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The hedging effectiveness of gold against US stocks in a post-financial crisis era

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FINANCIAL ECONOMICS | RESEARCH ARTICLE The hedging effectiveness of gold against US stocks in a post-financial crisis era

Najib Shrydeh¹, Mohammed Shahateet^{1*}, Suleiman Mohammad¹ and Mohammed Sumadi¹

Abstract: Purpose—The purpose of this paper is to examine the transmission mechanisms and dynamic spillover effects between gold spot prices and US equity prices following the 2007 Global Financial Crisis. It also aims at estimating hedging effectiveness between stocks and gold in major US financial market. Design/methodology/approach—There is large agreement in the literature that aold exhibits the main requirements to qualify as a risk-mitigating instrument against changes in stock prices and other market variables. To test the validity of this conception, this study applies a VAR-ADCC-BVGARCH model for 2,870 daily observations of US financial market during 2007-2017. Findings-The results suggest that the hedging effectiveness of gold against US stocks tends to diminish as stock market capitalization increases, implying that a marginal level of risk exposure is mitigated considering the relatively high proportion of funds that need to be invested in gold against stocks. Originality/value—The real economy is heavily influenced by financial markets, the implications of which are imperative for investors, policy makers and portfolio managers. The key findings of this study are critical in formulating optimal hedging strategies.

Subjects: Economics; Finance; Public Finance

Keywords: US equity market; gold market; volatility spillover and transmission; hedging; VAR; ADCC; BVGARCH JEL: F36; G15; G32

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PUBLIC INTEREST STATEMENT

This research examines the dynamic relationship between gold prices and the US stock market following the onset of the 2007 Global Financial Crisis, using 2,870 daily observations over the period 2007 through 2017. The results suggest that the hedging effectiveness of gold against US stocks tends to diminish as stock market capitalization increases, implying that a marginal level of risk exposure is mitigated considering the relatively high proportion of funds that need to be invested in gold against stocks. For investors, we recommend that they seek alternative commodities to effectively hedge against stocks in the US market. The key findings of this study are critical for policy makers, portfolio managers, institutional investors, and other market participants in formulating optimal hedging strategies.





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1. Introduction

The issue of volatility has long been an area of major concern among scholars and practitioners. Volatility is broadly defined as a statistical measure of risk underlying a market index or security. A highly volatile price index that changes dramatically over a short period of time is said to be risky. The concept of transmission, however, refers to the rate at which this volatility is able to travel from one market to another. Furthermore, volatility is namely driven by social, political, and economic events (or shocks), the occurrence of which might lead to significant return and price fluctuations, with potential spillover effects across sectors and markets. The mounting complexity of shocks, in addition to their implications (whether locally, regionally, or globally), has given rise to the importance of examining the effects of volatility spillover across markets.

The 2007 Global Financial Crisis is frequently reported as the most unrelenting since the Great Depression of 1929. The 2007 Global Financial Crisis is broadly characterized by excess volatility originating in the US market which created uncertainty and negative spillover effects in significant financial markets around the world, prompting investors and portfolio managers to become more concerned about cross-market interrelationships and mitigating asset risk exposure.

In addition to being affected by complex social, political, and economic events, stock prices are affected by commodity prices. Thus, practitioners are faced with the obstacle of selecting the appropriate risk-minimizing instrument(s) in an effort to offset potential losses during times of market stress. Kaufmann and Winters (1989) explain that central banks and financial institutions tend to retain substantial amounts of gold for diversification and security. Thus, the overall stability of capital markets is largely influenced by risk-mitigating commodities, including gold. Capie, Mills, and Wood (2005), Hillier, Draper, and Faff (2006), Kumar (2014), Lu, Wang, and Lai (2014), Gencer and Musoqlu (2014), and many others credit gold as a commodity which passes the criteria to qualify as a hedging instrument in addition to being a highly liquid physical asset. Gokmenoglu and Fazlollahi (2015) posit that gold has traditionally served as a hedging instrument against future inflation, which renders gold a significant choice of trading assets in the process of optimal portfolio allocation. Conversely, a new strand of literature that analyzes volatility spillover effects and transmission mechanisms between gold and other market variables is guestioning the accuracy of this hypothesis. Maghyereh, Awartani, and Tziogkidis (2017) and Naser (2017) are only a few examples. Therefore, understanding the dynamic relationship between gold and other investment variables is critical for policy makers, portfolio managers, institutional investors, and other market participants.

The aim of this paper is to evaluate the hedging effectiveness of gold against stock price fluctuations in the US market. To fulfill this aim, this paper examines the time-varying pairwise interaction between gold spot prices and US equity prices in the post-2007 Global Financial Crisis era. Specifically, this paper investigates the dynamic characteristics of spillover effects between gold and key US stock price indices, over the period 2007 through to 2017, by means of conjoining a vector autoregressive (VAR) model, an asymmetric dynamic conditional correlation (ADCC) model, and a bivariate generalized autoregressive conditional heteroskedasticity (BVGARCH) model. The VAR model captures the return spillover effects between gold and stocks. The ADCC model allows the dynamic conditional correlations to account for asymmetric effects. The BVGARCH model estimates the conditional volatilities of different asset classes simultaneously. The results of the VAR-ADCC-BVGARCH model are then used to produce the optimal hedge ratios for all possible pair-wise combinations, and subsequently, the hedging effectiveness of gold against stocks in the US market.

2. Review of literature

There is a vast literature, prior to the 2007 Global Financial Crisis, documenting the general relationship between principal commodities, namely gold and oil¹, and a wide range of macroeconomic factors. The strength of the relationship would then provide the basis for effective portfolio composition. If a weak or independent association is found, a commodity is said to exhibit the properties of a risk-mitigating instrument. Christie-David et al. (2000) use intra-day data covering the period 1992 through 1995, and examine the responses of gold and silver price trends to monthly macroeconomic-based news releases via a set of nonparametric tests. Specifically, the study finds that gold responds strongly to the release of the CPI, and also to a great extent, the releases of unemployment rate effects, GDP, and PPI. In addition, the study finds that gold responds weakly to the release of the federal deficit. In a similar study, Cai, Cheung, and Wong (2001) employ a regression of 5-minute gold futures on 23 US macroeconomic announcements from 1994 to 1997. Specifically, a two-step GARCH estimation and a flexible Fourier function are combined to account for intra-day return volatility in gold futures. Among the macroeconomic announcements in question, the study finds employment reports, GDP, CPI, and personal income to exert the most significant impact upon gold prices. Lawrence (2003) considers quarterly time series data from 1975 to 2001 and applies a VAR system to test the relationship between gold and a comprehensive set of macroeconomic variables. The study finds gold to be broadly independent of economic cycles throughout the specified period, suggesting that gold may serve as a useful portfolio diversifier.

The fear of currency devaluation arguably increases the demand for gold. To that end, many scholars recognize the merit of using gold as a hedging tool against exchange rate uncertainty. Capie et al. (2005) examine gold as a hedging instrument by means of assessing weekly data on the gold price and sterling-dollar and yen-dollar exchange rates. The data covers a 30-year time span, beginning 8 January 1971 and ending 20 February 2004. A linear autoregressive distributed lag (ARDL) model is used. The results report a negative relationship between gold returns and both the dollar-yen as well as the dollar-sterling exchange rates, suggesting that gold can be used as a hedging instrument against US dollar fluctuations, however, the strength of this relationship has shifted in the long-run mainly due to social, political, and economic events. Other studies sought to examine the impact of macroeconomic shocks on gold prices. Tully and Lucey (2007) examine the relationship between monthly gold prices and a set of macroeconomic variables over the period 1984 to 2003, highlighting the 1987 and 2001 equity market downturns. The authors use an asymmetric power GARCH model (APGARCH) to explain this relationship. The study concludes that the value of the US dollar is the primary macroeconomic variable which influences gold prices in their findings.

