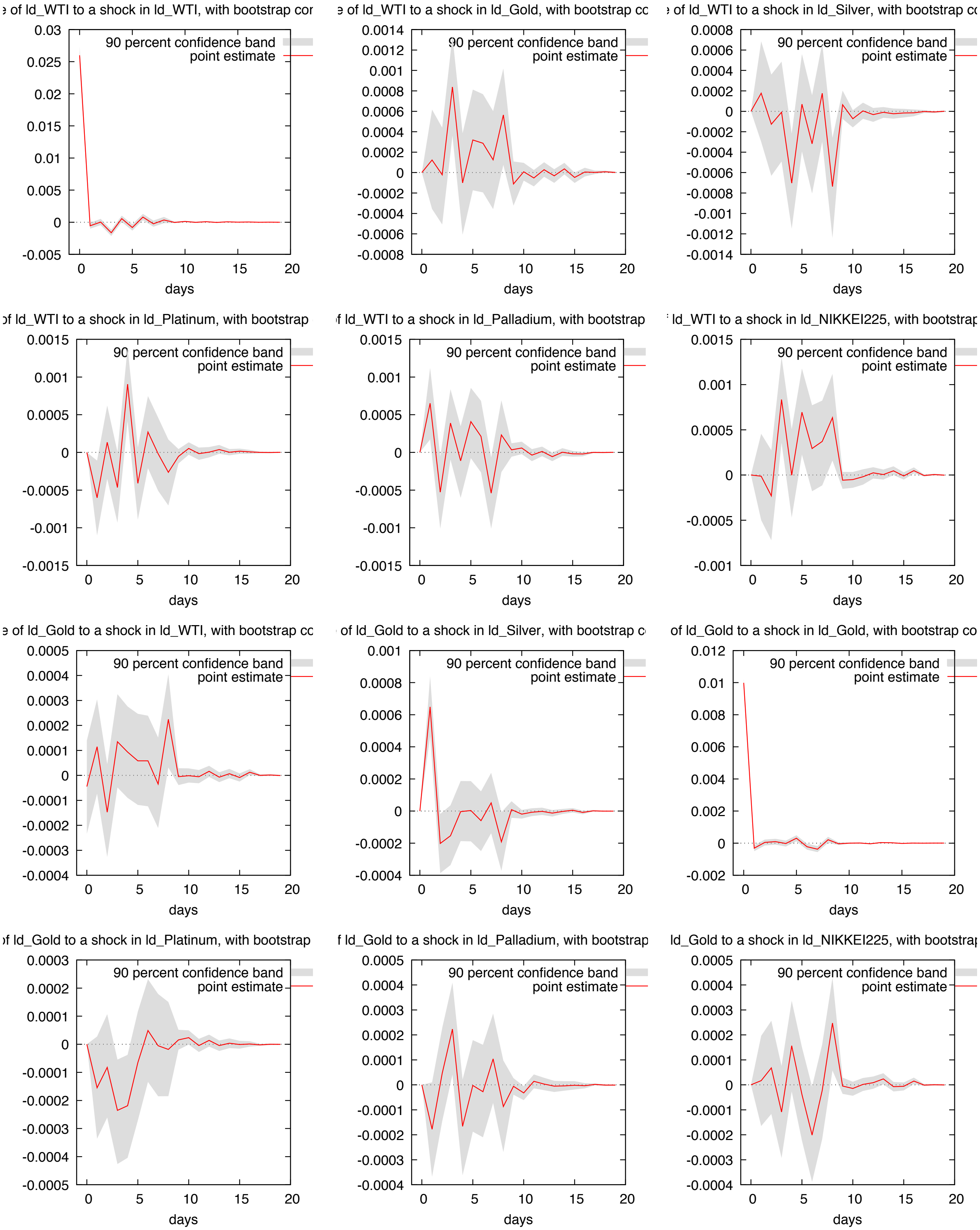
```
Decomposition of variance for ld_Silver

period     std. error      ld_WTI     ld_Gold    ld_Silver ld_Platinum ld_Palladium ld_NIKKEI225

   1        0.0186887      0.0025     52.3401     47.6574      0.0000      0.0000       0.0000
   2        0.0187486      0.0037     52.5587     47.3899      0.0058      0.0334       0.0085
   3        0.0187545      0.0139     52.5365     47.3734      0.0091      0.0364       0.0307
   4        0.0187643      0.0198     52.4925     47.3577      0.0384      0.0437       0.0480
   5        0.0187818      0.0228     52.3958     47.2715      0.1193      0.0739       0.1167
   6        0.0187873      0.0233     52.3649     47.2680      0.1292      0.0971       0.1175
   7        0.0187972      0.0265     52.3327     47.2188      0.1367      0.0972       0.1881
   8        0.0188098      0.0387     52.2758     47.2365      0.1371      0.1227       0.1893
   9        0.0188213      0.0639     52.2125     47.2684      0.1394      0.1230       0.1928
  10        0.0188217      0.0643     52.2104     47.2699      0.1396      0.1230       0.1928
```

```
Decomposition of variance for ld_Platinum

period     std. error      ld_WTI     ld_Gold    ld_Silver ld_Platinum ld_Palladium ld_NIKKEI225

   1        0.0124583      0.0000      2.6878      0.8652     96.4470      0.0000       0.0000
   2        0.0138436      0.0186     17.4881      3.7766     78.6950      0.0152       0.0065
   3        0.0138613      0.0264     17.4467      3.9574     78.5001      0.0203       0.0490
   4        0.0138678      0.0713     17.4348      3.9565     78.4674      0.0209       0.0490
   5        0.0138851      0.1344     17.4394      4.0131     78.2764      0.0877       0.0489
   6        0.0138945      0.1352     17.4235      4.0082     78.2834      0.0985       0.0512
   7        0.0139104      0.1554     17.4322      4.0313     78.1115      0.2090       0.0606
   8         0.013915      0.1762     17.4382      4.0397     78.0629      0.2153       0.0677
   9        0.0139172      0.1770     17.4395      4.0388     78.0476      0.2293       0.0678
  10        0.0139185      0.1804     17.4363      4.0487     78.0330      0.2297       0.0719
```

```
Decomposition of variance for ld_Palladium

period     std. error      ld_WTI     ld_Gold    ld_Silver ld_Platinum ld_Palladium ld_NIKKEI225

   1        0.0188154      0.0036      0.9404      0.7281     25.6296     72.6983       0.0000
   2        0.0199711      0.0050      9.2107      3.2248     22.8168     64.7256       0.0170
   3        0.0199987      0.0581      9.1857      3.3562     22.7698     64.5634       0.0668
   4        0.0200061      0.0694      9.1889      3.3586     22.7927     64.5234       0.0671
   5        0.0200105      0.0794      9.1848      3.3821     22.7832     64.4969       0.0736
   6        0.0200174      0.0814      9.1797      3.3978     22.7926     64.4745       0.0739
   7        0.0200425      0.0884      9.2112      3.4282     22.7409     64.4319       0.0994
   8        0.0200531      0.1278      9.2274      3.4318     22.7285     64.3698       0.1148
   9         0.020056      0.1324      9.2247      3.4376     22.7281     64.3539       0.1233
  10        0.0200573      0.1358      9.2235      3.4441     22.7252     64.3457       0.1256
```

```
Decomposition of variance for ld_NIKKEI225

period     std. error      ld_WTI     ld_Gold    ld_Silver ld_Platinum ld_Palladium ld_NIKKEI225

   1        0.0138567      0.1969      0.0017      0.0037      0.0000      0.0045      99.7931
   2         0.013881      0.3685      0.0438      0.0054      0.0577      0.0197      99.5051
   3        0.0138899      0.3863      0.0437      0.0515      0.0736      0.0348      99.4100
   4        0.0139002      0.4088      0.0441      0.0634      0.0736      0.0721      99.3380
   5        0.0139052      0.4492      0.0625      0.0704      0.0775      0.0732      99.2672
   6        0.0139091      0.4804      0.0627      0.0722      0.0822      0.0767      99.2259
   7        0.0139126      0.4965      0.0956      0.0721      0.0823      0.0774      99.1760
   8         0.013915      0.4967      0.1204      0.0755      0.0830      0.0785      99.1459
   9        0.0139349      0.5180      0.3198      0.0789      0.1208      0.0883      98.8742
  10        0.0139361      0.5181      0.3341      0.0799      0.1216      0.0888      98.8575
```

