

GRANGER CAUSALITY BETWEEN GOLD, MONEY SUPPLY, EQUITY MARKET, INFLATIONS, AND REAL INTEREST RATES IN A MULTIVARIATE MODEL

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ABSTRACT

This paper uses monthly data spanning from January 18, 1982 to December 2011 to examine the Granger causal relationship between gold, money supply, stocks, inflations, and real interest rates in a multivariate model. Financial economic theories consider money supply, stocks, and real interest rates to be determinants that help predict the future price direction of gold in the short run. This study found that real interest rate alone Granger-causes gold price in a uni-direction way and that there is a statistically significant negative correlation between the two. Federal Reserve's monetary policy shift to a tight money supply could cause the gold price bubble to break.

Keywords: Gold price bubble, real interest rates, multivariate causality

INTRODUCTION

The price of gold remained fairly stable as a store of value for about 140 years since dating back to 1833. The price of gold began to change since 1971 after it was de-linked from US dollar at fixed price of \$35 per ounce. Since then gold prices have become volatile whenever we have had a crisis national or global. They went up when Soviet Union invaded Afghanistan, they were high when we had stagflation in the late 70s early 80s. Gold prices were also at the lowest level in 1999 when stock markets were doing well, US dollar was strong, and U.S. had low inflation rates. Gold prices started rising during the tech bubble and have been increasing because we have had crisis after crisis since then, Sep 11, 2001, Afghanistan War, Iraq war, and the subprime lending mess that led to the worst recession since the great depression. The purpose of this paper is to investigate the cause of this gold bubble.

LITERATURE SURVEY

Previous research, Jaffe (1989) has found that gold is a hedge against stock market and inflation as the data that they used was during stagflation of late 70s and early 80s. Johnson and Soenen (1997) did their study during a different time period, which covered from the stagflation of the late 70s to the longest expansion of the 90s. Their findings suggest that gold is an attractive investment in terms of diversification only in specific periods such as 1978-1983, but yielded negative returns in 1984-1995. More recent studies have taken in account of the monetary standpoint Jensen *et al* (2002), they found that precious metals, yield higher returns during

phases of restrictive monetary policy in the US. Capie *et al.* (2005) found that the U.S. dollar exchange rate was negatively related to gold price over the period of 1971-2004.

McCown *et al* (2007) found that gold can be used as a hedge for inflation, but not for stocks. Baur and Lucey (2010) treated gold as a hedge or safe haven under times of stress in financial markets. They found gold to be a hedge for stocks but also a safe haven in the very short run. Baur and McDermott (2010) extended the study of Baur and Lucey (2010) by using different frequencies of data: daily, weekly, monthly and a number of stock markets including emerging markets. They found gold to be a safe haven during periods of high volatility on the stock market, but not during extreme return uncertainty. They also found gold to be a strong safe haven during the 2008 financial crisis. In general, the literature survey shows that the relationship between gold and stocks or gold and inflation is mixed.

This Paper's Contribution

Numerous previous studies looked into a relationship between gold and the other economic variables (Baur and Lucey, 2010, Blöse, 2010 and among others), which were framed in a bivariate time-series model. Based on a battery of economic theories provided in the financial economic literature, the current study constructs a multivariate time-series model to examine factors that have Granger-caused the price of gold to skyrocket in the past decade.

Unique to this decade is that various factors that were considered individually in the previous research with respect to gold have occurred all at the same time in this decade.

The economic model for the paper is In general, the economic model is:

1] M2 - Money supply; the main function of the Federal Reserve is to stabilize the economy, i.e. maintain low inflation rate and low unemployment rate. Due to the financial crisis of 2007 the Federal Reserve has increased money supply in order to reactivate the economy, [Quantitative easing 1 added about \$800 billion and Quantitative easing 2 added about \$600 billion to the economy].

2] CPI- Inflation; the growth in money supply has raised the fears of inflation. From a longer term perspective a wide consensus exists that gold is a useful hedge against inflation and a long term store of financial value.

3] S&P 500 – equity markets; economic uncertainty, such as the Sep 2001 attack on the World Trade Center, two wars, and the 2007 financial crisis took a toll on the equity markets. During difficult times, investors tried to preserve their wealth by investing in gold. Gold's liquidity, acceptability, and portability make it an important commodity at a time of crisis. It is treated as a safe haven as an asset as it protects investors' wealth.

4] $r - (1+i) = (1+r)(1+E(I))$ where i is nominal rate, r is real interest rate and $E(I)$ is expected inflation rate; real interest rate measures the systematic risk and the regulatory risk that the lenders need to be compensated for loaning money. The monetary policies of the Federal Reserve strongly influence real interest rates on short term loans. The expansionary monetary

policies of the last decade have kept the real interest rates lower. Since gold does not earn any interest, compared to other financial assets, when real interest are low, the price of financial assets goes down, whereas price of gold goes up.

