Assessing recent pattern of gold price volatility in Malaysia (2005–2018)

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Abstract: Gold price has been subjected to volatility clustering since the abolishment of the gold standard in August 1971. While there are myriad studies focused on developed economies, studies on the pattern of volatility in gold especially under the context of small open economy of Malaysia are still lacking. Attempting to fill in the gap, this study provides insight into the trend of gold price volatility as well as to examine the time variant nature of gold volatility surrounding the US subprime crisis. This study also provides a new perspective on the transmission between bilateral exchange rate (MYR/USD) and gold price. This study covered recent daily data from August 2005 to July 2018 using different models of ARCH-GARCH including ARCH, GARCH, EGARCH and TGARCH. Accordingly, gold price volatility was persistent across all periods. Enhanced volatility was evident during the 2008 global financial crisis (GFC) owing to high speculative activities and clustered news over the period. In term of asymmetry response, there was inverted asymmetry effect where positive shock raised volatility in gold. Finally, bilateral exchange rate (MYR/USD) affected gold price volatility with positive relationship, implicating the high sensitivity of gold investment during the depreciation of local currency.

Keywords: gold volatility; GARCH; TGARCH; EGARCH; MGARCH-GCC; Malaysia.

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1 Introduction

Volatility has become a very critical concept in the modern era of finance and economics since it has important implications for asset pricing and risk management. The prevalence of gold price volatility is wide and important, particularly under the context of small emerging economy of Malaysia. The issue has become an important subject in macroeconomics area, attracting vast interests from academics, policy makers and market participants. Besides, the protracted issue has great influence in international finance, external trade competitiveness, inflation, social welfare, financial risk management, profitability and portfolio investment. Gold is a precious commodity and has resemblance function with paper money as a medium of exchange throughout the history until recent time. Despite of economy downturn, gold remains precious metal and valuable. Classical gold standard has always been related to long run stability, reflecting non-deviation of price level from constant value. From 1880 until 1914, it was evident that the gold standard prevailed in western economies. The rule was simple where the value of national currency was pegged to the fixed weight of gold (USD 35 per ounce of gold). Given this, purchasing power is believed to be maintained producing stable inflation targeting and long run cost-benefit stability. However, unexpected high inflation experienced during 1970s forced authority to conduct substantial monetary reform leading to the regime switch from the gold standard to the fiat money system. Since the abolishment of Bretton Woods system in 1971, many economists exerted fiat money regime could be a superior monetary mechanism in abating unprecedented price hike. Fiat money is supported in anchoring important monetary policy such as inflation targeting. However, the persistence volatility of fiat money had attracted attention by authority body to reinstate the importance of gold as effective price stabilisation tool.

The interest in gold investment in Malaysia flourished during the post era of Asian financial crisis 1997–1998. Several conferences related to gold investment were conducted such as International Conference on Stable and Just Global Monetary System in 2002, International Conference on Gold in International Trade in 2003 and International Conference on Gold Dinar Economy in 2007 (Ibrahim, 2012). The *Kijang Emas* was introduced as the official national bullion gold coin in Malaysia by Tun Dr. Mahathir, the fourth prime minister of Malaysia in July 2001. The major aims of

Kijang Emas are to encourage society in making gold saving and facilitate international trade settlement. Since its inception in market, the *Kijang Emas* has gained significant demand by the local and international investors and collectors due to its highest and finest quality 24-karat (99.99%) gold purity in comparison to other national bullion. The *Kijang emas* minted in the Bank Negara Malaysia (National Bank of Malaysia) and its production comes out in three variations which are 1/4 oz (7.780 gram), 1/2 oz (15.550 gram) and 1 oz (31.105 gram) with the face value of $50, $100 and $200 respectively. The high demand of this type of bullion is also derived from its uniqueness and special design where the one side of the coin shows the face of 'Kijang' or barking deer in its natural rainforest habitat while another side of the coin displays hibiscus shape, the national flower. In term of trading, *Kijang Emas* can be bought or sold through several appointed local banks and dealers in Malaysia. The market price is consistently monitored by the Bank Negara Malaysia on daily basis and regularly updated in its official website. The prices are quoted in bid and ask price which solely determined by the supply and demand forces. In order to facilitate smooth trading activity and increases its competitiveness, the prices quoted in the website are also pegged to the international gold price. Due to high demand of *Kijang Emas*, the bullion needs to be ordered much earlier. *Kijang Emas* was used as the best representative for gold price because it is denominated in the Malaysian ringgit, the local currency. We did not employ the international gold price (denominated in the USD) as applied in many past studies due to relatively small economy of Malaysia and confounding effects of currency changes (Ibrahim and Baharom, 2011).

So far, a number of studies have been highlighted in examining gold pattern in Malaysia, with special emphasis given to safe haven and diversification characteristics of gold investment. Safe haven property is defined as an asset that is negatively correlated with another asset, where the loss in one asset can be offset by an increase in another asset (Ghazali et al., 2013). Thus, haven asset is a place where investors can preserve its returns and must be able to retain its value during extreme market storm. Ibrahim and Baharom (2011) assessed the diversification benefits of gold investment in Malaysia from August 2001 to March 2010. With the application of GARCH(1, 1) and EGARCH(1, 1), the study found that gold serves as the best diversification strategy for local investors during the formation of their asset portfolio. However, gold performed weak diversification role during the middle of the global financial crisis (GFC), implying that gold investment is time-varying in nature and highly sensitive during the financial crisis. In the same theme, Ibrahim (2012) investigated the potential role of gold returns against the stock index returns in Malaysia. The idea is straightforward, the author tried to investigate the sensitivity of gold values against the changes in market index values using daily data from August 2001 until March 2010. Based on TGARCH and EGARCH innovations specification, the study found significant positive and low correlation between gold and one-lagged market index returns, supporting diversification argument. Interestingly, the negative market returns did not affect so much the co-movement between gold-index relationship, thus supporting hedging property of gold within gold-stock portfolio during market downturn. Ghazali et al. (2013) put effort in investigating the role of gold as hedge during financial turmoil in Malaysia from 2001 until 2013. Under the same GARCH framework with certain level of extreme market thresholds, the key finding of the study lies upon the fact that gold serves as important hedge in short-term period. It was found that gold investment could not provide positive returns during the middle of financial crisis. Plus, the study reported weak safe haven property of gold during economy downturn, stressing minor role of gold in shielding its value when stock market slumps. Given this, it is found that investors favour regional diversification strategies, i.e., syphoning its capital from emerging markets to developed markets during local market slump. Consequently, having well diversified portfolio regionally provides more reasonable returns and protections for investors from economic uncertainty despite of increasingly popular gold investment in the recent few decades.

