Analysing the gold-stock nexus using VARMA-BEKK-AGARCH and Quantile regression models: New evidence from South Africa and Nigeria

Adeolu O. Adewuyi⁎, Olabanji B. Awodumi, Temitope T. Abodunde

Department of Economics, University of Ibadan, School of Business, University of Ibadan, Ibadan, Oyo state, Nigeria

ARTICLE INFO
Keywords:
VARMA-BEKK-AGARCH model
Quantile regression
Stock markets
Gold market
Diversification and hedging effectiveness

ABSTRACT
This study examines the nexus between gold and stock for Nigeria and South Africa using VARMA-BEKK-AGARCH (V-B-A) model and Quantile regression (QR) approach. A major distinguishing feature of the V-B-A model is its capacity to account for cross-market asymmetric shock spillover. This kind of shock spillover occurs within the gold market and the two countries’ stock markets. In addition, cross-market asymmetric shock spillover is noticed between each country's stock market and gold market. The quantile regression analysis shows instantaneous influence of South Africa's stock on gold in the low to intermediate quantiles where structural break is not considered, while no evidence of instantaneous response of gold to stock returns is found for Nigeria at all quantiles. In the presence of structural break, there is instantaneous gold response to stock returns in both countries in almost all quantiles. Effective portfolio allocation and hedging analysis based on the two methods used in this study reveals that, in the case of Nigeria (unlike South Africa) adding gold asset to a well-diversified portfolio of stocks may improve the risk-adjusted performance. This suggests that gold could be used to effectively hedge stock risk exposures in Nigeria as opposed to South Africa.

1. Introduction
The theoretical analysis of the relationship between financial assets originated from the modern portfolio theory pioneered by Markowitz (1952, 1959) in which mean-variance (return-risk) framework was used to analyse portfolio choice and diversification decisions. Thus, investors’ wealth is maximized via a mix of risky assets with less risky or risk-free assets in the investment portfolio (Markowitz, 1952 and Tobin, 1958). Portfolio diversification can be justified by the need to minimize risk and the idea that the sensitivities of assets or asset markets to changes in economic conditions (business cycles and technological changes) and economic fundamentals (changes in interest, exchange and inflation rates) vary across assets and over time as well as investment horizons (Ross, 1976; Markowitz, 1987, 1999).

The role of global gold market in facilitating portfolio diversification and risk minimization during adverse market conditions cannot be overemphasized (Gokmenoglu and Fazlollahi, 2015; Arfaoui and Rejeb, 2017). As a commodity and monetary asset, gold is a source of wealth; a unit of account and a medium of exchange. In the same vein, stock markets foster economic activities via financial resource pooling and distribution, risk sharing and portfolio diversification (Enisan and Olufisayo, 2008; Carp, 2012; Ewing and Malik, 2013). Activities in the stock and gold markets have been traced to influence inflationary trend, while stock and gold have been found to act as hedge against inflation (Kaufmann and Winters, 1989; Gokmenoglu and Fazlollahi, 2015; Iqbal, 2017). The adverse effects of the volatility of stock and gold prices developed into unpredictable investment conditions which disrupts hedging decisions and assets valuation (Ewing and Malik, 2013; Kumar, 2014; Sadorsky, 2014; Reboredo and Ugolini, 2017).

During the global financial crises when stock markets crashed and international investors were searching for alternative assets to minimize risk, the importance of gold in portfolio diversification and hedging was acknowledged (Sadorsky, 2014; Gokmenoglu and Fazlollahi, 2015; Arfaoui and Rejeb, 2017). Gold is also seen as a good standard and store of value that has little vulnerability to systematic risk as opposed to stock (Arfaoui and Rejeb, 2017). Against the above background, investigation of the link between stock and gold is imperative for portfolio allocation and diversification.

The motivation for this study derives from the observed gaps in the literature which need to be filled. Thus, the contributions of this study to the existing body of knowledge in this are discussed in the following. First, our review of literature shows that the gold-stock links have been investigated in virtually all the regions of the world except Africa. African countries such as South Africa and Nigeria should be studied...
because they are among the top five countries in terms of gold reserves and stock market development in Africa. These countries also rank among top 60 countries in the world in terms of gold reserve. Also, South Africa was the world leader in terms of gold production up till 2006, and currently she ranks number seven world producers of gold after China, Australia, Russia, United States, Canada and Peru, while Nigeria is also among the 100 world producers. Although African stock markets are still developing, Nigeria Stock Exchange was ranked by S&P Dow Jones indices as the third-best performing capital market in the world after Argentina and Turkey in 2017. In the same vein, in terms of market capitalization, South Africa’s stock market is among the top 20 world markets. Despite these developments recorded by South Africa and Nigeria, little or no study has been conducted to examine the dependence between gold and stock. The emerging issue is: how and to what extent are stock and gold linked especially in the case of the African countries with the foregoing feature? Empirical analysis of this issue will inform articulation of policy lessons for international portfolio diversification and hedging effectiveness.