HYPOTHESES

Based on the above observation, several hypotheses were tested concerning the granger causality relationship between gold price and real interest rates, gold price and money supply, gold price and equity markets and gold price and inflation.

The first set of competing hypotheses concerns the causal relation between gold price and money supply. If Granger causality runs from money supply to gold, there could be several reasons why this will occur, as money supply increases, interest rates will fall, and gold price will rise, as money supply increases, expected inflation would increase and gold price would rise. On the other hand Granger causality runs from gold to money supply, which would imply that monetary policy is based on the price of gold. Or there is no Granger causality in either direction.

The second set of hypotheses concerns the relationship between equity markets and price of gold. If Granger causality is from equity markets to gold price, implies when equity market are in trouble, investors would move to safer assets such as commodities like gold and silver as they maintain value. If Granger causality is from gold to equity markets means gold price contains useful information for predicting equity markets.

The third set of competing hypotheses concerns the relationship between inflation and gold price. If Granger causality runs from inflation to gold price, it implies that as inflation increases, the Federal Reserve will take action to raise interest rates which would lower the gold price. Or Granger causality runs from gold to inflation, which would imply that increases in gold price will imply that investors are expecting that eventually inflation would rise.

The forth set of competing hypotheses concerns the causal relationship between gold price and real interest rate. If there is a unidirectional Granger causality running from gold to real interest rates or no Granger causality in either direction means gold price contains useful information in predicting real interest rates (not observable). On the other hand if unidirectional Granger causality runs from real interest rates to gold price means that as long as interest rates are low the gold will be held as a safe haven, if real interest rates start rising, it would be a good time to sell gold.

DATA DESCRIPTION

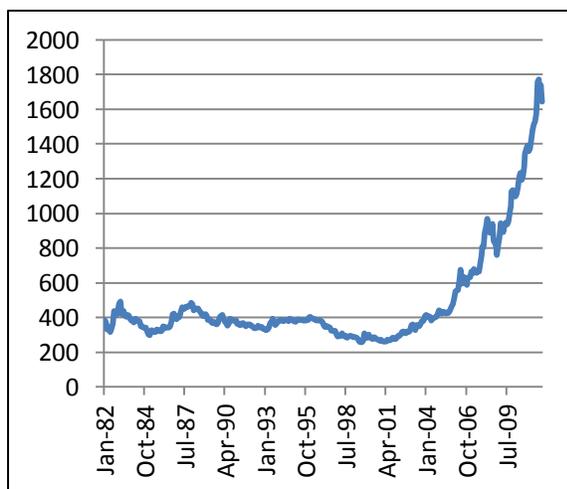
The study employs monthly time series data from January 1982 to December 2011 for gold price. Money supply is measured by monthly M2 data. Inflation is measured by monthly CPI index. Monthly S&P 500 index is used for equity markets. Monthly yield data for 10 year treasury notes is used to measure nominal interest rates and calculate monthly real interest rates using the Fisher Model as they are unobservable. M2, CPI, and gold price show an upward trend

especially after 2000 with increasing slope. S&P 500 shows a general upward trend till 2000 but after 2000 it has shown a lot of volatility matching to the tech bubble, September 2001 attack, and the housing bubble. And the yield on 10 year treasury notes has shown a general downward trend with a lot of volatility based on the monetary policy. All variables were transformed into natural logs prior to analysis because this helps to reduce heteroskedasticity.

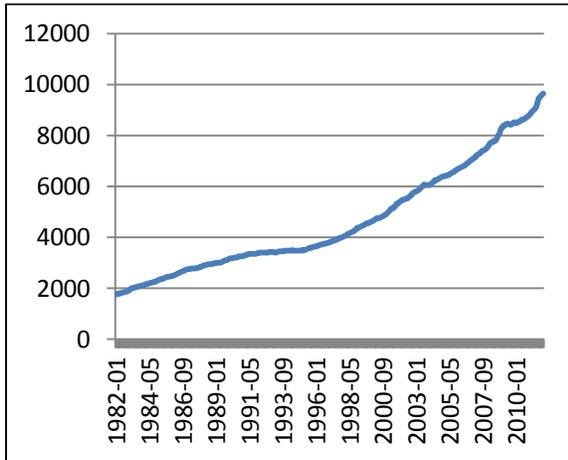
Fig 1. Time series plots for Yields on 10 year T-notes