Several issues are highlighted in this study. First, we would like to investigate the recent characteristics of gold volatility in Malaysia. Like other commodities, gold price is also not immune from unexpected movements, where there is a need to investigate different stylised facts of time series volatility such as volatility clustering, leverage effects and irregular volatility due to specific event. Volatility clustering is a phenomenon where volatility is clustered over time due to accumulation of news or information. While GARCH(1, 1) model is widely employed to model non-constant variance of a series, it assumes symmetric response of shocks to volatility and creates bias in estimation. Positive and negative news should have different sets of implications on future volatility and asymmetries matter for risk management routine. Thus, to address this issue, this study employs TGARCH and EGARCH models to specifically investigate asymmetry as well as leverage effects. Leverage effect rises from asymmetric response, where downward movement of gold price constituted a rise in volatility of the gold. The second important issue examines whether gold could be a natural hedge against paper money. This issue can be addressed by examining the co-movement between gold and exchange rate, in contrast to Ghazali et al. (2013) and Ibrahim (2012) who focused on co-movement between stock index and gold. Investors perceive gold as a viable investment tool that reflects better stability in value compared to paper money. Gold provides good protection against the risk value of economic, social and political. On the other hand, fiat money only contains face value, but has no intrinsic value. Accordingly, fiat money is highly sensitive to unprecedented movements in inflation and becomes invaluable during economic downturn. Such event causes foreign currency to fluctuate and lead to many negative outcomes including the erosion of purchasing power and unexpected rise in interest rates which indirectly constitutes to unsustainable gold price. The third issue focuses on time-varying gold volatility. Previous studies focused in investigating the volatility throughout all periods and missing the important feature of event specific volatility especially under financial distress. In Malaysia, after a series of financial crises that severely hit the domestic economy, particularly the 1997 Asian financial crisis that severely affected the Malaysian ringgit, the effort to highlight the importance of gold as alternative medium of exchange has been growing significantly till today. However, during the middle of the 2008 global subprime crisis, gold price once again exhibited volatility clustering (Abdul Wahab et al., 2017). Given this, one of important gaps we would like to address in this study is to investigate the susceptibility of gold movements across different time frames subject to the 2008 GFC where our observations are extended until the recent 2018. Motivated from all these issues, the objectives of the study are:

1 to model the pattern of gold volatility using the ARCH-GARCH models

2 to investigate the time-varying gold volatility surrounding the 2008 global subprime crisis

3 to estimate the relationship between exchange rate (MYR/USD) returns and gold volatility.

Our results offered several noteworthy contributions to literature. First, we found that the volatility of daily Kijang gold from August 2005 to July 2018 was persistent and volatility clustering was evident across all periods of study. In an event of any shock, the volatility response was captured in longer time period, recognising the importance of old information compared to recent information. Secondly, we found that conditional variance of gold price was event specific, where the volatility peaked in accordance to specific events such as the 2008 US subprime crisis, the European sovereign-debt crisis, the US quantitative easing (QE) and unanticipated global market uncertainty. The highest peak of volatility was depicted during the mid of the GFC compared to other periods which supported the findings of Ibrahim and Baharom (2011) and Ibrahim (2012). Thirdly, there was an inverted asymmetry effect, where positive shock caused an upward movement of gold volatility. Despite of contrary finding, it is believed that inverted asymmetry effect is driven by vigorous investment during the appreciation of gold price and causing enhanced volatility in gold price. Finally, we concluded that MYR/USD moved in tandem with gold price volatility. In other words, an appreciation in the US dollar (depreciation in the Malaysian ringgit) increases the volatility of gold price. Given this characteristic, this bring us conclusion that investors should take care extra precaution on their gold investment as it can be very sensitive under the depreciating local currency regime.

2 Literature review

2.1 Modelling gold volatility

Modelling gold price volatility remains important, given of its significance in many economic and financial applications such as for portfolio diversification, asset pricing, market timing, risk management and many more. In Malaysia, the Bank Negara Malaysia has introduced *Kijang Emas* or Malaysia's specific gold bullion coins as a viable alternative avenue for investment. As aforementioned, the prices of *Kijang Emas* are quoted on daily basis based on the movement of international gold price. Given this, *Kijang Emas* is not insulated from conditional variance changes between extreme and low international prices (Ahmad and Ping, 2014). Several studies have been devoted to study the behaviour of gold movements depicted under different markets and specifications. So far, mixed results were documented and general findings remained inconclusive. Ping et al. (2013) conducted forecast study on gold bullion *Kijang Emas* from 2001 to 2012 using ARIMA-GARCH model. They concluded that ARIMA(1, 1, 1) – GARCH(1, 1) is the best model in forecasting gold prices based on SIC and AIC performance criteria. Ahmad and Ping (2014) modelled Malaysian gold prices using GARCH family models, i.e., GARCH-M, TGARCH and EGARCH. The study found that TGARCH model as proposed by Glosten et al. (1993) was the best model in explaining the pattern of gold price in Malaysia, indicating the different effects of good news and bad news on volatility. The study concluded that traditional symmetric GARCH model was unable to capture the asymmetry volatility response and negative news induced greater volatility, signifying leverage effect. In the same vein, Yaziz et al. (2016)

examined the performances of ARIMA-TGARCH models of gold price with five innovations in estimation comprising Gaussian, student's-*t*, skewed student's-*t*, generalised error distribution and skewed generalised error distribution. Using a total of 2,845 daily gold series data from the years of 2003 to 2014, the study found that a hybrid ARIMA(0, 1, 0) – TGARCH(1, 1) embedded with *t*-innovation was the best model in forecasting international gold prices. The finding described the existence of leverage effect and heavy tail properties in the series. The recent study of Khair-Afham et al. (2017) investigated the premise that gold is able to hedge against inflation during both the short run and the long run periods in Malaysia from 1971 to 2011. Using nonlinear threshold vector error-correction model (TVECM), they found that the effectiveness of gold as inflation hedge varied across regimes. The study exerted that gold could effectively hedge against inflation during the high momentum regime in comparison to low momentum regime based on specified threshold level. For the long-term analysis of Engle-Granger and Johansen cointegration test, the study revealed the existence of long-term relationship between gold price and inflation. This finding infers that strategic gold investment in portfolio management by individual or institutional level could manage the risk of inflation effectively. Further, positive relationship between gold return as dependent and inflation as independent variable provides good signal for investor, as there would be expectation of increase in gold price when the household price increases.