FIGURE 4.A - IRF (WTI & GOLD RESPONSES)



71

FIGURE 4.B - IRF (SILVER & PLATINUM RESPONSES)

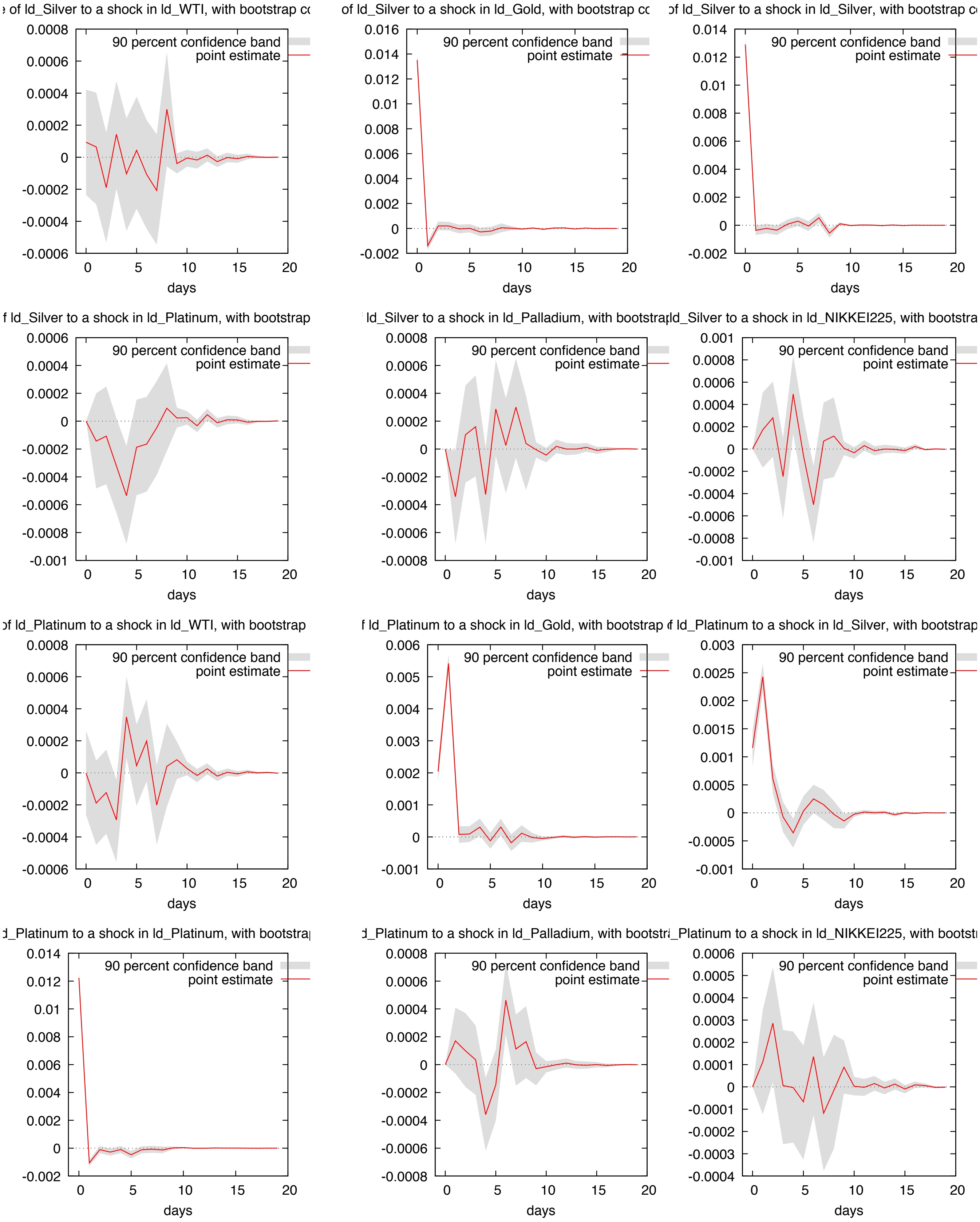


FIGURE 4.C - IRF (PALLADIUM & NIKKEI225 RESPONSES)

