Which precious metals spill over on which, when and why? – Some evidence.

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Abstract
Much academic and investor analysis and commentary sees the four main precious metals as a single market, integrated and to some degree with each metal a substitute for the other. This proposition, which can be explicit or implicit can be challenged on economic grounds and on statistical grounds. Using the Diebold and Yilmaz (2009) methodology we show that the market is only weakly integrated, that this degree of integration is time varying and that it differs as between returns and volatility.

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JEL Code C01, F49, G12, G15,
**Introduction**

Commodity markets, in particular those for precious metals, are large and important. Obtaining an accurate size of these markets is not simple – the largest part of them are typically settled over the counter. One estimated size (in gross traded volume per day) of the gold markets ranges, for 2012, between $150b-350b, for silver $28-54, for platinum $2-4b and for palladium $0.5-1 (see Lubber (2013)). Compare these figures for 2012 US daily trade in treasuries of just over $500b and for US corporate debt of $16b and we see that these markets are not trivial. OTC derivatives outstanding in Gold (as of mid 2013, via the BIS database) amount to a gross figure of some $461b; this is about 1/5 of all commodity derivatives. London Bullion Market Association clearing data suggest an approx. daily turnover for physical gold and silver of $30b and $2-$4b. Regardless of which figure one uses these markets are not small.

Our goal in this note is to investigate the extent to which these metals can be considered an asset class. An asset class should, it is generally agreed, amongst other features show a high degree of integration, arising from common shocks and common economic fundamentals, an alignment of forces that work on all the assets (see Greer (1997))

Commodities matter to investors, both for their size as markets and also for their diversification potential in portfolio management. For commodities in general there is a wide literature on the diversification benefits. For financial researchers, commodities are also of interest for their potential role in asset allocation decisions. In this regard, recent papers by Abanomey and Mathur (2001), Georgiev (2001), and Chan and Young (2006) argue that commodities provide risk reduction in portfolios along with stocks and bonds. Both Caglayan and Edwards (2001), Chow et al. (1999) suggest that commodities are in fact more attractive when the general financial climate is negative. These findings are confirmed in more recent work by Boido (2013), Cumming, Haß, and Schweizer (2013), Nijman and Swinkels (2011) and Skiadopoulos (2012).

While there is a significant body of work on the macroeconomic determinants of volatility in and between equity and commodity markets (e.g.
Fernandez (2008), and groups of commodities (e.g. Kroner, Kneafsey, and Claessens (1995) Gilbert and Brunetti (1995), Pindyck (2004) and Gilbert (2006)), there is limited evidence for relationships between precious metals. If similar macroeconomic or behavioral or other factors are important for all of these, it could be argued that they constitute a market.

As to whether commodities as a whole are an asset class, the evidence is mixed. Two highly cited papers, Erb and Harvey (2006) and Gorton and Rouwenhorst (2006) provide analyses of the risk-return tradeoff in commodity markets. They differ as to whether commodities should be seen as a single asset class. The conclusions of Gorton and Rouwenhorst (2006) imply that commodities can be best viewed as a single asset class that have attractive risk-return patterns and furthermore, are useful for portfolio diversification. Erb and Harvey (2006), however, question whether commodity markets can actually be considered as a single asset class since differences in the behavior of prices between individual commodities seem significant. More recently, Adams, Füss, and Kaiser (2011) and Batten, Ciner, and Lucey (2010) investigate the macroeconomic determinants of returns and volatility respectively. They conclude that in the main the commodities under investigation are exposed to different macroeconomic impacts and so cannot be considered as an asset class. Spillovers and integration in the precious metal market have also been considered by Hammoudeh et al. (2010) in a GARCH framework, concluding that gold and silver volatility both respond to monetary shocks, and that these are quite persistent. This long memory property of gold is confirmatory to the findings in Byers and Peel (2001).

**Methodology**
The model presented in this paper is drawn from Diebold and Yilmaz (2009), Diebold and Yilmaz (2012). These authors look at return and volatility spillovers using a Vector Autoregressive Models (VAR’s) following Engle, Ito, and Lin (1990) but concentrate on variance decompositions. This gives one measure of spillover based on spillovers from a number of markets. A recent application of this approach in the precious metal market is Lucey, Larkin, and O’Connor
(2014) who note the still limited impact of markets other than London and New York on gold price formation.

