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Volatility Spillovers on Precious Metals Markets: the Effects of the Asian Crisis

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Abstract

This paper investigates the nature of volatility spillovers between precious metals returns over the 1995- July 2007 period. We analyzed daily closing values for precious metals data, we took the US$/Troy ounce for gold, the London Free Market Platinum price in US$/Troy ounce, the London Free Market Palladium price in US$/Troy once, and the Zurich silver price in US$/kilogram. We divide our sample into a number of sub periods, prior to, during and after the Asian crisis, with the objective to provide a wide analysis of the behaviour of the precious metals markets during this crisis; we use GARCH and EGARCH modelling. The results show that there is clear evidence of volatility persistence between precious metals returns. In terms of volatility spillovers effects, the main findings are that there is evidence of volatility spillovers running in a bidirectional way in almost all the cases, with the exception of gold, that tend to generate effects in all the markets, but with little evidence in the case of the other precious metals influencing the gold market. Finally, the results from asymmetric spillover effects show that negative news have a stronger impact in these markets than positive news.

1. Introduction

The accurate representation and empirical modelling of metals market volatility is a very important matter, as volatility causes uncertainty to producers, consumers and stockholders with regard to revenues, costs and margins. The interest in commodity markets is that they are an outlet for speculative activities and therefore for the implementation and evaluation of trading and hedging strategies, and the conduct of risk management, McMillan and Speight (2001).

This paper employs GARCH and EGARCH techniques to investigate the effects on precious metals returns for daily closing values for precious metals data, (the US$/Troy ounce for gold, the London Free Market Platinum price in US$/Troy ounce, the London Free Market Palladium price in US$/Troy once and the Zurich silver price in US$/kilogram), over the period 1995-2007, with special attention given to the period of the Asian crisis 1997-1998. The objective is to analyse the reaction of precious metals returns during a long period and also of their behaviour during a crisis time where the major economies were affected by a serious economic crisis. The main motivation of conducting this analysis is supported by the current economic situation, where financial markets are facing increasing depreciation in their assets. Precious metals have been generally ignored by investors in the construction of their portfolios where uncertainty or risk is of major importance in financial analysis, given that one of the most important facts of returns of financial assets is that their volatility changes over time. In particular, periods of large movements in prices alternate with periods during which prices hardly change.

The variability of commodities, exchange rates and stock prices has been widely investigated for many years due to its implications for the participants involved in these markets. Special attention has been paid by the investors and the hedgers that attempt to offset their exposure and risks from theses markets, must adjust their hedge ratios in accordance with the movement of these main financial markets, while on the other hand speculators rely on price volatility in order to generate business opportunities that allow them get profits and at the same time provide liquidity to the markets.

While there is a substantial literature on the analysis of volatility spillovers between stock returns and domestic exchange rates, surprisingly, little empirical research has examined volatility spillovers between precious metals returns. This might appear as surprising given that these markets are of particular interest as they are important stores of value and monetary assets. Precious metals could be presenting stability properties especially during times of crisis that could help the investors to design portfolio management strategies. Our expectations are to find some stability behaviour in the precious metals returns, a characteristic that will be of major importance for designing financial strategies that allow investors to manage and hedge their risk in a more efficient manner.

The aim of the current paper is to extend the research in this area, and also to provide practical conclusions on the implications of precious metals returns volatility spillovers for risk management and hedging strategies in the financial markets, by using a GARCH and EGARCH analysis as modelling technique. The remaining of the paper is set out of as follow: section 2 presents the literature review, section 3 describes the methodology that is used to assess the nature of volatility spillovers between precious metals markets; section 4 presents our empirical results, and section 5 concludes the paper.

2. Literature Review

There is an extensive literature analysing volatility spillovers in stock markets; however, the interaction between stock markets and precious metals markets has received far less attention. It is well known that the price of various natural resource products is of high importance in both policy and business circles (Bernard, et al., 2005). Therefore the main objective of this article is to provide a comparative analysis of volatility spillover between precious metals markets (gold, platinum, palladium and silver) based on GARCH and EGARCH techniques. The motivation for this research is that precious metals markets could represent an important option for investors in order to diversify their investment strategies and portfolios, as the value of precious metals is more stable than that of the other commodities on the average and also more than the stock prices.

McMillan and Speight (2001) examined the conditional volatility of daily non-ferrous LME settlement prices (aluminium, copper, nickel, lead, tin and zinc) over the period 1972-1995. Their analysis provided a decomposition of volatility into its long-run and short-run components. Their main findings are that the half-life of shocks to markets-driven short-run volatility typically extends over periods of no more than 8 days, while the half-life of shock to fundamentals-driven long-run volatility extends over periods of up to 190 days, such that metals price volatility is only very slowly mean-reverting. Also, their findings shown superior results of their model in comparison with the standard model of conditional volatility widely applied in modelling financial market volatility. Their results confirmed the relevance and significance of the decomposition of metals price volatility and the presence of three separate principle components driving underlying metals volatility.

Mills (2003) investigated the statistical behaviour of daily gold price data from 1971 to 2002. He found that the phenomenon of volatility prices scaling with long-run correlations is important.

He found that gold returns are characterised by short-run persistence and scaling with a break point of 15 days. Daily returns are highly leptokurtic with multi-period returns only recovering gaussianity after 235 days.

Aggarwal and Lucey (2005) examined the existence of psychological barriers in a variety of daily and intraday gold price series. They analysed three data sets: daily gold prices from the official London AM fix over the period 2/11/1980-31/12/200, daily data from COMEX for cash and futures gold for the period 2/11/1982-28/11/2002, high frequency data set supplied by UBS London over the period 28/08/2001-09/01/2003. They found evidence that psychological barriers at the 100's digits (price levels such as $200, $300, etc) do exist in daily gold prices, while the evidence is weaker for high frequency data for gold. They also found significant evidence of changes in conditional means around psychological barriers.

Bernard, Khalaf, Kichian and McMahon (2005) analysed aluminium price series with daily, weekly and monthly frequencies. They used three econometric specifications that cover: i) random-walk models with ARCH or GARCH effects, ii) Poisson-based jump-diffusion models with ARCH or GARCH effects and iii) mean reverting models that allow for uncertainty in equilibrium price. Their results showed that in the case of high frequency (daily and weekly) data, the mean-reverting model with stochastic convenience yield outperforms to a large extent. All other competing models for all forecast horizons, within the class of non-mean reverting GARCH processes analysed for the same frequencies models with jumps or asymmetries fare best, yet the latter remain dominated by the mean reverting models. With monthly data, the mean-reverting model still fares well in comparison with the random-walk GARCH class.

Xu and Fung (2005) examined patterns of across-market information flows for gold, platinum, and silver futures contracts traded in both the U.S and Japanese markets. They analysed daily data for gold, platinum and silver futures contracts traded in U.S and Japan over the period from November 1994 to March 2001. Their results indicate that pricing transmissions for precious metals contracts are strong across the two markets, but information flows appear to lead from the U.S market to the Japanese market in terms of returns. There are strong volatility spillover feedbacks effects across both markets and their impact appears to be comparable and similar. They also found evidence that intraday pricing information transmission across the two precious metals futures markets is rapid, as offshore trading information can be absorbed in the domestic market within a trading day.

Batten and Lucey (2006) analysed the volatility structure of gold, trading as a futures contract on the Chicago Board of Trade using intraday (high frequency) data from January 1999 to December 2005. They used GARCH modelling and the Garman Klass estimator. They found significant variations across the trading days consistent with microstructure theories, although volatility is only slightly positively correlated with volume when measured by tick-count.

Fernandez and Lucey (2006) analyzed the implications for portfolio management of accounting for conditional heteroskedasticity and structural breaks in long-term volatility. They based their analysis in PGARCH models fitted to the return series. They used weekly data of the Dow Jones Country Titans CBT municipal bond, spot and futures prices of commodities for the period 1992-2005. They also applied their procedure to artificial data generated from distribution functions. They conclude that neglecting GARCH effects and volatility shifts may lead to overestimating financial risk at different time horizons.

Watkins and McAleer (2006) analysed data on 3-month futures contracts for aluminium, aluminium alloy, copper, lead, nickel, tin and zinc. They estimated various long-run models using daily London Metal Exchange price data for the period 1 February 1986 to 30 September 1998. They found that in most of the samples considered for the seven metals markets, the test for cointegration determined the existence of one statistically significant long-run relationship among the futures price, spot price, stock level and interest rate. They also found that the risk premium and carry models usefully are applied to each of the LME metals markets over different time periods.

Tully and Lucey (2006) investigated the macroeconomic influences on gold using the asymmetric power GARCH model (APGARCH). They examined cash and futures prices of gold and significant economic variables over the 1983-2003 period, paying special attention to two periods, around 1987 and in 2001, the year of the equity market crashes. Their results suggest that the APGARCH model provides the most adequate description for the data, with the inclusion of a GARCH term, free power terms and unrestricted leverage effect terms. They also found that the gold cash and futures data over a long period confirmed the US dollar is the main macroeconomic variable which influences gold.

Wolfle (2006) used a dataset of 19 commodities and two stock indices (S&P 500 and Dow Jones) daily data covering the period from December 31, 1999 through May 31, 2006. He applied GARCH procedures to analyse his time series. In general he found strong evidence of interdependence among commodities. He found that Dow Jones and S&P500 Index do not spillover to commodities. The Dow Jones Index reacts on innovations for coffee and soybeans. Information transmissions between stock and commodity markets are rejected which means that commodity and stock markets are not interdependent, which supports the use of commodities to diversify risk in stock portfolios.