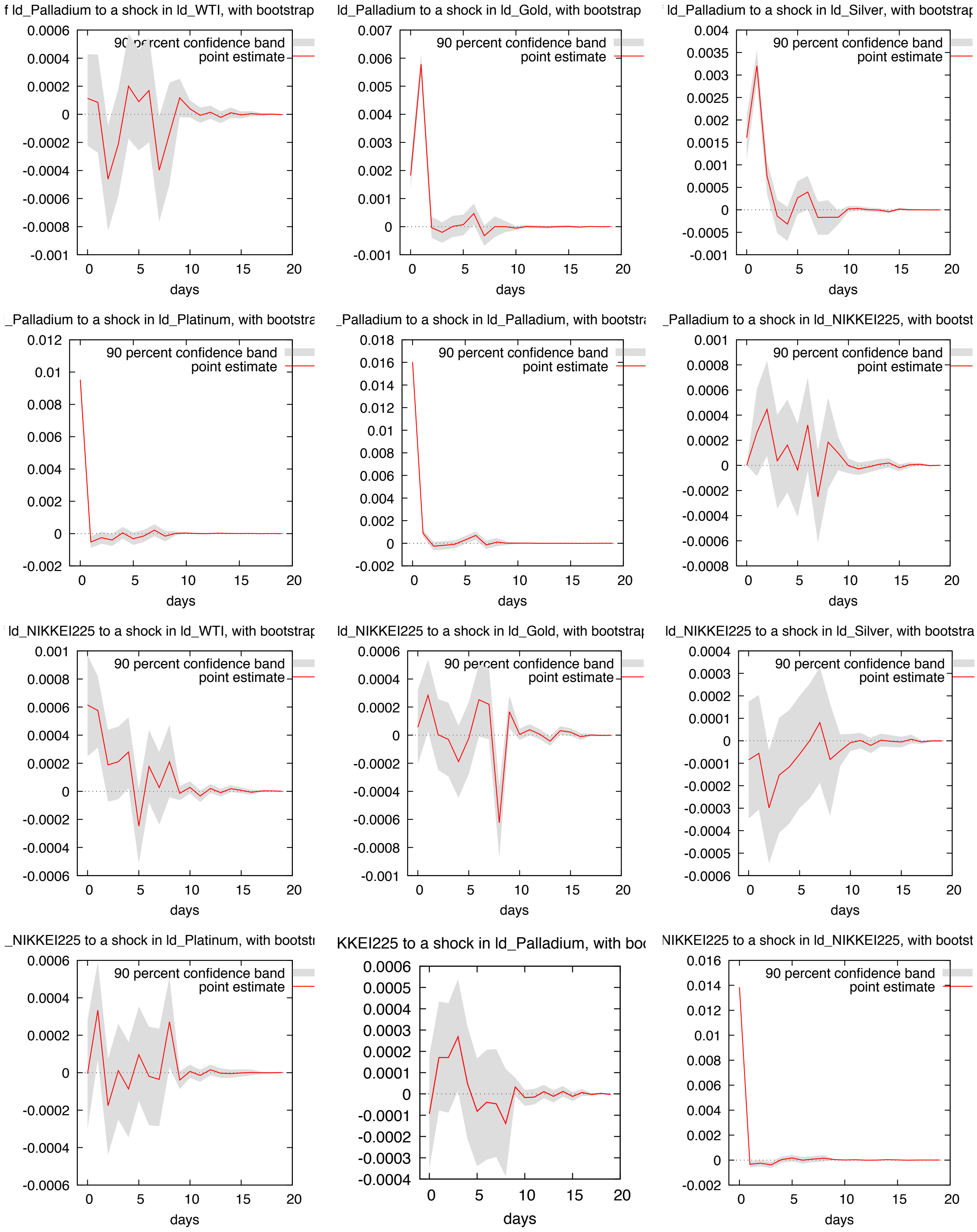


TABLE 10
GRANGER CAUSALITY TEST VAR_5

```
VAR system, lag order 6
OLS estimates, observations 1990-02-15-2020-05-08 (T = 7887)
Log-likelihood = 134866.56
Determinant of covariance matrix = 5.6546817e-23
AIC = -34.1434
BIC = -33.9471
HQC = -34.0762
Portmanteau test: LB(48) = 2387.66, df = 1512 [0.0000]

Equation 1: ld_WTI
Mean dependent var   0.000089   S.D. dependent var   0.026238
Sum squared resid    5.351453   S.E. of regression   0.026110
R-squared            0.014295   Adjusted R-squared   0.009775
F(36, 7850)          3.162311   P-value(F)           6.39e-10
rho                  0.000386   Durbin-Watson        1.998945

F-tests of zero restrictions:

All lags of ld_WTI         F(6, 7850) =   8.1582 [0.0000]
All lags of ld_Gold        F(6, 7850) =   1.6725 [0.1233]
All lags of ld_Silver      F(6, 7850) =   1.2342 [0.2851]
All lags of ld_Platinum    F(6, 7850) =   3.8963 [0.0007]
All lags of ld_Palladium   F(6, 7850) =   1.7495 [0.1054]
All lags of ld_SP500       F(6, 7850) =   1.6716 [0.1236]
All vars, lag 6            F(6, 7850) =   1.6497 [0.1292]

Equation 2: ld_Gold
Mean dependent var   0.000198   S.D. dependent var   0.010063
Sum squared resid    0.788081   S.E. of regression   0.010020
R-squared            0.013040   Adjusted R-squared   0.008514
F(36, 7850)          2.881076   P-value(F)           2.06e-08
rho                 -0.000709   Durbin-Watson        2.001398

F-tests of zero restrictions:

All lags of ld_WTI         F(6, 7850) =  0.62881 [0.7074]
All lags of ld_Gold        F(6, 7850) =   8.2902 [0.0000]
All lags of ld_Silver      F(6, 7850) =   6.4348 [0.0000]
All lags of ld_Platinum    F(6, 7850) =   1.9021 [0.0766]
All lags of ld_Palladium   F(6, 7850) =   1.5049 [0.1721]
All lags of ld_SP500       F(6, 7850) =   3.2935 [0.0031]
All vars, lag 6            F(6, 7850) =  0.71333 [0.6389]
```

```
Equation 3: ld_Silver
Mean dependent var   0.000207   S.D. dependent var   0.018822
Sum squared resid    2.761007   S.E. of regression   0.018754
R-squared            0.011684   Adjusted R-squared   0.007151
F(36, 7850)          2.577770   P-value(F)           7.37e-07
rho                 -0.000251   Durbin-Watson        2.000478

F-tests of zero restrictions:

All lags of ld_WTI         F(6, 7850) =  0.14796 [0.9895]
All lags of ld_Gold        F(6, 7850) =   2.8833 [0.0083]
All lags of ld_Silver      F(6, 7850) =   1.5793 [0.1487]
All lags of ld_Platinum    F(6, 7850) =   1.6144 [0.1387]
All lags of ld_Palladium   F(6, 7850) =   1.2092 [0.2980]
All lags of ld_SP500       F(6, 7850) =   2.7395 [0.0117]
All vars, lag 6            F(6, 7850) =  0.22291 [0.9695]