Second, review of the existing literature shows that findings on the link between gold and stock market are mixed, both at cross-country and single-country levels, which necessitate further studies. These studies have also employed various methods to explore this relationship, all of which failed to account for the possibility of both own-market and cross-market asymmetric shocks spillovers. The rationale for recognition of these spillover effects is that, apart from exposing the effects of news (good or bad news) in each market on own volatility or risks (own-market spillover), it is possible to reveal how news in one market such as stock market may trigger higher (lower) volatility in the other market such as gold market (cross-market spillover). These effects could be asymmetric (opposite in terms of direction and size) across markets because of the diverse sensitivities of the markets to changes in economic conditions and economic fundamentals across time as well as investment horizons. This analysis is very important to aid portfolio diversification and hedging decisions of international investors especially during turbulent market periods. This present study therefore fills this gap by investigating the link between gold and stock markets among the top Africa’s stock markets, using the recently developed and applied VARMA-BEKK-AGARCH (V-B-A) model by Salisu and Oloko (2015) to analyze oil-stock link. However, unlike Salisu and Oloko (2015), which involves bivariate V-B-A model, we articulated the multivariate version of the model since the gold-stock relationship is complex (being influenced by other variables). Also, we modified the bivariate quantile regression technique earlier applied by Mensi et al. (2014), Reboredo and Ugolini (2016) and Iqbal (2017) by transforming it into a multivariate form to trace the quantile dependence between stock and gold markets across the whole range of quantiles in the presence of control factors or variables. This approach recently applied in the literature is capable of discovering asymmetries and providing rich information concerning the correlation between markets at various conditions. The combination of the two methods is considered worthwhile so as to allow complementary analysis and provide robustness checks. Third, a recently developed unit root test by Narayan and Liu (2015), which has not been applied in this area, is used to analyse structural breaks before examining its effect on our results.

This study therefore examines the dependence between gold and stock markets for South Africa and Nigeria. The rest of this paper is structured as follows; Section 2 presents stylized facts on gold and stock prices; Section 3 provides the literature review, while Section 4 explains the theory and methodology of the study. Section 5 presents and discusses the empirical results, while Section 6 summarises the paper with policy implications.

2. Stylized facts on world gold price and stock prices of South Africa and Nigeria

Stock prices (indexed in US dollars) of Nigeria and South Africa, as well as gold price (per ounce in US dollars), experienced frequent fluctuations between June 2002 and May 2017 (Fig. 1). Gold price rose from US$321 (per ounce) in June 2002 to a peak of about US$1759 (per ounce) after which it fell gradually to a recent minimum of US$1086 (per ounce) in November 2015. Nigeria’s stock price (index) reached a peak of about 380 in March 2008 before it recorded a major decline that lasted for a year as it settled at 96 in March 2009. After some recovery, Nigeria’s stock price witnessed another noticeable downturn in the recent years, especially beginning from mid-2014. In the case of South Africa’s stock price (index), similar trend is observed as Nigeria’s stock price between June 2002 and January 2009, after which the two prices moved in the opposite direction for most part of the remaining period. Meanwhile, unlike Nigeria’s stock market, price shocks appear less pronounced in the South Africa’s stock market.

The major shocks in Nigeria’s stock market coincided with the various episodes of financial and economic downturn. For instance, the period 2008–2009 was associated with economic uncertainty that followed the global financial meltdown with noticeable impact on both stock markets, while the oil price induced economic recession of the 2015–2017 period was observed to have far reaching influence on stock prices in Nigeria. It therefore appears that positive relationship exists between global gold prices and stock prices in both countries prior to the onset of the global financial meltdown rather than after the crisis.

