Revisiting the volatility of gold: Is gold a hedge or a safe haven?*

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Abstract

The main goal of this study is to examine what factors influence gold volatility and to investigate the role of gold as a hedge or a safe haven. The main finding is that asymmetry, volatility transmission effect of US dollar exchange rate and that of stock price influence the volatility in gold markets. Taking into account all of these effects, empirical estimates show that gold still serves as a hedge and a safe haven against US dollar exchange rate and stock markets.

JEL classification: F3, F31, G1, G15

Keywords: Gold, Volatility, Hedge, Safe haven, Volatility Transmission

1 Introduction

1.1 Background

Investors tend to diversify their portfolios by holding some assets which can hedge risks. They hold gold for the sake of hedging inflation when money loses its value. The role of gold as a means of storing value has been examined in many literatures (Ghosh et al., 2004; Worthington and Pahlavani, 2007; Tully and Lucey, 2006). Gold is also considered has played an important role in financial markets, being a means of hedging risks. In periods of financial crisis happened in 2008, we were impressed by the performance of gold price which rose drastically. For this reason, gold has been cited by media as a way of hedging risks during the market turmoil.

The hedging abilities of gold have been evaluated in recent years. Gold could protect investors against US dollar exchange rate risks. Capie et al. (2005) analyze whether gold is a hedge against currency risks, specifically a hedge against Sterling/US dollar or Yen/US dollar exchange rate. They show that gold can act as an exchange rate hedge, because gold has a negative and inelastic relationship with US dollar. Joy (2011) analyzes gold's hedging ability against US dollar with 16 major dollar-paired exchange rates. He came to a conclusion that gold has behaved as a hedge but the

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ability of acting as a safe haven is weak in the lower quantiles because gold and US dollar sometimes are co-move during market turmoil.

Furthermore, some other literatures examine the relationship of gold with bond and stock price respectively. Baur and Lucey (2010) analyze the relationship between gold and bond, stock returns. They find that gold is a hedge and a safe haven against stock market, but not against bond in the U.S.. Another study is Baur and McDermott (2010), by which they expand the data to 53 countries. They confirm that gold is both a hedge and a safe haven against the U.S. and major European stock markets, but not for Australia, Canada, Japan and large emerging countries.

Lots of empirical studies have examined the relationship of gold and other assets, but only a few of them investigate what drives the volatility of gold. Batten, Ciner, and Lucey (2010) investigate the volatility of several precious metals. They consider some macroeconomic factors such as money supply and inflation jointly influence the volatility of gold. They also find that some financial variables like stock market returns and dividend yields could jointly affect the movements of gold. Smales (2014) analyses that there is an asymmetric response to news releases, that is, negative news invokes a greater response in gold returns than positive news.

In the studies of stock returns and volatility, some papers find that asymmetric and day-of-the-week effects drive the volatility of stock (Engle and Ng, 1993: Watanabe, 2000). Except for asymmetric, day-of-the-week, holiday effects, Tanizaki (2004) examines these factors and volatility transmission effect simultaneously in the stock market of Japan.

Refer to the empirical studies with respect to stock returns and volatility, some factors could be expected to affect gold volatility:

(i) Asymmetric effect: a fall/rise in the gold return yesterday leads to a fall/rise in the gold volatility today.

(ii) Weekend effect: gold volatility on the day after holidays are volatile in financial markets.

Except for these effects mentioned above, other spillover effects could also be taken into consideration. (iii) Financial Transmission effect: the fluctuations of gold volatility could be influenced by the changes of US dollar exchange rate or stock markets.

This paper aims to answer whether asymmetric effect and holiday effect still exist in gold as the way of stock markets and to estimate each factors which influence gold volatility by how much. In addition, by taking into account some factors which could influence gold volatility, empirical results show that gold still be a hedge or a safe haven or not.