Equation 4: ld_Platinum
Mean dependent var   0.000103   S.D. dependent var   0.013918
Sum squared resid    1.225288   S.E. of regression   0.012494
R-squared            0.197950   Adjusted R-squared   0.194272
F(36, 7850)          53.81716   P-value(F)           0.000000
rho                  0.000475   Durbin-Watson        1.999039

F-tests of zero restrictions:

All lags of ld_WTI         F(6, 7850) =   2.0147 [0.0602]
All lags of ld_Gold        F(6, 7850) =   35.839 [0.0000]
All lags of ld_Silver      F(6, 7850) =   55.552 [0.0000]
All lags of ld_Platinum    F(6, 7850) =   10.481 [0.0000]
All lags of ld_Palladium   F(6, 7850) =   4.0385 [0.0005]
All lags of ld_SP500       F(6, 7850) =   1.4062 [0.2079]
All vars, lag 6            F(6, 7850) =   3.4419 [0.0021]

Equation 5: ld_Palladium
Mean dependent var   0.000384   S.D. dependent var   0.020056
Sum squared resid    2.795611   S.E. of regression   0.018871
R-squared            0.118716   Adjusted R-squared   0.114674
F(36, 7850)          29.37373   P-value(F)           2.6e-185
rho                  0.000974   Durbin-Watson        1.998036

F-tests of zero restrictions:

All lags of ld_WTI         F(6, 7850) =   1.2226 [0.2910]
All lags of ld_Gold        F(6, 7850) =   11.146 [0.0000]
All lags of ld_Silver      F(6, 7850) =   39.473 [0.0000]
All lags of ld_Platinum    F(6, 7850) =   4.9176 [0.0000]
All lags of ld_Palladium   F(6, 7850) =   5.0770 [0.0000]
All lags of ld_SP500       F(6, 7850) =   1.3132 [0.2472]
All vars, lag 6            F(6, 7850) =   2.0805 [0.0521]
```

```
Equation 6: ld_SP500
 Mean dependent var   0.000324   S.D. dependent var   0.011468
 Sum squared resid    1.022668   S.E. of regression   0.011414
 R-squared            0.014026   Adjusted R-squared   0.009504
 F(36, 7850)          3.101868   P-value(F)           1.36e-09
 rho                  0.000971   Durbin-Watson        1.998039

 F-tests of zero restrictions:

 All lags of ld_WTI         F(6, 7850) =   1.0098 [0.4167]
 All lags of ld_Gold        F(6, 7850) =   1.1502 [0.3302]
 All lags of ld_Silver      F(6, 7850) =   1.9441 [0.0700]
 All lags of ld_Platinum    F(6, 7850) =  0.41550 [0.8692]
 All lags of ld_Palladium   F(6, 7850) =  0.87347 [0.5134]
 All lags of ld_SP500       F(6, 7850) =   13.761 [0.0000]
 All vars, lag 6            F(6, 7850) =   2.8878 [0.0082]

 For the system as a whole:

   Null hypothesis: the longest lag is 5
   Alternative hypothesis: the longest lag is 6
   Likelihood ratio test: Chi-square(36) = 63.7704 [0.0029]

   Comparison of information criteria:
   Lag order 6: AIC = -34.1434, BIC = -33.9471, HQC = -34.0762
   Lag order 5: AIC = -34.1445, BIC = -33.9800, HQC = -34.0881
```