Over the past decade, a growing research interest has gravitated towards investigating volatility spillovers and transmission mechanisms between food and energy commodities, financial securities, gold, and other precious metals, using a variety of different datasets and econometric models. Moreover, a multitude of research papers emphasized the importance of differentiating between a "hedge", a "diversifier", and a "safe haven". In a leading study, Baur and Lucey (2010) define a hedge as an asset that is uncorrelated or negatively correlated with another asset or portfolio on average. In other words, a hedge does not retain the property of minimizing losses in periods of market turbulence since it may exhibit a positive correlation with another asset during such periods, and a negative correlation during non-crisis periods with a negative correlation on average.² A diversifier is defined as an asset that is positively, but not perfectly, correlated with another asset or portfolio on average. Akin to a hedge, a diversifier does not have the characteristic of minimizing losses under extremely volatile market conditions since the positive correlation condition is expected to hold on average. A safe haven is defined as an asset that is either uncorrelated or negatively correlated with another asset or portfolio on average, particularly during periods of market stress. That is to say, the correlation may generally be positive or negative, but tends to be zero or negative specifically during turmoil periods. Thus, if the safe haven asset is negatively correlated with another asset during turbulent periods, it is subsequently curtailing losses for the investor, namely because the price of the haven asset would be moving in the opposite direction of the other asset in question (i.e. when the price of the haven asset increases, the price of the other asset decreases and vice versa). Further, Baur and Lucey (2010) examine the constant and time-varying dynamics between US, UK, and German stock-bond-gold returns to identify whether gold is a hedge, diversifier, or a safe haven. To that end, the authors

carry out a GARCH-based regression with dummy variables for lower quantiles. The dataset comprises of daily MSCI stock and bond price indices as well as US closing gold spot prices, starting 30 November 1995 and ending 30 November 2005. Stock and bond prices are in local currency (i.e. dollar, sterling, and euro) and gold price is converted when needed.³ In the subsample analysis, a bearish market is identified between two bullish markets. The study concludes that gold can be used (on average) as a hedge against stocks and as a safe haven during extremely volatile conditions in all of the three stock markets under investigation. However, gold cannot function as a safe haven against bonds in any of the markets selected. In addition, the study demonstrates via a portfolio analysis that the safe haven characteristic is short-lived. In other words, investors tend to hold on to gold for a limited period of time. More specifically, investors are likely to buy gold when stock returns are negative and sell it when market confidence is restored. It is widely accepted that gold occupies a distinctive investment position when compared with other precious metals, in that it can be used as a tool to mitigate portfolio risk. Sari, Hammoudeh, and Soytas (2010) examine the degree to which precious metal returns and the dollar-euro exchange rate respond to oil price shocks. Specifically, the study analyzes the co-movements and information transmission among the price trends of four precious metals (gold, silver, platinum, and palladium), the dollar-euro exchange rate, and oil price. To examine the extent to which the variance of a variable can be explained by shocks to another variable, the authors apply a VAR-based generalized forecast error variance decomposition (FEVD) function. In simpler terms, a generalized FEVD function is regarded as an out-of-sample causality analysis. A generalized impulse response function (IRF) is then used to capture the direction of the dynamic responses of a variable to changes in other variables. To test for cointegration (i.e. an equilibrium relationship), the authors employ the methods developed by Johansen (1991, 1995)) and Johansen and Juselius (1990), in addition to the bounds testing approach developed by Pesaran, Shin, and Smith (2001). Daily time series data are obtained from 1999 to 2007. In this period, three major events are considered: the OPEC price band in 2000, the 9/11 attacks in 2001, and the Iraq War in 2003. The empirical findings indicate the presence of a strong asymmetric relationship between oil and precious metals in the short-run. In other words, precious metal prices are temporarily sensitive to a shock in any of the prices of the other precious metals in addition to the exchange rate. Due to their limited supplies, gold, and to a lesser extent, silver, may be exploited as hedging tools against short-term inflationary expectations, specifically in the event that the dollar weakens against the euro. However, the cointegration between oil and precious metals tends to weaken over the long-run, consequently diminishing the risk-reduction benefits of investing in precious metals. In a similar research paper, Hammoudeh, Yuan, McAleer, and Thompson (2010) investigate the conditional volatility and correlation dependency and interdependency among gold, silver, platinum, and palladium, whilst accounting for geopolitics within a multivariate system. To examine these interactions, the study employs multivariate GARCH models; specifically, VARMA-GARCH and DCC-GARCH. Daily time series data are acquired for the four precious metals, the federal fund rate⁴, and the dollar-euro exchange rate, over the period 1999 through to 2007. In addition, the authors contend that since precious metals (gold in particular) are sensitive to geopolitical crisis episodes, a geopolitical dummy variable is included to mark the beginning of the 2003 Iraq War. The authors believe this event to be more pervasive than the 9/11 attacks. The empirical findings demonstrate that all precious metals respond moderately to own news, and to a lesser degree, to news spilled over from other metals in the short-run. This finding accentuates the significance of hedging in the short-run, however, the gains are limited when precious metals are hedged against one another. On the other hand, precious metals exhibit strong volatility sensitivity to own prior shocks in the long-run. The strongest sensitivity is found for silver and the weakest is found for gold. The study finds spillover volatilities to be more significant than spillover shocks or news, inferring that these volatilities can be predicted. Moreover, Precious metal returns tend to exhibit stronger sensitivity when the dollar-euro exchange rate and federal funds rate are considered. The study chiefly concludes that gold is the safest hedging tool against exchange rate volatility. Hoang (2011) examines the role of gold in the diversification of French portfolios over the period 2004 through to 2009, covering the 2007 Global Financial Crisis. The study analyzes monthly data on French stocks, bonds, paper gold, and physical gold, in an effort to examine the rise in gold prices in France during the selected period. The author follows the efficient frontier and portfolio diversification approach developed by Markowitz (1952, 1959)). The main findings suggest that the increase in gold prices is largely explained by the weak correlation that exists between gold and stocks, and, to a lesser extent, between gold and bonds, enticing investors to expand the role of gold in the diversification of French portfolios. In other words, the incorporation of gold in French portfolios significantly reduces their risk, and in turn, significantly improves the performance of these portfolios. However, the study finds physical gold to be a more efficient portfolio diversifier than paper gold.

Furthermore, Kim and Dilts (2011) examine the causal relationship between the value of the US dollar and the prices of gold and oil, using monthly data for the period January, 1970 through July, 2008. The authors commence by producing Augmented Dicky-Fuller (ADF) and Philippe-Perron (PP) unit root tests to determine the order of integration of the variables. A VAR process is then applied in order to assess the evolution and interdependencies among the variables. To test for cointegration, the authors rely on Johansen's multivariate cointegration tests. The cointegrated variables are subsequently represented by an error correction model (ECM) which separates the short-run dynamics and the long-run equilibrium condition of the variables. The presence of causality among the variables is captured using Granger causality testing. Finally, the authors perform an IRF and FEVD analysis to examine the dynamic relationships among the variables. The results confirm the presence of a significantly negative relationship between the value of the dollar and the price of both commodities. This finding suggests that the price of both gold and oil increases as the value of the dollar decreases. Moreover, a significantly positive relationship is found to exist between gold and oil prices, inferring that gold and oil may both serve as risk-alleviating tools against rising uncertainty in the value of the dollar. Specifically, investors tend to pursue safer commodities as the volatility in the price of the dollar increases, confirming the premise for a flight to quality. Similar results are echoed by Bhunia (2013), who investigates the long-term causal relationship among crude oil price, domestic gold price, and a selection of financial variables, namely exchange rates and stock price indices in India. Daily data are considered for the analysis, covering the period 2 January 1991 to 31 October 2012. The methodological framework includes an ADF unit root test, a VAR-based Johansen cointegration analysis, and a Granger causality test. The empirical findings suggest the presence of a long-run equilibrium relationship among all of the underlying variables. Also, a significant bidirectional causality is found to exist between gold and stock prices. The study explains that despite the occurrence of major international crises during the selected period (the 1997 Asian Financial Crisis, the 2007 Global Financial Crisis, and the 2010 European Debt Crisis), gold prices continued to increase in India because of its safe haven investment status. When compared to oil, gold continues to be a preferred haven investment of choice in India. The study postulates that increasing oil prices will increase production costs, thereby decreasing cash flows and, subsequently, oil stock price. Therefore, investing in gold increases its price and alleviates the fear of future loss. India remains the world's largest market for gold consumption. Together with China, both markets account for over 50% of global demand, according to the World Gold Council.