Hiller, Draper and Faff (2006) investigated the role of precious metals in financial markets by analysing daily data for gold, platinum and silver from 1976 to 2004. They include the S&P 500 Index as a proxy for stock market returns from the US investors' perspective. They found that all three precious metals have low correlations with stock index returns which suggest that these metals may provide diversification within broad investment portfolios. They found that normally financial portfolios that contain precious metals perform significantly better than standard equity portfolios. They also found that precious metals exhibit some hedging capability during periods of abnormal market volatility.

Spargoli and Zagaglia (2007) studied the linkages between prices of oil futures traded on the New York Mercantile Exchange and the Intercontinental Exchange of London. They estimated a structural BEKK-GARCH model on daily data from the 26th of April 1998 to the 26th of April 2007 data series on prices of futures. The main conclusion from their analysis is that in normal periods, NYMEX and ICE futures are used by investors for hedging purposes. However, in turbulent periods when there are peaks in the structural conditional variance of both innovations, the structural correlation between them is positive and hedging is no more feasible.

Most of the research that have been done until now have been mainly focused on the analysis of the gold market; a main area of interest has been the role of this precious metal as a hedger against inflation; some studies have also analysed variables that could be affecting the behaviour of gold prices, but little has been done with regard to the other precious metals (silver, platinum and palladium) as can be seen from the literature review presented. It seems that the trend is changing and researchers are starting to pay more attention to the other precious metals markets and their behaviour, as they are becoming aware of the importance of these markets in terms of portfolio risk management. There is a lack of studies analysing the reaction of precious metals markets to the different financial crisis that had impacted the financial markets in the past. These studies are of key importance as they could provide important information to investors in order to help them diversify their portfolio and design their hedging strategies.

Our contribution to the existing literature in this area is that we provide new evidence on the volatility spillovers analysis. Our approach focuses on a comparative analysis of volatility spillovers between the four precious metals returns (gold, palladium, platinum and silver) over the time period 1995 to July 2007, using GARCH and EGARCH modelling.

3. Data and Methodology

Our analysis focuses on the period 1 January 1995 to 31 July 2007. We will analyse the whole sample and also we decided to split it into three sub samples in order to provide greater details and a better understanding of volatility spillovers between precious metals returns. Thus our first sub sample spans over the years 1995-June 1997, the period prior to the Asian crisis. As we are interested in examining if the Asian crisis could generate volatility spillovers between these financial markets the second subsample will cover the July 1997-1998 period where the crisis hit the markets, and finally our last sample period covers the years 1999-2006, where we intend to analyse the behaviour of these markets after the major shock, and how they have behaved afterwards. The data set consists of daily closing values for precious metals data. We took the US$/Troy ounce for gold, the London Free Market Platinum price in US$/Troy ounce, the London Free Market Palladium price in US$/Troy once and the Zurich silver price in US$/kilogram. All our data series are from DataStream International, giving a total of 3282 observations for each series. Following Kanas (2000) we use continuously compounded stock returns; we also applied the same procedure to work out the precious metals returns, calculated as the first difference of the natural log. That is, S= Stock Prices; $S_t = \ln\left(P_t^s\right) - \ln\left(P_{t-1}^s\right)$, and PM= Precious Metals Prices; $PM_t = \ln\left(P_t^{PM}\right) - \ln\left(P_{t-1}^{PM}\right)$.

As an initial step we provide descriptive statistics for stock returns and exchange rates, in order to summarise the statistical characteristics of our sample. We then proceed and perform a stationarity test on each of the relevant variables that are included in our analysis to ensure that the results from the analysis are not spurious. We apply the Dickey Fuller (DF) test, or Augmented Dickey-Fuller test (ADF) procedure if serial correlation is present. We also apply the Lagrange Multiplier (LMF) test, to ensure that a sufficient number of lags have been added in the ADF test to ensure that there is no serial correlation present, and that the results of the ADF test are valid. The LMF test is applied given that it is valid in the presence of lagged dependent variables as well as having the advantage of testing for first and higher orders of serial correlation. We estimate the lag selection tests up 20 lags. In terms of choosing between the various lag length selection criteria we follow Johansen *et al.* (2000) who suggest that when different information criteria suggest different lag lengths, it is a common practice to select the Hannan-Quinn (HQ) criteria. We ensure that the lag length selected for the VAR model is free from serial correlation by applying the LMF test to test for serial correlation up to the number of lags in the VAR model.

We then proceed with our volatility analysis and apply a bivariate extension of the EGARCH (*p,q*) model in order to examine whether the volatility of precious markets returns affects and is affected by the volatility of the other precious metals returns within each market.

There are several methods that analyse the volatility issue. In this study it have been decided to implement the analysis using the generalized autoregressive conditional heteroscedasticity or GARCH model (Bollerslev, 1986) that has been proved successful at modelling stock returns volatility by allowing the mean of stock returns to depend on its time-varying variance and other causes for the mean or the changing variance. We will apply two methodologies in order to analyse the behaviour of precious metals markets returns, and in order to capture the impact of precious metals returns depreciation on each market and its volatility. The form of the GARCH and EGARCH specification are specified as follow:

The Generalized Autoregressive Conditional Heteroscedasticity (GARCH) models were introduced by Engle (1982) and Bollerslev (1986). With regard to the precious metal markets, the EGARCH specification can be written as:

$$PMy_t = a_{PMy,0} + \sum_{i=1}^{r} a_{PMy,i} PMy_{t-i} + \sum_{i=1}^{r} a_{PMx,i} PMx_{t-i} + e_{PMy,t} \quad \textbf{(1)}$$

$$PMx_t = a_{PMx,0} + \sum_{i=1}^{r} a_{PMx,i} PMx_{t-i} + \sum_{i=1}^{r} a_{PMy,i} PMy_{t-i} + e_{PMx,t} \quad \textbf{(2)}$$

$$e_{PMy,t} / \Omega_{t-1} \approx N(0, \sigma^2_{PMy,t})$$
$$e_{PMx,t} / \Omega_{t-1} \approx N(0, \sigma^2_{PMx,t})$$

The conditional variances of stock returns and exchange rates changes are specified as follows:

(3)

$$\sigma^2_{PMy,t} = \exp\left\{ c_{PMy,0} + \sum_{j=1}^{pPMy} b_{PMy,j} \log(\sigma^2_{PMy,t-j}) + \delta_{PMy,PMy}\left[\left(\left|z_{PMy}\right| - E\left|z_{PMy,t-1}\right| + \theta_{PMy,PMyz_{s,PMy-1}}\right) + \delta_{PMy,PMx}\left[\left(\left|z_{PMx,t-1}\right| - E\left|z_{PMx,t-1}\right| + \theta_{PMy,PMxzPMx,t-1}\right)\right]\right]\right.$$

(4)

$$\sigma^2_{PMx,t} = \exp\left\{ c_{PMx,0} + \sum_{j=1}^{pPMy} b_{PMx,j} \log(\sigma^2_{PMx,t-j}) + \delta_{PMx,PMx}\left[\left(\left|z_{PMx,t-1}\right| - E\left|z_{PMx,t-1}\right| + \theta_{PMx,PMzy}\right) + \delta_{PMx,PMy}\left[\left(\left|z_{S,t-1PMy}\right| - E\left|z_{PMy,t-1}\right| + \theta_{PMX,S\#PMyzPMx,t-1}\right)\right]\right]\right.$$

$$\sigma_{PMy,PMx,T} = \rho_{PMx}\, \sigma_{PMy,t}\, \sigma_{PMx,t}$$

Each of the relevant terms in equations (1-4) is explained in detail in Table A.

Table A: Description of Parameters Equations (1)-(4)

	Precious Metals Returns y	**Precious Metals Returns x**
Stochastic error terms	$e_{PMy,t}$	$e_{PMx,t}$
Information set at time *t-1*	Ω_{t-1}	Ω_{t-1}
Conditional (time varying) variances	$\sigma^2_{PMy,t}$	$\sigma^2_{PMx,t}$
Standardised residuals assumed to be normally distributed with 0 mean and variances of $\sigma^2_{PMy,t}, \sigma^2_{PMx,t}$	$z_{PMy,t} = e_{PMy,t} / \sigma_{PMy,t}$ $e_{PMy,t} / \Omega_{t-1} \sim \mathrm{N}(0,\ \sigma^2_{PMy,t})$	$z_{PMx,t} = e_{PMx,t} / \sigma_{PMx,t}$ $e_{PMx,t} / \Omega_{t-1} \sim \mathrm{N}(0,\ \sigma^2_{PMx,t})$
Persistence of Volatility	$\sum_{j=1}^{pPMy} b_{PMy}$	$\sum_{j=1}^{pmx} b_{PMx,j}$
ARCH effect where the parameters $\theta_{PMy,PMy}, \theta_{PMx,PMx}$ allow this effect to be asymmetric	$\left[\lvert z_{PMy,t} \rvert - E\lvert z_{PMy,t} \rvert + \theta_{PMy,PMyPM_{x,t}}\right]$	$\left[\lvert z_{PMx,t} \rvert - E\lvert z_{PMx,t} \rvert + \theta_{PMx,PMx_{PMx,t}}\right]$
Volatility Spillover	$\delta_{PMy,PMx}\left[\lvert z_{PMx,t-1} \rvert - E\lvert z_{PMx,t-1} \rvert + \theta_{PMy,PMx:}\right.$	$\delta_{PMx,PMy}\left[\lvert zP_{PMy} \rvert - E\lvert z_{PMy,t-1} \rvert + \theta_{PMx,PMy z_{PM}}\right.$
Measures of spillovers	$\delta_{PMy,PMx}$	$\delta_{PMx,PMy}$
Asymmetry of Spillovers	$\theta_{PMy,PMx}$	$\theta_{PMx,PMy}$
Correlation Coefficient for Standardised Residuals	$\rho_{PMy,PMx}$	$\rho_{PMx,PMy}$

We specify the number of lags for the conditional mean equations (1) and (2) using the Hannan-Quinn (HQ) criterion; the test was conducted up to 20 lags, selecting the number of lags where the HQ criteria was minimum. Griffin *et al.* (2005), Andersen *et al.* (2004), and Stulz *et al.* (2002) all note that the HQ criterion is preferable to the more commonly used Akaike's Information Criteria (AIC), as the latter tends to overparameterize the models. Next we apply the likelihood ratio (LR) test to determine the lag truncation length, *p*. We perform separate LR tests on the stock returns and exchange rate conditional variance equations (3) and (4) to determine the optimal lag length for the EGARCH specification of each equation. Hamilton (1994) defines the LR test as follows: $2\left[L(\hat{\theta}) - L(\tilde{\theta})\right] \approx \chi^2(m)$, where $L(\hat{\theta})$ denotes the value of the log likelihood function of the unrestricted estimate and $L(\tilde{\theta})$ denotes the value of the log likelihood functions of the restricted estimate. Bollerslev-Woolridge robust *t*-statistics are derived to take into account possible non-normality of the residuals.

