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## Determinants of the asymmetric gold market

### Abstract

The purpose of this paper is to explore in the shortrun the effects of energy (crude oil) and financial (equity, currency and bond) markets on the gold market. A GJR-GARCH model is used to test these relationships for the period from January 1, 1999 to August 31, 2009 using daily data. The results suggest that the energy market positively influences the gold market. There is also evidence that the equity, currency and bond markets exert negative impact on the gold market. A possible explanation for this relationship is the way that the gold market functions as a mobilization factor of hedge against portfolio and geopolitical risks. Furthermore, the results show that the volatility of the U.S. dollar/yen exchange rate influences significantly the volatility of the gold market. Additionally, the authors found indications of volatility persistence in the gold market. Finally, the structural analysis of gold market volatility showed, at least in the shortrun, that the volatility is not only asymmetric but it also tends to overreact in response to positive shocks, contrary to the equity markets, since in times of market stress or turmoil the increased volatility from other markets is transmitted to the gold market which acts as a safe haven.

**Keywords:** GJR-GARCH model, gold futures, crude oil, equity market, exchange rates, bond market.

**JEL Classification:** F39, G10, G15.

### Introduction

Gold investment market has highly grown worldwide in the last seven years. Many investors tend to have a proportion of gold in their portfolios due to the fact that the price of gold is expected to rise in line with inflation and act as an inflation hedge (Levin and Wright, 2006). In general, during periods of political and economic uncertainty, investors tend to purchase gold and gold related instruments as a store of value, as a diversification tool and as protection from stock and currency shocks and from the new complex off-balance-sheet investments which sometimes are not in transparency. According to the World Gold Council (2006b), central banks hold gold reserves since gold provides economical safety. Currencies are prone to bad decisions made by governments and their value changes accordingly. The price of gold is unaffected by these decisions. History has shown that many countries frequently impose exchange controls affecting the free transfer of their currencies or, in the worst case, they freeze the total asset, in an attempt to prevent other countries accessing their cash or securities. War, hyperinflation, worldwide currency crisis or any other major crisis could lead to full or partial collapse of the present system. In this case, gold acts as an option for uncertain future.

This paper examines for the first time the impact on gold prices, in the shortrun (day by day), in relation to four factors such as energy, equity (stock), exchange rate and bond. More specifically, we propose to analyze the implications of the Generalized Autoregressive Conditional Heteroskedasticity model developed by Glosten, Jagannathan and Runkle

(1993) on gold future prices within a new empirical modeling framework of the internationalization and integration of the above mentioned markets. The scope of this paper is to address the gap in the literature in this area by conducting an in-depth analysis of the energy, equity, currency and bond market spillovers effects on gold market. Specifically, the contribution of this paper is twofold. First, it uses recent data on the gold market and tests for the spillover effect of specific financial determinants on its price and volatility for the first time. Secondly, it contributes to the literature on this important relation by showing that the conditional variance of gold future prices appears to be more volatile in response to positive shocks than to negative ones, contrary to the equities market.

In our model, the gold market is very well represented by the gold future prices (i.e. GC Gold 100 Troy Oz. COMEX). The variables that were finally tested as parameters which determine the gold future price are the CL Crude Oil Light Sweet index, the S&P 500 Stock index, the exchange rate of the U.S. dollar/yen, and the TNX 10-Year Treasury Note.

This paper is structured as follows. Section 1 presents an overview of the existing relevant literature. Section 2 displays the methodological considerations. The following Section describes the data used. Section 4 exposes the econometric methodology and presents the empirical findings.

### 1. Literature review

There are many factors that contribute to the formation of the gold futures price statistical moments. Specifically, industrial use, jewelry use, investment use and purchases by the central banks are factors that affect the demand of gold (Levin and Wright,

2006), while the supply is influenced by the quantity being extracted from gold mines, the refining of recycled gold, the current market price of gold and the interest rates (Levin and Wright, 2006; Elfakhani et al., 2009).