3. Literature review

The dynamic link between gold and stock markets has been widely studied in recent time. Particularly, the role of gold as a hedge or safe haven for stock has been investigated for markets in Europe (Charlot and Marimoutou, 2014; Hoang et al., 2015; Shahzad et al., 2017), Asia (Ziaei, 2012; Kumar, 2014; Mensi et al., 2015; Tiwari and Sahadudheen, 2015; Arouri et al., 2015; Huang et al., 2016; Bouri et al., 2017a; Bouri et al., 2017b) and USA (Mensi et al., 2013; Creti et al., 2013; Hood and Malik, 2013; Akgül et al., 2015; Barunik et al., 2016; Gokmenoglu and Fazlollahi, 2015; Bekiros et al., 2016; Baumöh and Lyócsa, 2017). While considerable efforts have been directed towards comparative analysis of two or more stock markets (Baur and Lucey, 2010; Ciner et al., 2013; Charlot and Marimoutou, 2014; Choudhry et al., 2015; Iqbal, 2017), some attentions of empirical studies have been focused on cross-country analysis (Baur and McDermott, 2010; Ziaei, 2012; Beckmann et al., 2015; Gürgün and Ünalmuş, 2015; Chkilí, 2016; Raza et al., 2016; Basher and Sadorsky, 2016; Shahzad et al., 2017).

Cross-country evidences on the role of gold under different stock market conditions are mixed. A good number of existing studies support the role of gold both as a hedge and a safe haven for stock. For instance, Baur and Lucey (2010) examined the hedge and safe haven properties of gold for stock and bond using quantile regression approach. They found that gold is both a hedge and a safe haven for stocks in the United States and United Kingdom but not in Germany. Similarly, Baur and McDermott (2010) used maximum likelihood approach for the case of G7, BRIC countries, Australia and Switzerland. They found that gold served both as a hedge and a safe haven for stock markets in Europe and the US, but not in Australia, Canada, Japan and the BRIC countries.
Besides, their estimates provide evidence that, during extreme negative market shocks, gold reduced losses, thus moderating the financial system. Using smooth transition regression, Beckmann et al. (2015) reported similar findings, although the role of gold as a hedge and a safe haven is market specific. Gürgün and Ünalmuş (2014) showed that these results are also valid for emerging and developing countries for both domestic and foreign investment in most of these countries both in the pre and post-2008 crisis period.

For emerging countries, Raza et al. (2016) employed nonlinear ARDL approach to analyse gold, oil and stock markets data where gold prices are found to have negative effect on stock prices of Mexico, Malaysia, Thailand, Chile and Indonesia. However, the effect on stock prices of BRICS economies is positive. In the short-run, as well as the long-run, the impact of gold on stock is negative for all emerging economies. In the six GCC stock markets, Mensi et al. (2015) used a vine copula approach and provided evidence that, gold is both a hedge and a safe haven for the GCC stock, with the exception of UAE and Saudi Arabia where it does not serves as a hedge.

Contrary to these findings, some studies revealed that gold only provides a hedge for stock market instability. This is evident in Shahzad et al. (2017) where Quantile-on-quantile (QQ) approach was applied for five developed markets and five Euro-zone countries. Asymmetric DCC model applied by Chkili (2016) suggests that gold acts as a safe haven against abnormal market behaviours, while risk-adjusted return can be enhanced by including gold in the stock portfolio.

Few studies also provided evidence that gold is neither a hedge nor a safe haven for stock market risks. For example, Basher and Sadorsky (2016) employed dynamic conditional correlation (DCC), asymmetric DCC (ADCC) and GO-GARCH for emerging markets and reported that oil, rather than gold and bond, is the best hedge for emerging market stocks. Similar findings were reported by Charlot and Marimoutou (2014) using Regime-Switching Decision Tree.

With respect to country specific studies, in Asia and Europe, including Australia, there seems to be some level of consensus that gold only provides a hedge for stock. This is evident in Kumar (2014) who adopted Generalized VAR-ADCC-BVGARCH model and submitted that, during the periods of market turbulence and crisis, gold is a hedge, while portfolios with only stock are less beneficial than portfolio with a stock-gold mix. Analysing the case of China, Arouri et al. (2015) used VAR-GARCH framework of Ling and McAleer (2003) and found the existence of significant volatility cross-effects between world gold price and Chinese stock. Moreover, they discovered that adding gold asset to a well-diversified portfolio of stocks improved the risk-adjusted performance, which implies that gold could be used to effectively hedge stock risk exposures. Using Johansen cointegration test in the time domain, with discrete and continuous wavelet transform and wavelet coherence, Huang et al. (2016) found that Brent, gold and Chinese stock prices are integrated while their causality are heterogeneous among various frequency bands. In addition, they showed that different frequency components of the stock, crude oil and gold markets interact in diverse manner. For the case of India, Bouri et al. (2017a) analysed the cointegration and nonlinear causality among international gold, crude oil, and stock. Adopting ARDL bounds test and Kyrtou-Labys nonlinear symmetric and asymmetric non-causality test, their results showed evidence of integration of the gold, oil and stock markets. The implied volatilities of gold and oil produce a nonlinear and positive effect on the implied volatility of the Indian stock. The implied volatilities of gold and oil prices have an inverse bi-directional causality.