1.2 Main contribution

The contribution of this paper is two-fold. First, some factors which expect to affect gold volatility are taken into account to construct the model. Asymmetric, holiday and spillover effects from exchange markets or stock markets are added into gold volatility simultaneously. Based on this framework, we could know which effects influence gold volatility and by how much. In addition, revisiting the factors by taking into account all of these factors which could affect the volatility of gold, we further investigate whether gold is a hedge or a safe haven against exchange markets and stock market risks.

The remainder of this paper is presented as follows. Section 2 describes the data. Section 3 discusses the method. The empirical results and conclusions are presented in Section 4 and 5.

2 Data

This study focuses on whether gold has behaved as a hedge or a safe haven against exchange rate depreciations or stock market risks, using daily data from 4 January, 1999 to 30 December, 2018. The start of the sample data is based on the introduction of euro as an accounting currency from January 1999 in financial markets. Gold price data is taken from DataStream, all of the data on exchange rate and oil price are downloaded from Federal Reserve Bank of St. Louis (https://www.stlouisfed.org/), and S&P500 data is obtained from Yahoo Finance (https://finance.yahoo.com/).

This paper employs the most actively traded gold futures which traded on Chicago Mercantile Exchange (COMEX) as gold price[1]. Exchange rates include 7 currencies between US dollar, consist of key currency countries and some of the major gold mining countries. We also consider Trade Weighted US Dollar Index (DTWEXB) as a proxy of US Dollar exchange rate. Trade Weighted US Dollar Index (DTWEXB) is a weighted average of the foreign exchange value of the U.S. dollar against the currencies of a broad group of major U.S. trading partners, a drop in Trade Weighted US Dollar Index means US dollar depreciation.

Figure 1 depicts daily movement of gold prices on the left vertical axis and Trade Weighted US Dollar Index on the right vertical axis. In our sample period, gold prices and US dollar move in opposite directions. Especially, in periods of US Dollar fall sharply in 2011, gold price rises drastically. Figure 2 shows the evolutions of gold price and S&P500 index. Gold price is measured on left vertical axis and S&P index is on the right vertical axis. From Figure 2, we can see that gold and stock price move in opposite directions in certain periods and co-move in other periods.

3 Empirical methodology

The role of gold is a hedge or a safe haven depends on the correlation with other assets. According to Baur and McDermott (2010), we define a hedge and a safe haven as follows:

-**Hedge**: A hedge is defined as an asset that is negatively correlated with another asset on average. We say that gold is a hedge against exchange rate if it is negatively correlated with exchange rate.

-**Safe haven**: A safe haven is defined as an asset that is negatively correlated with another asset in certain periods only, e.g. in periods of severe US dollar depreciation. We say gold is a safe haven if it negatively correlated with extreme US dollar depreciation.

In this paper, we use GARCH models to deal with volatility clustering, aiming to investigate the gold volatility and the role of gold as a hedge or a safe haven. Based on empirical studies with respect

[1] As in Lucey and Tully (2006), gold price was measured by COMEX gold price which represents the world's leading benchmark futures contract, instead of using London PM Fix price. The London PM fix occurs at 3 pm London time, which is still at mid-morning time in New York. In this sense, the COMEX gold price is more appropriate to this study.