However, factors like the industrial and jewelry use, the quantity being extracted from gold mines and the refining of recycled gold generally occur slowly and, thus short-term price movements are rarely driven by either of these phenomena. In addition, the role of central banks in market interventions has recently been diminished. Prior to the Washington Agreement on Gold Sales in 1999, central banks bought and sold large quantities of gold affecting its price as well. On the contrary, gold prices seem to respond rapidly to actual and anticipated changes in financial conditions as gold exchange traded funds (ETF) and non-commercial speculators have steadily increased their activities.

In this research, we identify four main significant determinants that affect gold price and its volatility: the energy market, the equity market, the bond market and the currency market. A general reason why these markets affect the gold market, apart from the specific factors that implied by the relative economics of gold, is the integration of financial markets, particularly in the last decade. The internationalization of economies has led gold, stock, energy, currency and bond markets to become more and more popular and easily accessed (through the development of the Internet technologies and the increasing popularity of electronic markets exchanges) while it has increased their interdependence. Accessibility of financial instruments for foreign capital has become a reality in the above markets, even for investors with a small capital. Hence, the integration of the markets has been induced since anyone can participate in trading at those markets, even with a small deposit fund. In addition, world trade has become more liberalized, and the role of governments in market interventions has been diminished, while several major countries (China, the Former Soviet Union and Eastern Europe) have undergone significant economic restructuring. Consequently, the dynamic interaction of these factors has provoked the financial investors to built investment strategies using progressively more gold in their portfolios. Gold is said to be uncorrelated or negatively correlated with other types of assets, which is an important feature in the context of internalization of markets in which correlations increased dramatically among most asset types. Actually, many studies have shown that gold is good hedge in traditional investment portfolios and could be considered as an

alternative approach (Jaffee, 1989; Ciner, 2001; Capie et al., 2005). Furthermore, gold plays an important role as a store of value and a safe haven investment especially in times of political and economic uncertainty (Baur and McDermott, 2010).

Regarding the effects of oil prices to gold market, they influence the cost of production of goods and services, a fact that predicts the future of the other industries and also affects the profit margins. Liao and Chen (2008) found that oil affects the gold prices. Additionally, oil prices influence the financial markets since anticipated changes in economic activity, in corporate earnings, in inflation and in monetary policy follow the oil price fluctuations. Cunadoa and Gracia (2005) and LeBlanc and Chinn (2004) have argued that oil prices have significant impacts on the inflation rates, while Abken (1980) and Kolluri (1987) claimed that inflation influences gold prices with positive correlation. Moreover, the oil and gold prices are often considered interconnected in a cause and effect relationship through their link to inflation. Specifically, inflation follows the same direction of oil prices and gold has been considered as a good inflation hedge tool. In other words, the increase of crude oil price often provokes inflationary pressures and since gold is regarded as a more secure way for storing wealth, the demand of gold and, hence, its price is anticipated to increase. Nevertheless, despite the importance of the relationship between oil and gold prices for investors and consultants, studies relevant to this issue are relatively scarce (Zhang and Wei, 2010).

Taking all the above mentioned literature into consideration, the model of this paper uses the CL Crude Oil Light Sweet index to estimate the short-run energy market influence to gold market.

On the other hand, the effect of equity markets on the gold market could be considered particularly important in the process of defining portfolios, evaluating, tracking and studying portfolio performance. According to Tully and Lucey (2007), gold functions traditionally as a hedge for stocks and responds with higher prices during equity market crashes. Johnson and Soenen (1997) came to similar conclusions claiming that gold is an attractive investment in terms of diversification only in specific periods of equity turmoil. Hiller et al. (2006) studied the role of gold and commodities on equity markets. They discovered that in the period of 1976-2004 gold had a small negative correlation with S&P 500 index. They found that portfolios which had 5% to 10% in gold performed better than portfolios without gold. Jaffe (1989) proved that the low correlation of gold with equities grants it a place in a well

diversified portfolio. Smith (2002) also concluded that after the September 11, 2001 terrorist attack, the prices of U.K. equities have fallen whereas the price of gold has risen. However, gold has recently been used in combination with equities as a useful tool not only for diversification purposes but also for the development of speculative investment strategies. Batten et al. (2010) found that, for the period of 1996-2006, the S&P 500 index price is more important for gold price movements than monetary variables such as the U.S. Consumer Price index and the monetary aggregate M2.