Stochastic dominance (SD) approach applied by Hoang et al. (2015) shows that, at the second and third orders, French stock portfolios with gold stochastically overweight those without gold. The results also hold during unstable or crisis periods, which suggests that risk-averse investors would maximize their expected returns by including gold in their stock portfolios. However, in the case of bond or risk-free assets for which the portfolios without gold dominate those with gold, these results do not hold. Like those from Paris, portfolios including gold quoted in London show similar results. In the case of Australia, Bekiros et al. (2015) employed dependence matrix estimation using the c-vine, d-vine and r-vine copula models. They found that gold stocks are less risky than the iron ore-nickel stocks during times of financial uncertainty and crisis periods characterized by low or no confidence in the stock markets. They further submitted that gold and iron ore-nickel stocks are a better investment choice when the markets behave normally.

For the U.S. market, findings on the role of gold are mixed. Some studies established that gold only serves as a hedge for stock as evident in Hood and Malik (2013) which focused on the U.S. stock market under changing volatility conditions. Employing correlation and regression models proposed by Baur and McDermott (2010), they proved that gold provides a strong hedge and a weak safe haven for U.S. stock. However, in periods of extremely low or high volatility, there is no evidence of negative correlation of gold prices with the US stock price, whereas, volatility index performs better as a hedging tool and safe haven. Using ARDL bound-test approach, Gokmenoglu and Fazlollahi (2015) showed that gold can act as a substitute for stock. In the short-run, volatilities of oil and gold produced insignificant impact on US stock, while they exerted significant effect in the long-run.

Akgül et al. (2015) applied Markov-Switching Bayesian VAR models and found that, in the pre-crisis and crisis periods, gold price exhibited diminishing response to S&P 500 shocks, reinforcing the role of gold as a hedge for US stock, although the response becomes reversed in the second period (growth period). However, US stock price (S&P index) responded differently to gold price shocks in all regimes. VAR-GARCH estimates of Mensi et al. (2013) showed that previous shocks and volatility of the stock prices have significant effect on the oil and gold markets. The results showed that the overall risk-adjusted return performance improves with the addition of commodities such as gold to a stock-diversified portfolio. In the same vein, Bekiros et al. (2016) adopted wavelet analysis and their results indicated that equity and commodity markets exhibited time-varying co-movement patterns and behaved differently across investment horizons, with time-frequency causality existing between the equity and gold markets. For the same
country, Sadorsky (2014) used multivariate GARCH to confirm that gold and oil produce the biggest conditional correlation, while average hedge ratios and portfolio weights for DJSI are similar to that of SP500 for each of gold and oil. Further, DCC GARCH and wavelet approaches of Barunik et al. (2016) revealed heterogeneity in correlations particularly between gold and stocks, especially during periods of economic downturn and financial turbulence. However, correlations among the three assets rose and became homogenous after the 2008 crisis, although the timing varies for the three pairs.

Other studies conducted for the US found that gold can only provide a safe haven for stock rather than a hedge. These studies include Baumöhl and Lyócsa (2017) who employed Bivariate cross-quantilogram of Han et al. (2016) to show evidence that gold performs as a safe haven only in the healthcare, information technologies and telecommunication services, though safe haven feature of gold is dynamic for the pre- and post-crisis periods. In the same vein, Creti et al. (2013) used the dynamic conditional correlation (DCC) GARCH techniques to reveal that correlations between gold and stock returns are negative, and reduce in periods of declining stock prices, which shows that gold performs the safe-haven function.