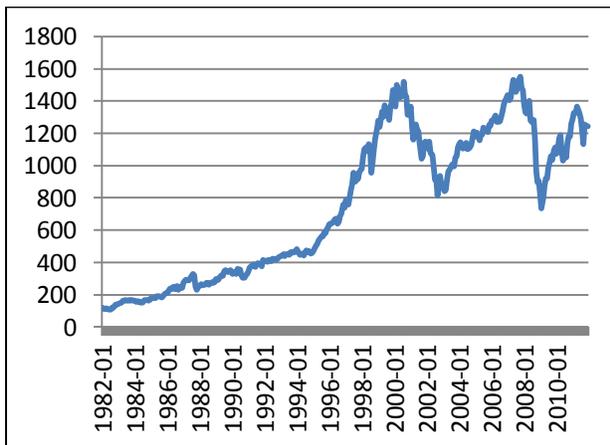
Gold Prices



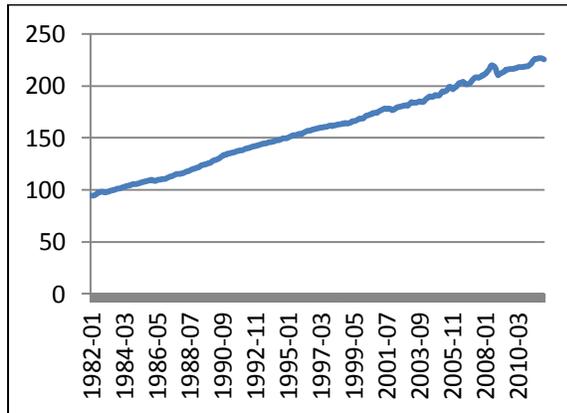
M2 – money supply



S&P 500 Index



CPI Index



ECONOMETRIC METHODOLOGY

Vector Error-Correction Model And Multivariate Granger Causality

The paper applies Johansen co-integration methodology (1999) to estimate the long run relationship among the five economic variables along with the estimation of short-run disequilibrium and adjustment mechanism (error correction terms). If all series are integrated as the same order, say $I(1)$, then the first differences of all the series can be modeled using a Vector Autoregressive (VAR) augmented by an additional error correction term as follows:

$$\begin{aligned} \Delta \ln MS_t = & \beta_{1,1,0} + \sum_{i=1}^I \beta_{1,2,i} \Delta \ln MS_{t-i} + \sum_{i=1}^I \beta_{1,3,i} \Delta \ln SP_{t-i} + \sum_{i=1}^I \beta_{1,4,i} \Delta \ln PI_{t-i} \\ & + \sum_{i=1}^I \beta_{1,5,i} \Delta \ln RI_{t-i} + \sum_{i=1}^I \beta_{1,6,i} \Delta \ln GD_{t-i} + \eta_{1,1} (\ln MS_{t-1} \\ & - \varphi_{1,2} \ln SP_{t-1} - \varphi_{1,3} \ln PI_{t-1} - \varphi_{1,4} \ln RI_{t-1} - \varphi_{1,5} \ln GD_{t-1}) + \varepsilon_{1,t} \end{aligned}$$

$$\begin{aligned} \Delta \ln SP_t = & \beta_{2,1,0} + \sum_{i=1}^I \beta_{2,2,i} \Delta \ln MS_{t-i} + \sum_{i=1}^I \beta_{2,3,i} \Delta \ln SP_{t-i} + \sum_{i=1}^I \beta_{2,4,i} \Delta \ln PI_{t-i} \\ & + \sum_{i=1}^I \beta_{2,5,i} \Delta \ln RI_{t-i} + \sum_{i=1}^I \beta_{2,6,i} \Delta \ln GD_{t-i} + \eta_{2,1} (\ln MS_{t-1} \\ & - \varphi_{2,2} \ln SP_{t-1} - \varphi_{2,3} \ln PI_{t-1} - \varphi_{2,4} \ln RI_{t-1} - \varphi_{2,5} \ln GD_{t-1}) + \varepsilon_{2,t} \end{aligned}$$

$$\begin{aligned} \Delta \ln PI_t = & \beta_{3,1,0} + \sum_{i=1}^I \beta_{3,2,i} \Delta \ln MS_{t-i} + \sum_{i=1}^I \beta_{3,3,i} \Delta \ln SP_{t-i} + \sum_{i=1}^I \beta_{3,4,i} \Delta \ln PI_{t-i} \\ & + \sum_{i=1}^I \beta_{3,5,i} \Delta \ln RI_{t-i} + \sum_{i=1}^I \beta_{3,6,i} \Delta \ln GD_{t-i} + \eta_{3,1} (\ln MS_{t-1} \\ & - \varphi_{3,2} \ln SP_{t-1} - \varphi_{3,3} \ln PI_{t-1} - \varphi_{3,4} \ln RI_{t-1} - \varphi_{3,5} \ln GD_{t-1}) + \varepsilon_{3,t} \end{aligned}$$

