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GRANGER CAUSALITY TESTS FOR PRECIOUS METALS RETURNS

Monika Krawiec
Department of Econometrics and Statistics
Warsaw University of Life Sciences – SGGW
e-mail: krawiec.monika@gmail.com
Anna Górska
Department of Agricultural Economics and International Economic Relations
Warsaw University of Life Sciences – SGGW
e-mail: anna_gorska@sggw.pl

Abstract: The aim of the paper was examining Granger causality between rates of return of precious metals. The study covers the period from 2008 through 2013 and includes gold, silver, platinum, and palladium. After developing statistical analysis and confirming stationarity of time series under consideration, the Granger causality test was run. Its results revealed a bilateral causation between silver and platinum rates of return. The study also detected causal relationships flowing from gold and palladium rates of return to silver returns.

Keywords: precious metals, stationarity, Granger causality

INTRODUCTION

Since early 2000s, commodity markets have become more like financial markets. The phenomenon of their financialization brings about the need of adopting methods originally designed for investigating financial markets, namely methods of financial econometrics. Beginnings of financial econometrics are often dated back to 1982 when Robert Engle published his paper presenting autoregressive conditional heteroscedasticity (ARCH) model. It opened a door to further development of various models, such as family of generalized ARCH (GARCH) models, autoregressive conditional duration (ACD) model, dynamic conditional correlation (DCC) model etc. [Jajuga 2007]. There were also developed some other concepts of dynamic econometrics, such as cointegration and testing causal relationships between economic variables often referred to as Granger causality.

When applied to commodity markets, Granger causality tests can tell us the nature of inter-relationships between the various markets and categories of commodities. The aim of the paper is to test Granger causality for markets of precious metals. Our study covers rates of return series of four basic precious metals: gold, silver, platinum and palladium. The occurrence of pairwise Granger causality among them would indicate the possibility of improving forecasts by including the lagged values of respective variables in adequate VAR (vector autoregressive) models. Recognizing relationships between precious metals prices and returns is important as on one hand they are considered attractive assets for portfolio investments, and on the other hand all of them have distinct technical uses.

Gold (Au) is found in nature mainly as either high-quality free gold or as finely distributed minerals mixed with silver, copper or mercury. It has seven money properties: it is a luxury good valued by most people; it is dividable in almost any denomination; it is easy to transport; it remains completely stable over time; it can be weighted exactly; it is not easy to forge or artificially producible; and it cannot be multiplied. Gold can also fulfill three money functions: it can be used as a means of exchange or means of payment, it comes in an arithmetic unit, its purchasing power does not diminishes over time [Eller and Sagerer 2008]. Nowadays, gold is used as a monetary commodity, for jewelry, and dental industry, but in fact its use in jewelry production dates back to the 4th millennium BCE.

Silver (Ag), similarly to gold, has been used since the 4th millennium before Christ as both, jewelry and money. It occurs 15-20 times more often than gold, however almost never in pure form. The majority (about 60%) is extracted as a secondary metal during copper, zinc or lead production, 25% comes from pure silver mines, and the smallest part (15%) comes from gold production. Silver, the same as gold, fulfills the three money functions. It is typically used for jewelry, photography, silverware, and in a diverse range of electronic products.

Platinum (Pt) was first used by pre-Columbian South American natives. When Antonio de Ulloa published his report on a new metal of Colombian origin in 1748, it became investigated by scientists. In early 1800's William Wollaston – English chemist became the first one who produced pure, malleable platinum. Platinum occurs with the same frequency as gold and is primarily generated as a byproduct of copper and nickel production. It is used heavily by the dental, chemical, electronics, and auto industries. Because of its chemical qualities, platinum is often used in catalytic converters to reduce emissions.

The last one of the metals we are interested in – palladium (Pd) was discovered in 1803 by William Wollaston during platinum exploration in America. It usually occurs with other platinum metals and it has similar industrial uses as platinum. Very often it substitutes platinum in engines exhaust systems [Balarie 2007].