A comparative analysis of major markets has also confirmed inconsistent results that dominate the literature. In the UK, US and Japan, nonlinear causality analysis adopted by Choudhry et al. (2015) revealed that, while gold may serve as a safe haven during stable financial conditions, it may not perform well during the financial crisis period. Significant nonlinear feedback effect was reported among gold returns, stock returns and stock market volatility during the financial crisis period for the three countries. However, very limited evidence of significant feedback was found during the pre-crisis period. Based on volatility indices and frequency domain analysis, similar results are reported by Bouri et al. (2017b) where gold provides a safe haven, though this feature is unstable. They also provided evidence that, in both high and low frequencies, there is significant bi-directional causality between gold and the Chinese as well as Indian stocks.

Mensi et al. (2017) used the spillover index of Diebold and Yilmaz (2012) and DECO-FIGARCH model to explain that, except for Japanese market, all the stock markets (USA, Europe and Asia) are contributors to volatility spillovers, while the precious metal markets are net recipients of volatility spillovers, particularly during the crisis periods. Results from Generalized Method of Moment (GMM) employed by Ziaei (2012) suggested that, any negative changes in equity market produce positive effects on gold price, suggesting that gold is a hedge for equity among ASEAN economies and China, Japan, India and Korea.

In contrast to the foregoing results, few studies have provided empirical evidence that gold is neither a hedge nor safe haven. Ciner et al. (2013) could not establish gold either as a hedge or a safe haven for equity or bond in an ARCH and quantile regressions analysis. Similar results were reported by Iqbal (2017) for stock markets of India, Pakistan and the United States using EGARCH and quantile regression methods.

The foregoing shows that findings on the link between gold and stock markets are mixed, both at cross-country and single-country levels, which necessitates further studies. These studies have also employed various methods and techniques to explore this relationship, all of which failed to account for the possibility of both own-market and cross-market shocks asymmetric spillover. It is also observed that the gold-stock nexus have been investigated in virtually all the regions of the world except Africa, both at individual country and multi-country levels. This present study therefore fills these gaps by investigating the link between gold and stock markets in top Africa’s stock markets (Nigeria and South Africa), using the recently developed VARMA-BEKK-AGARCH model and the quantile regression technique. The summary of literature is presented in Table 1.

4. Theory and methodology

The modern theory of optimal asset selection (modern portfolio theory with mean-variance analysis) has its origin in Markowitz (1952) where expected (mean) return and variance (risk) of return on the entire portfolio are criteria for portfolio selection. This means that the expected return on the portfolio is a weighted average of the expected returns on individual securities and the variance of return on the portfolio depends on the variances of, and the covariances between, securities and their weights in the portfolio. It implies that the investments in a financial asset (such as stock) should be based on their correlation to other alternative assets (such as bond or gold) so as to diversify the asset portfolio and minimize risk (Markowitz, 1952, 1959, 1987, 1999). A refinement of this theory led to the development of the capital asset pricing model (CAPM), which predicts a linear relationship between the expected rate of return on an asset and risk associated with the asset. The expected rate of return on a risky asset is the sum of the expected rate of return on assets that are uncorrelated with the market, and a premium for the risk that the investor has to tolerate as a result of holding asset.

Analysis of the international dimension of portfolio diversification results in the expansion of the CAPM into international capital asset pricing model (ICAPM) where international market risk factors are incorporated into the return-risk (mean-variance) framework for optimal assets selection, allocation and portfolio diversification (Guesmi and Nguyen, 2014). With this framework, investors can shift their funds from domestic assets such as stocks to international assets such as gold during the collapse of the stock market prices (returns) following poor performance of an economy (or global economic crisis) until economic performance improves. Hence, when economic activities crumple, stock markets seem less attractive, and the exchange rates become unfavourable, gold is regarded as a good investment option (hedge or safe haven) to the investors (Arfaoui, and Rejeb, 2017). Therefore return on gold (which drives demand for gold) is a function of return on alternative investment such as stock, oil and bond as well as the global risk factor (Mensi et al., 2014, 2015; Basheer and Sadorsky, 2016 and Raza et al., 2016). Thus, mean-variance analysis in the international context appear to be a suitable method for estimating the expected (mean) return and risk (variance) associated with gold and stock and analyse their relationship. This framework therefore forms the basis for the development and application of the methodology of this study, which is a combination of a multivariate version of the V-B-A and Quantile regression models.