The importance of spillover effects between gold and other market variables in formulating optimal hedging strategies is generally well-documented by a number of authors in the extant literature. In a notable study, Mensi, Beljid, Boubaker, and Managi (2013) rely on a VAR-GARCH econometric framework to investigate constant conditional correlations and volatility spillovers across the S&P 500 and commodity price indices for energy, food, gold, and beverages. Daily closing returns are considered for the period 2000 through 2011. This time frame is specified in order to evaluate the response of commodity market returns to the effects of three major crises: the events of 9/11, the 2003 Iraq War, and the 2007 Global Financial Crisis. The VAR-GARCH approach includes the multivariate (constant conditional correlation) CCC-GARCH in which correlations between system shocks are assumed constant. The constant conditional correlations between equities and commodities are all positive but marginally greater than zero, inferring that gains can be made by investing in the S&P 500 and commodity markets that are described

by weaker correlation estimates. Also, there is evidence of a significant volatility transmission among the S&P 500 and all of the commodity markets selected. These spillovers have markedly increased throughout the overall period, but more particularly during the crisis episodes. Further, the study shows that the prior shocks and volatility of the S&P 500 strongly, and positively, influence gold and oil return trends; more so than the opposite. The optimal portfolio weight and hedge ratio analysis highlights the short and long-term benefits of generally including commodities to a stock-diversified portfolio in order to improve its overall performance. The results validate that gold is a relatively inexpensive hedge against equities in comparison with other commodities, albeit not the cheapest alternative. Moreover, Gencer and Musoqlu (2014) examine the bidirectional volatility transmission mechanisms between gold, stocks, and bonds in Turkey, over the period June 2006 through to November 2013. Daily time series data are analyzed on the basis of a bivariate GARCH framework, developed as BEKK-GARCH by Engle and Kroner (1995). The authors describe the overall period as excessively volatile due to the fact that it highlights the 2007 Global Financial Crisis, the 2010 European Debt Crisis, and the FED's monetary policy decisions in mid-2013. The results confirm the presence of a significantly negative bidirectional shock transmission between gold and stocks, given the highly negative correlation found between the two variables throughout the overall period, albeit much stronger during the 2007 Global Financial Crisis. This finding underlines the safe haven property of gold against stocks, as defined by Baur and Lucey (2010). Further, the results indicate a significant bidirectional volatility transmission that exists between gold and stocks, whereby prior gold return volatility negatively impacts current stock return volatility, however, the impact is positive from stocks to gold. This result is similar to that which has been reported by Mensi et al. (2013). Most likely, this is due to the shortcomings associated with the CCC-GARCH specification which fails to capture cross-market volatility spillover effects. The authors explain that the comovement of gold and stocks is driven by the rising level of uncertainty in the stock market; thus, in line with the findings of Baur and Lucey (2010) and Coudert and Raymond (2011), Gencer and Musoglu (2014) classify gold as a weak safe haven asset during the overall (exceedingly) volatile period. Furthermore, the study finds a unidirectional positive shock as well as a negative volatility transmission from gold to bonds, namely because Turkish investors are traditionally inclined to buy gold when interest rates decline. Finally, optimal portfolio weights and hedge ratios are calculated for the gold-stock and gold-bond portfolio combinations. Gold is found to outweigh both stocks and bonds in the optimal portfolios. In addition, the gold-stock hedge ratio is found to be negative, outperforming the gold-bond portfolio in that same vein, which gives rise to the assertion that gold optimizes portfolio efficiency.

In addition to the subject matter of optimal portfolio composition, numerous scholars continue to investigate the time-varying dimensions of the relationship between gold and other variables. Kumar (2014) employs a VAR-ADCC-BVGARCH model to examine the first and second orders moment transmission between gold and a variety of industrial sectors in India (auto, finance, energy, service, pharmaceuticals, and commodities). More explicitly, the study addresses return and volatility spillover between gold and the Indian industrial sector. Weekly data are analyzed for the period 1999 through to 2012. This period takes three major crises into account: the 2000 Dotcom Bubble, the 2007 Global Financial Crisis, and the 2010 European Debt Crisis. The results establish evidence of a significant unidirectional return spillover from gold to stocks, however, no evidence of volatility spillover is found to exist between the two markets. Specifically, the dynamic conditional correlations for each gold-stock pair vary considerably between positive and negative estimates throughout the overall period. The negative estimates are mainly observed in the course of the aforementioned crises, underlining the diversification opportunities that might arise during such periods. The study also examines optimal weights, hedge ratios, and hedging effectiveness for gold-stock portfolios and concludes that gold can provide better (short-run) diversification advantages when compared with stock portfolios. Arouri, Lahiani, and Nguyen (2015) investigate return and volatility spillovers between world gold prices and Chinese stock prices. The sample data consists of daily stock returns and 3-month gold futures beginning 22 March 2004 and ending 31 March 2011. Accordingly, the authors rely on a wide set of multivariate GARCH corollaries, including CCC-, DCC-, BEKK-, diagonal BEKK-, and VAR-GARCH. The main crisis considered in the study is that which occurred in 2007. The findings report the existence of significant cross-market return and volatility effects between gold and stocks. Moreover, the empirical evidence shows that prior gold returns are critical in explaining the dynamics of conditional return and volatility of Chinese stocks, and should therefore be taken into account when forecasting the volatility of future stock returns. Specifically, the conditional volatility of gold returns is significantly affected by unexpected changes in stock returns. In other words, a shock to the Chinese stock market is indicative of an increase in the volatility of gold returns, irrespective of its sign. This result corroborates that which has been presented by Gencer and Musoalu (2014). Nonetheless, there is no evidence to suggest that prior stock return volatility significantly affects gold return volatility. and equally so, the impact of prior gold volatility upon the conditional volatility of Chinese stocks is statistically negligible. Furthermore, the constant conditional correlation estimates demonstrate a relatively weak (positive) connection between gold and stock returns, indicating that gains could be made by including both assets in a single portfolio. The optimal weights and hedge ratios confirm that adding gold to a stock-dominated portfolio enhances its overall performance and reduces its gold risk exposure at a relatively low hedging cost, mainly during turbulent periods. In particular, the stock investment risk is hedged most effectively via a short position in gold futures. Gokmenoglu and Fazlollahi (2015) follow a Granger causality approach to investigate the timevarying interactions among gold and oil prices, in addition to gold and oil price volatility indices, on the S&P 500 Index. Daily time series data are analyzed over the period January 2013 through November 2014. The results indicate the presence of a significant mutual long-run equilibrium across the variables in question, however, gold prices appear to exert the highest impact upon stock prices, both in the short-run as well as in the long-run. Whilst administering a different methodological approach, the presence of this unidirectional spillover (from gold to stocks) substantiates the outcome posited by Kumar (2014). The authors argue that investors tend to be sensitive to changes in gold prices namely because gold continues to be a widely available alternative to stocks, and also because gold qualifies as a useful hedging asset against inflation. The short-run price volatilities for both gold and oil appear to have no significant impact on the S&P 500, which implies that capital flight is unlikely to take place in the short-run, therefore, investors are likely to pay more attention to the price volatilities of gold and oil in the long-run. Moreover, the study underlines the short-term impacts of oil price changes on the stock market due to the fact that energy sector companies account for 10% of the S&P 500, the stock prices of which are shown to increase in response to a rise in oil prices.