EMPIRICAL DATA AND RESEARCH METHODS

Numerous researchers analyzing various inter-relationships between precious metals prices or returns base their studies on time series of different length. For example, Wahab et al. [1994] examine the period from 1982 through 1992, Escribano and Granger [1998] – the period from 1971 through 1990, Ciner [2001] – the period: 1992 – 1998, Lucey and Tully [2006]: 1978 – 2002, Kearney and Lombra [2009]: 1985-2006, Tsuchiya [2010]: 2002-2010, Śmiech and Papież [2012]: 2000 – 2011. Our data set covers a 6-year-period from January 2008 to December 2013 and consists of London daily closing prices of four precious metals (gold, silver, platinum and palladium) in USD per ounce. The quotations are available at www.kitco.com.

First, rates of return series were calculated as follows:

$$r_t = \ln\left(\frac{P_t}{P_{t-1}}\right) \tag{1}$$

where P_t is the price at time *t* and P_{t-1} is the price in the previous period.

Both, prices of the precious metals and their rates of return are displayed in Figure 1.

The rates of return series became the base to evaluate descriptive statistics for considered precious metals. Then, normality of distributions was verified by adopting the Jarque-Bera test. The results are given in Table 1.

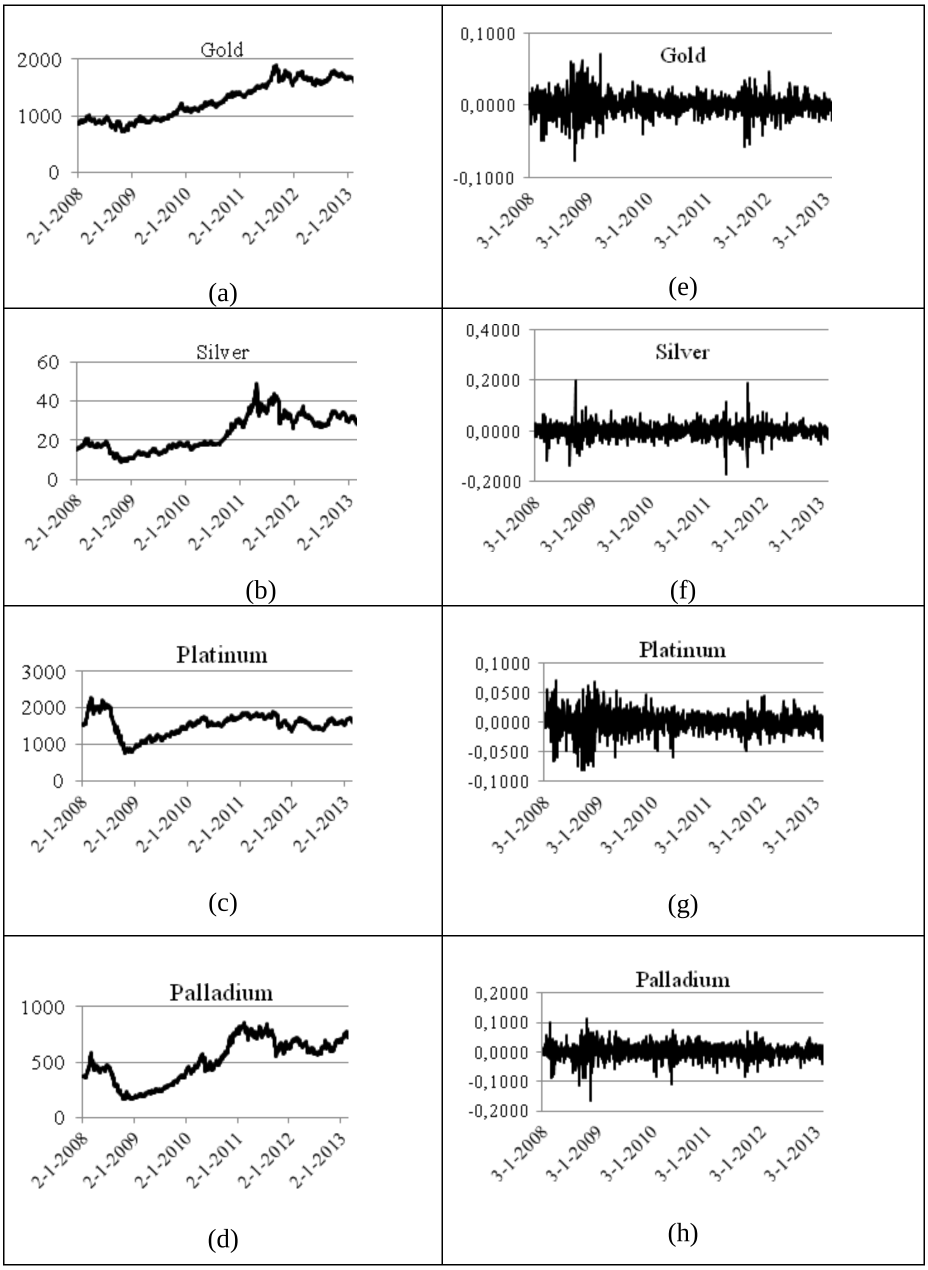
Table 1. Descriptive statistics for daily logarithmic returns of precious metals (2008-2013)