2.2 Factors influencing gold volatility

Recent studies have examined several factors affecting gold price ranging from macroeconomic factors to individual preference. Marathe (2016) investigated the impact of inflation, crude oil prices, and exchange rate on gold prices fluctuations in India and China. This study applied co-integration, vector error correction model (VECM), vector auto regressive (VAR) and Granger causality from 1996 until 2015. This study discovered that exchange rate had short-term relationship and there was unidirectional causality in India, while no significant relationship between all the stated factors and gold price documented in China. Under the context of Thailand's economy, Jaraskunlanat (2016) found that world gold price, Dow Jones industrial average, USD index, consumer price index and time lag became significant factors that influenced gold price movement in Thailand. At individual level, Chaisuriyathavikum and Punnakitikashem (2016) examined the factors that influenced customer's purchasing intention of gold ornament. The study employed factor analysis and multiple linear regressions (MLR). The study found that self-reputation and prior expectation of gold price appreciation became major factors that influenced buyer's reference in purchasing gold ornament.

In relation to the co-movement between exchange-rate and gold price, Subhashini and Poornima (2014) determined the co-integration and causality relationship between three macroeconomic indicators which were gold price, exchange rate and crude oil in India. The weekly data were taken from 2009 until 2013 and analysed using co-integrations and causality test. As a result, domestic currency had a positive relationship between crude oil and gold prices. Sjaastad (2008) investigated the co-movement between gold price and exchange rate. The study used spot and forward rates of the USD, the GBP, the JPY and the Deutsche Mark. The study reported strong positive relationship between spot and forward prices. Interestingly major gold producer countries such as Australia, South Africa and Russia exhibited no significant relationship between exchange rate and gold.

Toraman et al. (2011) studied several factors affecting gold price under the US market. The monthly data were derived from 1992 until 2010 involving several determinants such as oil price, the US dollar, inflation rate and real interest rate. This study found that, gold price and exchange rate had a negative relationship. On the other hand, oil price, inflation rate and real interest rate documented positive correlation with gold prices. Under the same US market, Ghosh et al. (2004) examined the impact of several macroeconomic factors comprising inflation, interest rate, USD movements and national income on gold price using VAR and cointegration specification from 1975 until 1999. The study found significant relationship between gold price with the USD, interest rate and consumer price index. Christie-David et al. (2000) investigated the impact of macroeconomic news release on gold within the period of 1992 and 1995. Gold was highly sensitive to changes in consumer price index, industrial price index and gross domestic product. The study found that there was no significant impact between news on budget deficit and gold. Lawrence (2003) studied the sensitivity of gold price to changes in selected macroeconomic variables, commodities and financial assets. The study found no significant connection between gold returns and changes in interest rate, inflation and GDP. Furthermore, the study reported less correlation between gold returns and equity and bonds.

From all these findings, it could be concluded that the role of gold in hedging exchange rate movement is rather mixed across different regions due to different specifications, varied exchange rates and varied types of gold. Some displayed positive while other studies showed negative co-movement between gold and exchange rate. This warrants us to unveil more recent evidence of co-movement between gold and exchange rate with special highlight given under the context of open economy of Malaysia.

3 Methodology

3.1 Types and sources of data

The main sources of secondary data were extracted from *Thompson Reuters Datastream* and *Bank Negara Malaysia*. The data were solely based on daily basis from August 2005 to July 2018. For the first objective, this study employed different models of ARCH and GARCH family models to analyse the data, specifically to capture the effects of volatility clustering and long memory properties. To address second objective, i.e., time varying volatility, sub-period analysis was conducted where whole observations of the study period were partitioned according to the different time frames surrounding the 2008 GFC. With respect to the third objective, i.e., examining the connection between gold volatility and exchange rate, the bilateral exchange rate (MYR/USD) was embedded in the GARCH model. In addition, we conducted MGARCH-DCC to examine dynamic conditional correlation (DCC) between gold returns and exchange rate changes to enrich our results.

3.2 The ARCH model

The autoregressive conditional heteroscedasticity (ARCH model) was introduced by Engle (1982). Basically, ARCH(q) model is the base model that tests the existence of non-constant variance over time (*heteroscedaticiticy*) in the series (Engle, 2001). It captures short memory process whereby the most q squared shocks are used to estimate the recent shock. The significance of ARCH effect signifies the existence of non-constant variance of error term across the series. To test for ARCH effect, it could be made by extracting the residual $(\hat{u}_t^2)$ and run an auxiliary regression of squared shocks $(\hat{u}_t^2)$ upon the lagged squared terms and a constant as in:

$$\hat{u}_t^2 = \gamma_0 + \gamma_1 \hat{u}_{t-1}^2 + \cdots + \gamma_q \hat{u}_{t-q}^2 + w_t \tag{1}$$

Rejection of null hypothesis at 5% significance level (H_0: the constant of error variance) indicates the existence of ARCH(q) effect.

3.3 The GARCH(1, 1) model

One of significant drawbacks of ARCH is that it sacrifices higher degree of freedom for higher order of ARCH model. To estimate less parameter, Bollerslev (1986) introduced a solution to embed the lagged conditional variances as well as historical shocks in a model called generalised autoregressive conditional heteroscedasticity (GARCH) model. From here, GARCH is perceived as an augmented version of ARCH with less parameter. The GARCH model is often utilised in estimating volatility of financial time series. The model GARCH responds asymmetric shocks equally which has been criticised by previous studies. The general specification for GARCH(p, q) model is:

$$Y_t = a + \beta' X_t + u_t \text{ (mean equation)}$$

$$u_t | \Omega_t \sim iid\ N(0, h_t)$$

$$h_t = \gamma_0 + \sum_{i=1}^{p} \delta_i h_{t-i} + \sum_{j=1}^{q} \gamma_j u_{t-j}^2 \tag{2}$$

Model (2) shows that the value of conditional variance (h_t) is dependent to the past value of shocks μ_t as well as historical conditional variance, captured by the lagged term of h_t. In order to determine the appropriate lag for each variable, Akaike information criterion (AIC) and Schwarz information criterion (SIC) were used accordingly.