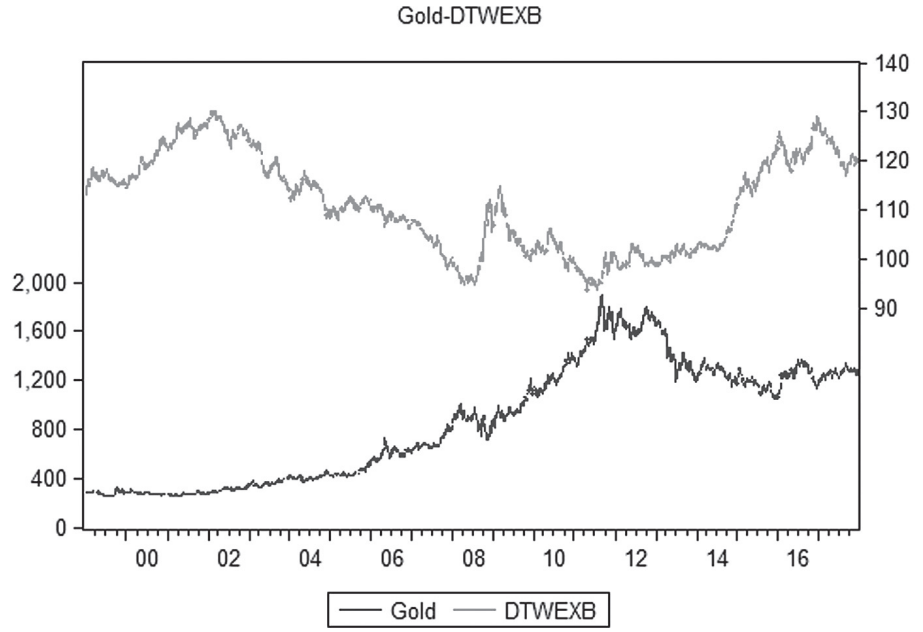

Figure 1: Gold price and Trade Weighted US Dollar Index (DTWEXB)

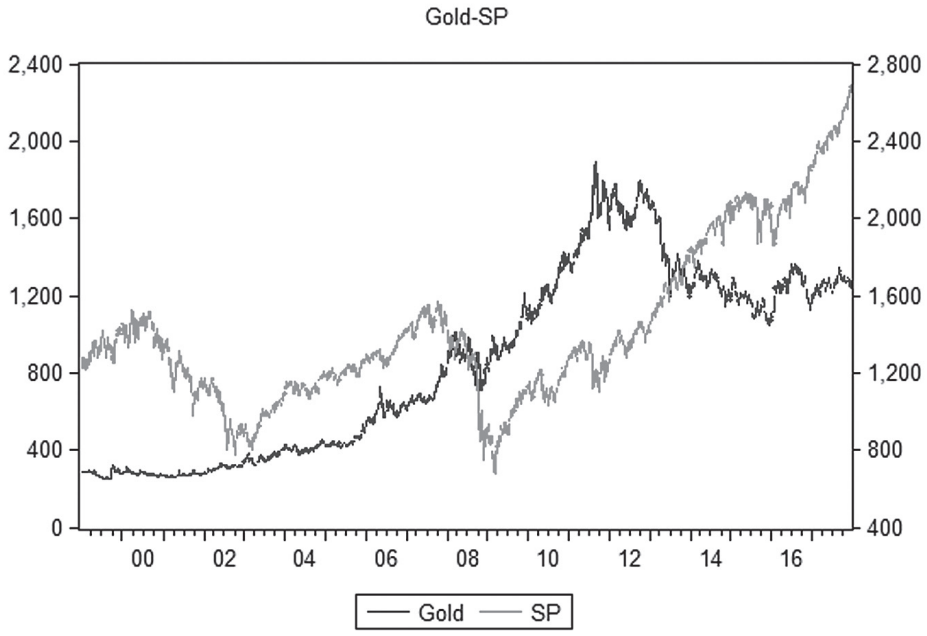

Figure 2: Gold price and SP 500 index

to stock returns and volatility, we assume that the change of gold price is specified as follows:

$$\begin{aligned} y_t &= z_t\alpha + \varepsilon_t \\ \sigma_t^2 &= x_t\gamma + \delta\sigma_{t-1}^2 + \eta\varepsilon_{t-1}^2 \end{aligned}$$

y_t is gold return and ε_t is the error term, where ε_t equals to $\sigma_t\ \upsilon_t$ and υ_t is distributed by N(0, 1). z_t represents a $1 \times k_1$ vector of exogenous variables and α denotes a $k_1 \times 1$ vector. In Models 1 - 9, we focus on volatility in the change of the gold price, where $k_1 = 0$ is taken. x_t represents a $1 \times k_2$ vector of exogenous variables and r_t denotes a $k_2 \times 1$ vector.

Model 1 In this model, $k_2 = 1$ and $x_t = 1$ are taken.