Measure	Metal			
	Gold	Silver	Platinum	Palladium
Minimum	-0.09596	-0.18693	-0.08493	-0.17859
Maximum	0.06841	0.18279	0.06940	0.10920
Mean	0.00023	0.00018	-0.00008	0.00043
Standard deviation	0.01386	0.02676	0.01687	0.02303
Coeff. of variation	59.9911	151.8322	202.1752	53.6307
Skewness	-0.38924	-0.40619	-0.64145	-0.66024
Kurtosis	4.51254	7.39392	3.69171	4.84103
J-B	1312.88	3466.22	956.50	1577.07

Source: own calculations

On the base of data in Table 1, one can notice that mean daily returns range between - 0.008% for platinum and 0.04% for palladium. The maximum of daily returns (18,3%) was observed for silver on September 18, 2008. The minimum of daily returns (-18,7%) was also registered for silver on May 12, 2011. The lowest standard deviation was the one obtained for gold (0.01386), while silver exhibited the highest value of standard deviation (0.02676). However, platinum was the precious metal showing the highest volatility.

Figure 1. Prices of precious metals from 2008 through 2013: gold (a), silver (b), platinum (c), palladium (d) and their returns: gold (e), silver (f), platinum (g), palladium (h)



Source: own elaboration

The lowest volatility was exhibited by palladium (see values of coefficient of variation). In all cases, distributions of returns are negatively skewed. Positive values of kurtosis indicate more acute distributions in comparison to the normal distribution. The Jarque-Bera test confirms the non-normality of daily returns distributions at 0.05 significance level.

Table 2 reports values of Pearson correlation coefficient calculated for various pairs of precious metals. As expected, all values are found to be positive[1] and significant at the 0.05 level. The highest positive correlation was observed for the pair: platinum – palladium (as it is mentioned in the introduction, palladium often substitutes platinum in technical applications), the lowest one for the pair: gold – palladium (they are not close substitutes to each other).

Table 2. Coefficients of correlation between selected precious metals

Metal	Gold	Silver	Platinum	Palladium
Gold	1	0.6061	0.5827	0.4891
Silver	0.6061	1	0.5771	0.5133
Platinum	0.5827	0.5771	1	0.7506
Palladium	0.4891	0.5133	0.7506	1

Source: own calculations

In the next step of research, for answering the question whether past returns of a given precious metal can help better forecast returns of other selected precious metals, Granger causality test will be applied. Generally, since the future cannot predict the past, if variable X Granger-causes variable Y, then changes in X should precede changes in Y. In other words: when we identify one variable as the dependent variable (Y) and another as the explanatory variable (X), we make an implicit assumption that changes in the explanatory variable induce changes in the dependent variable. Therefore, in a regression of Y on other variables (including its own past values) if we include past or lagged values of X and it significantly improves the prediction of Y, we can say that X Granger-causes Y. A similar definition applies if Y Granger-causes X [Gujarati 2003]. If X causes Y and Y causes X, the two variables are jointly determined and there is a bilateral causation.