Consider a set of assets. For each asset \( i \) the shares of its forecast error variance coming from shocks to asset \( j \), for all \( j \neq i \), are summed. These are then added for all \( i = 1, \ldots, N \). Considered as a covariance stationary first-order two variable VAR it can be written as

\[
x_t = \emptyset x_{t-1} + \varepsilon_t
\]  

(1)

where \( x_t = (x_{1t} x_{2t}) \) and \( \emptyset \) is a 2 x 2 parameter matrix. In this paper \( x_t \) with represent either a vector of gold returns or gold returns volatilities. Diebold and Yilmaz (2009) show that by covariance stationarity we can represent this VAR as a moving average given by equation (2) below.

\[
x_t = \Theta(L)\varepsilon_t
\]  

(2)

Where \( \Theta(L) = (I - L\emptyset)^{-1} \). This can be rewritten as below for ease.

\[
x_t = A(L)\mu_t
\]  

(3)

Where \( A(L) = \Theta(L)Q_t^{-1} \), \( \mu_t = Q_t\varepsilon_t \), \( E(\mu_t\mu_t') = I \), and \( Q_t^{-1} \) is a unique lower triangular Cholesky factor of the covariance matrix of \( \varepsilon_t \).

The Wiener-Kolmogorov linear least-squares forecast is an optimal 1 step ahead forecast from the above can be shown as:

\[
x_{t+1,t} = \emptyset x_t
\]  

(4)

with a 1 step ahead error vector:

\[
e_{t+1,t} = x_{t+1} - x_{t+1,t} = A_0\mu_{t+1} = \begin{bmatrix} a_{0,11} & a_{0,12} \\ a_{0,21} & a_{0,22} \end{bmatrix} \begin{bmatrix} \mu_{1,t+1} \\ \mu_{2,t+1} \end{bmatrix}
\]  

(5)

which has a covariance matrix of:

\[
E(e_{t+1,t}e_{t+1,t}') = A_0A_0'.
\]  

(6)

Using this approach allows us to say what proportion of the error variance in forecasting any particular \( x \) (a specific gold market e.g. London) is due to shocks to itself, or spillover from shocks to another market e.g. New York. Diebold and Yilmaz (2009) define own variance shares as “to be the fractions of the 1-step-ahead error variances in forecasting \( x_i \) due to shocks to \( x_i \)” for all \( i \) and cross variance shares, or spillovers, to be “the fractions of the 1-step-ahead error variances in forecasting \( x_i \) due to shocks to \( x_j \)” for all \( j \), where \( i = j \).

In this 2 variable illustration the variance of the one step ahead error in forecasting \( x_1 \) at time \( t \) is then \( a_{0,11}^2 + a_{0,12}^2 \) from equation (5) above. \( a_{0,12}^2 \) can
then be thought of as a $x_{1,t}$’s spillover that effects the forecast error variance of $x_{2,t}$ and $a_{0,21}^2$ can then be thought of as a $x_{2,t}$’s spillover that affects the forecast error variance of $x_{1,t}$. Total spillover is then $a_{0,12}^2 + a_{0,21}^2$. Using these we can calculate a spillover index measure as total spillover divided by the total forecast error variation $(a_{0,11}^2 + a_{0,12}^2 + a_{0,21}^2 + a_{0,22}^2 = \text{trace}(A_0A'_0)$ as in (7).

$$S = \frac{a_{0,12}^2 + a_{0,21}^2}{\text{trace}(A_0A'_0)} \times 100$$

(7)

This first-order two variable case can be generalised into a $p^{th}$-order $N$-variable case using 1 step ahead forecasts giving:

$$S = \frac{\sum_{i,j=1}^{N} a_{0,ij}^{2}}{\text{trace}(A_0A'_0)} \times 100$$

(8)

For a $H$-step ahead forecasts:

$$S = \frac{\sum_{i=0}^{H-1} \sum_{j=1}^{N} a_{0,ij}^{2}}{\sum_{i=0}^{H-1} \text{trace}(A_0A'_0)} \times 100$$

(9)

While it is commonplace to measure asset volatility based on the standard deviation of the log difference across a regular time interval, we also utilise a more complex measure, the GKe measure, which incorporates information about the open, close, high and low prices within a particular time interval. As discussed in Molnár (2012) the GK Range based estimator is amongst the most efficient estimators for volatility estimation. From Garman and Klass (1980) the GKe is:

$$\text{GKe} = \sigma^2 = 0.511 (H- L)^2 - 0.019 (C- 0)(H+L- 2C) (I- C) - 0.383 (C- O)^2$$

(10)

where $H = \log$ of interval high

$L = \log$ of interval low

$O = \log$ of interval open

$C = \log$ of interval close

Data
We examine the four main precious metals – gold, silver, platinum and palladium. Data are drawn from Thomson Reuters Ecowin, and consist of the nearest month futures closing price for each commodity, on NYMEX. Data are initially collected on a daily basis and converted to weekly to facilitate both a smoother data series and to allow the calculation of the Garman and Klass (1980) volatility. Shown in Figure 1 is the evolution of the series.