In addition, many portfolio managers use the equity/gold ratio as a measure of corporate market value versus a decades-long measure of real asset value. In this context, we examine the hypothesis that equities play a significant role in the formation of gold prices at all times. The S&P 500 index has been used in our model as a proxy for the world equity markets. The S&P 500 is the index of the largest economy in the world which predicts the future of other economies.

As far as the exchange rate market is concerned, it has long been thought that gold was a good protection against fluctuations in the U.S. dollar, the world's main trading currency. The movements of the U.S. dollar and specifically the dollar depreciation and the related risk of further devaluation probably strengthen investor demand for gold affecting its price as well. Baker and Van-Tassel (1985) in their study on the gold price provide evidence suggesting that U.S. variables, such as U.S. dollar, drive the price of gold. Kaufman and Winters (1989), as well as Sjaastad and Scacciavillani (1996), also asserted that the gold market was influenced by the U.S. dollar and that foreign exchange rates of major currencies have been a significant source of price instability in the world gold market. The level of the U.S. dollar is a determinant for the gold price (Baker and Van-Tassel, 1985; Elfakhani et al., 2009). Moreover, Capie et al. (2005) examined one aspect of the second role of gold, as a hedge against the U.S. dollar. Using data from 1971 to 2002, they applied a variety of statistical techniques to explore the relationships between gold and the exchange rates of various currencies against the U.S. dollar, paying particular attention to the hedging properties of gold in episodes of economic or political turmoil. The gold price was found to move in opposition to the U.S. dollar and the movement was essentially contemporaneous. Furthermore, in this study examining the short-run spillover effect of U.S. dollar/yen exchange rate on gold mean and conditional volatility we have also taken into account financial factors like the carry trade (investors borrow low-yielding currencies and lend/invest in high-yielding

currencies) because this effect is likely to play a more vital role to the formation of spillover effects in the general context of investment portfolio management. Overall this approach suggests the use of U.S. dollar/yen exchange rate as a proxy for the effects of exchange rate on gold prices in order to have more informative and measurable results. Specifically, we have used the U.S. dollar/yen exchange rate for a number of reasons. First of all, the U.S. dollar is the biggest traded invoice currency, so it is considered as the predominant currency (McKinnon and Schnabl, 2002). Furthermore, the majority of currency reserve is in U.S. dollars and, hence, the variability of the U.S. dollar could disturb the economic environment. Moreover, the major proportion of the globally traded and quoted is in U.S. dollars. In addition, the yen is one of the major currencies of carrying trade and as gold has been included in the modern portfolio strategies, the level of the yen in relation to the U.S. dollar is probably a crucial factor to gold market.

Finally, the importance of bonds in the formation of gold prices could be explained not only by their involvement in the modern portfolio management but also through the role of interest rates in economy. More specifically, interest rates affect the level of investments in the economy and are considered to be a measurement of the borrowing cost. When the trend of interest rates is increasing, the financial environment is more insecure, which can even lead to bankruptcies (Bautista, 2003). In this context, assets like gold could be considered as safe havens resulting in a rush to buy them. On the other hand, when interest rates decrease, investors operate in a stable environment where unexpected negative conditions are limited forcing investors to change gold into more risky assets. Koutsoyiannis (1983), Cai et al., (2001) and Hammoudeh and Yuan (2008) have argued that interest rates fluctuations affect gold prices.

In this paper, the 10-Year Treasury Note has been used as a proxy for the twofold role of bonds, being an asset in investment portfolios, as well as a tool related to the prevailing interest. We must point out that we have used this particular bond issued by the U.S. Treasury since the U.S. economy is regarded as leading economy and plays a substantial role to all economies. For example, a change in the U.S. interest rate usually causes as a consequence not only the change in the interest rate policy of developed economies, but also in the evaluation of general business risk globally.