There are several different procedures for testing Granger causality[2]. In our paper, following Ramanathan [2002], we consider the model:

$$Y_t = \sum_{i=1}^{p} \alpha_i Y_{t-i} + \sum_{j=1}^{q} \beta_j X_{t-j} + u_t \,, \tag{2}$$

[1] According to Kearney and Lombra [2009], price fluctuations of silver, platinum and palladium seem to follow closely the price of gold over the last two decades.

[2] According to Osińska [2008], in economic practice the most popular are three procedures, differing in construction and in results they provide, that are based on likelihood ratio, Wald test, and Lagrange multiplier.

where u_t is white noise, p is the order of the lag for Y, and q is the order of the lag for X. The null hypothesis that X does not Granger-cause Y is that $\beta_j = 0$ for $j = 1, 2, ..., q$.
Then we have the restricted model:

$$Y_t = \sum_{i=1}^{p} \alpha_i Y_{t-i} + \upsilon_t . \tag{3}$$

The test statistic is the standard Wald F-statistic:

$$F = \frac{(ESSR - ESSU)/q}{ESSU/(n-p-q)} , \tag{4}$$

where n is the number of observations used in unrestricted model in equation (2), ESSU is the error sum of squares for equation (2), ESSR is the error sum of squares for the restricted model (3). Under the null hypothesis of X not Granger-causing Y, F has the F-distribution with q d.f. for the numerator and $n-p-q$ d.f. for the denominator. The orders of the lags (p and q) are arbitrary and are usually chosen to be large [Ramanathan 2002].

As a pre-requisite condition for Granger causality testing, time series need to be stationary. Stationarity in the weak sense implies that the mean of the variable, its variance and covariance shell be time invariant. There are several stationarity tests. In the paper we use the augmented Dickey-Fuller test (the ADF-test). The null hypothesis assumes nonstationarity. The first step is to estimate one of the following equations [Witkowska et al. 2008]:

$$\Delta y_t = \alpha_1 y_{t-1} + \sum_{i=1}^{p} c_i \Delta y_{t-i} + \varepsilon_t , \tag{5}$$

$$\Delta y_t = \alpha_0 + \alpha_1 y_{t-1} + \sum_{i=1}^{p} c_i \Delta y_{t-i} + \varepsilon_t , \tag{6}$$

$$\Delta y_t = \alpha_0 + \lambda_1 t + \alpha_1 y_{t-1} + \sum_{i=1}^{p} c_i \Delta y_{t-i} + \varepsilon_t . \tag{7}$$

The statistic of the test is given by:

$$\tau = \frac{\hat{\alpha}_1}{S(\hat{\alpha}_1)} , \tag{8}$$

where: $\hat{\alpha}_1$ – OLS estimate of α_1 in any of equations (5) – (7), $S(\hat{\alpha}_1)$ – standard error of α_1 estimate.
If the tau value is lower than the critical value, the null hypothesis is rejected. Hamulczuk et al. [2012] note that tau follows the distribution that differs from

other standard distributions, thus it is necessary to use special statistical tables. However, the GRETL software that we use, computes the probability value (p). If $p < 0.05$, H_0 can be rejected.

RESULTS OF GRANGER CAUSALITY TESTS FOR PRECIOUS METALS RETURNS

As it was mentioned in the previous section, when testing Granger causality, it is assumed that the variables are stationary. That is why we start with performing the ADF-test for our data. Its results (values of tau-statistic based on estimates of equation (7)) are presented in Table 3. Since they let us conclude that all considered time series are stationary, the following series of hypotheses can be verified:

H_0: *rates of return of precious metal X are not Granger cause of rates of return of precious metal Y.*

Table 3. The ADF-test results for returns of separate precious metals

Precious metal	Tau-statistic	p-value
Gold	-17.5023	4.37E-056
Silver	-12.6803	1.42E-031
Platinum	-7.3073	3.06E-10
Palladium	-8.4474	5.88E-14