$$\begin{aligned} \Delta \ln RI_t = & \beta_{4,1,0} + \sum_{i=1}^I \beta_{4,2,i} \Delta \ln MS_{t-i} + \sum_{i=1}^I \beta_{4,3,i} \Delta \ln SP_{t-i} + \sum_{i=1}^I \beta_{4,4,i} \Delta \ln PI_{t-i} \\ & + \sum_{i=1}^I \beta_{4,5,i} \Delta \ln RI_{t-i} + \sum_{i=1}^I \beta_{4,6,i} \Delta \ln GD_{t-i} + \eta_{4,1} (\ln MS_{t-1} \\ & - \varphi_{4,2} \ln SP_{t-1} - \varphi_{4,3} \ln PI_{t-1} - \varphi_{4,4} \ln RI_{t-1} - \varphi_{4,5} \ln GD_{t-1}) + \varepsilon_{4,t} \end{aligned}$$

$$\begin{aligned} \Delta \ln GD_t = & \beta_{5,1,0} + \sum_{i=1}^I \beta_{5,2,i} \Delta \ln MS_{t-i} + \sum_{i=1}^I \beta_{5,3,i} \Delta \ln SP_{t-i} + \sum_{i=1}^I \beta_{5,4,i} \Delta \ln PI_{t-i} \\ & + \sum_{i=1}^I \beta_{5,5,i} \Delta \ln RI_{t-i} + \sum_{i=1}^I \beta_{5,6,i} \Delta \ln GD_{t-i} + \eta_{5,1} (\ln MS_{t-1} \\ & - \varphi_{5,2} \ln SP_{t-1} - \varphi_{5,3} \ln PI_{t-1} - \varphi_{5,4} \ln RI_{t-1} - \varphi_{5,5} \ln GD_{t-1}) + \varepsilon_{5,t} \end{aligned}$$

Where Δ is the first difference operator, $\eta_{i,j}$ is error correction term, $\beta_{i,j}$ is parameter in the co-integration equation that captures a long-run relationship among the variables. Notice that the VECMs include the parameters representing short-run relationships, $\beta_{i,j}$, long-run equilibrium relationships, $\varphi_{i,j}$, and the correction mechanism $\eta_{i,j}$ for any short run deviations from long-run equilibrium. More importantly, Granger causality is a short-run phenomenon.

Therefore, in order to draw the inference about the direction of Granger causality, the null hypotheses are:

$H_{01}: \sum \beta_{1,3,i} = 0$, meaning the equity market does not Granger causes money supply (M2);

$H_{02}: \sum \beta_{2,2,i} = 0$, meaning the money supply does not Granger causes equity market;

$H_{03}: \sum \beta_{4,6,i} = 0$, meaning the gold price does not Granger causes real interest rate;

$H_{04}: \sum \beta_{5,5,i} = 0$, meaning the real interest rate does not Granger causes gold price;

and so on for the other variables (i.e., twenty null hypothesis are possibly constructed in total).

A test statistic for the hypothesis testing has an asymptotic chi square distribution with k degrees of freedom (Hamilton, 1994, p305).

EMPIRICAL RESULTS

Prior to implementing the multivariate Granger causality test, the study conducted unit root tests using both the Augmented Dickey Fuller (ADF) and Phillips and Perron (PP) tests to determine the order of integration of the variables. Based on the ADF and PP tests, each of the variables are found to be integrated of order one, $I(1)$ (Test results are not reported but available upon request). Then, in order to confirm the long and short run equilibrium relationship of the economic model, the VECMs are estimated with the optimal lag lengths of 3, which is selected using AIC and SBC lag selection criteria.

Prior to the estimation of the VECMs, the co-integration test was preceded using Johansen and Julius procedure (1992). The study rejected the null of no integrating equation, failed to reject the null of at least one co-integration equation, but reject more than one co-integration equation using both Lambda Trace and Max test statistics. More specifically, lamda trace test statistic (76.19) and lamda max test statistic (41.34) are less than the corresponding critical values (69.82 and 33.88, respectively) at the 5% significance level in Table 1.