## 2. Methodological considerations

There are some special characteristics in the financial price/return time series which define them. Therefore, there are particular methodologies and

econometric techniques that have been developed for the analysis of these characteristics. An important feature of the distribution of the returns is that it tends to be leptokurtic with fat tails compared with the normal distribution (Fama, 1963; 1965). Another feature of financial returns, mainly equity returns, is the leverage effect, a phenomenon to which asymmetries are attributed (Black, 1976; Christie, 1982). Black connected operating and financial leverage with volatility, while Christie, as well as many other researchers after him, suggested that only financial leverage was connected to volatility. Nevertheless, the effect of leverage on the market volatility is questioned by many researchers. Braun et al. (1991), and Campbell and Hentshel (1992) added that the expectation of greater volatility increases the required rate of return due to increased risk premium, resulting to a decrease of the relative price. This theory is reported in the literature as the volatility feedback hypothesis. Others, like Bekaert and Wu (2000), examined the validity of both theories. In their study on the Japanese stock market, they employed a multivariate GARCH model including variables to control both theories and concluded that asymmetries are observed due to the volatility feedback. The third important feature of financial returns is the volatility clustering, which appears when there is a tendency of larger changes in stock return prices following large changes, and smaller changes following small changes (Kyle, 1985). Finally, another important feature of daily and squared daily return series is the autocorrelation structure of the series, which means that volatility is persistent over time (Akgiray, 1989). The Autoregressive Conditional Heteroskedasticity (ARCH) model introduced by Engle (1982) and its extension to the Generalized Autoregressive Conditional Heteroskedasticity (GARCH) model (Bollerslev, 1986) allow the fat tails which are often observed in financial distributions and impose an autoregressive structure on the conditional variance. Therefore, they are capable of capturing not only the volatility persistence of return series over time, but also the volatility clustering as well. An important weakness of the ARCH and GARCH model, though, is that they account for the volatility reactions in positive and negative changes (shocks) in a symmetric way. A solution was given by the asymmetric models which are capable of capturing the asymmetric features of the data. According to Engle and Ng (1993), who analyzed various models for the daily Japanese stock returns, the best parametric model is the GJR-GARCH, introduced by Glosten et al. (1993). The diagnostic tests they applied provided evidence that although the EGARCH model, introduced by Nelson (1991), can also capture most of the asymmetry, it expresses the

variability of the conditional variance in a higher than normal level. Another advantage of the GJR-GARCH model is that it has fewer parameters to be estimated.

The GJR model is a simple extension of the GARCH model accounting for any asymmetries involved. Statistically, asymmetry occurs when an unexpected drop in price due to bad news increases volatility more than an unexpected increase in price due to good news of similar magnitude. This model expresses the conditional variance of a given variable as a nonlinear function of its own past values of standardized innovations. The estimation of GJR-GARCH model involves the joint estimation of a mean and conditional variance equation. The GJR-GARCH (1,1) model is stated as follows:

The mean equation is:

$$Y_t = X_t' \theta + u_t, \quad (1)$$

where,  $X_t$  is a vector of exogenous variables.

The conditional variance equation is:

$$\sigma_t^2 = \alpha_0 + \alpha_1 \sigma_{t-1}^2 + \alpha_2 u_{t-1}^2 + \alpha_3 S_{t-1}^- u_{t-1}^2, \quad (2)$$

where  $u_t \sim GED(0, \sigma_t^2)$ , it is assumed to follow the *GED* (Generalized Error Distribution). We employ the *GED* because of its ability to accommodate leptokurtosis. Also,

$$S_{t-1}^- = 1 \text{ if } u_{t-1} < 0,$$

$$S_{t-1}^- = 0 \text{ elsewhere.}$$

The leverage effect occurs when  $\alpha_3 > 0$ . The condition for a non-negative variance requires that  $\alpha_0 \geq 0$ ,  $\alpha_1 \geq 0$ ,  $\alpha_2 \geq 0$ ,  $\alpha_2 + \alpha_3 > 0$ .

When  $R_t - \hat{R}_t < 0$ , then  $u_t < 0$ , which means that the observed return  $R_t$  is less than the estimated return (in other words, the mean return). Consequently, when  $S_{t-1}^-$  is equal to 1, the negative change  $u_{t-1}^2$  at time  $t-1$  correlates with the volatility at time  $t$ .