The direction of return and volatility spillovers (i.e. transmission mechanisms) across gold and other markets continues to be the subject of debate among academics and practitioners. Raza, Shahzad, Tiwari, and Shahbaz (2016) undertake a nonlinear ARDL approach to explore the short and long-run asymmetric impact of gold and oil prices, as well as their respective volatility indices, on emerging stock markets (China, India, Brazil, Russia, South Africa, Mexico, Malaysia, Thailand, Chile, and Indonesia). Monthly data are acquired for the period January 2018 through to June 2015. The authors propose that the volatility indices for gold and oil are tradable securities that differ from their price indices, therefore, different profitable strategies may be exploited by investors. The key results indicate that gold prices bear a significantly positive impact on stock prices, whereas gold price volatility carries a significantly negative impact upon the emerging stock markets included in the study; corroborating the findings reported by Tully and Lucey (2007), Mensi et al. (2013), Baur and Lucey (2010), and many others. With respect to oil prices, the findings suggest a significantly positive effect mainly on large BRICS stock markets, whereas oil price volatility has a short-run significant effect on the stock prices of Brazil, India, and Thailand, with varying degrees. The results also confirm that the volatility indices for gold and oil exhibit a negative impact upon all of the emerging stock markets in question, both in the short-run as well as in the long-run, suggesting that higher volatility in gold and oil prices may be interpreted as bad news for investors; thereby leading to a decrease in their respective stock prices. In their concluding remarks, the authors infer that emerging market economies are more sensitive to uncertain economic conditions (i.e. bad news) in comparison with developed markets. In a related study, Arfaoui & Ben Rejeb, 2017) evaluate the interdependencies among gold prices, oil prices, the

MSCI world stock market index, and the broad trade-weighted average of the foreign exchange values of the US dollar against the currencies of a broad group of major US trading partners. To fulfill this aim, the authors employ the simultaneous equations approach put forth by Imbs (2004). Monthly data are obtained for the sample period covering January 1995 to October 2015. The principal findings divulge the presence of significant interactions among the prices of all variables included in the study. More specifically, the results illustrate that oil price is significantly influenced by stock markets, gold, and trade-weighted US dollars. The authors further argue that changes in gold prices are largely shaped by changes in oil prices, stock prices, and the value of the US dollar, and to a lesser extent, are dependent upon US oil gross imports and default premium. The trade-weighted US dollar exchange rate is mainly determined by the prices of gold, oil, and stocks, and, is negatively affected by the US CPI. The study underscores the unavoidable existence of indirect effects, namely due to the presence of global market interdependencies in addition to what the authors allude to in their concluding remarks as the "financialization" of commodity markets; thus, increasing the reliance on commodities, such as gold and oil, as hedging tools by investors.

There is a large consensus in the literature on the capitalization of gold as a risk-mitigating instrument. This claim is broadly substantiated by the negative, or weak, association between gold and other market variables (including stocks), particularly during adverse market conditions. However, a new literature branch has emerged in recent years, in which doubts are casted over the viability of this proposition; giving rise to many caveats associated with the relevance of gold in the process of optimal portfolio selection. Maghyereh et al. (2017) employ a DCC-GARCH framework to examine volatility spillover effects and cross-hedging between gold, oil, and equity prices in the Gulf Cooperation Council (GCC) markets. Categorically, the study questions the practicality of using gold and oil in hedging equity portfolios. Daily data are gathered for the period January 2004 through May 2016 in order to evaluate the dynamic correlations and hedge ratios for the variables in question. The authors make a distinction between a hedge and a safe haven, adopting the same definitions as those proposed by Baur and Lucey (2010). The findings report the presence of significant spillover effects from oil to equities, delineating the excessive reliance of the local economies on the oil sector. In addition, the empirical results show no evidence of significant spillover effects from gold to stocks, which explicitly suggests that gold price volatility has no significant impact upon equity-based investment decisions. In addition, the study finds no evidence of significant spillover effects from stocks to either of the two commodities. According to the authors, this is largely explained by the relatively small capitalization of the stock markets under investigation. Finally, the study outlines two main conclusions. First, with the exception of a few surges during periods of market stress, the results demonstrate low dynamic correlations and hedge ratios, which renders both gold and oil inexpensive, yet ineffective, hedging tools. Second, both commodities may be regarded as weak safe havens, although at a substantial cost. Similarly, Naser (2017) probes the effectiveness of investing in gold as a hedging instrument against inflation risks in the US via a Granger causality testing framework. Monthly data are analyzed for the period 1986 through to 2016. The main findings indicate that gold does not gualify as a useful hedge in the short-run to the same extent that it does so in the long-run. This is in contrast to the primary argument found in the literature, whereby gold is found to be an effective hedge against marketrelated risks particularly during turmoil periods. Balcilar, Ozdemir, Shahbaz, & Gunes, 2018) examine the predictability of changes in gold prices based upon inflation for G7 markets. The authors rely on a nonparametric causality-in-quantiles methodology to test for causality in mean and variance. These tests detect nonlinearity and demonstrate the misspecification errors produced by linear Granger causality testing. This hybrid approach combines the techniques proposed by Nishiyama, Hitomi, Kawasaki, and Jeong (2011) and Jeong, Härdle, and Song (2012). Monthly data are analyzed for the period 1979 through 2016. The results propose that gold does not serve as a hedge against inflation during periods when price fluctuations in the gold market are either very high (i.e. turbulent periods) or very low (i.e. tranquil periods).

It is noteworthy to mention that a number of earlier research papers have brought into question the relevance of using gold as a risk-minimizing instrument against other assets. These studies, however, are quite limited in number. This is largely due to the differences in definitions and econometric methodologies adopted. For instance, even though Baur and Lucey (2010) demonstrate that gold may serve as a strong hedge and haven asset against US and European stocks during the 2007 Global Financial Crisis, there are a few exceptions in their overall findings. In particular, the study finds gold to be neither a hedge nor a safe haven against stocks in Australia, Canada, Japan, and the large BRIC markets. By the same token, Ciner, Gurdgiev, and Lucey (2013) explore the dynamic relationship between gold, oil, currency, stocks, and bonds in the US as well as in the UK. The authors build on the approach proposed by Baur and Lucey (2010). Specifically, the study applies a DCC-GARCH framework to analyze daily returns for the variables in question over the period 1990 through to 2010. First, the study examines the time variation in conditional correlations to establish whether these variables can be used as a hedge against one another. Second, the study investigates whether the dependencies between the variables differ during extreme price shifts by utilizing quantile regressions. The empirical findings conclude that gold can function as a haven asset against a significant drop in both exchange rates, however, the study finds that gold cannot be treated as a safe haven for UK stocks during turmoil periods. Moreover, Lu et al. (2014) employ a VAR-DCC-GARCH model to investigate the volatility spillover effects between gold and stocks in the UK. In particular, the study examines daily gold spot prices in the London Gold Market as well as daily stock prices in the FTSE 100 Index, covering the period 4 January 2000 to 31 December 2012. The empirical findings report evidence of a persistent bidirectional volatility spillover effect between gold and stocks, albeit more significant from gold to stocks in the long-run. The results also demonstrate that the time-varying conditional correlation between the two assets becomes more significant when the price of gold increases. Although the conditional correlations observed during the 2007 Global Financial Crisis are mostly negative. the estimates are found to vary substantially between positive and negative throughout the entire sample period; suggesting that investors should pursue divergent strategies under different economic circumstances.⁵

In determining whether gold is an effective hedging instrument against other asset price fluctuations, earlier approaches have documented the sensitivity of gold prices to macroeconomic news releases by means of employing a wide range of nonparametric tests, flexible Fourier functions, and ARDL testing frameworks. Moreover, the studies which have utilized a Granger causality approach are much more closely related to capturing long-term causality trends between two variables in a time series. These approaches, however, do not take into account several critical aspects of hedging effectiveness such as asymmetry, dynamic conditional correlation, and optimal portfolio weights. These factors constitute a pivotal component in an investor's hedging strategy. To that extent, GARCH-based models are far more robust, particularly when accounting for cross-market return and volatility spillovers. In addition, very few studies to date examine the dynamic relationship between gold and stocks in the US market, particularly in the post-global financial crisis period. This paper aims to fill these literature gaps by constructing a VAR-ADCC-BVGARCH model to investigate the dynamic relationship between gold and stocks in the post-global financial crisis era.

3. Methodology

The methodology of this paper is divided into parts. The first part deals with capturing crossmarket return and volatility spillover effects. The second part relates to the issue of hedging effectiveness.

