Price modeling: Analysis with a Vector Error Correction Model

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ABSTRACT

This paper focuses on the relationship between gold and the 4 explanatory variables such as oil, platinum, palladium and silver. This work uses the Johansen multivariate approach (VECM), co-integration and Granger causality test. Our findings are that gold only depends on WTI prices; the Johansen approach result reveals the existence of a long-run relationship between analyzed variables. The Toda and Yamamoto version Granger causality shows that there is a bidirectional relationship between gold and WTI while a unidirectional causality between gold and precious metal.

Keywords— Gold, oil, platinum, palladium, silver, *co-integration test, Johansen approach, Vector Error Correction Models, Toda & Yamamoto causality.*

I. INTRODUCTION

Precious metals (Gold, Silver, Platinum, and Palladium), and Oil have received much attention from researchers and investors because of their recent price increase. In particular, gold has been an important precious metal for many centuries. It used in jewellery as an investment asset and reserve asset. Thus, the investors include gold in their portfolios because it is durable, divisible and it is a hedge or safe haven against the fluctuation of many financial assets. The increasing interest is also due to the fact that rising oil price generates higher inflation which increases the demand for gold and hence pushes up the gold price (for instance, Zhang et al.2010, Thai and Chang, 2011, Wang et al. 2013).

There is actually increasing literature that investigates these relationships. Kearney and Lombra (2008) point out the rapid changes of correlation between gold and platinum prices over a short period from positive to negative (1996-2001). Hamilton (2000) point out that platinum is a leading indicator of gold. Narayan et al. (2010) used a daily data from 1995 to 2009 to examine the long relationship between gold, oil and futures markets. They note that when the oil prices rises, it creates an inflationary pressure that's push investors to buy the gold as a hedge against inflation. They find also that oil market can be used to predict the gold market prices.

Zhang et al (2010), find a significant co-integrating relationship between oil and gold. The results indicate that oil price returns significantly and linearly causes the gold price returns. It is shown that the increasing price of oil tends to cause inflation, gold plays a role in the coverage of this inflation and it is a hedge against uncertainty and instability. Baur and Tran (2012) studied the long run relationship between gold and silver. They extend the study of Escribano and Granger (1998) using a 40 year period from 1970 to 2010 and study the role of bubbles and financial crisis for this relationship. They found that the global financial crisis of 2008 does not exhibit an impact on the gold-silver relationship. The Error-correction model and Granger causality tests expose that gold drives the price of silver i.e. the long-run relationship. Also, they show that the two prices relationship is not stable. Lucey and Tully (2003) studied the relationship between gold and silver in the period (1978-2002), they found that a stable long-run relationship exists.

More recent research attempts to combine more than price commodity. Thai and Chang (2011) examine the long-term relationship between oil prices, gold prices and the USD index. The results indicate that there exists a long run correlation between the 3 variables and the oil prices can be used to predict the gold prices.

Wang et al. (2013) used the threshold model to examine the dynamic transmission between the interest rate, Gold, oil and US dollar. The results indicate that Gold and oil prices posivitly influence each other. Interest rates have a negative influence on the gold prices and positive influence in the oil prices. International Gold and oil prices have a feedback effects on interest rates.

Conover et al. (2009) examines the effects of adding precious metals (gold, silver and platinum) to U.S. equity portfolios. They estimate different weights (from 5% to 25%) of these metals in a portfolio and find that adding a 25% allocation of precious metals in a portfolio consisting of equities substantially improves the portfolio performance. They found that gold relative to platinum and silver has a better performance and a better hedge against inflation pressures.

Chang et al. (2013) used a daily spot gold prices from 2007 to 2010 to examine the inter-relationship between the 5 countries (UK, USA, Japon, Hong Kong and Taiwan). The Toda and Yamamoto procedure (1995) based on the augmenting level-VAR models show a bi-directional causality between London and New York gold market also a uni-directional causality between New York and the other markets.