3.4 The threshold GARCH (TGARCH) model

The threshold GARCH model was proposed by Zakoian (1994) and Glosten et al. (1993). This model focused in capturing asymmetric effect in terms of negative (bad news) and positive shocks (good news). In order to check the significance of bad news or good news on volatility, an interactive dummy would be embedded into the model. TGARCH(1, 1) specification is given as below:

$$h_t = \gamma_0 + \gamma u_{t-1}^2 + v u_{t-1}^2 d_{t-1} + \delta h_{t-1} \tag{3}$$

where d_t takes the value of 1 for $u_t < 0$, and 0 otherwise. To cater for higher order of TGARCH, the model can be extended as below:

$$h_t = \gamma_0 + \sum_{i=1}^{q} (\gamma_i + v_i d_{t-i}) u_{t-i}^2 + \sum_{j=1}^{q} \delta_j h_{t-j} \tag{4}$$

3.5 The exponential GARCH (EGARCH) model

Nelson (1991) initiated the development of the exponential GARCH model, an extension of original GARCH model specifically to capture leverage effect. The equation for exponential conditional variance EGARCH model is given by:

$$\log(h_t) = \gamma + \sum_{j=1}^{q} \varsigma_j \left| \frac{u_{t-j}}{\sqrt{h_{t-j}}} \right| + \sum_{j=1}^{q} \xi_j \frac{u_{t-j}}{\sqrt{h_{t-j}}} + \sum_{i=1}^{p} \delta_i \log(h_{t-i}) \tag{5}$$

where γ, ζ_j, ξ_j and δ_i are the parameters of estimates. The EGARCH model was used to test the symmetry of a series similar with TGARH model with additional property of non-negative restrictions of the parameters as embedded in GARCH(1, 1) specification. If $\xi_j = 0$, then the model is symmetric. When $\xi_j < 0$, it asserts that negative shocks constitute higher volatility than positive shocks.

3.6 The impact of exchange rate on the gold price volatility

To effectively capture the influence of exchange rate movement on the gold price volatility, exchange rate variable was included in the GARCH model. The augmented version of GARCH with exchange rate as independent variable is as follows:

$$h_t = \gamma_0 + \sum_{i=1}^{p} \delta_i h_{t-i} + \sum_{j=1}^{q} \gamma_j u_{t-j}^2 + \beta_{USD,t} USD_t \tag{6}$$

where USD_t = exchange rate (MYR/USD).

3.7 Multivariate GARCH-DCC

To provide more insight on the relationship between exchange rate returns on the gold volatility, we conducted multivariate GARCH (MGARCH), specifically focused on DCC model as proposed by Engle (2002). The MGARCH-DCC was applied to capture time variation in the correlation matrix between gold volatility and exchange rate volatility. Engle (2002) specification assumes Gausian standardised innovations. The estimation of MGARCH-DCC was done in two-stage procedure where the first part involved the estimation of individual conditional volatility of gold and exchange rate. Second part used standardised residuals estimated from the first part to calculate parameters of conditional volatility and conditional correlation which were volatility decay factor (lambda) and correlation decay factor (delta). The second stage process was reiterated using maximum likelihood estimation (MLE). Thus, the joint estimation based on MLE as proposed by Engle (2002) could be represented as:

$$h_{i,t-1} = \overline{\sigma}_i^2 (1 - \lambda_{1i} - \lambda_{2i}) + \lambda_{1i} h_{i,t-2} + \lambda_{2i} r_{i,t-1}^2 \tag{7}$$

where i = gold or exchange rate (MYR/USD).

$h_{i,t}$ represents conditional variance for item i and $\overline{\sigma}_i^2$ denotes unconditional variance of asset i. λ_{1i} and λ_{2i} represent unknown volatility decay factor for item 1 (gold) and item 2 (exchange rate) respectively while $r_{i,t}^2$ reflects squared returns of asset i.

For conditional pairwaise correlation $q_{gold,USD}$ between r_{gold} and r_{USD}, the specification is defined as:

$$q_{gold,USD,t-1} = \overline{\rho}_{gold,USD}\left(1-\delta_{1i}-\delta_{2i}\right)+\delta_{1i}q_{gold,USD,t-2}+\delta_{2i}\overline{r}_{gold,t-1}\overline{r}_{USD,t-1} \tag{8}$$

where $\overline{\rho}_{gold,USD}$ denotes unconditional pairwise correlation between gold and exchange rate MYR/USD. The calculation for unconditional pairwise correlation can be estimated using following formula:

$$\overline{\rho}_{gold,USD} = \frac{q_{gold,USD}}{\sqrt{q_{gold,gold} * q_{USD,USD}}} \tag{9}$$

δ_{1i} and δ_{2i} represent unknown correlation decay factor for item 1 (gold) and item 2 (exchange rate) respectively. $\overline{r}_{gold,t-1}$ and $\overline{r}_{USD,t-1}$ represent standardised returns for gold and exchange rate.

3.8 Robustness checks

Several goodness-of-fit statistics were conducted to compare the best volatility model for gold price in Malaysia. The robustness checks covered several indicators such as log-likelihood, mean of square error (MSE), AIC and Schwarz's Bayesian information criterion (SBC). For MGARCH-DCC, we tested the validity of our model by examining the existence of mean reversion process for volatility decay parameters in equation (7).

4 Results and findings

4.1 Descriptive statistics

This study employed daily dataset of *Kijang Emas* gold bullion price and bilateral exchange rate of the MYR per the USD from August 2005 till July 2018. The results of descriptive statistics explain the characteristics of distribution for each series as presented in Table 1. By taking reference to Table 1, there was negative skewness for daily gold price series while positive skewness was exhibited by exchange rate. This non-normality distribution was supported by Jarque-Bera test at 1% significance level and consistent with most financial time series. In term of dispersion, gold price exhibited a smaller amount of standard error relative to exchange rate, implying the better stability of gold price compared to fiat money.