The returns are calculated as the log of the ratio of a given period's price to that of the previous period where:

$$r_t = \ln\left(\frac{p_t}{p_{t-1}}\right) \tag{1}$$

Where r_t is the return of an index at time (t), p_t is the price index at time (t), and p_{t-1} is the price index of the previous period. Next, a VAR(1) process is applied to capture the spillover in mean returns. More specifically, the VAR(1) model accounts for changes in market returns in addition to a market's response to news releases. Thus, the return for market *i* at time *t* is denoted by $r_{i,t}$ as follows:

$$r_{i,t} = \mu_{i0} + \sum_{i=1}^{2} \mu_{ij} r_{j,t-1} + \varepsilon_{i,t}, \quad i,j = 1,2$$
(2)

Such that $E[\varepsilon_{i,t}|.\xi_{i,t-1}] = 0$, wherein $\xi_{i,t-1}$ represents the information available at time t - 1. The conditional mean return for each market is defined by its own prior returns in addition to cross-market prior returns. The lead/lag relationship between market returns is estimated via the coefficient μ_{ij} where $i \neq j$. A significant estimate indicates that the current return in market j can be used in forecasting the future return in market i. The VAR model accounts for cross-market correlations in addition to autocorrelations in returns. In terms of modeling conditional volatility and capturing volatility spillover effects, an ADCC-BVGARCH model is employed. As proposed by Ling and McAleer (2003), the conditional variance is specified as VAR-GARCH(1,1), where:

$$\varepsilon_{i,t} = z_{i,t} \sqrt{h_{i,t}}$$

$$h_{i,t} = \omega_{i0} + \sum_{i=1}^{2} \alpha_{ij} \varepsilon_{i,t-1}^{2} + \delta_{i} \varepsilon_{i,t-1}^{2} D_{i,t-1}^{-} + \beta_{i} h_{i,t-1}, \quad j = 1, 2$$
(3)

The standardized residuals are denoted by $z_{i,t}$ and the conditional variance is denoted by $h_{i,t}$. A dummy variable is denoted by $D_{i,t-1}^-$ which is equal to 1 when $\varepsilon_{i,t-1}<0$ and zero otherwise. The term $\delta_i D_{i,t-1}$ differently impacts the conditional variance, capturing good news when $\varepsilon_{i,t-1}>0$ and bad news when $\varepsilon_{i,t-1}<0$. This procedure is valuable in evaluating the effects of large shocks among two markets.

The DCC model is a two-step procedure developed by Engle (2002). It is designed to capture the time-varying conditional correlation between two variables. It calculates the parameters of the GARCH model in the first step, and it estimates the dynamic correlation in the second step. Thus, the DCC-GARCH model is determined as follows:

$$H_t = D_t P_t D_t \tag{4}$$

The 2 \times 2 conditional covariance matrix is defined by H_t , the conditional correlation matrix is defined by P_t , and a diagonal matrix with time-changing standard deviations is defined by D_t , where:

$$D_{t} = diag\left(\sqrt{h_{11}}, \sqrt{h_{22}}\right) \tag{5}$$

And

$$P_t = diag\left((Q_t)^{-1/2}\right)Q_t diag\left((Q_t)^{-1/2}\right)$$
(6)

As Kumar (2014) explains, Q_t is a (2×2) symmetric positive definite matrix, where $Q_t = (q_t^{ij})$, and is defined as follows:

$$Q_{t} = (1 - \theta_{1} - \theta_{2})\bar{Q} + \theta_{1}Z_{t-1}Z_{t-1}^{'} + \theta_{2}Q_{t-1}$$
(7)

Whereby \overline{Q} denotes a (2×2) matrix of the unconditional correlation of the standardized residuals. The sum of the non-negative scalars, θ_1 and θ_2 , is assumed to be less than 1. The correlation estimates are provided as follows:

$$\rho_{ij,t} = \frac{q_{ij,t}}{\sqrt{q_{ij,t}}} \tag{8}$$

It is worth mentioning that a large body of literature on GARCH-based specifications has evolved over the past few decades. Specifically, the models differ in terms of conditional volatility specifications as well as conditional variance-covariance matrix specifications. For instance, the restricted BEKK approach developed by Engle and Kroner (1995) guarantees the positive definiteness of the covariance matrix in addition to the CCC. The DCC model developed by Engle (2002) eased the constancy criterion of the CCC model. Cappiello, Engle, and Sheppard (2006) extended the DCC model to the ADCC model in order to account for (asymmetric) leverage effects in the specified correlation structure. As Katzke (2013) explains, the ADCC model nests both the DCC and the CCC, thus, the goodness of fit between the series can be compared using the log-likelihood estimates. Moreover, the results demonstrate that the ADCC model largely outperforms the other two models based upon higher log-likelihood statistics as well as lower Akaike Information Criterion (AIC) and Bayesian Information Criterion (SBIC) estimates.

To test for hedging effectiveness, it is necessary to establish a hedging process. This study adopts the optimal hedge ratio proposed by Kroner and Sultan (1993). The optimal hedge ratio is a risk minimizing hedge ratio between two assets (*i* and *j*) which is calculated using the estimates of the conditional variance and covariance based upon the minimization of the variance of the portfolio return, given as:

$$\delta_{ij,t} = \frac{h_{ij,t}}{h_{jj,t}} \tag{9}$$

The conditional variance of asset *j* at time *t* is defined by $h_{j,i,t}$ and the conditional covariance between asset *i* and asset *j* at time *t* is denoted by $h_{i,j,t}$. Kumar (2014) explains that a long position in one dollar for asset *i* can be hedged by a short position in $\delta_{i,i,t}$ dollars of asset *j*.

Next, the optimal portfolio weights are estimated using the method proposed by Kroner and Ng (1998), which are calculated on the basis of minimizing the risk of the portfolio without affecting the expected return, such that:

$$w_{ij,t} = \frac{h_{jj,t} - h_{ij,t}}{h_{i,i,t} - 2h_{ij,t} + h_{jj,t}}$$
(10)

And

$$w_{ij,t} = \begin{cases} 0, & \text{if } w_{ij,t} < 0\\ w_{ij,t}, & \text{if } 0 \le w_{ij,t} \le 1\\ 1, & \text{if } w_{ij,t} > 1 \end{cases}$$
(11)

Investors could reduce their risk exposure against turbulent movements in asset *j* by holding asset *i*, whereby $w_{i,j,t}$ is calculated as the proportion assigned to the first asset, in one-dollar portfolio consisting of two assets (*i* and *j*), at time *t*. Conversely, the proportion assigned to the second asset is calculated as $1 - w_{i,j,t}$.

Finally, the hedging effectiveness across the specified portfolio combinations is determined using the method put forward by Ku, Chen, and Chen (2007) and suggested by Kumar (2014), which can be established by evaluating the realized hedging errors as follows:

$$Hedging \ Effectiveness = \frac{Variance_{unhedged} - Variance_{hedged}}{Variance_{unhedged}}$$
(12)

The variance of returns for a portfolio comprised of gold and stocks (i.e. a hedged portfolio) is defined by $Variance_{hedged}$, whereas the variance of returns for a portfolio solely comprised of stocks (i.e. an unhedged portfolio) is defined by $Variance_{unhedged}$. A comparatively higher hedging effectiveness estimate for a given portfolio is indicative of a favorable hedging strategy, based on the significant amount of portfolio risk reduced. It should be noted that there are several methods

through which hedging effectiveness can be produced, which mainly differ in terms of how the hedge ratio is estaimated. These methods can be divided into two main groups, a static hedge ratio and a dynamic hedge ratio. Among the most notable methods are the ordinary least squares (OLS) method and the error correction model (ECM). For the purposes of this paper, the results based upon the optimal (time-varying) hedge ratio proposed by Kroner and Sultan (1993) are compared to those produced by the static OLS hedge ratio. A static hedge ratio assumes a constant relationship between two underlying variables over a given period of time, whereas a time-varying hedge ratio assumes that the variables of interest are described by a correlation which changes over time. Since the purpose of hedging is to effectively minimize the risk of a given portfolio, it is therefore the highest degree of risk reduction (i.e. hedging effectiveness) which determines the superiority of one method over the other.

4. Data and descriptive statistics

4.1. Data

In terms of gold, the dataset consists of spot prices per ounce (in USD). The stock price indices considered in this study include the Nasdaq Composite Index (NASDAQ) in addition to the closing prices of the Dow Jones Industrial Average Index (DJIA) and the S&P 500 Index (S&P500). For all variables considered, daily time series data are obtained from the Bloomberg database, spanning an 11-year period from 1 January 2007 to 31 December 2017. Thus, a total of 2,870 daily observations per variable are sampled. It is worth mentioning that three US market indices are included in this paper in order to account for differences in market size and capitalization vis-à-vis hedging effectiveness against gold. Figures 1 and 2 below illustrate the daily price indices and the daily log returns, respectively, for the markets in question. The price indices for the stock markets



Figure 1. Price charts.



demonstrate a sharp decrease in value from year-end 2007 through to mid-year 2009. However, the price index for gold exhibits a different trend. A sharp increase in value can observed between year-end 2007 and early 2008, followed by a steady decrease until early 2009, and an overall increase from thereon after, reaching its highest value by year-end 2011. In terms of log returns, the heaviest volatility clustering for all markets can be seen from year-end 2007 to mid-2009.