TABLE 11
VARIANCE DECOMPOSITION VAR_5

```
Decomposition of variance for ld_WTI

period     std. error       ld_WTI     ld_Gold    ld_Silver ld_Platinum ld_Palladium      ld_SP500

   1        0.0260483    100.0000      0.0000      0.0000      0.0000      0.0000        0.0000
   2        0.0260694     99.8840      0.0009      0.0041      0.0528      0.0574        0.0008
   3        0.0260821     99.7867      0.0012      0.0063      0.0562      0.0944        0.0553
   4        0.0261523     99.6268      0.1100      0.0063      0.0834      0.1152        0.0581
   5        0.0261917     99.3710      0.1111      0.0694      0.2101      0.1162        0.1222
   6        0.0262124     99.3003      0.1271      0.0700      0.2348      0.1415        0.1263
   7        0.0262325     99.2331      0.1423      0.0835      0.2437      0.1461        0.1514
   8        0.0262343     99.2213      0.1436      0.0866      0.2471      0.1461        0.1553
   9        0.0262352     99.2179      0.1436      0.0869      0.2479      0.1469        0.1568
  10        0.0262359     99.2149      0.1436      0.0869      0.2496      0.1469        0.1580

Decomposition of variance for ld_Gold

period     std. error       ld_WTI     ld_Gold    ld_Silver ld_Platinum ld_Palladium      ld_SP500

   1       0.00999608      0.0017     99.9983      0.0000      0.0000      0.0000        0.0000
   2        0.0100278      0.0126     99.4730      0.4112      0.0277      0.0321        0.0434
   3        0.0100315      0.0310     99.4008      0.4561      0.0339      0.0338        0.0444
   4        0.0100399      0.0441     99.2443      0.4821      0.0982      0.0835        0.0477
   5         0.010044      0.0521     99.1644      0.4817      0.1380      0.1121        0.0518
   6        0.0100579      0.0549     98.9803      0.4804      0.1449      0.1117        0.2278
   7        0.0100614      0.0590     98.9519      0.4817      0.1532      0.1145        0.2398
   8        0.0100618      0.0590     98.9462      0.4843      0.1538      0.1147        0.2420
   9        0.0100618      0.0591     98.9457      0.4843      0.1538      0.1151        0.2420
  10        0.0100618      0.0591     98.9452      0.4843      0.1538      0.1153        0.2422
```

```
Decomposition of variance for ld_Silver

period     std. error      ld_WTI     ld_Gold    ld_Silver ld_Platinum   ld_Palladium     ld_SP500

   1        0.0187102      0.0028     52.3231     47.6741      0.0000         0.0000        0.0000
   2        0.0187705      0.0030     52.5493     47.4043      0.0057         0.0280        0.0097
   3        0.0187742      0.0099     52.5380     47.3997      0.0084         0.0301        0.0139
   4        0.0187869      0.0117     52.4783     47.3674      0.0436         0.0392        0.0599
   5        0.0187977      0.0125     52.4192     47.3139      0.1155         0.0716        0.0674
   6        0.0188165      0.0126     52.3147     47.2432      0.1238         0.0959        0.2098
   7          0.01882      0.0143     52.3116     47.2282      0.1295         0.0966        0.2199
   8        0.0188202      0.0144     52.3108     47.2277      0.1304         0.0966        0.2201
   9        0.0188202      0.0145     52.3107     47.2276      0.1304         0.0966        0.2202
  10        0.0188203      0.0145     52.3103     47.2272      0.1305         0.0969        0.2207

Decomposition of variance for ld_Platinum

period     std. error      ld_WTI     ld_Gold    ld_Silver ld_Platinum   ld_Palladium     ld_SP500

   1        0.0124642      0.0000      2.7156      0.8822     96.4023        72.6675        0.0000
   2        0.0138397      0.0188     17.3649      3.7990     78.7753        64.7203        0.0018
   3        0.0138568      0.0288     17.3247      3.9931     78.5867        64.5885        0.0030
   4        0.0138638      0.0714     17.3115      3.9939     78.5516        64.5034        0.0735
   5         0.013882      0.1294     17.3141      4.0479     78.3506        64.4839        0.0735
   6        0.0138904      0.1307     17.3009      4.0436     78.3556        64.4572        0.0788
   7        0.0139163      0.1508     17.2884      4.0582     78.0692        64.4010        0.1013
   8        0.0139173      0.1509     17.2952      4.0576     78.0613        64.3947        0.1017
   9        0.0139174      0.1510     17.2950      4.0584     78.0603        64.3935        0.1020
  10        0.0139174      0.1512     17.2948      4.0587     78.0599        64.3932        0.1021

Decomposition of variance for ld_Palladium

period     std. error      ld_WTI     ld_Gold    ld_Silver ld_Platinum   ld_Palladium     ld_SP500

   1        0.0188271      0.0054      0.9522      0.7012     25.6737        72.6675        0.0000
   2          0.01998      0.0063      9.1851      3.2143     22.8721        64.7203        0.0018
   3        0.0200028      0.0616      9.1650      3.3477     22.8341        64.5885        0.0030
   4        0.0200173      0.0696      9.1629      3.3491     22.8416        64.5034        0.0735
   5        0.0200206      0.0783      9.1599      3.3698     22.8345        64.4839        0.0735
   6        0.0200284      0.0818      9.1541      3.3851     22.8430        64.4572        0.0788
   7        0.0200537      0.0879      9.1852      3.4217     22.8028        64.4010        0.1013
   8        0.0200547      0.0879      9.1929      3.4214     22.8014        64.3947        0.1017
   9        0.0200549      0.0881      9.1931      3.4223     22.8009        64.3935        0.1020
  10         0.020055      0.0881      9.1931      3.4227     22.8008        64.3932        0.1021


Decomposition of variance for ld_SP500

period     std. error      ld_WTI     ld_Gold    ld_Silver ld_Platinum   ld_Palladium     ld_SP500

   1        0.0113871      0.0092      0.0195      0.0088      0.0019         0.0486       99.9119
   2         0.011437      0.0242      0.0195      0.0503      0.0054         0.0483       99.8523
   3         0.011441      0.0451      0.0376      0.0627      0.0054         0.0632       99.7861
   4        0.0114437      0.0607      0.0382      0.0648      0.0065         0.0912       99.7386
   5        0.0114519      0.0698      0.0754      0.0922      0.0138         0.0990       99.6498
   6         0.011457      0.0731      0.0782      0.1279      0.0142         0.1001       99.6066
   7         0.011467      0.0748      0.0806      0.1778      0.0189         0.1080       99.5399
   8        0.0114676      0.0752      0.0834      0.1787      0.0190         0.1082       99.5355
   9        0.0114676      0.0752      0.0835      0.1787      0.0190         0.1082       99.5353
  10        0.0114677      0.0753      0.0835      0.1788      0.0190         0.1083       99.5351
```