The GARCH specification can be written as is presented in equation (5) and equation (6). In equation (7) we present the error that will be included in equation (5) and equation (6) in order to improve the original model.

$$PMy = c_0 + \sum_{i=1}^{m} \alpha_i PMx_{t-i} + \varepsilon_{yt}\,; \qquad \textbf{(5)}$$

$$PMx = a_0 + \sum_{i=1}^{n} \delta_i PMy_{t-i} + \varepsilon_{xt} \qquad \textbf{(6)}$$

$$\varepsilon_{yt} = \mu_{yt} - \theta\mu_{yt-1} \;\; ; \;\; \varepsilon_{xt} = \mu_{xt} - \theta\mu_{xt-1} \qquad \textbf{(7)}$$

Equation (8) and equation (9) are presenting our model after the error term is included in each original equation:

$$PMy = c_0 + \sum_{i=1}^{p} \alpha_i PMx_{t-i} + \sum_{i=1}^{q} \theta\mu_{yt-1} + \mu_{yt} \;\; ; \qquad \textbf{(8)}$$

$$PMx = a_0 + \sum_{i=1}^{r} \delta_i PMy_{t-i} + \sum_{i=1}^{s} \phi_{yt-1} + \mu_{yt} \qquad \textbf{(9)}$$

$$\mu_{yt} \left| \psi_{yt-1} \sim N(0, h_{yt})\,; \quad \mu_{xt} \right| \psi_{xt-1} \sim N(0, h_{xt}) \qquad \textbf{(10)}$$

Equation (11) is presented the variance of the error terms for equation (8) and equation (12) is presenting the variance of the error term for equation (9).

$$h_{yt} = \beta_0 + \sum_{i=1}^{a} \beta_1 h_{yt-1} + \sum_{i=1}^{b} \kappa_1 \mu_{yt-1}^2 \;\; ; \qquad \textbf{(11)}$$

$$h_{xt} = b_0 + \sum_{i=1}^{c} b_1 h_{xt-1} + \sum_{i=1}^{d} c_1 \mu_{xt-1\,xt-1}^2 \qquad \textbf{(12)}$$

We consider that is important to take into account the effect of the depreciation of the alternative precious market in each model, therefore equation (11) and equation (12) are modified as follow:

$$h_{yt} = \beta_0 + \sum_{i=1}^{f} \beta_1 h_{yt-1} + \sum_{i=1}^{g} \kappa_1 \mu_{yt-1}^2 + \sum_{i=1}^{j} \gamma_1 (PMx_{t-1})^2 \;\; ; \qquad \textbf{(13)}$$

$$h_{xt} = b_0 + \sum_{i=1}^{l} b_1 h_{xt-1} + \sum_{i=1}^{v} c_1 \mu_{xt-1}^2 + \sum_{i=1}^{w} \lambda_1 (PMy_{t-1})^2 \qquad \textbf{(14)}$$

Where PMy is one precious metals return (e.g. gold) and PMx is the other precious metals return (e.g. platinum) on day t; the serially correlated errors ε_{yt} and ε_{xt} follow an MA(1) process. The variance h_{yt} of the error term μ_{yt} is obtained on the information set ψ_y available at time t-1(ψ_{yt-1}). In the model ψ_{yt-1} consists of past conditional variances and past squared error terms, PMx is the precious metals returns of the alternative market, and the conditions $\beta_0 \geq 0, 1 \geq \beta_1 \geq 0, 1 \geq \kappa_1 \geq 0, \gamma \geq 0, (\beta_1 + \kappa_1 \leq 1)$ are the customary constraints applied to the parameters to enforce stationarity and a positive conditional variance. The variance h_{xt} of the error term μ_{xt} is obtained on the information set ψ_x available at time t-1(ψ_{xt-1}); in the model ψ_{xt-1} consists of past conditional variances and past squared error terms, PMy is the precious metals returns of the alternative market, and the conditions $b_0 \geq 0, 1 \geq b_1 \geq 0, 1 \geq c_1 \geq 0, \lambda \geq 0, (b_1 + c_1 \leq 1)$ are the customary constraints applied to the parameters to enforce stationarity and a positive conditional variance. The parameters of the models: ($a_0, \delta, \phi,\ b_0, b_1, c_1, \lambda_1$) and $(c_0, \alpha, \theta, \beta_0, \beta_1, \kappa_1, \gamma_1)$ are estimated using the maximum likelihood method by the BHHH algorithm (Berndt et al., 1974).

The GARCH (1,1) model will examine the effects of precious metals returns depreciation effects in each respective market through the mean returns equation (Equation 5). The other is through the variance equation (Equation 8) that depends on the depreciation of the alternative market. The square rate is used to guarantee a positive value of the variance. Bollerslev-Woolridge robust *t*-statistics are derived to take into account possible non-normality of the residuals.

The diagnostic tests on the standardised residuals are performed for the GARCH and EGARCH models which includes the Jarque-Bera test for normality, the Bollerslev-Woolridge robust t-statistics, The Ljung-Box (LB) statistics that will detect that there are no residual linear or non linear dependencies in the errors, and the LB statistics for the cross products of the standardised residuals for the two equations are calculated as these statistics indicate if the assumption of constant correlation over time can be accepted. Finally, the ARCH-LM residual test will be performed, to test whether the standardised residuals exhibit additional ARCH. If the variance equation is correctly specified, there should not be an ARCH effect left in the standardised residuals.

4. Empirical Results

Our empirical results are presented through sections 4.1 to 4.7. First we start presenting the basic descriptive statistics of our dataset which provide us with the details and characteristics of our series; second we will present the results of the unit roots analysis, the likelihood ratio tests performed and the basic tests that will provide the necessary information to identify which EGARCH(p,q) specification will be the most appropriate to model our two financial variables. Finally, we present the results of the EGARCH analysis, results that will provide information of volatility persistence, volatility spillovers and asymmetric spillovers effects from stock returns to precious metals returns and vice versa.

4.1 Descriptive Statistics

The analysis of the descriptive statistics of precious metals returns are presented in table 1. During the four periods of analysis, almost all markets present positive and small values, the exceptions being gold and silver for the period before to the Asian crisis (1995-June 1997) where the means are negative. During the Asian crisis (July 1997-1998) the results show negative means in the case of gold and platinum. After the financial crisis all the means for the four precious metals are positive. The analysis of the returns volatility for all our samples shows that overall Palladium is the most volatile of the four precious metals, moving in a range of 1,64% prior to the crisis to 2.75% during the crisis time. Gold is the less volatile with a 0.44% standard deviation prior to the crisis as the minimum value and with a 0.97% as the highest value after the financial crisis. Platinum and Palladium standard deviations move around 1.01% to 1.83% during the four periods. The skewness and kurtosis coefficients indicate that precious metals returns are leptokurtic relative to the normal distribution. The Jarque-Bera test also rejects the hypothesis that precious metals returns are normally distributed in all the cases.

4.2 Unit Roots and Likelihood Tests

The results from the ADF tests are given in table 2. The values of the test statistics indicate that we can reject the null hypothesis of the existence of a unit root in levels for all variables during all periods indicating that all series are *I(0)*.[1] Given that all variables are integrated of the same order, (i.e. *I(0),* we proceed directly to perform our volatility analysis using EGARCH (*p,q*) modelling.

In order to establish the correct lag length for the EGARCH model, we apply the Likelihood Ratio test. The results from this test for each of ours series are set out in table 3.

We have marked with one asterisk where the EGARCH (1,1) was selected and with two asterisks were the EGARCH (2,1). There is a mix of (1,1) and (2,1) models chosen for the different bivariate models, with the (1,1) model being the dominant one.

The estimated parameters from the EGARCH estimation and the diagnostic test for the models are set out in tables 4 to 10, for the four periods of analysis (1995-2006, 1995-June 1997, July 1997-1998 and 1999-06). And the results for the GARCH (1,1) and the diagnostic test are presented in tables 11 to 18. The *p*-values are given in parentheses beneath each coefficient estimate.

4.3 Volatility Persistence (EGARCH)

With regard to the coefficients on the volatility persistence term (table 4) the results vary depending on the type of precious metal and on the equation under analysis, but we find that in the majority of the cases the coefficients are significant. This result is not surprising given that persistence is a feature of many financial markets data; therefore we expected to find evidence of significant coefficients in most of the cases. For the first sub-period (1995-July 2007), the coefficients are significant in all the cases. The coefficients are all significant before the Asian crisis (1995-June 1997); the exception is Palladium-Gold for which the coefficient appear to be insignificant. An interesting feature of our results is the insignificant coefficients obtained for the period where the Asian financial crisis happened; we expected to find significant coefficients during this particular time as the effect of the Asian crisis could be dragging all the markets into recession, expectations that are not supported by our results. Almost all the coefficients appear to be insignificant with the exception of the results for the equation analysis palladium-silver, silver-gold, silver-palladium and silver-platinum. The results for the coefficients for the final period 1999-July 2007 are all significant.