4.2. Descriptive statistics

Table 1 presents the descriptive statistics for the daily price index changes within the four markets under investigation, that is, the logarithm of price indices is used to estimate stock returns.

The highest average mean and median daily return can be observed for the Nasdaq Index over the 11-year period. Moreover, the highest degree of uncertainty (i.e. volatility or standard deviation) is also observed for the Nasdaq Index, followed by the S&P 500 Index, gold, and the Dow Jones Industrial Average Index, respectively. All daily returns are leptokurtic and negatively skewed. As expected, the Jarque-Bera test results confirm that the null hypothesis of normality is rejected for all markets. The Ljung-Box *Q*-test results show that the null hypothesis of no autocorrelation in the first 36 lags is rejected for all markets at the 5% significance level. Based on 10 lags, the Lagrange multiplier (ARCH-LM) test results indicate the presence of conditional heteroskedasticity in all return series. The unconditional correlations between gold and stock returns are relatively low; ranging between a minimum of 1% and a maximum of 3%. The highest correlation with gold is observed for the S&P 500 Index, followed by the Nasdaq Index and the Dow Jones Industrial Average Index, respectively.

Figure 2. Return charts.

Table 1. Descriptive statistics—returns						
	DJIA	S&P500	NASDAQ	GOLD		
Mean	0.000239	0.000221	0.000366	0.000249		
Median	0.000343	0.000323	0.000642	0.000397		
Maximum	0.105083	0.109572	0.111594	0.102451		
Minimum	-0.082005	-0.094695	-0.095877	-0.095121		
Standard Deviation	0.011413	0.012426	0.013247	0.011570		
Q1	-0.003628	-0.003746	-0.004582	-0.005247		
Q3	0.004944	0.005282	0.006423	0.006348		
Skewness	-0.109898	-0.352199	-0.287250	-0.259790		
Kurtosis	14.30235	14.42968	10.94828	9.503091		
Jarque-Bera	15,276.39	15,675.95	7591.511	5087.712		
Probability	0.000000	0.000000	0.000000	0.000000		
ARCH LM	112.8262	114.2004	92.63897	17.27686		
Prob. F(10, 2848)	0.000000	0.000000	0.000000	0.000000		
Sum of Deviations	0.684805	0.633971	1.050193	0.715815		
Sum of Sq. Deviations	0.373597	0.442843	0.503269	0.383896		
Q(36)	121.09	118.93	72.548	35.666		
Correlation with Gold	0.015824	0.032400	0.011829	1		
N	2869	2869	2869	2869		

5. Results and discussion

5.1. Unit root test

The Ng and Perron (2001) unit root test is applied in order to evaluate the order of integration in gold and stock returns. Kumar (2014) and many others argue that the conventional unit root tests, such as ADF and Philips and Perron (PP), are likely to yield biased results as they suffer from finite sample power and size problems. The results in Table 2 indicate the presence of a unit root at level data for all the markets in question, however, all return series are stationary at the first difference. This means that all return series are integrated at I (1)

5.2. The main model

Table 3 demonstrates the maximum likelihood estimates as well as the post-diagnostic test results on the standardized residuals produced by the main VAR(1)-ADCC-BVGARCH(1,1) model for the gold-stock pairs under scrutiny (equations 2–7). Based on the mean equation, the results show that none of the current stock returns are significantly affected by the lagged gold returns at the 5% level (indicated by μ_{12}). This finding implies that there is no evidence of significant return spillover from the gold market to the stock markets under investigation. In other words, prior gold returns cannot be used in forecasting current stock returns. However, the results demonstrate that current gold returns are significantly affected by lagged stock prices (indicated by μ_{21}). This outcome suggests the presence of a (significant) negative return spillover from stocks to gold, inferring that prior stock returns can help in predicting current gold returns.

The conditional variance equation relates to the issue of volatility persistence. The short-run dependence is captured by the ARCH coefficient (denoted as α_{ii}). A significant estimate suggests that prior information shocks in one market significantly affect the present conditional volatility in another market. The results show that the present conditional volatility for all stock returns can be explained by past shocks in gold returns at a conventional level of significance (indicated by α_{12}). On the other hand, there is no evidence to suggest that prior shocks in stock returns bear

Table 2. Ng-Perron unit root test							
		MZa	MZt	MSB	МРТ		
Level		•			•		
DJIA		-1581.59	-28.1203	0.01778	0.01588		
S&P500		-1580.67	-28.1121	0.01778	0.01588		
NASDAQ		-1425.41	-26.6954	0.01873	0.01782		
GOLD		-34.4447	-4.14997	0.12048	0.71133		
Asymptotic critical values*:	1%	-13.8000	-2.58000	0.17400	1.78000		
	5%	-8.10000	-1.98000	0.23300	3.17000		
	10%	-5.70000	-1.62000	0.27500	4.45000		
First Difference							
ΔΟΙΙΑ		-0.02825	-0.05252	1.85913	174.992		
ΔS&P500		-0.06804	-0.14029	2.06190	211.270		
ΔNASDAQ		0.06024	0.12879	2.13784	234.798		
ΔGOLD		0.30649	0.99586	3.24921	569.592		
Asymptotic critical values*:	1%	-13.8000	-2.58000	0.17400	1.78000		
	5%	-8.10000	-1.98000	0.23300	3.17000		
	10%	-5.70000	-1.62000	0.27500	4.45000		

*Critical values are acquired from Table 1 of Ng and Perron (2001).

Table 3. Maximum likelihood estimates of the VAR-ADCC-BVGARCH model							
	DJIA	Gold	S&P500	Gold	NASDAQ	Gold	
μ _{io}	0.000	0.000	0.000	0.000	0.000	0.000	
μ_{i1}	-0.104***	0.019	-0.106***	0.026	-0.078***	0.021	
μ _{i2}	-0.039*	0.004	-0.039*	0.004	0.000	0.004	
ω _{io}	-0.000***	0.000	0.000***	0.000***	-0.000***	0.000	
α _{i1}	0.031	0.063*	0.008	0.059	0.025*	0.059	
α _{i2}	0.097***	-0.020	0.061***	-0.013	0.072***	-0.014	
β _i	0.829***	0.949***	0.904***	0.945***	0.856***	0.946***	
δι	0.000***	0.000	-0.000***	-0.000	0.000***	-0.000	
$\boldsymbol{\Theta}_i$	0.039***	0.945***	0.039***	0.944***	0.035***	0.948***	
v	9.416***		9.986***		8.793***		
LLF	-3878.103		-3822.704		-3854.125		
Q(36)	65.892***	33.424	76.153***	33.470	52.558**	33.672	
Qs(36)	33.175	31.002	33.635	30.551	30.897	31.053	
ARCH(10)	1.395	1.734*	1.377	1.659*	0.869	1.746*	
Sign Bias	0.000***	0.000*	0.000***	0.000*	0.000***	0.000*	
Negative Size	-0.014***	-0.006***	-0.014***	-0.006***	-0.013***	-0.006***	
Positive Size	0.002**	0.000	0.002**	0.000	0.002*	0.000	
Joint Test	13.939	17.301*	13.762	16.556*	8.706	17.417*	

*, **, and *** indicate the levels of significance at 10%, 5%, and 1%, respectively. The log likelihood function is denoted by LLF. The Ljung-Box test statistics based on 36 lags for standardized and squared standardized residuals are captured by Q(36) and Qs(36) respectively. The Lagrange multiplier test for conditional heteroskedasticity based on 10 lags is represented by ARCH(10). a significant impact upon the current conditional volatility in gold returns at the 5% level (indicated by α_{21}). The long-run volatility persistence is captured by the GARCH coefficient (denoted as β_i). This coefficient also deals with a market's sensitivity to its own prior shocks. A significant estimate indicates that the present volatility in a given market is sensitive to its own past volatility. It can be seen that the GARCH coefficient is highly significant for both gold and stocks, suggesting that the current volatility in the returns of each asset class is significantly explained by its own historical return volatility. Moreover, it can be observed that the GARCH coefficient estimates are considerably greater than the ARCH coefficient estimates for all gold-stock pairs, confirming that the longrun volatility persistence in each market is higher than that of its short-run persistence. In addition, this finding suggests that the estimated conditional volatility in gold and stock returns is likely to fluctuate more aggressively due to a significant impact of own past volatility. In other words, the effect of prior volatility is more helpful in detecting rapid changes in the estimated conditional volatility series than that which can be explained by the return shocks. To that end, it is useful for market participants and other practitioners to consider analyzing long-term (historical) volatility persistence to explain future information shocks in their investment strategies.