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The present study contributes to the aforementioned literature by combining five price commodities in one model. More precisely, it examines the long term relationship between Gold and oil, platinum, silver and palladium. To this end, we make use the Johansen co-integration approach (Johansen, 1988; Johansen and Juselius, 1990 ;) and the Granger causality test in the since of the Toda and Yamamoto (1995).

The remainder of this paper is organized as follows. The following section presents the empirical methodologies, the section after present the data definition. Then, Section 4 provides the estimation approach and empirical findings. Section 5 concludes the paper.

II. METHODOLOGY

This section presents the econometric models used to study co-integration and causality between gold and WTI, platinum, silver and palladium prices.

1. Co-integration approach

To test the presence of co-integration between the variables investigated in this study, the Johansen's approach is employed. The Johansen method uses a statistical model involving up to p lags as follows:

$$\Delta Y_t = \Gamma_1 \Delta Y_{t-1} + \ldots + \Gamma_p \Delta Y_{t-p} + \Pi \Delta Y_{t-p} + \varepsilon_t,$$

where Δ is the difference operator, Yt is a vector with the 5 variables (gold, WTI, platinum, silver and palladium), Γ1,... Γp-1 represents the matrix of the short-run dynamics, Π=αβ' with α and β are both matrices containing the adjustment coefficients and the cointegrating vector respectively and Π represents the long-run dynamics.

In order to identify the number of cointegration vectors, Johansen (1988) proposes the trace and maximum eigenvalue statistics while the trace statistic is designed for testing the null hypothesis of r cointegration vector, the maximum eigenvalue statistic tests for the null hypothesis of r cointegration vector against the alternative of r +1.
The trace test equation is established as:

$$\lambda_{trace} = -T \sum_{j=r+1}^{n} \ln(1-\lambda_j),$$

where T represents the number of observations and λj shows the estimated values of the roots.
In the second case, the eigenvalue test equation is presented as follow:

$$\lambda_{max} = -T \ln(1-\lambda_{r+1}).$$

2. Causality approach

As regards the causality test method, several tests have been developed later in the literature (for instance, Granger, 1969 Sims et al. (1990) Toda and Phillips, 1993; Toda and Yamamoto (1995), Dolado and Lutkepohl (1996). Causality testing in Granger sense is conventionally conducted by estimating autoregressive or vector autoregressive (VAR) models. But this model still suffers of the non stationary problem. The most difficult parts of testing multivariable Granger causality are how to confirm the cointegrating relationship and how to estimate the VAR accurately when its system is integrated. Sims et al. (1990) and Toda and Phillips (1993) have shown that the Wald test for non-causality in an integrated or cointegrated unrestricted VAR system will have nonstandard limit distributions.

In 1995, Toda and Yamamoto (1995) changed the Wald tests and proposed an interesting simple approach which guarantees the asymptotic distribution of the Wald statistic (χ-distribution) to study the causal relationship between two variables. This approach allows us to estimate a vector autoregressive model in order (p + d max) instead of a VAR in order p as following:

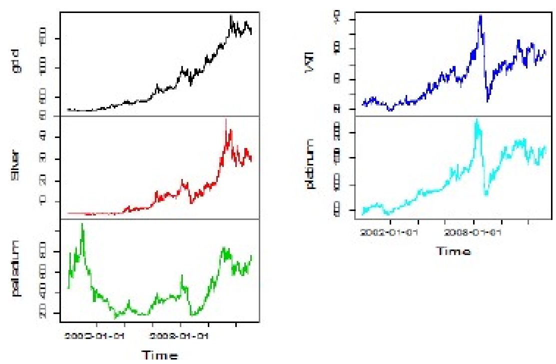
$$X_t = \alpha_1 + \sum_{i=1}^{h+d} \beta_{1i} X_{t-1} + \sum_{j=1}^{l+d} \gamma_{1j} Y_{t-j} + \varepsilon_{1t}$$

$$Y_t = \alpha_2 + \sum_{i=1}^{h+d} \gamma_{2i} Y_{t-i} + \sum_{j=1}^{l+d} \beta_{2j} X_{t-j} + \varepsilon_{1t}$$