Volatility persistence is a common finding in a financial market returns situation; this is reflected by the findings of significant coefficients. If the following coefficients are significant

[1] The LMF test results indicated that the ADF tests were free from serial correlation; for brevity we do not show the test results here.

and greater than zero (i.e. $\sum_{j=1}^{Pmy} b_{P_{MY},j}$ and $\sum_{j=1}^{Pmx} b_{Pmx,j}$ >0), this implies that a deviation of the price from its expected value will cause the variance of the price to be larger than otherwise, this means that the amplitude of returns fluctuations represents the amount of variation of the returns during a short-time. In the presence of a long memory process affecting volatility, this implies that the fluctuations will remain in the markets for a while with the uncertainty that this situation will bring to the markets, a situation that has important consequences in terms of risk management. Investors base their decisions on expectations; therefore, the diversity of expectations cause a variability of stock returns. The insignificance of the volatility persistence coefficients found in this analysis in the precious metals returns could reflect that as a general rule the Asian crisis did not generate a great impact on these markets, as investors expect stability in the precious metals prices. Therefore, their expectations tend to be constant and stable over a long time, a situation that will be translated in the precious metals markets returns as a lower fluctuation in their prices. The appreciation of precious metals as a store of value directly leads implies the expectation of stability in prices; this means that prices are expected to be moving gradually in an upward trend.

Therefore, our volatility persistence analysis shows that overall there are significant coefficients on precious metals returns. This result indicates that precious metals returns fluctuations do generate a mutual impact on these markets, indicating that when any of the precious metals markets face fluctuations, these movements will be transmitted to the others.

Wu (2005) notes that a necessary condition for the volatility persistence terms to be stable is that the value of the estimated coefficients be less than one. For our results, this applies in all cases for the four periods in the case of the persistence terms for both stock returns and exchange rates where the magnitude of the coefficients are all less than one in all the cases and more importantly in the case where the coefficients are significant.

4.4 Volatility Spillovers (EGARCH)

The analysis of the coefficients for the volatility spillovers are presented in table 5, where it can be seen that results are quite mix across time periods. The main results are showing evidence of volatility spillovers between precious metals markets at 1%, 5% and 10% significance levels. Some exceptions are found with regard to this evidence but most of them are affecting particular time periods. For example if we start to analyse the results per sample period we found that during the whole sample 1995-July 2007 the coefficients are significant in the case of volatility running from gold to the other metals, but there is weal evidence of the opposite trend, where the only coefficient that is significant is volatility spillovers running form platinum to gold. In relation to the period prior to the Asian crisis (1995-June1997), the results show insignificant coefficients in the case of volatility spillovers from gold to any of the other metals, while we found the opposite effect appears to be significant, meaning that the other metals are generating an impact on the gold market. Regarding the Asian crisis period (July1997-1998) the coefficients are insignificant in the case of volatility from gold to the other precious metals, they are significant for volatility spillovers running from platinum to gold and from silver to gold. Regarding the rest of the metals, there are spillover effects running from platinum to silver, platinum to palladium, silver to palladium and silver to platinum. And finally during our last period of study (1999-July 2007) the results are quite mixed. The trend being significant volatility spillovers from gold to palladium and platinum, silver to gold, platinum to palladium, silver to platinum and platinum to silver.

Significant coefficients are indicative of integration between precious metals markets as well as indicating that the volatility of precious metals returns was a determinant of the volatility between these markets, meaning that information contained in precious metals markets impact on the other markets. These results are showing that these markets are initially influenced, this is especially the case for the gold market, that appears to generate effects in the rest of the metals but there is no strong evidence for an effect in the opposite direction.

4.5 Asymmetric Spillovers (EGARCH)

The results for the asymmetric spillover effects are presented in table 6. We found that the coefficients are significant in almost all cases for all periods, with the following exceptions: during 1995-June1997 the coefficient is insignificant in the case of the equation for silver-platinum. And during July1997-1998, the coefficients are insignificant in the cases of gold-palladium, gold-silver, palladium-silver, platinum-silver, platinum-palladium, silver-palladium and silver-platinum. The existence of insignificant coefficients indicates that the spillover effects in these instances are symmetric, that is that positive and negative shocks have the same impact on volatility. Our results are showing that, in general, bad news will generate a greater impact on these markets than good news.

4.6 GARCH Results

The analyses of the coefficients for the volatility persistence are presented in tables 11 to 14.

The parameter conditions constraints are: $b_0 \geq 0, 1 \geq b_1 \geq 0, 1 \geq c_1 \geq 0, \lambda \geq 0, (b_1 + c_1 \leq 1)$ $\beta_0 \geq 0, 1 \geq \beta_1 \geq 0, 1 \geq \kappa_1 \geq 0, \gamma \geq 0, (\beta_1 + \kappa_1 \leq 1)$. These constraints are applied to the parameters to enforce stationarity and a positive conditional variance. Volatility persistence will be measured through the sum of the following coefficients for each equation $(b_1 + c_1 \leq 1)$ and $(\beta_1 + \kappa_1 \leq 1)$ The depreciation of the precious metals returns could be a cause of market volatility (i.e. $\lambda>0$ and $\gamma>0$), the squared rate is used to guarantee a positive value of the variance.

Regarding the returns-generating process, we can draw the following conclusion. First there is a significantly positive relation between the precious metals returns. And overall there is a significant negative relation between precious metal returns and metals returns depreciation, with most of the coefficients appearing to be negative. This situation reflects that, in generally when the precious metals markets are appreciating there is a trend of increasing returns for almost all the markets, but when the prices of any of these markets depreciates, the prices of the rest of the markets will tend to drop as well.

Examining the estimates we can appreciate that for all four periods of analysis all variance parameters are positive and statistically significant. If we analysed the results for each period we would find that during 1995-July 2007 (table 11), and for the palladium-silver equations the coefficients are negative, with GARCH parameter sums indicating high volatility shock persistence for all the cases, with the exception of palladium-silver, where the coefficients sum is 0.018 for the palladium-silver, and 0.31 for silver-palladium.

During 1995-June1998 (table 12) the estimates are positive and statistically significant in all the cases. The exception is the silver-platinum equation where the coefficient is negative. The GARCH parameter sum is quite high for all equations with the exception of silver-palladium (0.57) and silver-platinum (0.24).

The results for the Asian crisis period (table 13) show that gold-platinum and silver-platinum equations coefficients are the only ones that appear to be negative. The GARCH parameter sum is moving between 0.54 as the lowest value to 0.98 as the highest.

The results for the finally sample, 1999-July 2007, (table 14) show that the coefficients are positive in all the cases, with a GARCH parameter sum moving between 0.63 to 0.94, which indicates high volatility shock persistence for all the cases.

The coefficients that take into account precious metals returns depreciation ($\lambda>0$ and $\gamma>0$) are positive and significant in almost all the cases with the exceptions of palladium-silver and silver-platinum during 1995-June 1997. During the Asian crisis the parameters are negative in the case of gold-palladium, palladium-silver, palladium-gold, silver-gold, and silver-palladium and silver-platinum. Overall, the results show that precious metals depreciation is a source of volatility.

These results are consistent with the findings of the EGARCH model where we also found evidence of volatility persistence between these markets.

4.7 Standardised Residuals

The diagnostic tests on the standardised residuals for the EGARCH model are listed in tables 7-10, and for the GARCH specification through tables 15 to18. The Jarque-Bera test indicates that we reject the hypothesis that the residuals are normally distributed in all the cases, hence justifying the use of the Bollerslev-Woolridge robust *t*-statistics. In the case of the EGARCH model the Ljung-Box statistics for all four periods for all precious metals equations indicate that there are no residual linear or non linear dependencies in most of the cases. There are some exceptions where the coefficient was not significant but the problem was corrected after introducing more lags into the test. A similar situation was found in the case of the GARCH results. Finally to check the validity of the assumption of constant correlation adopted in the estimation of the bivariate models (Kanas, 2000), the LB statistics for the cross products of the standardised residuals from the precious metals returns equation are calculated and these statistics indicated that the assumption of constant correlation over time can be accepted in almost all the cases, with the exception of palladium-gold during 1995-July 2007, during July 1997-1998 in the cases of palladium-platinum, palladium-silver, and finally during 1999-July 2007 in the cases of palladium-gold and silver-palladium, in the case of the EGARCH model. Regarding the GARCH results, the exceptions were found for the 1995-July 2007 period in the cases of gold-palladium, palladium silver and platinum silver. During July 1997-1998 in the case of gold-platinum and palladium-silver, and finally during the 1999-July 2007 period the exception was gold-palladium. These exceptions are normally corrected after increasing or decreasing the number of lags in the test.

The ARCH-LM residual test results show that overall the variance equation for the EGARCH model is correctly specified, as we reject the null hypothesis of remaining ARCH effects in the equation in almost all the cases. The exceptions are: during the crisis period (July

1997-1998) in the case of palladium-platinum, palladium-silver, palladium-gold, silver-gold, silver-palladium and silver-platinum. This problem is corrected after increasing or decreasing the number of lags using on the estimation. The test results show that the variance equation is correctly specified as well for the GARCH model, as we reject the null hypothesis in almost all the case, with the following exceptions: silver-palladium for the whole sample during the Asian crisis (1995-July 2007, July 1997-1998).