4.1. Description and specification of multivariate VARMA-BEKK-AGARCH model

This study develops a multivariate version of the VARMA-BEKK-AGARCH model articulated and applied by Salisu and Oloko (2015) to analyse oil-stock link. Following Salisu and Oloko (2015), the VARMA-BEKK-AGARCH model is estimated within the BEKK framework in order to account for both own-market and cross-market asymmetric effects. The rationale behind the adoption of the BEKK framework against the other variants of VARMA-AGARCH models (DCC and CCC) is that the BEKK variant can reveal whether a positive or negative shock in one market will lead to either a positive or negative shock in another market (cross-market asymmetric effect). The VARMA-BEKK-AGARCH model consists of both mean and variance equations. The mean equation is specified in a vector autoregressive moving average (VARMA) form, while the specification of the conditional variance equation follows multivariate asymmetric generalized conditional heteroscedasticity (AGARCH) process. Furthermore, the model is modified to account for structural breaks endogenously using general structure for analysing unit roots with structural break proposed by Perron (2006) and Narayan and Liu (2015).
Table 1

Summary of literature on gold price-stock return link.

<table>
<thead>
<tr>
<th>S/N</th>
<th>Author and year</th>
<th>Country and scope</th>
<th>Methodology</th>
<th>Major findings</th>
</tr>
</thead>
</table>
| 1   | Arour et al. (2015) | China: March 22, 2004 to March 31, 2011 | The MSCI China Index; 3-month gold future prices(traded at COMEX (Commodity Exchange) in New York) | The correlations between gold and stock returns are mostly positive. Although all precious metals responded to the same shocks, the impact of Gold and oil on stock prices there was also found in the post-2008 crisis period. Gold can be regarded as a safe haven only in the Healthcare, IT, and Telecommunications services. However, results for the pre-crisis period and the long-run show that gold have no dynamic effects. Gold and stock returns are mostly negatively and reduce in periods of declining stock prices. Although marketspecific, gold plays the role of both a hedge and a safe haven.
| 2   | Beckmann et al. (2015) | US; January 2001 to November 2011 | S&P500 index; Commodity Research Bureau (CRB) index | The correlations between gold and stock returns are mostly negative and reduce in periods of declining stock prices. Although marketspecific, gold plays the role of both a hedge and a safe haven.
| 3   | Baumberg and Sayasere (2017) | India; 02-June-1999–30-June-2012 | Gold prices and six Indian industrial sectoral indices | The correlations between gold and stock returns are mostly positive. Although all precious metals responded to the same shocks, the impact of Gold and oil on stock prices there was also found in the post-2008 crisis period. Gold can be regarded as a safe haven only in the Healthcare, IT, and Telecommunications services. However, results for the pre-crisis period and the long-run show that gold have no dynamic effects. Gold and stock returns are mostly negatively and reduce in periods of declining stock prices. Although marketspecific, gold plays the role of both a hedge and a safe haven.
| 4   | Huang et al. (2016) | China: January 1991 to September 2014 | The daily Brent oil prices, London gold fixing price; Spot prices of the gold and US industry stock market indices (MSCI) | The correlations between gold and stock returns are mostly positive. Although all precious metals responded to the same shocks, the impact of Gold and oil on stock prices there was also found in the post-2008 crisis period. Gold can be regarded as a safe haven only in the Healthcare, IT, and Telecommunications services. However, results for the pre-crisis period and the long-run show that gold have no dynamic effects. Gold and stock returns are mostly negatively and reduce in periods of declining stock prices. Although marketspecific, gold plays the role of both a hedge and a safe haven.