In this model, the good news ( $u_{t-1} > 0$ ) related to the bad news ( $u_{t-1} < 0$ ) has a different effect on the conditional variance. If  $u_{t-1} > 0$ , it implies that at time  $t-1$  we had good news, which had a positive effect on the return (over the mean return), and this is why the residual is positive. Good news reflects on the coefficient  $\alpha_2$  ( $\alpha_3$  absorbs the effect of the bad news). However, bad news has an effect on  $\alpha_2 + \alpha_3$ , because if  $S_{t-1}^- = 1$ , then the equation (2) becomes:

$$\begin{aligned} \sigma_t^2 &= \alpha_0 + \alpha_1 \sigma_{t-1}^2 + \alpha_2 u_{t-1}^2 + (\alpha_3 u_{t-1}^2 * 1) = \alpha_0 + \\ &+ \alpha_1 \sigma_{t-1}^2 + (\alpha_2 + \alpha_3) u_{t-1}^2. \end{aligned} \quad (3)$$

When  $\alpha_3 > 0$ , we have the leverage effect, which means that bad news has a greater effect on conditional volatility. When  $\alpha_3 \neq 0$ , we simply state that the effect of news is asymmetrical.

### 3. Data

Concerning the empirical analysis, daily observations of the GC Gold 100 Troy Oz. COMEX (*Gold*), the CL Crude Oil Light Sweet index (*Crude*), the S&P 500 Stock index (SP), the TNX 10-Year Treasury Note (*Bond*) and the U.S. dollar/yen exchange rate (*D/Y*) have been used. The sample covers the period from January 1, 1999 to August 31, 2009. These data have been obtained through the Reuters DataLink database of the Thomson Reuters Company. Moreover, the preliminary analysis of the above series has revealed that the daily squared returns of the U.S. dollar/yen exchange rate affects the volatility series of the *Gold*. It should also be noted that at the 1% significance level, the hypothesis that the mean return of the U.S. dollar/yen exchange rate returns is equal to zero was not rejected, which implies that daily volatility of the U.S. dollar/yen influences the volatility of gold returns. Therefore, the squared returns of the U.S. dollar/yen exchange rate were used as a proxy variable for the volatility of the U.S. dollar/yen exchange rate.

Daily continuously compounded returns for the selected data are calculated as  $R_t = 100 \cdot \log(p_t/p_{t-1})$ , where  $R_t$  and  $p_t$  are the daily returns and prices, respectively.

### 4. Methodology and empirical findings

Table 1 presents the summary statistics for the *Gold*, *Crude* oil, S&P 500, *Bond* and dollar/yen return time series. The sample mean returns of these series are close to zero and we cannot reject the null hypothesis that the mean returns are not statistically different from zero. Also, by using the Jarque-Bera (JB) statistics, we came up to the conclusion that essential departures from normality occur while the series are slightly asymmetric, except the one of bond, and leptokurtic. Moreover, the augmented Dickey-Fuller (ADF) test, allowing for both an intercept and a time trend, showed that the sample series had been produced by stationary series.

Table 2 shows the sample autocorrelation function (ACF) and partial autocorrelation function (PACF) for daily returns and squared daily returns of *Gold* time series. It can be observed that the Ljung-Box statistics show an autocorrelation on daily returns and strong autocorrelations in the squared daily returns, indicating conditional heteroskedasticity (Bollerslev, 1987).

Table 1. Sample statistics

Statistics	<i>Gold</i>	<i>Crude</i>	SP	<i>Bond</i>	<i>D/y</i>
Observations	2672	2672	2672	2672	2672
Mean	0.000448	0.000656	-0.000109	0.002612	-0.000081
Std. dev.	0.011901	0.025966	0.013952	0.065814	0.006862
Skewness	0.229	-0.196	0.074	21.192	-0.032
Kurtosis	8.68	6.94	12.65	480.38	6.29
Jarque-Bera	3618	1744	10367	25572149	1202
Augmented Dickey-Fuller (ADF)	-50.642	-53.696	-41.315	-52.407	-54.630