Furthermore, the empirical findings suggest no evidence of volatility spillover among the selected gold-stock combinations. The presence of asymmetric volatility in a given series is indicated by δ_i in the conditional variance equation. The significant estimates of δ_1 indicate the existence of asymmetric volatility in all stock returns. In contrast, the insignificant values of δ_2 rule out the presence of asymmetric volatility in gold returns. The DCC model's estimated coefficients are indicated by θ_1 and θ_2 . Both coefficients are positive and statistically significant at the 1% level for all gold-stock pairs. In addition, the satisfaction of the $(\theta_1 + \theta_2) < 1$ criterion accentuates the mean reverting nature of the dynamic conditional correlations between gold and stock returns. The estimated values for the degrees of freedom are denoted by v. The significant values indicate that the main model is able to detect the leptokurtic nature of the estimated residuals, based upon the Student's t-distribution.

The Lagrange multiplier test statistic, based on 10 lags, is indicated by ARCH(10). The insignificant estimates infer that the main model is able to account for the heteroskedasticity in the return series. The significant sign bias test results are mainly observed for stock returns. That is to say, the effect of both positive and negative shocks observed in the stock market is significantly different from that which has been predicted by the main model. It is worth noting that GARCH models disregard the sign of the excess return and only account for the magnitude of an underlying innovation. In addition, the results confirm the presence of negative size bias for all market returns and positive size bias for the Dow Jones Industrial Average and the S&P 500 Index. However, the results of the joint test reject the presence of both sign and size bias, confirming that the main model is able to account for asymmetry in the volatility process.

As indicated by Q(36), the estimates of the standardized residuals are significant for all stock returns, suggesting the presence of autocorrelation at the 1% level of significance. Nevertheless, this outcome is nullified when the standardized residuals are squared, as shown by Qs(36). Thus, it can be concluded that the abovementioned model is adequately specified. It is worth mentioning that several normality tests, including the modified Ljung-Box test (1978), have been conducted. As expected, the results confirm non-normality in the standardized residuals for the series in question. In other words, the null hypothesis of normality is significantly rejected at the 1% level. Normality tests are likely to demonstrate non-normality in the standardized residuals as sample size increases. Burns (2002) explains that as the tails extend beyond a *t* with 10 degrees of freedom, the null distribution of the Ljung-Box test loses power. This is a major drawback of the Ljung-Box and other normality tests. Nevertheless, this means that it is very problematic to mitigate this limitation.

5.3. Dynamic conditional correlation (DCC)

Figure 3 illustrates the time-varying conditional correlation estimates produced by Equation (8) for all the gold-stock combinations in question. Even though highly negative conditional correlation estimates can be observed during the 2007 Global Financial Crisis, a wide-ranging (positive and



2007 2009 2011 2013 2015 2017

negative) variation is found to exist throughout the overall period. This finding underlines the importance of examining the potential benefits of combining both gold and stocks in the portfolio optimization process.

5.4. The optimal hedge ratio

Figure 4 illustrates the optimal hedge ratio using Equation (9), as suggested by Kroner and Sultan (1993), for all the stock-gold and gold-stock combinations in question.

The optimal hedge ratios are based on the conditional variance/covariance estimates produced by the main model. Kumar (2014) explains that the risk in taking a long position in asset *i* can be offset by taking a short position in asset *j*. A widespread fluctuation of positive and negative estimates can be seen in the optimal hedge ratios for all the pairwise combinations throughout the entire sample period. This finding suggests that it is imperative for investors to continuously adjust their portfolios in order to effectively minimize their risk exposure over time. The (higher) negative hedge ratios indicate that both assets, *i* and *j* are negatively correlated or, in other words, move in opposite directions. During such (crisis) periods, investors can take a long position in asset *j* to hedge against a short position in asset *i*. Table 4 reports the descriptive statistics of the optimal hedge ratio for all possible asset combinations over the specified sample period.

The average ratio is generally low for all the pairs in question. The highest average stock-gold hedge ratio (i.e. the most expensive hedge) is that which is indicated by S&P500– Gold, followed by NASDAQ–Gold and DJIA–Gold, respectively. This means that a \$1 long position in the S&P 500

Figure 3. Dynamic conditional correlations.

DJIA-Gold

Gold-DJIA

Figure 4. Optimal hedge ratios.

0.6 0.8 **Optimal Hedge Ratio Optimal Hedge Ratio** 0.6 0.4 0.4 0.2 0.2 0 0.2 -0.2 -0.4 -0.4 -0.6 -0.6 4/29/2016 5/26/2010 10/15/2013 8/20/2014 6/25/2015 9/11/2007 9/15/2008 7/21/2009 3/2/2012 .0/12/2012 6/3/2017 6/25/2008 4/1/2007 3/31/2011 3/20/2009 9/9/2010 4/11/2015 7/29/2016 1/10/2007 2/15/2009 2/29/2012 1/23/2012 8/20/2013 5/15/2014 9/2/2015 4/25/2017 4/1/2007 6/6/2011 S&P500-Gold Gold-S&P500 0.6 0.8 **Optimal Hedge Ratio Optimal Hedge Ratio** 0.4 0.6 0.4 0.2 0 -0.2 0.2 0 -0.2 -0.4 -0.4 -0.6 0.6 4/29/2016 5/26/2010 9/15/2008 3/2/2012 10/15/2013 8/20/2014 6/25/2015 6/25/2008 3/20/2009 2/15/2009 9/9/2010 7/21/2009 0/12/2012 6/3/2017 7/29/2016 4/1/2007 9/11/2007 3/31/2011 1/10/20076/6/2011 2/29/2012 .1/23/2012 8/20/2013 5/15/2014 9/2/2015 4/11/2015 4/25/2017 4/1/2007 NASDAQ-Gold **Gold-NASDAQ** 0.6 0.6 **Optimal Hedge Ratio Optimal Hedge Ratio** 0.4 0.4 0.2 0.2 0 0 -0.2 -0.2 -0.4 -0.4 -0.6 -0.6 4/29/2016 9/15/2008 7/21/2009 5/26/2010 3/2/2012 10/15/2013 8/20/2014 6/25/2015 1/10/2007 6/25/2008 3/20/2009 12/15/2009 9/9/2010 1/23/2012 8/20/2013 5/15/2014 9/2/2015 4/11/2015 7/29/2016 4/1/2007 9/11/2007 3/31/2011 10/12/2012 6/3/2017 6/6/2011 2/29/2012 4/25/2017 4/1/2007

Table 4. Descriptive statistics—optimal hedge ratio							
	Mean	Median	Std. Dev.	Minimum	Maximum		
DJIA-Gold	0.005203	0.001923	0.129539	-0.48532	0.389958		
NASDAQ-Gold	0.016103	0.012201	0.147318	-0.54268	0.362656		
S&P500- Gold	0.026573	0.02036	0.138294	-0.51833	0.420838		
Gold-DJIA	0.017314	0.002536	0.200722	-0.48446	0.67518		
Gold-NASDAQ	0.027341	0.010097	0.160639	-0.42636	0.487357		
Gold-S&P500	0.044871	0.026029	0.189958	-0.44851	0.637435		

Index can be hedged against a 3 cent short position in gold. Moreover, a \$1 long position in the Nasdaq Index can be hedged with a 2 cent short position in gold, and a \$1 long position in the Dow Jones Industrial Average Index can be shorted against a one-half cent in gold. Considering the gold-stock combinations, the cheapest hedging option is to take a \$1 long position in gold against

a 2 cent short position in the Dow Jones Industrial Average Index. It is slightly more expensive to hedge gold against the Nasdaq Index, where a \$1 long position in gold is shorted with approximately 3 cents in stocks. By the same token, the most expensive hedge is to take a \$1 long position in gold with a 5 cent short position in the S&P 500 Index.