Model 2 (Asymmetric Effect) In stock markets, the asymmetric effect refers to a negative shock yesterday yields high volatility today but a positive shock yesterday does not. However, it may not be the case in the gold market, as demonstrated in Baur (2012), positive shocks increase gold volatility by more than negative shocks. In this model, we examine how the sign of gold return yesterday affect the volatility today. $k_2 = 2$, $x_t = (1, d_t)$ are taken, where $d_t = 1$ if $y_{t-1} < 0$. Note that if the performance of gold is opposite to the stock markets, then the coefficient of x_t would take a negative value.

Model 3 (Holiday Effect) During a holiday, the volatility of some assets like stocks and bonds accumulate much more information than usual. This causes the volatility increase in a holiday. For this reason, if we have much information, gold return would become unstable. We use the dummy variable to investigate whether gold volatility on the day after a holiday become volatile. $k_2 = 2$, $x_t = (1, D_t)$ are taken, where D_t denotes the dummy variable. If yesterday is a holiday, the dummy variable takes one, zero otherwise. The amount of information increases during a holiday, then the coefficient of x_t would take a positive value.

Model 4 (Volatility Transmission Effect of US dollar) Gold price is measured in the value of local currency, therefore, gold volatility is affected by the fluctuations of exchange market. Especially, gold price is dominated by US dollar, the change of US dollar largely affects gold price. To capture the volatility transmission effect of US dollar exchange rate, $k_2 = 2$, $x_t = (1, |y_t^{Dollar}|)$ are taken, where y_t^{Dollar} denotes return of exchange rate at time t.

Model 5 (Asymmetric Effect of US dollar) Except for the volatility transmission effect of US dollar in Model 5, we wonder whether a rise or fall in US dollar exchange rate would result in different changes in gold volatility. $k_2 = 2$, $x_t = (1, d_t^{Dollar})$ are taken, where $d_t^{Dollar} = 1$ if $y_{t-1}^{Dollar} < 0$. It is examined whether gold volatility depends on either negative or positive sign of the US dollar exchange rate change.

Model 6 (Volatility Transmission Effect of Stock Price) The fluctuation of stock price is one of the potential factors that affects gold volatility. To capture whether the change of stock price has an impact on gold market, $k_2 = 2$, $x_t = (1, |y_t^{SP500}|)$ are taken, where y_t^{SP500} denotes return of stock price at time t.

Model 7 (Asymmetric Effect of Stock Price) In stock markets, we accept the fact that asymmetric effect of stock price exists, that is, a fall in stock return would lead to stock volatility increase more. It may be the same in the gold market, that is, a uncertainty in stock market has larger impact on gold

Table 1: Marginal Log-likelihood Function $\log f_Y$

Model	$\log f_Y$	k_1	k_2
1	-3009.97	0	1
2	-3000.14	0	2
3	-3007.99	0	2
4	-3005.22	0	2
5	-3008.62	0	2
6	-3004.23	0	2
7	-3008.59	0	2
8	-3009.97	0	2
9	-3009.14	0	2
10	-2990.05	0	6

market. In this model, $k_2 = 2$, $x_t = (1, d_t^{SP500})$ are taken, where $d_t^{SP500} = 1$ if $y_{t-1}^{SP500} < 0$.

Model 8 (Volatility Transmission Effect of Oil Price)

Oil is a driver of inflation, and inflation is also a driver of gold. For this reason, the fluctuation of oil price is another potential factor would influence the gold market. $k_2 = 2$, $x_t = (1, |y_t^{Oil}|)$ are taken, where y_t^{Oil} denotes return of oil price.

Model 9 (Asymmetric Effect of Oil Price) In stock markets, we accept the fact that asymmetric effect of stock price exists, that is, a fall in stock return would lead to stock volatility increase more. It may be the same in the gold market, that is, a uncertainty in stock market has larger impact on gold market. In this model, $k_2 = 2$, $x_t = (1, d_t^{Oil})$ are taken, where $d_t^{Oil} = 1$ if $y_{t-1}^{Oil} < 0$.