Table 2. Test for serial dependence in first and second moments of gold variable

Returns				Squared returns			
Lags	Autocorrelation	Partial correlation	LB(n)	Lags	Autocorrelation	Partial correlation	LB(n)
1	0.02	0.02	1.0771	1	0.179	0.179	86.104
2	-0.024	-0.025	2.6582	2	0.09	0.06	107.81
3	0.009	0.01	2.8688	3	0.129	0.107	152.22
4	0.028	0.027	5.0051	4	0.125	0.085	194.18
5	0.03	0.029	7.3935	5	0.134	0.091	242.23
6	-0.049	-0.049	13.761	6	0.065	0.008	253.51
12	-0.038	-0.034	35.358	12	0.091	0.041	371.19
24	-0.024	-0.025	52.465	24	0.112	0.053	647.49
36	-0.02	-0.02	66.73	36	0.058	0.01	818.41
70	0.011	0.009	101.41	70	0.044	-0.015	1180.5

Notes: LB(n) are the n-lag Ljung-Box statistics for  $Gold_t$  and  $Gold_t^2$  respectively. LB(n) follows chi-square distribution with n degree of freedom; the sample period contains 2672 daily returns.

Summarizing all these, it is observed that the *Gold* return time series is best described by an unconditional leptokurtic distribution and possesses significant conditional heteroskedasticity. This renders the ARCH models as a very good choice for modeling the *Gold* return time series.

The preliminary statistical results and the application of the LR test on the GARCH(p,q) model demonstrated the final specification for the estimation of the mean and volatility for the *Gold* return time series. The specification is (mean equation):

$$Gold_t = b_1 + b_2 Crude_t + b_3 SP_t + b_4 (D/Y)_t + b_5 Bond_{t-1} + u_t \quad (4)$$

Variance equation:

$$\sigma_t^2 = a_0 + a_1 \sigma_{t-1}^2 + a_2 u_{t-1}^2 + a_3 S_{t-1}^- u_{t-1}^2 + a_4 (D/Y)_t^2 \quad (5)$$

$$u_t \sim GED(0, \sigma_t^2).$$

Diagnostic tests were performed to establish goodness of fit and appropriateness of the model. First, it was examined whether the standardized residuals and squared standardized residuals of the estimated model were free from serial correlation. As we can see in Table 3, the  $LB(n)$  statistics for standardized residuals are not statistically significant and the  $LB(n)$  statistics for standardized squared residuals show that the ARCH effect has disappeared. The ARCH LM Test concerning four lags in the residuals ( $N * R^2 = 6.2$ ) verifies that we do not need to encompass a higher order ARCH process. Furthermore, the coefficient estimation  $\nu = 1.21$  for tail thickness regulator with 0.035 standard error, confirms the pertinence of the *GED* assumption. Specifically, the assumption of normal distribution is rejected, a fact that verifies the theory for thick tails in the stock returns. An LR test of the restriction  $\nu = 2$  (for  $\nu = 2$  the *GED* is essentially the normal distribution) against the unrestricted models clearly supports this conclusion.

Table 3. Diagnostics on standardized and squared standardized residuals

Residuals				Squared residuals			
Lags	Autocorrelation	Partial correlation	LB(n)	Lags	Autocorrelation	Partial correlation	LB(n)
1	0.006	0.006	0.0903	1	0.045	0.045	5.3984
2	0.011	0.011	0.4075	2	-0.013	-0.015	5.8473
3	0.009	0.009	0.6245	3	-0.012	-0.01	6.2137
4	0.006	0.006	0.7345	4	0.001	0.001	6.2146
5	0.006	0.006	0.8362	5	0.022	0.022	7.4924
6	-0.036	-0.036	4.3352	6	-0.016	-0.018	8.1422
12	-0.034	-0.035	19.4	12	-0.022	-0.024	12.595
24	-0.022	-0.021	28.945	24	0.013	0.014	17.992
36	-0.02	-0.019	39.104	36	-0.024	-0.022	26.304
70	0.026	0.027	70.242	70	-0.009	-0.011	39.957

Notes:  $LB(n)$  are the  $n$ -lag Ljung-Box statistics for the residual series.  $LB(n)$  follows chi-square variable with  $n$  degree of freedom; the series of residual contains 2671 elements.