III. DATA DEFINITION

The data used in this paper are daily closing prices of gold, oil, platinum, palladium and silver. The data cover a 13-year period, from January 4, 2000, through February 28, 2013. Each time series contains 3169 observations. Our data is obtained from the Federal Reserve Bank and all the precious metals are measured in US dollars per troy ounce. The oil is measured in US dollars per Barrel. Inflation is excluded mainly due to the lack of daily data. The highest correlation is located between gold and silver (0.6593), followed by correlation between platinum and palladium. The saying goes "if you want to buy gold buy silver, and if you want to sell gold sell silver". We note too that correlation between gold and oil is positive.

Fig. Daily spot prices 2000-2013



We note that gold and silver move in the same way, the same note for WTI and platinum. We can see that the price of gold seems to be in general trend meanwhile the other variables prices have more severe up and down than gold price. Through this graph it is possible to detect how these series have been affected by different financial crisis during this period (i.e. the global financial crisis 2008).

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IV. THE ESTIMATION APPROACH AND EMPIRICAL FINDINGS

As mentioned before, we will use the method of Johansen. We test at first the stationarity of the time series using the Dickey-Fuller (1979) ADF test and the Kwiatkowski et al. (1992) KPSS test. The ADF test do not reject the null hypothesis of a unit root for the levels of the five prices The KPSS test, in which the null hypothesis is stationarity instead of non-stationary, indicates that the null hypothesis is clearly rejected for the level forms of all series. When the tests are applied to the first-differences of the variables, the results strongly implies that all variables are stationary, being integrated of order one, I(1), this favor Brooks's (2008) statement which note that the majority of financial and economic time series have a single unit root. Once, the series are integrated of the same order a long-run relationship (co-integrating vector) could be exist i.e. our series can be co- integrated.

Tab. ADF, KPSS test at level and at difference

	ADF test		KPSS test	
	At level	at difference	At level	at difference
Gold	-2.353	-40.501	32.713	0.051
Platinum	-2.603	-39.675	4.449	0.035
WTI	-2.773	-41.027	5.0053	0.0293
Silver	-2.7061	-38.9366	19.688	0.056
Palladium	-1.3806	-40.0988	25.5888	0.0662
5%level	-3.41	-3.41	0.146	0.146

After having specified our model, we will determine the number of lags p of the VAR (p) model. Within the four usual criteria: Final prediction error (FPE), Akaike (AIC),Schwartz (SC) and Hannan-Quinn(HQ), Liew (2004) report that AIC and FPE are recommended to estimate autoregression Lag length. According to the previous study we follow the result demonstrated by AIC criteria and the FPE criteria. The output is shown as below:

Tab. Lag Length Selection

Lag	AIC	FPE	SC	HQ
1	-4.12e+01*	1.24e-18*	-4.12e+01*	-4.12e+01*
2	-4.13e+01	1.25e-18	-4.12e+01	-4.12e+01
3	-4.13e+01	1.26e-18	-4.11e+01	-4.13e+01
4	-4.13e+01	1.26e-18	-4.11e+01	-4.12e+01

Note: *indicates lag order selected by the criterion

Although the optimal number of lags is one because it represents the minimum value for all these criteria. To test for the cointegration between gold and the other variables we utilize the multivariate cointegration approach based on maximum likelihood principle in a vector error correction modeling frame- work advocated by Johansen (1988).