FIGURE 5.A - IRF (WTI & GOLD RESPONSES)

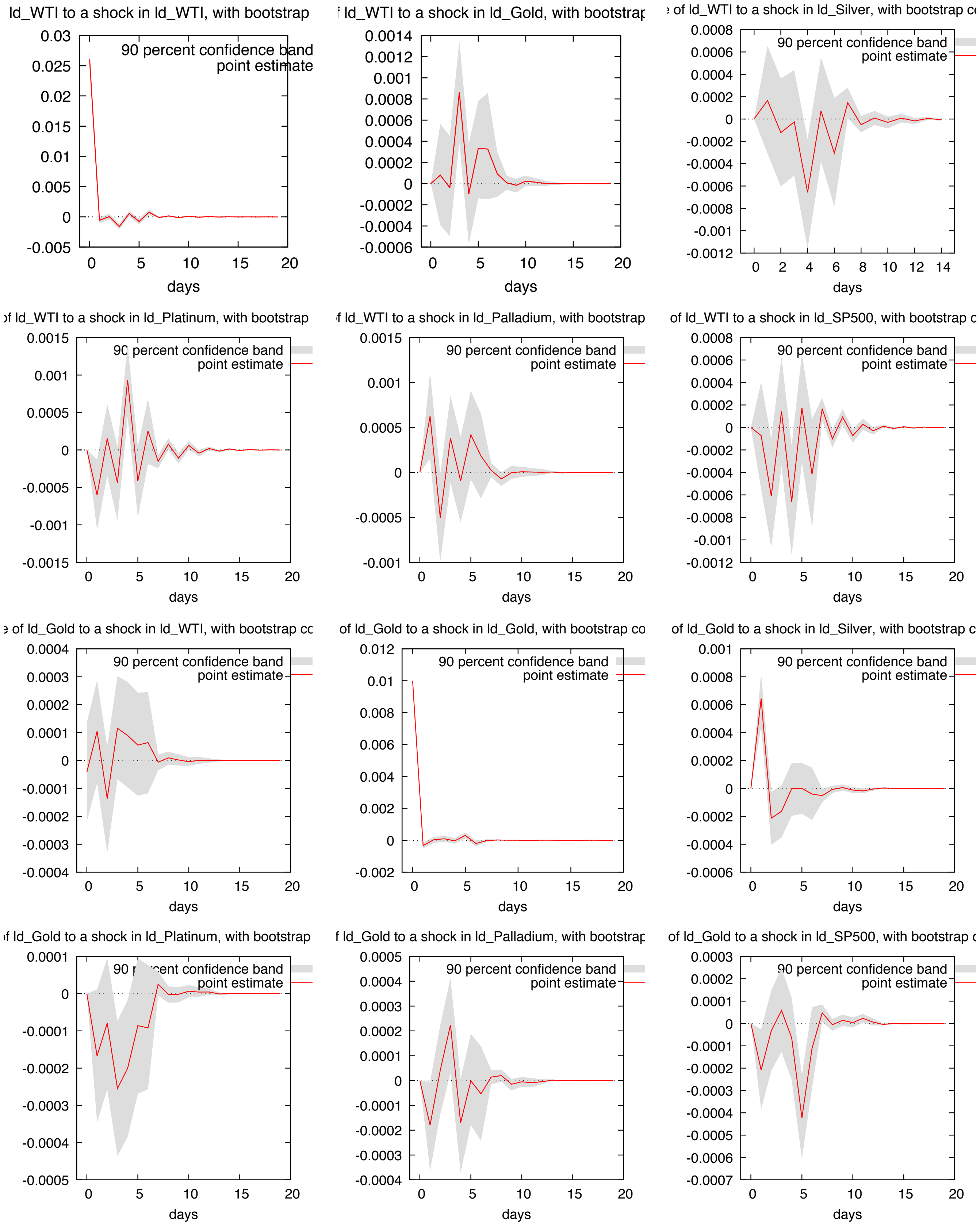


FIGURE 5.B - IRF (SILVER & PLATINUM RESPONSES)