5. Conclusions

This paper investigates the existence of volatility effects in precious metals returns, using GARCH and EGARCH modelling. The empirical results indicate that the depreciation of precious metals under conditions of stable and unstable markets situations tends to decrease the mean stock return and also to increase market volatility. The results show that there is clear evidence of volatility persistence between precious metals returns. In terms of volatility spillovers effects, the main findings are that there is evidence of volatility spillovers running in a bidirectional way in almost all the cases, with the exception of gold, that tend to generate effects in all the markets. There is however little evidence in the case of the other precious metals influencing the gold market. And finally, the results from asymmetric spillover effects show that negative news have a stronger impact on these markets than positive news.

The investment demand for precious metals is rising as institutional and high net worth investors in developed and developing economies are increasing their interest in precious metals as investment. Financial markets continually evolve. One of the recent developments is the emergence of the Exchange Traded Fund or ETFs; this has had a major impact on precious metals markets. The ETFs will increase the volume of investment in precious metals, because investors who otherwise would not invest in precious metals are and will buy shares of ETFs. Thus the ETFs represent an upward shift in the investment demand curve. The ETFs provide the markets greater transparency regarding an investor's attitude toward these metals. Metals and energy markets seem to be markets that will attract investment for the rest of the decade. By analysing the characteristics of these markets it is clear that the supply of metals is scarce. Added to the fact that consumption on these markets from developing countries such China and India could raise their price, precious metals markets appear therefore an increasingly good option for investment.

These results provide evidence of the need for further research in this area, as precious metals markets could have important implications in terms of risk management, hedging activities and as new market options to locate capital.

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Table 1: Descriptive Statistics Precious Metals Returns

	Mean	SD	Skewness	Kurtosis	JB
1995- July 2007					
Gold	0.000168	0.0086	0.1096	10.2094	7112
Palladium	0.000258	0.0215	0.0967	9.6825	6110
Platinum	0.000345	0.0134	-0.6478	19.2013	36113
Silver	0.00029	0.0173	-0.6922	12.8068	13410
1995-June 1997					
Gold	-0.00021	0.0044	0.3319	6.4210	329
Palladium	0.000312	0.0164	1.0173	11.9374	2275
Platinum	4.91E-05	0.0101	2.3290	33.2392	25353
Silver	-7.95E-05	0.0143	0.6299	10.4756	1557
July 1997-1998					
Gold	-0.00038	0.0072	-0.0111	3.9738	15
Palladium	0.001321	0.0275	0.2410	6.2832	180
Platinum	-0.00048	0.0149	-0.1976	4.4165	35
Silver	0.000173	0.0183	0.2691	6.1449	166
1999-July 2007					
Gold	0.000374	0.0097	0.0639	9.0372	3399
Palladium	4.64E-05	0.0217	-0.0873	9.8476	4373
Platinum	0.000569	0.0139	-1.0661	20.4116	28681
Silver	0.000419	0.0179	-1.0660	13.9877	11677

Table 2: Augmented Dickey-Fuller Test

	1995-July 2007	1995-June 1997	July 1997-1998	1999-July 2007
Precious Metals				
Gold	-14.11*	-12.34*	-44.47*	-63.55*
Palladium	-25.69*	-4.97*	-10.44*	-8.16*
Platinum	-18.08*	-5.03*	-16.26*	-19.18*
Silver	-18.37*	-14.62*	-36.78*	-53.698

*1% significance level

Table 3: Likelihood Ratio Precious Metals

Precious Metals	1995-July 2007	1995-June 1997	July 1997-1998	1999-July 2007
Gold-Palladium	29.68**	0.77*	0.31*	96.43**
Palladium-Gold	1.83*	13.64**	34.95**	0.00*
Gold-Platinum	28.16**	0.39*	0.34*	75.14**
Platinum-Gold	4.00*	2.22*	0.84*	5.28*
Gold-Silver	32.1**	1.99*	1.04*	79.41**
Silver-Gold	116.15**	20.43**	2.10*	28.29**
Palladium-Platinum	6.14**	0.01*	16.35**	1.43*
Platinum-Palladium	1.01*	3.48*	1.02*	0.17*
Palladium-Silver	2.13*	15.74**	45.33**	1.19*
Silver-Palladium	99.39**	23.22**	1.92*	10.82**
Platinum-Silver	3.16*	0.10*	0.01*	1.57*
Silver-Platinum	104.84**	20.63**	2.2*	25.01**

Note: H_0: EGARCH (1,1), H_1: EGARCH(2,1)** The 5% critical value for the LR test distributed as χ^2 with 2 degrees of freedom is 5.99.

Table 4: EGARCH RESULTS VOLATILITY PERSISTENCE

1995-July 2007						1995-June 1997					
Gold-Palladium	Gold-Platinum	Gold-Silver	Palladium-Platinum	Palladium-Silver	Platinum-Silver	Gold-Palladium	Gold-Platinum	Gold-Silver	Palladium-Platinum	Palladium-Silver	Platinum-Silver
0.2324	0.2312	0.2354	0.1934	0.2451	0.2026	0.1877	0.2548	0.2048	0.1527	0.3993	0.2515
(0.006)*	(0.006)*	(0.003)*	(0.000)*	(0.000)*	(0.000)*	(0.149)	(0.001)*	(0.005)*	(0.069)***	(0.000)*	(0.000)*
Palladium-Gold	Platinum-Gold	Silver-Gold	Platinum-Palladium	Silver-Palladium	Silver-Platinum	Palladium-Gold	Platinum-Gold	Silver-Gold	Platinum-Palladium	Silver-Palladium	Silver-Platinum
0.2517	0.2864	0.4561	0.2870	0.4638	0.4607	0.2518	0.2310	0.4698	0.2318	0.6009	0.4693
(0.006)*	(0.000)*	(0.000)*	(0.000)*	(0.000)*	(0.000)*	(0.000)*	(0.000)*	(0.000)*	(0.000)*	(0.000)*	(0.000)*
July 1997-1998						**1999-July 2007**					
Gold-Palladium	Gold-Platinum	Gold-Silver	Palladium-Platinum	Palladium-Silver	Platinum-Silver	Gold-Palladium	Gold-Platinum	Gold-Silver	Palladium-Platinum	Palladium-Silver	Platinum-Silver
0.1041	0.1134	-0.0037	0.2008	0.3660	0.1045	0.2391	0.2412	0.2602	0.2908	0.2569	0.2092
(0.376)	(0.322)	(0.963)	(0.141)	(0.034)**	(0.420)	(0.011)**	(0.010)**	(0.001)*	(0.000)*	(0.000)*	(0.000)*
Palladium-Gold	Platinum-Gold	Silver-Gold	Platinum-Palladium	Silver-Palladium	Silver-Platinum	Palladium-Gold	Platinum-Gold	Silver-Gold	Platinum-Palladium	Silver-Palladium	Silver-Platinum
0.2312	0.0762	0.3632	0.0716	0.3388	0.3551	0.2631	0.2351	0.5220	0.2341	0.5271	0.5193
(0.115)	(0.569)	(0.001)*	(0.571)	(0.004)*	(0.000)*	(0.000)*	(0.000)*	(0.000)*	(0.000)*	(0.000)*	(0.000)*

Table 5: EGARCH RESULTS VOLATILITY SPILLOVERS

1995-July 2007						1995-June 1997					
Gold-Palladium	Gold-Platinum	Gold-Silver	Palladium-Platinum	Palladium-Silver	Platinum-Silver	Gold-Palladium	Gold-Platinum	Gold-Silver	Palladium-Platinum	Palladium-Silver	Platinum-Silver
0.0608	0.0627	0.0708	0.7386	0.0085	0.0646	0.0383	-0.0183	0.0528	0.1067	0.1272	0.1549
(0.000)*	(0.000)*	(0.000)*	(0.000)*	(0.806)	(0.003)*	(0.411)	(0.776)	(0.321)	(0.022)**	(0.041)**	(0.003)*
Palladium-Gold	Platinum-Gold	Silver-Gold	Platinum-Palladium	Silver-Palladium	Silver-Platinum	Palladium-Gold	Platinum-Gold	Silver-Gold	Platinum-Palladium	Silver-Palladium	Silver-Platinum
0.0127	0.0713	0.0405	0.0693	0.0385	0.0401	0.0815	0.1406	-0.2097	0.1565	-0.0037	-0.2110
(0.703)	(0.000)*	(0.205)	(0.000)*	(0.269)	(0.233)	(0.008)*	(0.033)**	(0.002)*	(0.001)*	(0.933)	(0.002)*
July 1997-1998						**1999-July 2007**					
Gold-Palladium	Gold-Platinum	Gold-Silver	Palladium-Platinum	Palladium-Silver	Platinum-Silver	Gold-Palladium	Gold-Platinum	Gold-Silver	Palladium-Platinum	Palladium-Silver	Platinum-Silver
0.0357	0.0324	0.0702	0.0836	0.0243	0.2289	-0.1824	-0.1844	0.0347	-0.0072	-0.0113	0.0596
(0.528)	(0.574)	(0.367)	(0.644)	(0.936)	(0.004)*	(0.047)**	(0.042)**	(0.641)	(0.863)	(0.789)	(0.030)**
Palladium-Gold	Platinum-Gold	Silver-Gold	Platinum-Palladium	Silver-Palladium	Silver-Platinum	Palladium-Gold	Platinum-Gold	Silver-Gold	Platinum-Palladium	Silver-Palladium	Silver-Platinum
0.0343	0.2313	0.3976	0.2180	0.2938	0.3471	-0.0041	0.0642	-0.2361	0.0645	-0.2012	-0.2270
(0.717)	(0.007)*	(0.000)*	(0.009)*	(0.001)*	(0.000)*	(0.919)	(0.028)**	(0.039)**	(0.027)**	(0.132)	(0.045)**