The results from the cointegration analysis based on the trace statistic are illustrated in below:

Tab. Results of co-integration tests

Test	λ -max	trace
r=0	44.42	98.72
r<=1	22.16**	54.30**

**denote significance level at 5%

According to the Johansen test; we do not reject H_0 of co-integration if the calculated traces value and the eigenvalue are less than their critical values at 5%. This table confirms that there is a unique co-integrating vector (a long run relationship) between the variables. The presence of co-integration between variables suggests a long term relationship among the variables under consideration. Thus, the presence of co-integration implies that there is a long-run equilibrium relationship between the 5 series. This suggests causality in at least one direction. After determining the cointegration relationships between the five prices a VECM model can be applied. The long run relationship between the variables (Gold, oil, platinum, palladium and silver) in the period 2000-2013 is displayed below:

Tab. Results of error correction model

	Gol	Plat	WTI	Pal	Sil
ECT1	-1.24e-03	1.558e-05	5.417e-04	-1.07e-04	-1.608e-05
Δ Gol(-1)	-0.096**	0.229**	-2.251e-03	0.086**	3.14e03**
ΔPlat(-1)	-0.007	-0.006	-1.877e-03	-0.026**	-1.6e-03**
ΔWTI(-1)	1.736 ***	3.674**	-5.95e-02**	1.383**	8.35e-02**
ΔPal(-1)	-0.023	0.072**	-1.98e-04	0.112**	-2.1e-04**
Δ Sil(-1)	0.124	-3.477***	2.309e-01**	-2.251**	4.940e-03

** denote significance level at 5%, ***denote significance level at 1%

From this table, we show that gold, palladium and silver have a negative ECT coefficient that's mean that gold, palladium and silver have a feedback to long-run equilibrium: adjusting in the short-run to restore long-run equilibrium.ECT coefficient for platinum and WTI is statistically positive, which implies that these two variables do not fit where they suffer a shock and do not adjust to restore their equilibrium. Gold only depends positively of WTI price delayed by one period. The silver depend positively on gold and WTI and negatively on platinum and palladium. The platinum depends positively of Gold and WTI, as we know that Gold and platinum have considered attractive assets for portfolio investment.

The disadvantage of VECM model is that it does not allow us to detect the direction of causality between the variables. In order to isolate clearly the direction of causality, a Toda and Yamamoto version of Granger causality is applied. The results presents in table below:

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Tab. Toda and Yamamoto Causality Test

Null Hypothesis	Chi-sq	p-values	Decision
H_0: gold does not Granger-cause silver	24.4	4.9e-06	Reject H0
H_0:silver does not Granger-cause gold	0.095	0.99	accept H_0
H0: gold does not Granger-cause palladium	7.1	0.028	Reject H0
H0:palladium does not Granger-cause gold	0.88	0.83	accept H_0
H0: WTI does not Granger-cause gold	17.32	0.017	Reject H0
H0: gold does not Granger-cause WTI	6.8	0.033	Reject H0
H0: platinum does not Granger-cause gold	0.25	0.97	accept H_0
H0: gold does not Granger-cause platinum	48.4	3.1e-11	Reject H0

The findings obtained from this table provide that there is a unidirectional causality between gold and silver which run strictly from gold to silver, that's mean, that gold drives silver price. Thus, gold prices cause the fluctuation of palladium prices. From the Toda and Yamamoto causality table there is a unidirectional relationship between the two variables from gold to palladium. Also, there is a unidirectional causality between gold and platinum. However, there exist significant bidirectional linear granger causality between gold and WTI, consequently, oil prices used to predict the gold prices.

V. Conclusions

This paper examines the price relationship between the Gold and the four explanatory variables such as the WTI, silver, platinum and palladium. The results obtained from the tests indicate that there exists one co-integrating relationship among these variables. Our results shows the presence of relationship between these variables specifically between gold and WTI. This finding was confirmed by the research of Hammoudeh and Yuan (2008) whose find that gold prices are influenced by fluctuations in oil .The Toda and Yamamoto version Granger causality test indicates a unidirectional relation exist within gold and each precious metal, while a bidirectional causality between gold and WTI. Therefore, future studies can focus on this issue within the context of linear and nonlinear econometric methods.

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