Note: The table continues on the next page.
<table>
<thead>
<tr>
<th>S/N</th>
<th>Author and year</th>
<th>Country and scope</th>
<th>Methodology</th>
<th>Estimation method</th>
<th>Major findings</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sadorsky (2014)</td>
<td>US: Weekly data from December 31, 1998 to May 31, 2012</td>
<td>Price index of socially responsible companies, oil prices, and gold prices</td>
<td>DiAG; CCC; DCC M-GARCH;</td>
<td>Gold and Oil produce the biggest conditional correlation, while DJI. Average hedge ratios and portfolio weights for DJI are similar to average hedge ratios of SP500 for each of gold or oil.</td>
</tr>
<tr>
<td></td>
<td>Bekiros et al. (2015)</td>
<td>Australia daily series from January 2005 to July 2012</td>
<td>20 gold and 20 iron ore-nickel stock return</td>
<td>Dependence matrix estimation using the c-vine, d-vine and r-vine copula models</td>
<td>Gold stocks are less risky than the iron ore-nickel stocks during times of financial uncertainty and crisis periods characterized by low or no confidence in the stock markets.</td>
</tr>
<tr>
<td></td>
<td>Bekiros et al. (2016)</td>
<td>US: January 1990 and October 2013.</td>
<td>Prices of oil products, precious metals, &amp; agric products and S&amp;P 500 index.</td>
<td>Wavelets analysis</td>
<td>Previous shocks and volatility of the S&amp;P 500 have significant effect on the oil and gold markets. Overall risk-adjusted return performance improves with the addition of commodities such as gold to a stock-diversified portfolio.</td>
</tr>
<tr>
<td></td>
<td>Gokmenoglu and Fazollahi (2015)</td>
<td>US; daily prices and indexes from January 2013 to November 2014</td>
<td>Gold price, oil price, gold price volatility (GVZ) and oil price volatility (OVX) &amp; US S&amp;P500</td>
<td>ARDL bound-test approach</td>
<td>Gold price has the highest effect on US stock market price in long-run and short-run. Thus, gold can act as a substitute for stock.</td>
</tr>
<tr>
<td></td>
<td>Bouri et al. (2017)</td>
<td>India; daily closing price from June 2009 to May 2016</td>
<td>GVZ, crude oil volatility index (OVX), and the volatility index for the NIFTY Indian stock market</td>
<td>ARDL bounds test; Kyrtos-Labys nonlinear symmetric and asymmetric noncausality test</td>
<td>There is integration of the gold, oil and stock markets. The implied volatilities of gold and oil produce a nonlinear and positive effect on the implied volatility of the Indian stock market.</td>
</tr>
<tr>
<td></td>
<td>Hood and Malik (2013)</td>
<td>US stock market; Daily data from November 1995 to November 2010</td>
<td>Daily closing spot prices for gold, silver, platinum, the S&amp;P 500 Index, and VIX.</td>
<td>Correlation and regression model proposed by Baur and McDermott (2010)</td>
<td>Gold provides a hedge and a weak safe haven for US stock market. Gold does not have a negative correlation with the US stock market in periods of extremely low or high volatility.</td>
</tr>
<tr>
<td></td>
<td>Mensi et al. (2017)</td>
<td>USA, Japan, Europe and Asia; Precious metal markets; January 4, 2000, to May 5, 2016</td>
<td>S&amp;P 500 index, STXX 600 index, TSX index, Nikkei 225 index, &amp; DJASIA index) &amp; precious Metal prices.</td>
<td>multivariate DECO-FGARCH model &amp; Spillover index framework</td>
<td>There is evidence of volatility spillovers between stock and precious metal markets. Overall risk-adjusted return performance could be improved by including precious metals in stock-diversified portfolio.</td>
</tr>
<tr>
<td></td>
<td>Choudhry et al. (2015)</td>
<td>UK (FTSE 100), the US (S&amp;P 500) and Japan (NIKKI 225); Daily data Jan. 2000 to Mar2014</td>
<td>Gold returns based on the UK pound, the US dollar and the Japanese yen; FTSE100, S&amp;P 500 and Nikkei 225</td>
<td>Nonlinear Granger causality (Hemstra and Jones, 1994; Bai et al., 2010)</td>
<td>During the financial crisis period, gold may not perform well as a safe haven, while it may during stable financial conditions.</td>
</tr>
<tr>
<td></td>
<td>Iqbal (2017)</td>
<td>India, Pakistan and the United States:</td>
<td>World index; Stock indexes &amp; Gold price</td>
<td>EGARCH and quantile regression approach</td>
<td>The evidence of gold hedging stock market risk is not uniformly strong in varying gold market conditions.</td>
</tr>
<tr>
<td></td>
<td>Baur and McDermott (2010)</td>
<td>(G7), (BRIC countries) and Australia and Switzerland; March 2, 1979 until March 2, 2009</td>
<td>Gold returns based on the UK pound, the US dollar and the Japanese yen; FTSE100, S&amp;P 500 and Nikkei 225</td>
<td>Econometric approach</td>
<td>Gold is both a hedge and a safe haven for big stock markets in Europe and the US, while it is not for Australia, Canada, Japan and the BRIC countries.</td>
</tr>
<tr>
<td></td>
<td>Bouri et al. (2017)</td>
<td>China and India; March 16, 2011 to March 16, 2017</td>
<td>Implied volatility index of gold, Chinese equities, and Indian equities</td>
<td>Frequency domain analysis</td>
<td>In both high and low frequencies, there is significant bi-directional causality between gold and the Chinese as well as Indian stock markets. Thus, the safe-haven feature of gold is unstable.</td>
</tr>
</tbody>
</table>
### 4.1.1. Conditional mean equation