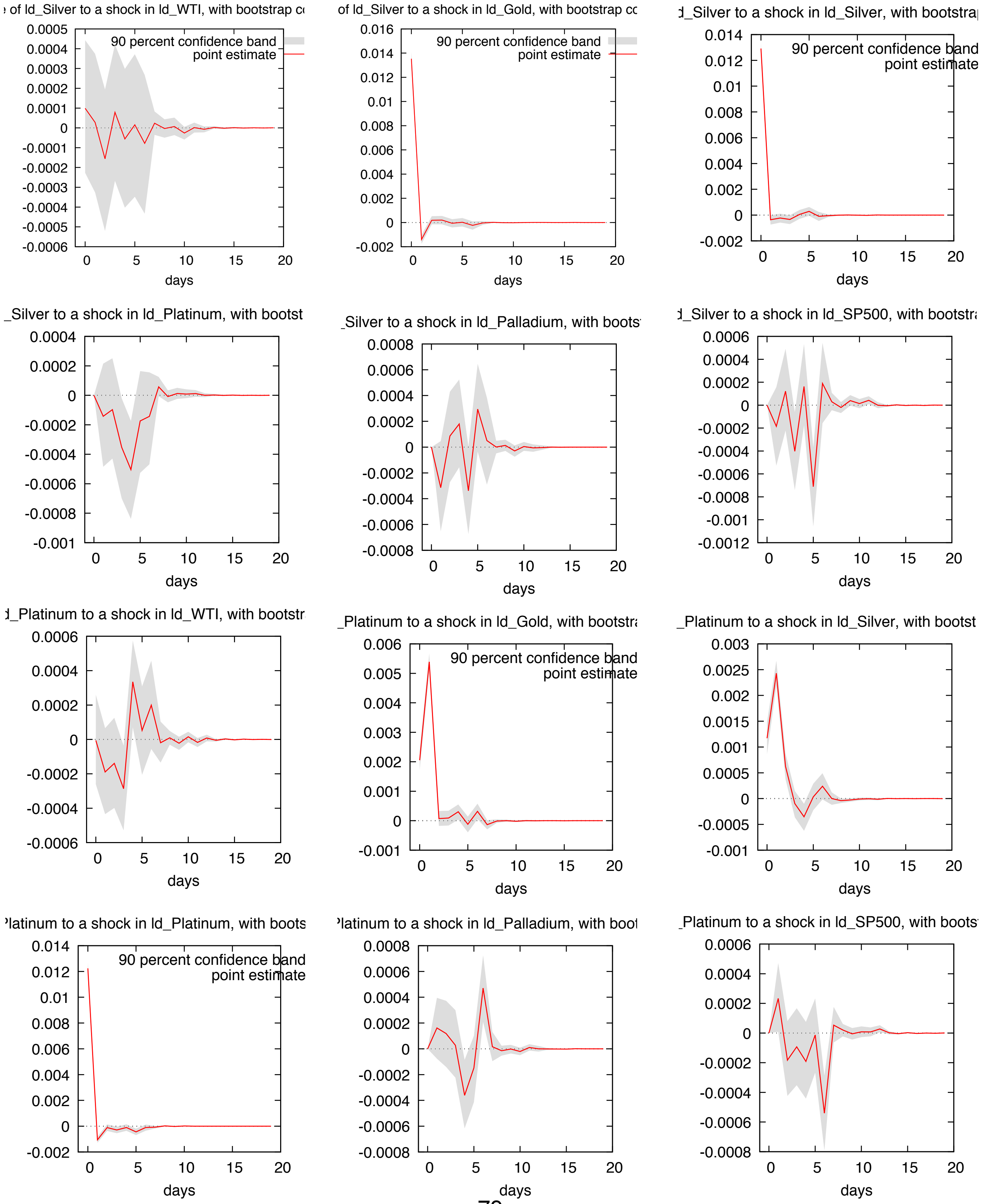


FIGURE 5.C - IRF (PALLADIUM & S&P500)