Table 4 presents the results for the mean equations. The statistical significance of the  $b_2$  coefficient indicates that the energy market exert positive effect on the conditional mean return of the gold variable, while the statistical significance and the sign of the  $b_3$ ,  $b_4$  and  $b_5$  coefficients suggests that the capital, currency and bond markets, respectively, affect the gold market negatively.

In Table 5, the results for the variance equation are presented. We observe that the value of the  $\alpha_1$  coefficient (0.938), which reflects the influence of  $\sigma_{t-1}^2$ , is much higher than the value of the  $\alpha_2$  coefficient (0.0755), which correlates the price variation of the present day to the price variation of the previous day. This results in the volatility of gold futures returns being persistent over time and, consequently, the volatility shocks (information) are slowly

assimilated to the gold market. Furthermore, the statistical significance of the  $a_4$  indicates that the shocks of the dollar/yen exchange rate returns negatively affect the conditional volatility of the gold return time series. Finally, the coefficient  $a_3$ , which allows the conditional variance to asymmetrically respond to positive and negative shocks, suggests that there is a statistically significant negative asymmetric effect. This implies, contrary to the equity markets, that positive shocks provoke a larger response than negative shocks of equal magnitude. The price of gold normally rises as a result of increased hedging positions after market stress or turmoil. Therefore, positive changes in the price of gold are associated with negative financial news which means that the volatility is transmitted from the other markets to the gold market leading to an increased volatility.

Table 4. Mean equations

$$Gold_t = b_1 + b_2 Crude_t + b_3 SP_t + b_4 (D/Y)_t + b_5 Bond_{t-1} + u_t$$

$b_1$	$b_2$	$b_3$	$b_4$	$b_5$
0.000531*	0.068354*	-0.03231**	-0.28822	-0.00398***
(0.000157)	(0.006522)	(0.013123)	(0.024222)	(0.002307)

Notes: Standards errors are shown in parentheses. \*indicates statistical significance at the 1% level. \*\*indicates statistical significance at the 5% level. \*\*\*indicates statistical significance at the 10% level.

Table 5. Variance equations

$$\sigma_t^2 = a_0 + a_1 \sigma_{t-1}^2 + a_2 u_{t-1}^2 + a_3 S_{t-1}^- u_{t-1}^2 + a_4 (D/Y)_t^2$$

$a_0$	$a_1$	$a_2$	$a_3$	$a_4$
8.64E-07***	0.938*	0.0755*	-0.049*	0.015678**
(5.04E-07)	(0.00857)	(0.01233)	(0.0143)	(0.007458)

Notes: Standards errors are shown in parentheses. \*indicates statistical significance at the 1% level. \*\*indicates statistical significance at the 5% level. \*\*\*indicates statistical significance at the 10% level.

## Conclusion

This paper examined the role of financial factors in the gold market using a GJR-GARCH model. More specifically, we have examined the influence of the Crude Oil Light Sweet index, S&P 500 Stock index, the U.S. dollar/yen exchange rate and the TNX 10-Year Treasury Note on the gold future price. The empirical results show that the first determinant

factor, the crude oil, reflects a positive transmission effect from the leading energy market to the gold market. The importance of these spillover effects reflects, to a large extent, the world economic activity. On the other hand, the S&P 500 Stock index, the U.S. dollar/yen exchange rate and the TNX 10-Year Treasury Note influence negatively the gold market not only because gold is a hedge against economic or political turmoil, but also because it offers alternative approaches in portfolio management.

Furthermore, the structural analysis of volatility showed that the impact of old news on conditional volatility was higher than that of the current news. In addition, the volatility of the U.S. dollar/yen exchange rate returns exerts significant influence on the conditional variance of the gold series. Finally, the results have shown that the volatility of the gold market tends to overreact in response to positive shocks contrary to the equity markets. The explanation of this empirical fact is that in times of market stress or turmoil the increased volatility from the other markets is transmitted to the gold market which acts as a safe haven. This empirical evidence of our study suggests that the role of gold in a portfolio investment is beneficial, since the increased volatility of gold enhances the useful negative correlation of gold with other markets. The increased price and positive shocks of gold as a financial instrument protects against declining movements in the price of other assets.

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