Table 6: EGARCH RESULTS ASYMMETRIC SPILLOVERS

1995-July 2007						1995-June 1997					
Gold-Palladium	Gold-Platinum	Gold-Silver	Palladium-Platinum	Palladium-Silver	Platinum-Silver	Gold-Palladium	Gold-Platinum	Gold-Silver	Palladium-Platinum	Palladium-Silver	Platinum-Silver
0.9864	0.9859	0.9784	0.1679	0.9364	0.9778	0.9444	0.9463	0.9465	0.9592	0.7920	0.9392
(0.000)*	(0.000)*	(0.000)*	(0.000)*	(0.000)*	(0.000)*	(0.000)*	(0.000)*	(0.000)*	(0.000)*	(0.000)*	(0.000)*
Palladium-Gold	Platinum-Gold	Silver-Gold	Platinum-Palladium	Silver-Palladium	Silver-Platinum	Palladium-Gold	Platinum-Gold	Silver-Gold	Platinum-Palladium	Silver-Palladium	Silver-Platinum
0.9334	0.9701	0.9590	0.9720	0.9466	0.9522	0.9768	0.9521	-0.3552	0.9445	0.9936	-0.3534
(0.000)*	(0.000)*	(0.000)*	(0.000)*	(0.000)*	(0.000)*	(0.000)*	(0.000)*	(0.251)	(0.000)*	(0.000)*	(0.255)
July 1997-1998						**1999-July 2007**					
Gold-Palladium	Gold-Platinum	Gold-Silver	Palladium-Platinum	Palladium-Silver	Platinum-Silver	Gold-Palladium	Gold-Platinum	Gold-Silver	Palladium-Platinum	Palladium-Silver	Platinum-Silver
-0.7072	-0.7230	0.6558	0.8855	0.5863	-0.2353	0.9844	0.9844	0.8219	0.8770	0.9206	0.9723
(0.116)	(0.054)***	(0.363)	(0.000)*	(0.130)	(0.516)	(0.000)*	(0.000)*	(0.000)*	(0.000)*	(0.000)*	(0.000)*
Palladium-Gold	Platinum-Gold	Silver-Gold	Platinum-Palladium	Silver-Palladium	Silver-Platinum	Palladium-Gold	Platinum-Gold	Silver-Gold	Platinum-Palladium	Silver-Palladium	Silver-Platinum
0.7328	-0.1952	0.3174	-0.3392	0.2849	0.3002	0.9218	0.9613	0.8547	0.9593	0.8115	0.8499
(0.003)*	(0.612)	(0.099)***	(0.362)	(0.309)	(0.205)	(0.000)*	(0.000)*	(0.000)*	(0.000)*	(0.000)*	(0.000)*

*1% significance level, **5% significance level, ***10% significance level

Table 7: Diagnostic on EGARCH residuals: 1995-July 2007

Precious Metals	Gold-Palladium	Gold-Platinum	Gold-Silver	Palladium-Platinum	Palladium-Silver	Platinum-Silver
JB						
LB(20)	27.689	26.788	25.015	65.144	56.077	16.978
	(0.117)	(0.141)	(0.201)	(0.000)	(0.000)	(0.654)
$LB^2(20)$	20.252	20.717	15.466	3.1955	3.8736	12.796
	(0.442)	(0.414)	(0.749)	(1.000)	(1.000)	(0.886)
ARCH-LM	0.93	0.95	0.72	0.16	0.19	0.60
	(0.55)	(0.53)	(0.81)	(1.00)	(1.00)	(0.92)
	Palladium-Gold	Platinum-Gold	Silver-Gold	Platinum-Palladium	Silver-Palladium	Silver-Platinum
JB						
LB(20)	60.22	17.823	27.532	17.105	26.806	27.562
	(0.000)	(0.599)	(0.121)	(0.646)	(0.141)	(0.120)
$LB^2(20)$	4.2919	6.0518	7.151	7.7502	7.8512	7.5869
	(1.000)	(0.999)	(0.996)	(0.993)	(0.993)	(0.994)
ARCH-LM	0.21	0.30	0.35	0.38	0.39	0.37
	(1.00)	(1.00)	(1.00)	(0.99)	(0.99)	(0.99)
Cross Products						
LB(20)	80.705	25.096	23.581	3.4841	33.653	22.614
	(0.000)	(0.198)	(0.261)	(1.000)	(0.029)	(0.308)
$LB^2(20)$	91.473	21.068	1.3085	0.0365	2.3852	1.3525
	(0.000)	(0.383)	(1.000)	(1.000)	(1.000)	(1.0000

Table 8: Diagnostic on EGARCH residuals: 1995-June 1997

Precious Metals	Gold-Palladium	Gold-Platinum	Gold-Silver	Palladium-Platinum	Palladium-Silver	Platinum-Silver
JB						
LB(20)	14.64	15.21	10.73	13.31	15.79	12.56
	(0.797)	(0.764)	(0.953)	(0.864)	(0.730)	(0.895)
$LB^2(20)$	19.08	18.47	26.22	7.29	5.57	10.06
	(0.516)	(0.557)	(0.159)	(0.996)	(0.999)	(0.967)
ARCH-LM	0.92	0.97	1.22	0.35	0.32	0.56
	(0.57)	(0.50)	(0.23)	(1.00)	(1.00)	(0.94)
	Palladium-Gold	Platinum-Gold	Silver-Gold	Platinum-Palladium	Silver-Palladium	Silver-Platinum
JB						
LB(20)	15.62	21.60	29.44	13.28	28.30	29.27
	(0.740)	(0.363)	(0.079)	(0.865)	(0.102)	(0.083)
$LB^2(20)$	8.25	14.03	22.19	10.03	12.05	22.03
	(0.990)	(0.829)	(0.331)	(0.968)	(0.914)	(0.339)
ARCH-LM	0.38	0.67	1.06	0.62	0.56	1.05
	(0.99)	(0.86)	(0.39)	(0.90)	(0.94)	(0.40)
Cross Products						
LB(20)	23.08	21.27	26.48	16.52	27.09	19.69
	(0.285)	(0.382)	(0.151)	(0.684)	(0.133)	(0.478)
$LB^2(20)$	1.27	8.75	1.73	0.52	24.20	2.99
	(1.000)	(0.986)	(1.000)	(1.000)	(0.234)	(1.000)

Table 9: Diagnostic on EGARCH residuals: July 1997-1998

Precious Metals	Gold-Palladium	Gold-Platinum	Gold-Silver	Palladium-Platinum	Palladium-Silver	Platinum-Silver
JB						
LB(20)	18.86	18.18	19.62	45.89	48.51	15.93
	(0.531)	(0.576)	(0.482)	(0.001)	(0.000)	(0.721)
LB²(20)	17.91	18.06	17.03	53.04	74.09	17.20
	(0.593)	(0.584)	(0.651)	(0.000)	(0.000)	(0.640)
ARCH-LM	1.08	1.07	0.89	2.81	3.48	0.87
	(0.37)	(0.38)	(0.61)	(0.00)	(0.00)	(0.63)
	Palladium-Gold	Platinum-Gold	Silver-Gold	Platinum-Palladium	Silver-Palladium	Silver-Platinum
JB						
LB(20)	48.32	25.57	47.38	26.20	25.94	22.74
	(0.000)	(0.180)	(0.001)	(0.159)	(0.168)	(0.302)
LB²(20)	66.18	16.12	41.40	16.33	42.84	42.43
	(0.000)	(0.709)	(0.003)	(0.696)	(0.002)	(0.002)
ARCH-LM	3.35	0.79	1.86	0.80	2.18	2.19
	(0.00)	(0.73)	(0.01)	(0.71)	(0.00)	(0.00)
Cross Products						
LB(20)	21.57	31.05	20.15	19.11	37.03	16.99
	(0.364)	(0.055)	(0.449)	(0.515)	(0.012)	(0.654)
LB²(20)	7.42	16.82	23.41	9.10	13.26	16.83
	(0.995)	(0.665)	(0.269)	(0.982)	(0.866)	(0.773)

Table 10: Diagnostic on EGARCH residuals: 1999-July 2007

Precious Metals	Gold-Palladium	Gold-Platinum	Gold-Silver	Palladium-Platinum	Palladium-Silver	Platinum-Silver
JB						
LB(20)	26.32	26.07	31.23	58.13	49.11	12.73
	(0.156)	(0.164)	(0.052)	(0.000)	(0.000)	(0.889)
LB²(20)	15.47	15.31	17.83	2.46	3.35	13.12
	(0.749)	(0.758)	(0.598)	(1.000)	(1.000)	(0.872)
ARCH-LM	0.71	0.70	0.85	0.12	0.16	0.60
	(0.82)	(0.83)	(0.65)	(1.00)	(1.00)	(0.92)
	Palladium-Gold	Platinum-Gold	Silver-Gold	Platinum-Palladium	Silver-Palladium	Silver-Platinum
JB						
LB(20)	55.36	13.20	16.38	11.58	18.53	18.73
	(0.000)	(0.869)	(0.693)	(0.930)	(0.553)	(0.539)
LB²(20)	3.31	7.82	18.69	9.66	25.91	19.84
	(1.000)	(0.993)	(0.592)	(0.974)	(0.169)	(0.468)
ARCH-LM	0.16	0.35	0.92	0.46	1.25	0.97
	(1.00)	(1.00)	(0.56)	(0.98)	(0.20)	(0.49)
Cross Products						
LB(20)	98.53	25.86	36.85	5.95	48.54	24.61
	(0.000)	(0.170)	(0.012)	(0.999)	(0.000)	(0.217)
LB²(20)	63.32	20.15	2.71	0.05	2.70	3.24
	(0.000)	(0.449)	(1.000)	(1.000)	(1.000)	(1.000)