4.2 Unit root test (augmented Dicker Fuller test) results

It is well known that majority of financial and economic series are non-stationary at the level form due to the existence of some trends in the series. From here, trended series are always being subjected to violation in classical linear regression model (CLRM) assumptions which leads to spurious regression. The study adopted augmented Dicker Fuller (ADF) test for testing stationary properties of the series. The results of ADF test are displayed in Table 2. A close observation to the plot of gold returns as exhibited in Figure 1 implies the characteristics of volatility clustering, where there were certain periods of higher volatility than other periods. This accumulated volatility in certain periods indicated the existence of heteroscedasticity (non-constant variance) and validated the use of GARCH in modelling gold volatility. To further tested the presence of heteroscedasticity in gold price, we adopted ARCH(1) test. The ML-ARCH (Marquardt)-normal distribution was employed to capture the ARCH effect for daily logarithmic gold price. Based on our observation, the coefficient of lagged term was significant at 5% level implying the presence of volatility clustering.

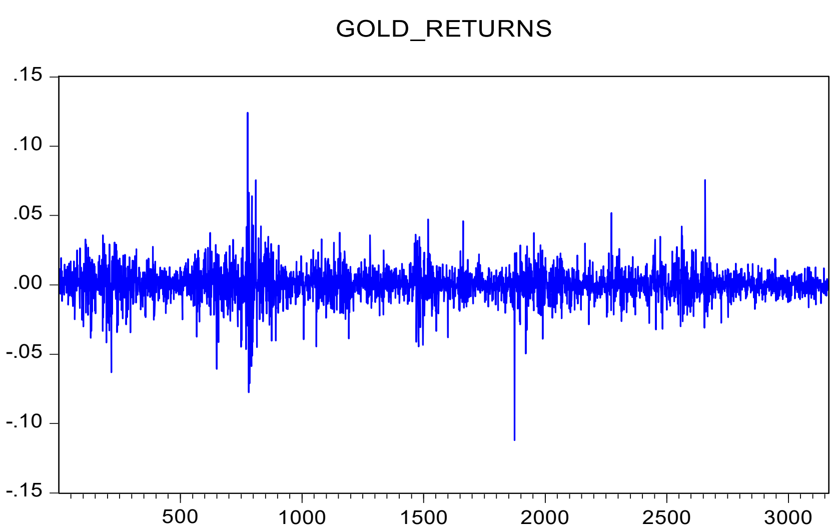
Table 1 Descriptive statistics for daily gold price

Descriptive statistics	*Gold price*	*Exchange rate (MYR/USD)*
Mean	8.269472	3.536706
Median	8.366603	3.4595
Maximum	8.66768	4.4975
Minimum	7.406711	2.9385
Std. dev.	0.323234	0.414542
Skewness	–0.824545	0.647108
Kurtosis	2.519209	2.324165
Observations	3,165	3,165
Probability (Jarque Bera)	0.0000	0.0000
Probability ARCH test	0.0000	0.0000

Table 2 Stationarity test results

Variables	*Level form*		*First difference*		*Series I(d)*
	ADF-stat	*Prob.*	*ADF stat*	*Prob.*	
Gold price	–1.9707	0.3001	–56.8157	0.0001	$Y_t \sim I(1)$
Exchange rate	–0.7315	0.8369	–54.1302	0.0001	$Y_t \sim I(1)$

Figure 1 Plot of stationary $I(1)$ series of gold price (see online version for colours)



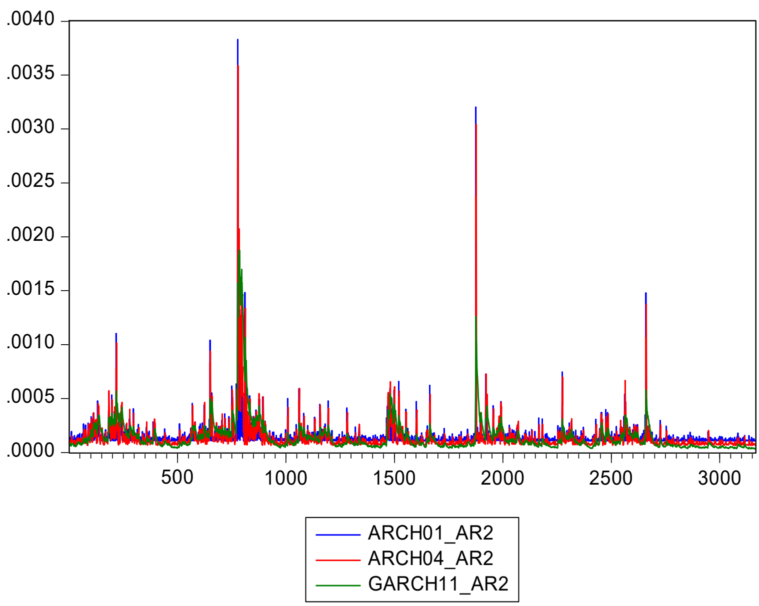
4.3 Higher order of ARCH model

In order to test higher order of ARCH(q) effects, we conducted test up to ARCH (4). The determination of the best ARCH(q) model decided based on the lowest results of AIC and Schwarz criterion (SIC). Referring to the significance of all lagged residual squares as well as AIC, SIC and HQ results in Table 3, the higher order ARCH model was better in capturing variability than lower order of ARCH model, indicating slow movements in the variability of gold returns. However, the high order of ARCH(4) model sacrificed more degrees of freedom. Besides, ARCH model mimicked moving average specification and not autoregressive. To solve this problem, GARCH(1, 1) provides essential alternative to high order ARCH model with less parameters to estimate and reduce loss in degree of freedom.

4.4 The GARCH(1, 1)

GARCH model is a generalisation of ARCH model and it imposes symmetric response function to any shock. It captures long memory process compared to ARCH model. GARCH model weights the average of past squared residuals and the lag of conditional variance. GARCH model offers less parameter to estimate and minimal loss degree of freedom (Abdul Wahab, 2017).