Source: own calculations

Gujarati [2003] suggests the direction of causality may depend critically on the number of lagged terms included. That is why in Table 4 we present the results of the F-test using several lags[3]. Since our interest is testing for causality, we do not show the estimated coefficients of models (2) and (3). In most cases the lag length does not influence test results (the only exception at the 5% rejection rate is relationship silver→platinum). Thus, regardless the lag length, there is causality running from gold returns, platinum returns, and palladium returns to silver returns. One may also notice Granger causality flowing from silver returns to platinum returns, so there is a bilateral causality between them (silver↔platinum). There are no causal relationships at all, between gold and platinum, gold and palladium, and platinum and palladium, although the last pair exhibited the highest value of correlation coefficient. It confirms that correlation does not imply causality.

[3] According to Waściński [2010], the lag length should reflect natural interactions between variables. For example, the recommended number of lags in the case of quarterly data is 4. Our study is based on daily observations, so we start with 1 lag and next we test 5 lags (precious metals quotations are observed on each of 5 weekdays). Finally, taken into account Ramanathan's recommendation to choose large numbers of lags, we consider 10 lags.

Table 4. The Granger causality test results for precious metals returns

Relationship	Number of lags	F-statistic	p-value	Decision at 0.05
gold→silver	1	148.7900	0.0000	Reject
	5	33.7090	0.0000	Reject
	10	17.4740	0.0000	Reject
silver→gold	1	0.4256	0.5142	Do not reject
	5	1.3219	0.2520	Do not reject
	10	1.0048	0.4269	Do not reject
gold→platinum	1	0.3128	0.5760	Do not reject
	5	0.9788	0.4294	Do not reject
	10	1.1091	0.3519	Do not reject
platinum→gold	1	0.1162	0.7332	Do not reject
	5	0.4072	0.8440	Do not reject
	10	0.6358	0.7840	Do not reject
gold→palladium	1	0.2693	0.6039	Do not reject
	5	0.2931	0.9169	Do not reject
	10	0.3557	0.9650	Do not reject
palladium→gold	1	0.1155	0.7340	Do not reject
	5	0.1756	0.9718	Do not reject
	10	0.3468	0.9680	Do not reject
silver→platinum	1	8.8647	0.0030	Reject
	5	2.7424	0.0179	Reject
	10	1.7222	0.0707	Do not reject
platinum→silver	1	70.5640	0.0000	Reject
	5	14.0840	0.0000	Reject
	10	8.1067	0.0000	Reject
silver→palladium	1	2.7338	0.0985	Do not reject
	5	1.0086	0.4111	Do not reject
	10	0.5908	0.8226	Do not reject
palladium→silver	1	57.9310	0.0000	Reject
	5	11.5880	0.0000	Reject
	10	6.3584	0.0000	Reject
platinum→palladium	1	0.3832	0.5360	Do not reject
	5	0.3556	0.8788	Do not reject
	10	1.0521	0.3967	Do not reject
palladium→platinum	1	0.8592	0.3541	Do not reject
	5	0.3675	0.8711	Do not reject
	10	0.6307	0.7885	Do not reject

Source: own calculations

CONCLUDING REMARKS

The paper was aimed at answering the question whether returns of separate precious metals are Granger causes of returns of other precious metals. The study covered the period from 2008 through 2013 and included four precious metals: gold, silver, platinum, and palladium. On the base of their logarithmic returns, there were calculated descriptive statistics and coefficients of correlation. Then tests for normality and stationarity were conducted. Finally, to achieve the purpose of the study, Granger causality test was performed. Our results revealed Granger causality running from gold, platinum, and palladium returns to silver returns, and from silver returns to platinum returns as well. Thus, including lagged values of gold, platinum, and palladium returns improves the prediction of silver returns, whereas including lagged values of silver returns can improve the prediction of platinum returns solely. The analysis presented in the paper is a part of more complex study of precious metals markets the authors have been developing in the last few years (see [Górska and Krawiec 2011, Górska and Krawiec 2013, Górska and Krawiec 2014]).

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