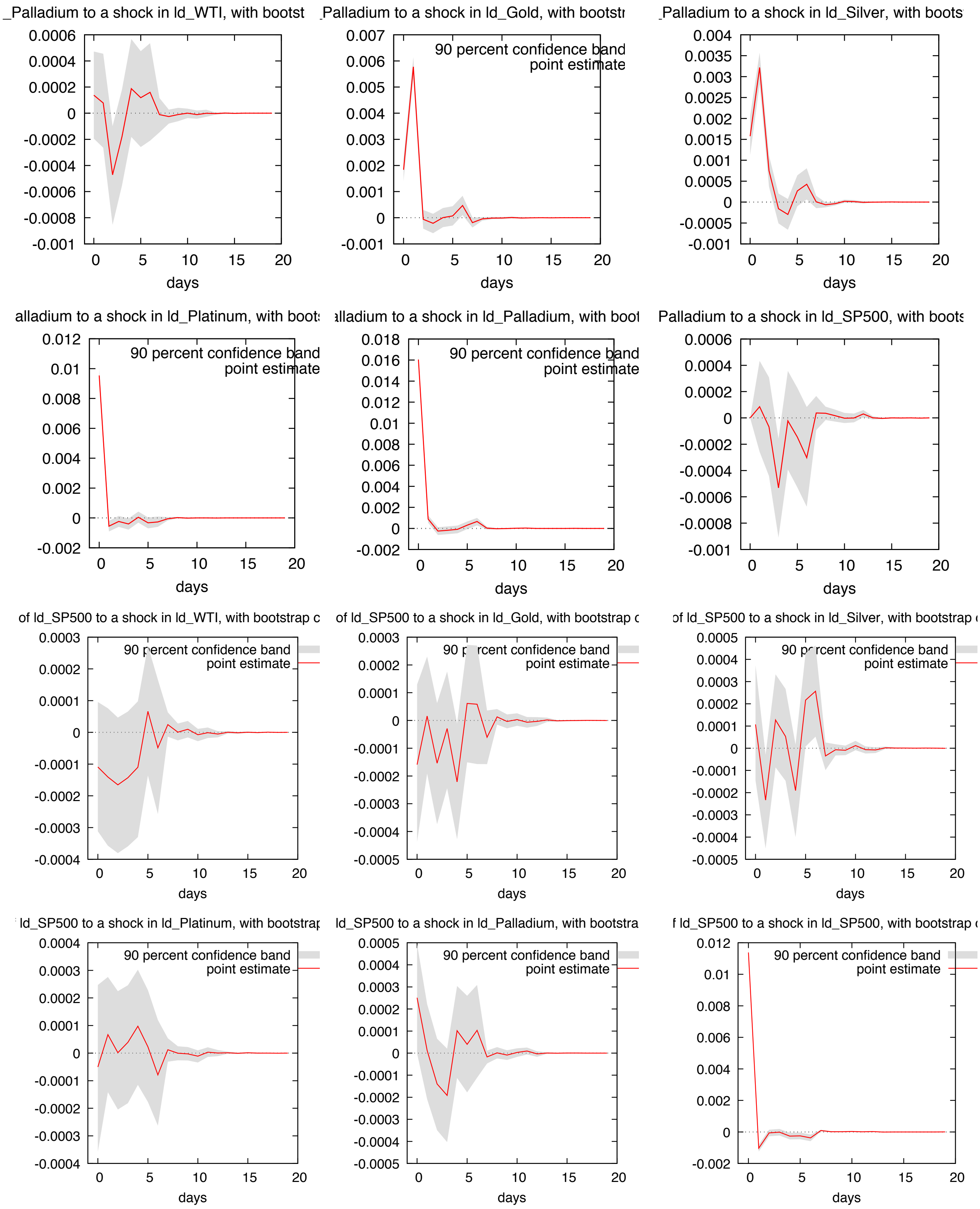


FIGURE 6: VAR_1 INVERSE ROOTS

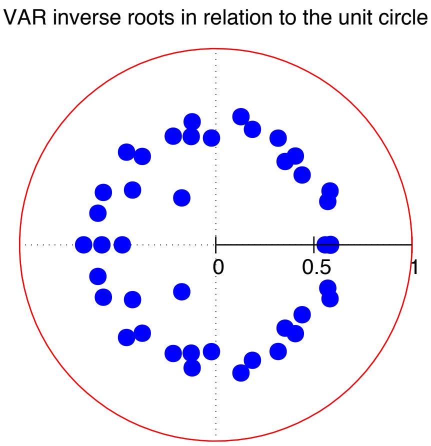


FIGURE 7: VAR_2 INVERSE ROOTS

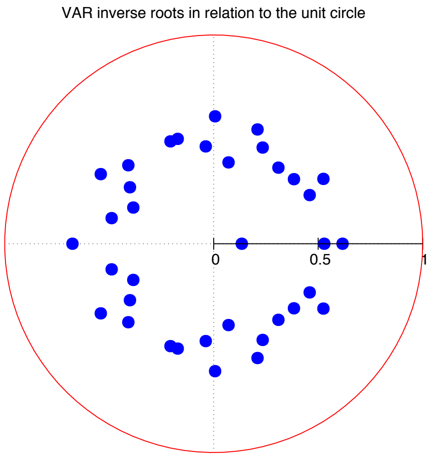


FIGURE 8: VAR_3 INVERSE ROOTS

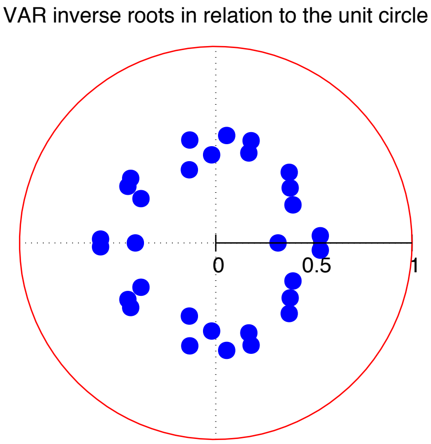


FIGURE 8: VAR_4 INVERSE ROOTS

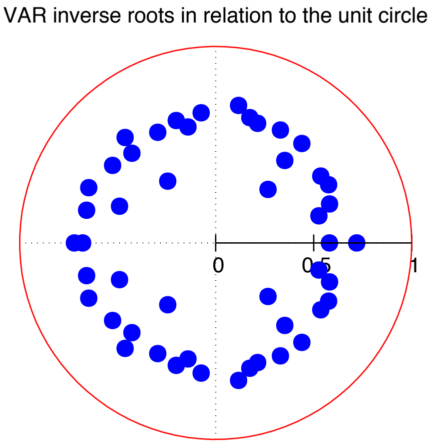


FIGURE 9: VAR_5 INVERSE ROOTS