5.5. Optimal portfolio weight allocation

Figure 5 presents the time-changing optimal portfolio weights for both gold and stocks on the basis of the conditional variance/covariance estimates produced by the main model, as proposed by Kroner and Ng (1998), using Equations (10) and (11).

The occurrence of sharp fluctuations for each optimal portfolio can be observed over the sample period. This particular finding does not necessarily imply that investors are required to adjust their portfolio weights at each point in time. Doing so may lead to an increase in transaction costs, as Kumar (2014) explains. Alternatively, investors may allocate a mean (optimal) weight for each asset in a portfolio over a certain period of time, thereby adjusting the portfolio by purchasing the under-allocated component and selling the over-allocated component accordingly.

Table 5 shows the descriptive statistics relating to the optimal weights for each portfolio over the specified sample period. The mean (optimal) weights for all the asset pairs under investigation are quite high compared to those produced by Kumar (2014). The highest can be observed for the DJIA–Gold portfolio, followed by the S&P500– Gold and NASDAQ–Gold portfolios, respectively. This means that for a \$1 portfolio, approximately 61 cents (on average) are to be invested in the Dow



Figure 5. Optimal portfolio weights.

Table 5. Descriptive statistics—optimal portfolio weights							
	Mean Median Std. Dev. Minimum Maximu						
DJIA-Gold	0.606288	0.614807	0.126401	0.249724	0.969561		
NASDAQ–Gold	0.511704	0.510087	0.121271	0.205219	0.920058		
S&P500- Gold	0.578738	0.592309	0.135102	0.215212	0.951741		

Jones Industrial Average Index and the remaining 39 cents are to be invested in the gold market. Moreover, 58 cents are to be allocated to the S&P 500 Index and the remaining 42 cents are to be allocated to gold in a \$1 portfolio. Finally, for every 51 cents invested in the Nasdaq Index, 49 cents are to be apportioned to gold in a \$1 portfolio.

5.6. Hedging effectiveness

Table 6 presents the hedging effectiveness of including gold in a stock-dominated portfolio based upon the optimal hedge ratio (Equation 12) in addition to the static OLS hedge ratio. The variance of an unhedged portfolio indicates the level of risk exposure for a stock-dominated portfolio, whereas the variance of a hedged portfolio indicates the degree of risk for a gold-stock portfolio. Based on the optimal hedge ratio, the highest degree of risk reduction subsequent to the inclusion of gold in an optimal portfolio can be observed for the Dow Jones Industrial Average (66%), followed by the S&P 500 Index (53%) and the Nasdaq Index (13%). These results are significantly lower than those which are produced using the static OLS hedge ratio. Specifically, the highest estimate of hedging effectiveness can be observed for the Dow Jones Industrial Average (70%), followed by the S&P 500 Index (68%) and the Nasdaq Index (32%). On a prima facie basis, these findings may suggest that utilizing the simpler methodology (i.e. the static hedge ratio) yields significantly higher hedging effectiveness estimates when compared with the more complex methodology (i.e. the optimal hedge ratio). This finding is not surprising as similar results are reported by Lien (2005), Gupta and Singh (2009), Wibowo (2017), and others. Miffre (2004) explains that the static OLS hedge ratio imposes the condition of a constant joint distribution for changes in both variables, which could result in substandard hedging decisions particularly during periods of high market volatility. In addition, static hedging strategies fail to consider the time-varying adjustments which are necessary in the overall hedging process. Thus, the approach proposed by Kroner and Sultan (1993) is considered more reliable in that the time-varying hedge ratios are estimated on the basis of conditional moments and thereby mitigating the drawbacks associated with the traditional methods in the hedging literature.

That being said, the empirical results suggest that incorporating gold in a portfolio reduces its overall risk exposure in the US market, however, not to the extent that can be observed in South Asia and the Middle East, where gold occupies a distinct sociocultural status. Moreover, it should be noted that the Dow Jones Industrial Average is comprised of 30 companies, whereas the S&P 500 Index consists of 505 stocks and the Nasdaq Index hosts over 3,300 listings. In other words, the hedging effectives of gold diminishes as stock market capitalization increases. Another probable explanation relates to the issue of market efficiency. Compared with the results reported by Kumar (2014) on the Indian market, the lower hedging effectiveness estimates in this study possibly suggest that it is less likely for gold to be considered an effective hedging tool against a strong form stock market, such as that in the US.

Table 6. Hedging effectiveness (HE)—optimal hedge ratio							
	Optimal Hedge Ratio			Static OLS Hedge Ratio			
	DJIA	NASDAQ	S&P500	DJIA	NASDAQ	S&P500	
<i>Variance</i> unhedged	4.6868	2.5871	4.1791	5.2688	2.1702	5.6784	
<i>Variance</i> _{hedged}	1.6153	2.2440	1.9462	1.5977	1.4706	1.8252	
HE	0.6553	0.1326	0.5338	0.6967	0.3223	0.6785	

Moreover, the increased number of alternatives to gold in the commodities market may offer greater effectiveness in a hedging strategy against stock price volatility. Nevertheless, these issues remain subject to future research and methodological specification. Considering the relatively high proportion of funds required to be invested in gold, a marginal amount of risk is hedged away for a stock index described by a large number of listed companies.

6. Conclusion

The central aim of this paper is to examine the hedging effectiveness of gold against stock price fluctuations in the US market. Specifically, this study examines the dynamic pairwise interaction between gold spot prices and US equity prices in the post-2007 Global Financial Crisis period by applying a VAR-ADCC-BVGARCH framework. Initially, the maximum likelihood estimates and post-diagnostic test results are produced. The results show no evidence of significant return spillover from gold to stocks. However, the findings indicate the presence of significantly negative return spillover from stocks to gold, which means that past stock returns can help in predicting current gold returns. Moreover, the empirical results demonstrate that the present conditional volatility of stock returns can be explained by prior shocks in gold returns. On the contrary, there is no indication that prior shocks in stock returns have a significant impact upon the present conditional volatility in gold returns. In addition, this study finds that the present volatility in the returns of each asset classification is significantly affected by its own past return volatility. The results further indicate that the long-term volatility persistence in both gold and stocks is higher than that of its short-term persistence, inferring that the conditional volatility in both asset classes is likely to fluctuate more aggressively as a result of own prior volatility. Further, there is no evidence of significant volatility spillover among the pairwise combinations in question. The dynamic conditional correlation estimates between gold and stocks are particularly negative during the 2007 Global Financial Crisis, however, a wide-ranging variation of positive and negative values can be observed throughout the entire sample period. The optimal hedge ratios indicate that it is relatively inexpensive to retain a short position in the gold market against a long position in the stock market, however, the optimal portfolio weights show that, on average, a significant proportion of funds need to be allocated to gold in an optimal portfolio with the objective of reducing its overall risk exposure. Finally, the hedging effectiveness estimates confirm that the benefits of including gold in a stock-dominated portfolio tend to diminish as stock market capitalization increases. In other words, very little risk is mitigated considering the high proportion of funds which need to be invested in gold against a stock market index characterized by a large number of listed companies. Therefore, it is recommended that investors seek alternative commodities to effectively hedge against stocks in the US market. The key findings of this study are critical for policy makers, portfolio managers, institutional investors, and other market participants in formulating optimal hedging strategies.

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Notes

- Gilbert and Mork (1984), Cunado and De Gracia (2005), and Worthington and Pahlavani (2007) among others wrote extensively on the links between commodities, such as gold and energy futures, and macroeconomic variables including GDP, inflation, and exchange rates.
- 2. "On average" refers to the overall period under investigation, including both stable and turbulent sub-periods.
- 3. The authors analyze the data in local currency in order to focus on the characteristics of gold for US, UK, and German investors.
- 4. The federal fund rate is incorporated to capture monetary policy effects.
- Whilst gold returns can be forecasted by observing stock returns in the short-run, Lu et al. (2014) recommend that investors assign greater value to changes in gold prices and avoid relying exclusively

on stock prices in order to predict gold prices in the long-run.

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