Table 1: Johansen λ Trace and λ Rank Test

Null Hypo: No of CE(s)	Alt. Hypo: No of CE(s)	Lambda Test stat.	Trace Crit. Val.	Lambda Max Test stat.	Crit. Val.	Eigen value
= 0	> 0	76.19*	69.82	41.34*	33.88	0.1096
≤ 1	> 1	34.85	47.86	16.56	27.58	0.0454
≤ 2	> 2	18.29	29.80	11.93	21.13	0.0323
≤ 3	> 3	6.36	15.49	6.34	14.26	0.0176
≤ 4	> 4	0.03	3.84	0.03	3.84	0.0000

The asterisk * denotes rejection of the null hypotheses at the 5% significance level.

So, the money supply, U.S. equity market, price levels, real interest rates, and gold prices are moving together in the long run, although each economic variable moves rather erratically in the short run and even in the long run.

The main object of this study is to examine the causal relationships between the gold price and the other economic variables, zero restrictions on the parameter estimates on $\beta_{i,j}$ are imposed to make inference about the direction of Granger causality. The several observations are summarized in Table 2.

First, the money supply does not Granger cause the equity market because chi square statistic (5.93) from the zero restrictions on parameter estimates on $\ln M2$ in the equity market equation of the VECMs is less than the critical value of 6.2514 at the 10% significance level. In fact, the money supply does not Granger cause any other variable in the model. So, the paper rejects the first null hypotheses of the Granger causal relationship between real interest rate and gold price.

Second, the paper found that the equity market does not Granger cause the money supply due to smaller chi square statistic (4.57) than the critical value. However, we found that the equity market Granger causes CPI at the 10% significant level and strongly Granger causes the real interest rate. Again, the equity market does not Granger cause the gold price, rejecting the second null hypotheses.

Third, the CPI strongly Granger causes money supply and real interest rate, which is expected and consistent with economic theory (i.e., Fisher equation). On the other hand, the CPI does not Granger cause the equity market and gold price, indicating that the aggregate price level is not useful for predicting the future direction of equity market and gold price. And this result does not support the third hypotheses of the causal relationship between the equity market and gold price. In addition, the paper found that the gold price does not Granger cause any other variable in the model.

Lastly, the zero restriction on parameter estimates on real interest rate lends an interesting result to the paper. Real interest rate does not Granger cause the equity market and CPI. However, the real interest rate Granger causes money supply as well as gold price. In fact, the real interest rate is the only variable that has a determining factor for predicting the future price of gold.

Table 2. Multivariate Granger causality test (χ^2 statistics)

Dependent Variables	Variable Granger causes				
	LnM2	lnSP	lnCPI	lnRI	lnGD
lnM2	-	4.57 (0.2061)	31.32** (0.0000)	26.86** (0.0000)	4.52 (0.2105)
lnSP	5.93 (0.1151)	-	3.79 (0.2851)	1.33 (0.7220)	3.78 (0.2862)
lnCPI	1.99 (0.5745)	6.95* (0.0735)	-	3.26 (0.3532)	3.27 (0.3518)
lnRI	3.27 (0.3518)	21.52** (0.0000)	27.25** (0.0000)	-	0.50 (0.9189)
lnGD	3.65 (0.3018)	2.40 (0.4936)	5.97 (0.1131)	7.63* (0.0543)	-

Note that asterisks * and ** denotes statistical significance at 10% and 5% levels, respectively. Numbers in parenthesis are p-values.

SUMMARY AND CONCLUSIONS

Unlike the previous studies of Granger causality, the paper examined a causal relationship between gold price and the other relevant economic variables in a multivariate time-series model. In order to carry out a comprehensive test, the paper began with four sets of hypothesis on the possible causal relationships among the variables based on economic literature.

First, the paper examined the time-series properties of variables by conducting the ADF and PP unit root tests. The unit root test results of each variable in the model warranted the co-integration testing procedure. The Johansen test indicated that all the non-stationary variables are co-integrated with one co-integrating equation. Thus, the paper proceeded to estimating the vector error correction model and implemented Granger causality test by restricting parameter estimates in each equation of the VECMs.

Several observations emerge from the empirical results. CPI Granger causes money supply (M2) and it also Granger causes real interest rates, which is well documented in Fisher Equation. On the other hand, real interest rate Granger causes money supply. The equity market index (S&P 500) Granger causes CPI and real interest rate, not vice versa. With respect to the causal relationship between gold price and any other variable, the paper rejected the first three null hypotheses but the last null hypothesis. That is, real interest rate Granger causes gold price.

In sum, although gold price, equity market index, money supply, and CPI are moving together in the long run, the real interest rate alone Granger causes the gold price in the short run. Since Monetary Policy by the Federal Reserve influences real interest rates on short term loans, their tightening the Monetary Policy could break the gold bubble.

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