Figure 2 Plot of ARCH(1), ARCH(4) and GARCH(1, 1) series of gold (see online version for colours)



From Figure 2, it could be clearly seen that ARCH(4) series was close to GARCH(1, 1) series, compared to ARCH(1) series. Based on Table 3, the coefficients of lag residual (order 1) and lag conditional variance (order 1) under GARCH(1, 1) model were significant at 1% level. From the same table, the combination of the ARCH(1) and the GARCH(1) coefficients was close to unity (0.0812 + 0.9109 = 0.9921), implying that the response to any shock is likely to die slowly. This signals that in the presence of new shock, it has long period implications to gold returns. In other words, old market information is still relevance to the recent time and it decays slowly. It is also found that GARCH (1, 1) model was the best fitted model compared to ARCH(4) as it exhibited the lowest AIC and SIC value. Given all these criteria, GARCH(1, 1) provided better representation of variability of gold price compared to ARCH(4) specification.

4.5 TGARCH(1, 1)

TGARCH(1, 1) was modelled to empirically test the presence of asymmetry effect. GARCH(1, 1) assumes that positive and negative shocks have the same implications on the volatility. However, in the commodity market, this is not the case. The fall of gold price is always being associated with enhanced volatility. To capture the asymmetry effect, dummy variable was introduced in the model. Based on Table 3, despite of insignificance in asymmetry coefficients, interestingly, negative sign indicated that negative news generated less volatility than positive news. This phenomenon somehow conforms the findings of Baur (2012) who introduced 'inverted asymmetric reaction', a situation where good news increases volatility. To further investigate the influence of good news over volatility, we conducted EGARCH(1, 1) modelling.

4.6 EGARCH(1, 1)

As aforementioned above, exponential GARCH model was estimated specifically to test the existence of leverage effect, i.e., to see whether positive shocks generate more or less volatility than negative shocks. It should be reminded that the dependent variable is the log of the variance series, guaranteeing non-negative conditional variance estimates. Based on Table 3, it is observed that the coefficient of ABS(RESID(–1) / SQRT(GARCH(–1))) was positive (0.18117) and significant at 1% level. This signifies that gold good news has greater effects on the volatility of gold returns than bad news. This finding is in line with TGARCH(1, 1) result. This inverted asymmetric reaction of volatility to good news could be explained by the nature of safe haven property of gold (Baur, 2012). From here, investor interprets an increase in gold price as a signal of future adverse shock and sparks greater volatility in the market.

4.7 Time varying volatility

The graph of GARCH(1, 1) for conditional variances is shown in Figure 3. There was a noticeable peak of volatility of gold price happened in year 2008. This was due to the impact of the 2008 subprime crisis. During the middle of 2008 crisis, the volatility was greater due to massive speculation activities by market players and market uncertainty. Persistence in the volatility was also depicted after the GFC which might be explained by the European sovereign-debt crisis and market uncertainty. This finding stresses that volatility pattern of gold price in Malaysia is event specific conforming the finding of Ibrahim (2012).

Table 3 The estimated coefficients for ARCH-GARCH models

	Coefficients	*p-value*	*Coefficients*	*p-value*	*Coefficients*	*p-value*
Variance models	*ARCH(1) model*		*ARCH(2) model*		*ARCH(4) model*	
Constant	0.0001	0.0000	0.0001	0.0000	0.0001	0.0000
RESID(-1)^2	0.2438	0.0000	0.2059	0.0000	0.1639	0.0000
RESID(-2)^2			0.1528	0.0000	0.1083	0.0000
RESID(-3)^2					0.2209	0.0000
RESID(-4)^2					0.0710	0.0000
GARCH(-1)^2						
RESID(-1)^2 * (RESID(-1) < 0)						
ABS(RESID(-1) / SQRT(GARCH(-1)))						
LOG(GARCH(-1)						
Performance indicators						
Akaike info-criterion	–6.0949		–6.1147		–6.1981	
Schwarz criterion	–6.0854		–6.1032		–6.1827	
Hannan-Quinn criterion	–6.0915		–6.1106		–6.1926	
SSE	0.4479		0.4478		0.4483	
Variance models	*GARCH(1,1) model*		*TGARCH(1,1) model*		*EGARCH(1,1) model*	
Constant	0.0000	0.0000	1.62×10^{-6}	0.0000	–0.2628	0.0000
RESID(-1)^2	0.0812	0.0000	0.0859	0.0000		
RESID(-2)^2						
RESID(-3)^2						
RESID(-4)^2						
GARCH(-1)^2	0.9109	0.0000	0.9115	0.0000		
RESID(-1)^2 * (RESID(-1) < 0)			–0.0099	0.2290		
ABS(RESID(-1) / SQRT(GARCH(-1)))					0.1812	0.0000
LOG(GARCH(-1)					0.9857	0.0000
Performance indicators						
Akaike info-criterion	–6.2729		–6.2725		–6.2676	
Schwarz criterion	–6.2614		–6.2590		–6.2561	
Hannan-Quinn criterion	–6.2688		–6.2676		–6.2634	
SSE	0.4481		0.4481		0.4479	

Table 4 Time varying volatility of gold price

Variance models (GARCH(1, 1))	*Coef.*	*Z-stat.*	*Prob.*	*Coef.*	*Z-stat.*	*Prob.*
	Mid GFC			*Post GFC*		
Constant	3.73E-06	2.926408	0.0034	2.13E-06	5.750474	0.0000
RESID(–1) ^ 2	0.082966	6.487684	0.0000	0.086331	19.83079	0.0000
GARCH(–1) ^ 2	0.909021	60.28525	0.0000	0.89778	165.1507	0.0000
Performance indicators						
AIC		–5.527821			–6.478419	
SIC		–5.475399			–6.462214	
HQC		–5.50721			–6.472482	
SSE		0.144151			0.219484	
Variance models (TGARCH(1, 1))		*Middle GFC*			*Post GFC*	
Constant	2.95E-06	2.319019	0.0204	2.27E-06	5.975388	0.0000
RESID(–1) ^ 2	0.115274	5.360468	0.0000	0.075171	7.894105	0.0000
GARCH(–1) ^ 2	0.91329	65.8262	0.0000	0.895286	148.368	0.0000
RESID(–1) ^ 2 * (RESID(–1) < 0)	–0.061559	–1.98550	0.0471	0.024313	2.361056	0.0182
Performance indicators						
AIC		–5.528508			–6.478538	
SIC		–5.467349			–6.459632	
HQC		–5.504461			–6.471612	
SSE		0.144096			0.219506	
Variance models (EGARCH(1, 1))		*Middle GFC*			*Post GFC*	
Constant	–0.266678	–4.97606	0.0000	–0.41510	–8.52059	0.0000
ABS (RESID(–1) / @SQRT(GARCH(–1)))	0.179754	7.11196	0.0000	0.21068	23.78163	0.0000
LOG (GARCH(–1))	0.983492	175.6513	0.0000	0.97192	189.0909	0.0000
Performance indicators						
AIC		–5.525261			–6.473973	
SIC		–5.47284			–6.457768	
HQC		–5.50465			–6.468036	
SSE		0.144228			0.219505	