Table 11: Estimates of the GARCH (1,1): 1995-July 2007

Parameters	Gold-Palladium	Gold-Platinum	Gold-Silver	Palladium-Platinum	Palladium-Silver	Platinum-Silver
c_0	0.0000	-0.0001	0.0000	-0.0003	0.0000	0.0000
	(0.710)	(0.528)	(0.878)	(0.115)	(0.949)	(0.794)
α	0.0733	0.2006	0.2150	0.7476	0.0456	0.1627
	(0.000)*	(0.000)*	(0.000)*	(0.000)*	(0.000)*	(0.000)*
θ	0.0000	-0.0002	-0.0004	0.0014	0.1756	-0.0006
	(0.968)	(0.055)**	(0.001)*	(0.000)*	(0.359)	(0.013)**
β_0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	(0.030)**	(0.179)	(0.002)*	(0.044)**	(0.000)**	(0.073)***
β_1	0.0583	0.0571	0.2078	0.1934	-0.0407	0.1137
	(0.000)*	(0.000)*	(0.000)*	(0.000)*	(0.017)**	(0.000)*
κ_1	0.9390	0.9398	0.6751	0.7386	0.0594	0.8724
	(0.000)*	(0.000)*	(0.000)*	(0.000)*	(0.003)*	(0.000)*
γ_1	0.0007	0.0026	0.0236	0.1679	0.8324	0.0088
	(0.060)**	(0.044)**	(0.000)*	(0.000)*	(0.000)*	(0.002)*
$\beta_1 + \kappa_1$	0.9973	0.9969	0.8829	0.9320	0.0187	0.9861
Parameters	Palladium-Gold	Platinum-Gold	Silver-Gold	Platinum-Palladium	Silver-Palladium	Silver-Platinum
a_0	0.0001	0.0000	0.0003	0.0002	0.0002	0.0001
	(0.194)	(0.800)	(0.165)	(0.147)	(0.084)**	(0.656)
δ	0.5425	0.4971	0.9334	0.3093	0.0640	0.3395
	(0.000)*	(0.000)*	(0.000)*	(0.000)*	(0.000)*	(0.000)*
ϕ	0.0008	-0.0007	-0.0030	-0.0001	-0.0014	-0.0025
	(0.044)**	(0.001)*	(0.000)*	(0.588)	(0.000)*	(0.000)*
b_0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001
	(0.014)**	(0.005)*	(0.000)*	(0.000)*	(0.000)*	(0.000)*
b_1	0.1307	0.1020	0.1733	0.1863	-0.0865	0.2826
	(0.000)*	(0.000)*	(0.000)*	(0.000)*	(0.000)*	(0.000)*
c_1	0.8341	0.8846	0.5800	0.6891	0.4012	0.3354
	(0.000)*	(0.000)*	(0.000)*	(0.000)*	(0.000)*	(0.000)*
λ_1	0.1188	0.0320	0.4010	0.0266	0.2838	0.2212
	(0.017)*	(0.000)*	(0.000)*	(0.000)*	(0.000)*	(0.000)*
$b_1 + c_1$	0.9649	0.9866	0.7533	0.8754	0.3147	0.6180

Table 12: Estimates of the GARCH (1,1): 1995-June 1997

Parameters	Gold-Palladium	Gold-Platinum	Gold-Silver	Palladium-Platinum	Palladium-Silver	Platinum-Silver
c_0	-0.0001	-0.0001	-0.0001	-0.0003	-0.0007	-0.0005
	(0.378)	(0.486)	(0.257)	(0.439)	(0.083)**	(0.069)***
α	0.0845	0.2806	0.1389	0.8995	0.2742	0.2505
	(0.000)*	(0.000)*	(0.000)*	(0.000)*	(0.000)*	(0.000)*
θ	-0.0002	-0.0005	-0.0003	0.0005	0.0002	-0.0008
	(0.283)	(0.002)*	(0.021)**	(0.294)	(0.692)	(0.002)*
β_0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	(0.020)**	(0.009)*	(0.180)	(0.290)	(0.134)	(0.064)***
β_1	0.1022	0.1498	0.1113	0.2078	0.1847	0.1857
	(0.000)*	(0.001)*	(0.011)**	(0.000)*	(0.000)*	(0.027)**
κ_1	0.8309	0.6185	0.8377	0.5995	0.7569	0.7154
	(0.000)*	(0.000)*	(0.000)*	(0.000)*	(0.000)*	(0.000)*
γ_1	0.0019	0.0274	0.0010	0.2781	-0.0105	0.0138
	(0.1758)	(0.000)*	(0.181)	(0.020)**	(0.314)	(0.022)**
$\beta_1 + \kappa_1$	0.9331	0.7683	0.9490	0.8074	0.9416	0.9012
Parameters	Palladium-Gold	Platinum-Gold	Silver-Gold	Platinum-Palladium	Silver-Palladium	Silver-Platinum
a_0	-0.0004	-0.0003	-0.0003	-0.0002	-0.0001	0.0001
	(0.328)	(0.325)	(0.439)	(0.368)	(0.849)	(0.849)
δ	0.8245	0.8977	0.8995	0.3705	0.2761	0.7744
	(0.000)*	(0.000)*	(0.000)*	(0.000)*	(0.000)*	(0.000)*
ϕ	-0.0003	-0.0010	0.0005	0.0000	-0.0009	-0.0027
	(0.595)	(0.001)*	(0.294)	(0.957)	(0.013)**	(0.000)*
b_0	0.0000	0.0000	0.0000	0.0000	0.0001	0.0001
	(0.371)	(0.045)**	(0.290)	(0.017)**	(0.000)*	(0.000)*
b_1	0.1006	0.2315	0.2078	0.0925	0.5521	0.2527
	(0.021)**	(0.001)*	(0.000)*	(0.004)*	(0.000)*	(0.003)*
c_1	0.8259	0.6787	0.5995	0.6343	0.0278	-0.0043
	(0.000)*	(0.000)*	(0.000)*	(0.000)*	(0.397)	(0.944)
λ_1	0.2215	0.0973	0.2781	0.0442	0.0347	0.5253
	(0.353)	(0.101)	(0.020)**	(0.000)*	(0.074)***	(0.000)*
$b_1 + c_1$	0.9264	0.9102	0.8074	0.7268	0.5799	0.2484

Table 13: Estimates of the GARCH (1,1): July 1997-1998

Parameters	Gold-Palladium	Gold-Platinum	Gold-Silver	Palladium-Platinum	Palladium-Silver	Platinum-Silver
c_0	-0.0004	-0.0003	-0.0006	0.0014	0.0007	-0.0003
	(0.230)	(0.348)	(0.066)***	(0.171)	(0.486)	(0.622)
α	0.0347	0.1386	0.1482	0.7310	0.0997	0.2243
	(0.004)*	(0.000)*	(0.000)*	(0.000)*	(0.117)	(0.000)*
θ	0.0005	0.0002	0.0001	0.0027	0.0036	-0.0014
	(0.185)	(0.048)**	(0.690)	(0.023)**	(0.008)*	(0.069)***
β_0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001
	(0.210)	(0.228)	(0.039)**	(0.643)	(0.192)	(0.206)
β_1	0.0278	-0.0194	0.0503	0.1240	0.1037	0.0971
	(0.390)	(0.498)	(0.166)	(0.014)**	(0.004)*	(0.193)
κ_1	0.7166	0.6825	0.6446	0.8335	0.8771	0.5983
	(0.000)*	(0.006)*	(0.000)*	(0.000)*	(0.000)*	(0.015)**
γ_1	-0.0008	0.0128	0.0187	0.1049	-0.0058	0.0255
	(0.453)	(0.140)	(0.001)*	(0.162)	(0.740)	(0.174)
$\beta_1 + \kappa_1$	0.7444	0.6631	0.6949	0.9575	0.9809	0.6954
Parameters	Palladium-Gold	Platinum-Gold	Silver-Gold	Platinum-Palladium	Silver-Palladium	Silver-Platinum
a_0	0.0007	0.0000	-0.0007	-0.0005	-0.0006	-0.0008
	(0.507)	(0.968)	(0.342)	(0.441)	(0.450)	(0.318)
δ	0.2155	0.5953	0.8391	0.2857	0.1017	0.2939
	(0.140)	(0.000)*	(0.000)*	(0.000)*	(0.002)*	(0.000)*
ϕ	0.0023	-0.0020	-0.0013	-0.0017	-0.0008	-0.0011
	(0.096)***	(0.011)**	(0.205)	(0.019)**	(0.452)	(0.283)
b_0	0.0000	0.0001	0.0002	0.0001	0.0003	0.0001
	(0.038)**	(0.044)**	(0.000)*	(0.068)***	(0.000)*	(0.000)*
b_1	0.0887	0.1058	0.4846	0.1129	0.1972	0.2617
	(0.002)*	(0.015)**	(0.000)*	(0.198)	(0.001)*	(0.014)**
c_1	0.9011	0.5081	0.0579	0.4597	-0.3174	0.3134
	(0.000)*	(0.011)**	(0.553)	(0.051)***	(0.000)*	(0.028)**
λ_1	-0.4434	0.0859	-0.3310	0.0204	0.0454	-0.0164
	(0.000)*	(0.565)	(0.000)*	(0.007)*	(0.010)**	(0.763)
$b_1 + c_1$	0.9898	0.6139	0.5424	0.5726	-0.1202	0.5752