Figure 1: Precious metal prices 1982-2003

Results
Show in Table 1 are the results of the Diebold-Yilmaz spillover analyses for the four assets. We note that gold and silver share the closest relationship. Gold accounts for 27.7% of silvers return and only a small percentage of that of platinum and less again of palladium. Silver contributes 27.5% of the gold return and similar percentages to that of gold in terms of return to platinum and palladium. In volatility terms the situation is starker – we can see significant spillovers from gold and silver to each other while platinum and palladium are almost insulated from each other. Overall there is a reasonable level of spillover in returns, 42% while for volatility this is much lower at 18%. We can interpret this as 43% of return being determined by the movements of the four assets, while only 18% of volatility is so determined.
We then proceed to a time varying analysis. Below we show the evolving importance of spillovers to returns between the 4 markets through the spillover index in Figure 2 for returns and Figure 3 for volatility. We use an initial window of 100 weeks, and then update this by 10 observations (weeks) each iteration. While the average result for the returns spillover index over the full sample given in the last section was 43%, we can see that this varies very substantially over time. In the 1998 – 2005 period return spillovers were low, suggesting a market that was not very integrated. The markets degree of integration in

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general fell throughout the 1980-1993 period, then reversed until 1996 when it resumed its path towards a low point of integration in the early 2000s. Since then the markets have returned to a high degree of integration in returns.

Figure 2: Rolling Return Spillover index.

Figure 3: Rolling Volatility Spillover index.

In Figure 4 and 5 we show the net spillovers from and to each market for returns and volatility, following Diebold and Yilmaz (2012). The interpretation is of a positive figure indicating a source and a negative a recipient of spillovers. Gold shows four distinct period when it acts as a source of return spillovers: 1992-96, 2000-2002, 2003-4 and 2006-8. Silver is a source of return spillovers in the 2004-8 period, palladium in the 2008-10 period and platinum rarely. The effect of the GFC is marked in Platinum, Silver and Palladium, the latter becoming a
source of spillovers (perhaps linked to the heavy industrial use of the metal) the other two becoming (even more) a recipient of spillovers. It is also clear in gold, the metal moving from being a source of return spillover to a neutral position.

In volatility we see that while in general there is little net spillover in any of the four metals when they do show such it tends to be large. While the largest returns spillovers are in the range of 40% the range in volatility exceeds 100% at times. Gold is a net positive volatility spillover in the 2001-3 period, matching a return spillover period. Similarly for palladium volatility shows positive spillovers in the 2008-9 period matching returns. Platinum spillovers in volatility match those for returns in the 2008 period alone.

Figure 4: Net Asset Spillover indices for Returns

Figure 5: Net Asset Spillover indices for volatility
Shown in Figure 6 and Figure 7 are bidirectional spillovers. These show the influence of a particular asset on another. We concentrate here on gold and silver. We see that in both cases there are distinct regimes. For both the pattern is generally to decline from about 25% to almost zero by 2002, rising thereafter. Gold-Silver and Silver-Gold show very similar bidirectional spillovers as we might expect. The aftermath of the 9/11 attacks and the Iraq/Afghan wars, plus the gradual increase in global money supply show clearly. In 2003/4, post the second Iraq war, we see a major sustained increase in the influence of gold on platinum and palladium and also of silver on the same metals. Interestingly the influence of gold on silver and vice versa fell in that period.

In volatility spillovers we see the influence of gold disappearing on platinum and palladium in the 2000-2003 period and diminishing significantly for silver in that period. However, Silver shows its largest level of volatility spillover on gold in that period.
Conclusions
We apply a new method of spillover/integration, and surface time-varying spillovers amongst the four main precious metals. The metals split into two categories: gold and silver show consistent spillovers between them, while platinum and palladium are much more disconnected. In terms of time variation, we can attribute shifts and changes to geopolitical and economics events.
References