Model 10 (Asymmetric Effect, Volatility Transmission Effect of US dollar or Stock Price, Asymmetric Effect of US dollar or Stock Price) According to estimation results in previous models will be shown in next section, asymmetric effect, volatility transmission effect of US dollar or stock price, asymmetric effect of US dollar or stock price are significantly different from zero. Therefore, taking into account these factors simultaneously, we can better analyze the fluctuation of gold price. $k_2 = 6$, $x_t = (1, d_t, |y_t^{Dollar}|, d_t^{Dollar}, |y_t^{SP500}|, d_t^{SP500})$ are taken.

Model 11 (Exchange rates and stock price in the extreme quantiles) Model 11 is based on Model 10, adding exchange rates and SP500 index to deterministic components to investigate whether gold acts as a hedge or a safe haven. The hedging ability of gold is measured by the relationship of gold and the exchange rates, as well as stock price. Moreover, whether gold functions as a safe haven is tested by applying dummy variables to the first equation. y_t^{Dollar} and y_t^{SP500} denote returns on US dollar exchange rate index and returns on SP500 respectively. The dummy variable denoted by D(...) captures extreme US dollar exchange rate declines or stock market turmoil. Taken SP500 index for example, the dummy variable is equal to one if the return of US dollar exchange rate lower than a certain threshold like fifth or first percentile of the return distribution. $k_1 = 4$, $z_t = (1, y_t^{SP500}, D_{q5}(y_t^{SP500}), D_{q1}(y_t^{SP500}))$, the estimated coefficients of z_t are taken from α_1 to α_4. $k_2 = 6$, $x_t = (1, d_t, |y_t^{Dollar}|, d_t^{Dollar}, |y_t^{SP500}|, d_t^{SP500})$ are taken.

If the coefficient y_t^{Dollar} is negative and statistically different from zero, gold serves as a hedge

Table 2: Estimation Results of Model 10

Variable	Coefficient	Std. Error	t-statistic	Prob.
ε_{t-1}^2	0.0503	0.0021	24.4851	0.0000
σ_{t-1}^2	0.9274	0.0034	272.5815	0.0000
d_t	-0.0099	0.0016	-6.3037	0.0000
$\lvert\mathrm{y}_t^{Dollar}\rvert$	0.0403	0.0068	5.9282	0.0000
d_t^{Dollar}	0.0019	0.0014	1.3110	0.1899
$\lvert\mathrm{y}_t^{SP500}\rvert$	0.0052	0.0014	3.6331	0.0003
d_t^{SP500}	0.0001	0.0017	0.0325	0.9741

against US dollar exchange rate. Gold acts as a safe haven against extreme US dollar depreciation in the 5th percentile if the sum of coefficients of y_t^{Dollar} and $\mathrm{D}_{q5}(\mathrm{y}_t^{Dollar})$ is negative, and a safe haven in the 1st percentile in the case of the sum of coefficients of y_t^{Dollar}, $\mathrm{D}_{q5}(\mathrm{y}_t^{Dollar})$ and D_{q1} (y_t^{Dollar}) is negative. Similarly, whether gold acts as a hedge of stock markets with respect to the sign of coefficient of y_t^{SP500}, if it is significantly negative, gold is a hedge against stock markets. Moreover, gold behaves as a safe haven if the sum of parameters is negative. Otherwise, gold would not act as a safe haven against stock market turmoil.

Model 12 (Exchange rates and stock price in periods of crisis) Instead of 5th and 1st percentiles, in this model we investigate whether gold still serves as a safe haven in periods of financial crisis. $\mathrm{k}_1 = 3$, $\mathrm{z}_t = (1, \mathrm{y}_t^{SP500}, \mathrm{D}_{crisis}(\mathrm{y}_t^{SP500}))$, the estimated coefficients of z_t are denoted from α_1 to α_3. $\mathrm{k}_2 = 6$, $\mathrm{x}_t = (1, \mathrm{d}_t, \lvert\mathrm{y}_t^{Dollar}\rvert, \mathrm{d}_t^{Dollar}, \lvert\mathrm{y}_t^{SP500}\rvert, \mathrm{d}_t^{SP500})$ are taken. We can also substitute $\mathrm{D}_{crisis}(\mathrm{y}_t^{SP500})$ to $\mathrm{D}_{pre}(\mathrm{y}_t^{SP500})$ or $\mathrm{D}_{post}(\mathrm{y}_t^{SP500})$ to test whether gold behaves as a safe haven before or after crisis.