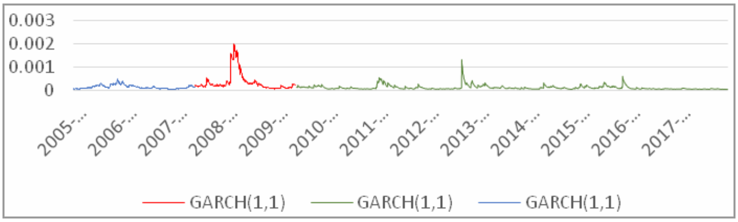
Notes: AIC = Akaike's information criterion, SIC = Schwarz information criterion, Hannan-Quinn criterion and SSE = sum square error.

Based on GARCH(1, 1) estimation in Table 4, it could be seen that the volatility was persistent across all sub-periods. Interestingly, the magnitude (=0.9090) of lagged conditional variance was higher during the middle GFC compared to post GFC. In term of asymmetry effects under TGARCH(1, 1) specification, the magnitudes of lagged GARCH effect (0.9132) and asymmetry effect (–0.0616) during the mid GFC were greater than post crisis (GARCH: 0.8953, asymmetry: 0.0243). In the same vein, EGARCH(1, 1) exhibited the identical pattern where GARCH effect was higher during the mid GFC. However, the effect of leverage during the mid GFC (=0.1798) was smaller than during the post GFC (=0.2107). Furthermore, it seems that all volatility peaks after GFC coincided with major events worldwide. In 2011, the European sovereign-debt crisis posed downside risk to Asian countries, however to a lesser scale than western economies. European countries have significant trade with Malaysia, thus the enhanced variability in gold price was due to close correlation that existed across European and Malaysian markets as well as cross correlation across different asset classes including gold. However, From Malaysia experience, despite of enhanced market uncertainty emanating from the external shocks, the country managed to provide a limited impact, supported from sound macroeconomic fundamentals, diversified trade structure, developed financial system and efficient regulations. Nevertheless, the intensity of the shocks emanated from the European crisis forced the Malaysian authority to enhance its monitoring and strengthen its regional cooperation primarily to improve regional surveillance towards the adverse impact from international capital flows.

Apart from European crisis in 2011, the gold volatility peak was captured during QE scale back period. The QE or massive injections of liquidity by major central banks in western world had triggered unexpected policy interventions in 2013. Such policy introduced by advanced economies as part of the post GFC recovery incentive had a significant spillover effect globally including Malaysia. The main objectives of such policy were to revive financial stability and to assist affected countries to gain its momentum in economic recovery. Despite of its benefits to emerging economies, captured from massive capital flows to developed economies, it injected abnormalities in varying degrees of monetary conditions. In Malaysia alone, the cumulative net foreign portfolio flows between first quarter of 2009 till second quarter of 2013 reached at USD71.9 billion. The massive surge in capital inflows constituted high upward pressure in the foreign exchange, equities and bond markets. This event had produced lower interest rate environment and encouraged significant growth in credit.

In May 2013, a news on possible scale-back of QE by federal reserve had caused chaos in the market, causing reassessment of portfolios positions in emerging markets by investors. The indications of the news forced investors to unwind its original investment positions and rebalance their global portfolios. The QE scale back news created expectations of narrowing yield rates differentials between advanced and developing economies and stringent financial conditions, causing massive capital outflows from Malaysia as well as global financial markets, with significant variability in financial markets and commodities markets. However, the conditions were normalised by the end of 2013 as a result of Fed's announcement to reduce risky asset purchases. This policy transition in the USA caused investors to frequently scrutinise their asset positions and keep monitoring the fundamentals of country. Meanwhile, the uncertainty in gold volatility in the middle of 2016 was subjected to the decline in most global markets and was weighed down by uncertainties surrounding the US economy as well as variability in global oil prices.

Figure 3 Gold returns' volatility across different episodes of the US GFC 2008 (see online version for colours)



4.8 The impact of exchange rate to the gold price volatility

According to the result in Table 5, exchange rate coefficient was significant at 1% level for all period segments. The exchange rate (MYR/USD) was significantly affecting the volatility of gold with positive direction. This signifies the strong impact of appreciation of the USD against the MYR towards volatility of gold price. Interestingly, the identical findings were also found during the pre, middle and post GFC. The impact of the appreciation of the USD against the MYR to the volatility of gold was greater during the middle GFC (=0.012), implying that the transmission effect of exchange rate on the gold's variability was event specific. To stress our finding, we conducted multivariate MGARCH-DCC to see the co-movement of volatilities between gold and exchange rate.

Table 5 The impact of exchange rate on the gold volatility

Variance models GARCH(1, 1)	*Coef.*	*Z-stat*	*Prob.*	*Coef.*	*Z-stat.*	*Prob.*
		Overall			*Pre GFC*	
Constant	0.0000	6.2778	0.0000	0.0000	1.9638	0.0496
RESID(–1) ^ 2	0.0808	21.8690	0.0000	0.0692	3.6185	0.0003
GARCH(–1) ^ 2	0.9102	200.7844	0.0000	0.9203	43.8116	0.0000
MYR_USD	0.0004	3.1990	0.0014	0.0006	1.0733	0.2831
Performance indicators						
Akaike info-criterion		–6.2735			–6.1330	
Schwarz criterion		–6.2582			–6.0814	
Hannan-Quinn criterion		–6.2680			–6.1129	
SSE		0.4481			0.0842	
Variance models GARCH(1, 1)		*Middle GFC*			*Post GFC*	
Constant	0.0001	3.4304	0.0006	0.0000	5.8536	0.0000
RESID(–1) ^ 2	0.0185	2.5633	0.0104	0.0885	19.3156	0.0000
GARCH(–1) ^ 2	0.5688	4.7675	0.0000	0.8917	139.3200	0.0000
MYR_USD	0.0120	6.7326	0.0000	0.0004	3.1775	0.0015
Performance indicators						
Akaike info-criterion		–5.3424			–6.4799	
Schwarz criterion		–5.2812			–6.4610	
Hannan-Quinn criterion		–5.3183			–6.4730	
SSE		0.1432			0.2195	