Table 14: Estimates of the GARCH (1,1): 1999-July 2007

Parameters	Gold-Palladium	Gold-Platinum	Gold-Silver	Palladium-Platinum	Palladium-Silver	Platinum-Silver
c_0	0.0004 (0.020)*	0.0003 (0.114)	0.0003 (0.055)***	-0.0005 (0.067)***	0.0003 (0.453)	0.0007 (0.005)*
α	0.1133 (0.000)*	0.2368 (0.000)*	0.2647 (0.000)*	0.7088 (0.000)*	0.2020 (0.000)*	0.1089 (0.000)*
θ	-0.0001 (0.690)	-0.0002 (0.323)	-0.0008 (0.000)*	0.0019 (0.000)*	0.0013 (0.009)*	-0.0005 (0.097)***
β_0	0.0000 (0.000)*	0.0000 (0.000)*	0.0000 (0.000)*	0.0000 (0.016)**	0.0000 (0.082)***	0.0000 (0.000)*
β_1	0.1546 (0.000)*	0.1407 (0.000)*	0.1777 (0.000)*	0.2079 (0.000)*	0.1713 (0.000)*	0.1866 (0.000)*
κ_1	0.5673 (0.000)*	0.5817 (0.000)*	0.4558 (0.000)*	0.7125 (0.000)*	0.7248 (0.000)*	0.7270 (0.000)*
γ_1	0.0115 (0.001)*	0.0340 (0.009)*	0.0535 (0.000)*	0.1603 (0.000)*	0.0461 (0.056)***	0.0165 (0.018)**
$\beta_1 + \kappa_1$	0.7219	0.7224	0.6335	0.9204	0.8961	0.9136
Parameters	Palladium-Gold	Platinum-Gold	Silver-Gold	Platinum-Palladium	Silver-Palladium	Silver-Platinum
a_0	0.0002 (0.608)	0.0005 (0.042)**	0.0005 (0.108)	0.0006 (0.001)*	0.0008 (0.044)**	0.0005 (0.139)
δ	0.5128 (0.000)*	0.4112 (0.000)*	0.8531 (0.000)*	0.2993 (0.000)*	0.1350 (0.000)*	0.2395 (0.000)*
ϕ	0.0012 (0.024)**	-0.0007 (0.009)*	-0.0034 (0.000)*	-0.0001 (0.708)	-0.0008 (0.067)***	-0.0025 (0.000)*
b_0	0.0000 (0.014)**	0.0000 (0.005)*	0.0000 (0.002)*	0.0000 (0.000)*	0.0001 (0.000)*	0.0001 (0.000)*
b_1	0.1667 (0.000)*	0.1410 (0.000)*	0.1416 (0.000)*	0.2077 (0.000)*	0.2192 (0.002)*	0.2285 (0.000)*
c_1	0.7610 (0.000)*	0.8081 (0.000)*	0.6021 (0.000)*	0.6070 (0.000)*	0.4926 (0.000)*	0.5124 (0.000)*
λ_1	0.1394 (0.037)**	0.0362 (0.013)**	0.3417 (0.000)*	0.0272 (0.000)*	0.0476 (0.004)*	0.1033 (0.025)**
$b_1 + c_1$	0.9277	0.9492	0.7437	0.8147	0.7119	0.7409

Table 15: Diagnostic on GARCH(1,1) residuals: 1995-July 2007

Precious Metals	Gold-Palladium	Gold-Platinum	Gold-Silver	Palladium-Platinum	Palladium-Silver	Platinum-Silver
JB						
LB(20)	27.69	33.22	28.70	29.69	42.73	13.10
	(0.117)	(0.032)	(0.094)	(0.075)	(0.002)	(0.873)
LB²(20)	33.94	27.12	14.62	32.90	343.47	11.77
	(0.027)	(0.132)	(0.798)	(0.035)	(0.000)	(0.924)
ARCH-LM	1.52	1.25	0.73	1.63	18.87	0.58
	(0.06)	(0.20)	(0.80)	(0.04)	(0.00)	(0.93)
	Palladium-Gold	Platinum-Gold	Silver-Gold	Platinum-Palladium	Silver-Palladium	Silver-Platinum
JB						
LB(20)	35.53	14.29	21.01	11.34	26.15	14.13
	(0.017)	(0.815)	(0.397)	(0.937)	(0.161)	(0.824)
LB²(20)	5.80	9.46	24.13	16.38	42.36	41.47
	(0.999)	(0.977)	(0.237)	(0.693)	(0.002)	(0.008)
ARCH-LM	0.28	0.45	1.16	0.81	1.90	2.01
	(1.00)	(0.98)	(0.28)	(0.71)	(0.01)	(0.00)
Cross Products						
LB(20)	54.97	26.01	17.59	35.29	26.40	40.88
	(0.000)	(0.165)	(0.614)	(0.019)	(0.153)	(0.004)
LB²(20)	4.17	8.14	2.43	15.80	259.36	7.16
	(1.000)	(0.991)	(1.000)	(0.729)	(0.000)	(0.996)

Table 16: Diagnostic on GARCH(1,1) residuals: 1995-June 1997

Precious Metals	Gold-Palladium	Gold-Platinum	Gold-Silver	Palladium-Platinum	Palladium-Silver	Platinum-Silver
JB						
LB(20)	15.68	14.13	11.79	17.75	17.46	26.43
	(0.736)	(0.824)	(0.923)	(0.604)	(0.623)	(0.152)
LB²(20)	16.91	34.37	16.19	12.78	3.48	9.90
	(0.659)	(0.024)	(0.705)	(0.887)	(1.000)	(0.970)
ARCH-LM	0.82	1.56	0.84	0.60	0.17	0.80
	(0.70)	(0.06)	(0.66)	(0.91)	(1.00)	(0.72)
	Palladium-Gold	Platinum-Gold	Silver-Gold	Platinum-Palladium	Silver-Palladium	Silver-Platinum
JB						
LB(20)	16.14	23.45	20.63	20.18	32.23	13.13
	(0.708)	(0.267)	(0.420)	(0.447)	(0.041)	(0.872)
LB²(20)	3.34	12.81	13.65	7.74	12.05	15.78
	(1.000)	(0.886)	(0.848)	(0.993)	(0.915)	(0.730)
ARCH-LM	0.14	0.59	0.69	0.39	0.59	0.81
	(1.00)	(0.92)	(0.84)	(0.99)	(0.92)	(0.71)
Cross Products						
LB(20)	18.51	15.90	12.25	26.34	34.63	25.76
	(0.554)	(0.723)	(0.907)	(0.155)	(0.022)	(0.174)
LB²(20)	0.98	20.68	2.93	7.86	27.24	10.79
	(1.000)	(0.426)	(1.000)	(0.993)	(0.129)	(0.951)

Table 17: Diagnostic on GARCH(1,1) residuals: July 1997-1998

Precious Metals	Gold-Palladium	Gold-Platinum	Gold-Silver	Palladium-Platinum	Palladium-Silver	Platinum-Silver
JB						
LB(20)	17.52	15.63	29.36	32.97	27.66	10.52
	(0.619)	(0.739)	(0.081)	(0.034)	(0.118)	(0.958)
LB²(20)	20.43	18.10	15.72	27.52	19.36	17.49
	(0.431)	(0.581)	(0.734)	(0.121)	(0.499)	(0.621)
ARCH-LM	0.96	0.83	0.78	1.94	1.18	0.93
	(0.51)	(0.67)	(0.74)	(0.01)	(0.27)	(0.55)
	Palladium-Gold	Platinum-Gold	Silver-Gold	Platinum-Palladium	Silver-Palladium	Silver-Platinum
JB						
LB(20)	31.28	12.36	37.79	18.23	20.57	20.78
	(0.052)	(0.903)	(0.009)	(0.572)	(0.423)	(0.410)
LB²(20)	17.86	17.12	36.42	18.52	38.63	42.89
	(0.597)	(0.645)	(0.014)	(0.553)	(0.007)	(0.002)
ARCH-LM	1.02	0.89	1.85	1.09	1.93	2.20
	(0.43)	(0.60)	(0.02)	(0.35)	(0.01)	(0.00)
Cross Products						
LB(20)	17.95	31.83	17.82	19.16	39.29	14.46
	(0.591)	(0.045)	(0.600)	(0.512)	(0.006)	(0.806)
LB²(20)	17.14	56.48	16.33	22.09	6.33	11.82
	(0.644)	(0.000)	(0.696)	(0.336)	(0.998)	(0.922)

Table 18: Diagnostic on GARCH(1,1) residuals: 1999-July 2007

Precious Metals	Gold-Palladium	Gold-Platinum	Gold-Silver	Palladium-Platinum	Palladium-Silver	Platinum-Silver
JB						
LB(20)	26.65	31.54	25.98	24.98	36.47	11.57
	(0.145)	(0.048)	(0.166)	(0.202)	(0.014)	(0.930)
LB²(20)	7.48	11.02	18.71	22.84	2.86	13.58
	(0.995)	(0.946)	(0.541)	(0.297)	(1.000)	(0.851)
ARCH-LM	0.35	0.51	0.89	1.10	0.14	0.80
	(1.00)	(0.96)	(0.60)	(0.34)	(1.00)	(0.72)
	Palladium-Gold	Platinum-Gold	Silver-Gold	Platinum-Palladium	Silver-Palladium	Silver-Platinum
JB						
LB(20)	35.49	10.93	13.28	13.82	29.04	7.73
	(0.018)	(0.948)	(0.865)	(0.839)	(0.087)	(0.993)
LB²(20)	3.32	11.39	19.40	23.43	19.72	20.80
	(1.000)	(0.935)	(0.496)	(0.268)	(0.476)	(0.409)
ARCH-LM	0.16	0.63	0.95	1.31	1.01	1.06
	(1.00)	(0.90)	(0.52)	(0.16)	(0.45)	(0.38)
Cross Products						
LB(20)	78.75	28.98	14.22	37.47	22.99	23.75
	(0.000)	(0.088)	(0.819)	(0.010)	(0.290)	(0.253)
LB²(20)	24.41	18.33	2.99	17.05	8.02	5.01
	(0.225)	(0.566)	(1.000)	(0.650)	(0.992)	(1.000)