If the coefficient y_t^{SP500} is negative and statistically different from zero, gold serves as a hedge against the stock market. Gold acts as a safe haven in periods of financial crisis if the sum of coefficients of y_t^{Dollar} and $\mathrm{D}_{crisis}(\mathrm{y}_t^{SP500})$ is negative. Similarly, whether gold acts as a safe haven against stock markets before or after crisis with respect to the sign of coefficient of y_t^{Dollar} and D_{pre} (y_t^{SP500}) or $\mathrm{D}_{post}(\mathrm{y}_t^{SP500})$, if it is significantly negative, gold is a safe haven against stock markets.

4 Empirical results

We can see from Table 1 marginal log-likelihood logf_Y in Model 1 is smaller than that in Model 2, which means that Model 2 is preferred to Model 1. In addition, the coefficient of asymmetric effect is significantly negative, which verifies the existence of an inverted asymmetric effect in the gold market. It is consistent with Baur (2012), he finds that positive shocks increase gold volatility by more than negative shocks. Volatility transmission effect of US dollar is found from Model 1 and Model 4, and volatility transmission effect of stock price is observed from Model 1 and Model 6. Moreover, asymmetric effect of US dollar and stock price are also presented by comparing Model 1 to Model 5 and Model 1 to Model 7 respectively. However, as far as we can see from Table 1, holiday effect and transmission effect of oil price make little difference with Model 1. Estimated results confirm that

Table 3: Estimation of Model 11.

	Hedge	Safe Haven	
		5%	1%
AUD	-0.5695**	-0.0696	0.2766**
	(0.0173)	(0.0503)	(0.0720)
CAD	-0.6164**	0.0748	0.0706
	(0.0271)	(0.0710)	(0.1068)
CNY	-1.0946**	-0.2376	0.4237
	(0.0792)	(0.2815)	(0.2814)
EUR	-0.6900**	-0.0047	0.2960**
	(0.0227)	(0.0508)	(0.0650)
JPY	-0.5544**	-0.0335	0.2189**
	(0.0206)	(0.0487)	(0.0517)
SWI	-0.6629**	-0.0073	0.3396**
	(0.0205)	(0.0514)	(0.0550)
GBP	-0.5742**	-0.0278	0.0931
	(0.0203)	(0.0623)	(0.0796)
DTWEXB	-1.5725**	0.0102	0.1408
	(0.0419)	(0.1053)	(0.1646)
SP500	-0.0272**	0.0047	-0.0929**
	(0.0161)	(0.0276)	(0.0337)

they are insignificant. Therefore, we remove them and combine asymmetric, volatility transmission effect of US dollar and that of stock price, asymmetric effect of US dollar and that of SP500 index simultaneously in Model 10. The results are shown in Table 2.

Asymmetric effect, volatility transmission effect of US dollar and that of SP500 index, asymmetric effect of US dollar and that of SP500 index are represented by d_t, $|\mathrm{y}_t^{Dollar}|$, d_t^{Dollar}, $|\mathrm{y}_t^{SP500}|$, d_t^{SP500}. In Table 2, the coefficient of d_t is -0.0099 and it is significantly negative, which means a rise in gold return yesterday tend to cause uncertainty in the gold market today. This result implies that an inverted asymmetric effect is observed in the gold market. Unlike to stock markets, positive shocks increase gold volatility by more than negative shocks because positive shocks are often related to bad economic circumstances, which result in uncertainties in the gold volatility. Moreover, the coefficient of y_t^{Dollar} and y_t^{SP500} are significantly positive, both of them have impact on the gold price. The volatility transmission of US dollar is much bigger than that of SP500 index, which implies the changes of US dollar exchange rate influence gold by more than that of stock price.