Based on the MLE of MGARCH-DCC in Table 6, it could be seen that the volatility decay parameters (lambda1, lambda2) were all highly significant. The estimates of lambda1 and lambda2 were very close to unity, implying mean-reverting process of volatilities to the long run equilibrium. The result was robust given by the significance of linear restriction (mean reverting process) in panel C. On the same vein, the delta parameters for both variables were significant and very close to unity. Panel B of Table 6 displays the magnitude of unconditional correlations matrix (off diagonal elements) and unconditional volatilities (on diagonal elements). There was a positive correlation between gold returns and exchange rate returns which reported to be 0.017956 which in line with the findings from GARCH model.

Table 6 Maximum likelihood estimates of the MGARCH DCC model on gold and exchange rate returns

Multivariate GARCH estimates			
Panel A			
Parameter	*Estimate*	*Standard error*	*T-stat (prob.)*
Lambda1 MYR_USD	0.8848	0.0089544	0.0000
Lambda1 Gold	0.90788	0.009787	0.0000
Lambda2 MYR_USD	0.10561	0.0077678	0.0000
Lambda2 Gold	0.081407	0.0080277	0.0000
Delta1 MYR_USD	0.98585	0.006459	0.0000
Delta2 MYR_USD	0.0085714	0.0030828	0.0000
Maximised log likelihood	23,101.2		
Estimated unconditional volatility matrix			
Panel B			
	R_USD		*R_GOLD*
R_USD	0.0043292*		0.017956**
R_GOLD	0.017956**		0.011937*
Robustness check MGARCH-DCC			
Panel C			
Testing for linear restrictions (mean-reverting volatility process)			
Linear restriction function: $1 - \lambda_1 - \lambda_2 = 0$			
Estimate		0.0107	
Standard error		0.0024	
P-value (t-stat)		0.0000	

Notes: *Unconditional volatilities (standard errors) on the diagonal elements.
**Unconditional correlations on the off-diagonal elements.

To be more specific, Figure 4 shows on how the volatility pattern of exchange rate returns followed closely the pattern of gold volatility. Figure 5 displays the variation of correlation between gold returns and exchange returns and one might see that most of the time correlations were positive excepting period between 2014 until 2016 which displayed alternating sign of relationship. From this positive relationship between gold and exchange rate, the effect of the ringgit's downward movement had stirred the confidence of investors on their current positions in gold investment in which consequently contributed to the variability in gold price. In term of hedging perspective, this finding has strong implications to asset allocation. Despite of several studies managed to empirically reveal the importance role of gold as a safe-haven investment tool against currency fluctuations (Aftab et al., 2017), however extra precautions need to be taken care of. Under the Malaysia context, it is highly recommended that short-term investors should conduct regular review on their underlying gold investment especially under the depreciating local currency regime. Strategic allocations should be concentrated more on gold investment when local currency appreciates against the USD and vice versa.

Figure 4 Conditional volatilities of gold returns and exchange rate returns (see online version for colours)

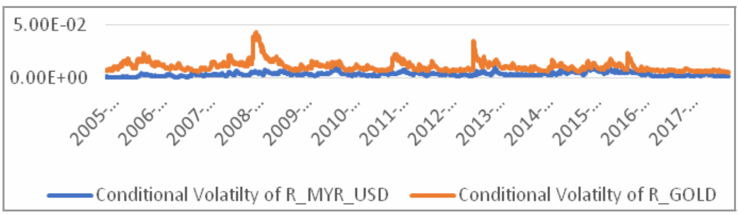
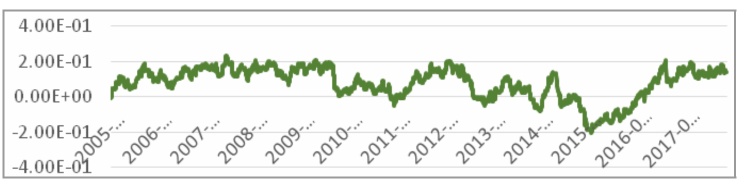


Figure 5 Conditional correlations between gold returns and exchange rate returns (see online version for colours)



5 Conclusions

Based on the investigation using large sample of daily Kijang gold data from August 2005 to July 2018, several noteworthy information could be extracted. First, our estimated GARCH(1, 1) exerted that gold volatility was persistent, volatility clustering was present and reaction to any shock was captured in a longer time period. Besides that, the Ljung box q-statistics revealed the suitability of long-term memory model of GARCH(1, 1) in comparison to higher order ARCH(4) model. Secondly, time varying conditional variance of gold price was different across varied segments of the 2008 subprime crisis. During the financial turmoil of GFC in 2008, the volatility of gold price was significantly high due to speculation and unprecedented market uncertainty. There was also persistence volatility after the crisis mainly driven by the European sovereign-debt crisis, QE by the US Federal Reserve and global market uncertainty. Thirdly, in term of asymmetric reaction to positive and negative shocks, TGARCH(1, 1) and EGARCH(1, 1) analyses concluded that there was inverted asymmetric effect where positive gold returns could enhance volatility. This phenomenon implies that gold investors in Malaysia tend to vigorously invest during appreciation of gold price and this indirectly increases gold volatility (Baur, 2012). Finally, we found that exchange rate (MYR/USD) affected gold price volatility significantly with positive relationship. From here, this study contributes to the existing literature by showing the suitability of gold investment during the appreciation of the local currency. Extra care on the current position of gold investment needs to be taken when local currency depreciates. Future study should place more emphasis on the impact of various factors such as inflation, interest rate and variability in oil price to better explain the property of time variant nature of gold price volatility. Further, future study should embark on wider sample of exchange rates so that more generalised results could be generated.

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