In addition, a rise or fall in US dollar exchange rate would result in different changes in gold volatility, in other words, US dollar depreciation increases gold volatility by more than US dollar appreciation. A possible explanation of this result is that bad financial and macroeconomic circumstances result in an decrease of US dollar exchange rate, US dollar depreciation further makes gold prices unstable. Though asymmetric effect of US dollar and that of SP500 index are significantly positive in Model 5 and Model 7 respectively, neither of them is significant in Model 10.

Table 4: Estimation of Model 12.

	Hedge	**Safe Haven**		
		Pre-Crisis	Crisis	Post-Crisis
AUD	-0.5919**	-0.1320	0.2327**	0.1189**
	(0.0177)	(0.1391)	(0.0495)	(0.0464)
CAD	-0.6244**	0.3801**	0.0650	0.1338*
	(0.0271)	(0.1515)	(0.0882)	(0.0677)
CNY	-1.0581**	-0.5330	-0.3416	-0.0083
	(0.0587)	(0.9414)	(0.3493)	(0.5064)
EUR	-0.6546**	-0.5466**	-0.5991**	0.1232*
	(0.0195)	(0.2004)	(0.0956)	(1.0641)
GBP	-0.5921**	-0.0048	-0.0909	0.1655**
	(0.0217)	(0.2554)	(0.0642)	(0.0723)
JPY	-0.5551**	0.3438*	-0.1657	0.3369**
	(0.0178)	(0.1583)	(0.0898)	(0.0570)
SWI	-0.5929**	-0.2105	-0.4557**	-0.0090
	(0.0122)	(0.1661)	(0.0858)	(0.0586)
DTWEXB	-1.5702**	-0.9845*	-0.3525*	0.2343*
	(0.0400)	(0.4702)	(0.1837)	(0.1174)
SP500	-0.0579**	0.1055	-0.0221	0.2476**
	(0.0124)	(0.1119)	(0.0388)	(0.0451)

The results of Model 11 are shown in Table 3. The hedging ability of gold is dependent on the sign of α_2. Whether gold acts as a safe haven is determined by the sum of coefficients α_2 and α_3 for the 5th quantile, the sum of α_2, α_3 and α_4 for the 1st quantile.

In the hedge column, all of the coefficients are negative and statistically different from zero. It implies that gold serves as a hedge against US dollar exchange rate on average. Moreover, the sum of coefficients for the 5th quantile and 1th quantile are also negative, which suggests gold is a safe haven against extreme US dollar depreciations.

In addition, gold serves as a hedge for stock markets as we can from the last row, the estimated coefficient is also significantly negative. Furthermore, even on the worst days of the U.S. stock market, gold is a safe haven which correlates negatively with the stock market both in 5th and 1th quantile cases.

From Table 4, the estimation results in column of hedge make no difference with that of Table 3. As a robust check for safe haven, we find that the sum with first column is negative in each column of safe haven, which means that no matter in periods of crisis, pre-crisis or post-crisis gold still acts as a safe haven.

5 Conclusion

This study evaluates the volatility of gold with daily data ranging from 4 January, 1999 to 30

December, 2018. The main finding is that asymmetry, volatility transmission effects of US dollar exchange rate and that of stock price influence the volatility in the gold market. Note that there is an asymmetric effect, that is, a rise in the gold market yesterday leads to a rise in gold volatility today. Moreover, volatility transmission effects of US dollar exchange rate affects gold by more than that of stock price. However, neither of holiday effect and volatility transmission effect of oil price is significant in our sample period. One of possible explanation is that gold is a homogeneous commodity traded in several major markets globally. The information is absorbed into gold price continuously partly explains why holiday effect is insignificant. Taking into account all of these effects which influence gold volatility, empirical results show that gold is not only a hedge but a safe haven in exchange rate markets. Furthermore, gold serves as a hedge and a safe haven in stock markets. All of these results provide evidence in favor of the statement that even in the worst days of US dollar exchange rate or stock markets, having gold in portfolios offsets loss due to a decline of US dollar or stock price.

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