The mean equation for the gold-stock link is specified along with the control variables derived from theoretical discussion above. Thus, the multivariate form of VARMA of the mean equation can be stated as:

\[
R_t = \pi + \phi R_{t-1} + \mu B_t + \epsilon_t + Z\varepsilon_{t-1}
\]

Where: \( \pi = D a_0 \)

\[ R_t = (r_{gold}, r_{stock}, r^{oil}, r^{spx\ volatility\ index}) \]

\( r_{stock} \) is the returns on the stock of either Nigeria or South Africa and \( r^{Gold} \) is the returns on gold; \( r^{oil} \) is the returns on oil and \( r^{spx\ volatility\ index} \) is return or change in SPX volatility index.

\( \pi \) is a 4 \times 1 vector of constant terms of the form:

\[
\begin{pmatrix}
\pi_{gold} \\
\pi_{stock} \\
\pi_{oil} \\
\pi_{spx\ volatility\ index}
\end{pmatrix}
\]

\[ \Phi \]

\[
\begin{pmatrix}
\mu_{11} & \mu_{12} \\
\mu_{21} & \mu_{22} \\
\mu_{31} & \mu_{32} \\
\mu_{41} & \mu_{42}
\end{pmatrix}
\]

and \( B_t = [b_{gold}, b_{stock}] \) where \( b_t = 1 \) if \( t \geq \) Break Date;

\[ \epsilon_t = (\epsilon_{gold}, \epsilon_{stock}, \epsilon_{oil}, \epsilon^{spx\ volatility\ index}) \]

with \( \epsilon_{stock} \) being error term from the mean equation of Nigeria’s stock or South Africa’s stock, \( \epsilon^{gold}, \epsilon^{oil}, \epsilon^{spx\ volatility\ index} \) are error terms from the mean equations of gold, oil and SPX volatility index respectively.

\( Z \) is a 4 \times 2 matrix of the coefficients of the lagged residuals in the form,

\[
\begin{pmatrix}
\lambda_{11} & \lambda_{12} \\
\lambda_{21} & \lambda_{22} \\
\lambda_{31} & \lambda_{32} \\
\lambda_{41} & \lambda_{42}
\end{pmatrix}
\]

which explains shock spillovers from stock and gold.

\[ D_t = \text{diag}(\sqrt{h_{r,\text{gold}}^t}, \sqrt{h_{r,\text{stock}}^t}, \sqrt{h_{r,\text{oil}}^t}, \sqrt{h_{r,\text{spx\ volatility\ index}}}) \]

\[ \Omega = \text{diag}(\gamma_{gold}, \gamma_{stock}, \gamma_{oil}, \gamma^{spx\ volatility\ index}) \]

\( h_{r,\text{gold}}, h_{r,\text{stock}}, h_{r,\text{oil}}, h_{r,\text{spx\ volatility\ index}} \) being the conditional variances of \( r^{gold}, r^{stock}, r^{oil}, \) and \( r^{spx\ volatility\ index} \) respectively.

\( \gamma_{r} \) refers to a 4 \times 1 vector of independently and identically distributed errors of the form:

\[
\begin{pmatrix}
\gamma_{gold} \\
\gamma_{stock} \\
\gamma_{oil} \\
\gamma^{spx\ volatility\ index}
\end{pmatrix}
\]

### 4.1.2. Conditional variance equation for VARMA-BEKK-AGARCH model

The conditional variance equation is given as follows:

\[
H_t = \Omega \Omega + \text{diag}(\gamma_{gold}, \gamma_{stock}, \gamma_{oil}, \gamma^{spx\ volatility\ index}) A H_{t-1} B + \text{diag}(\gamma_{gold}, \gamma_{stock}, \gamma_{oil}, \gamma^{spx\ volatility\ index}) C H_{t-1} \Omega
\]

Where \( A, B \) and \( C \) are square matrices and \( \Omega \) is a lower triangular matrix expressed as follows:

\[
A = \begin{pmatrix}
a_{11} & a_{12} & a_{13} & a_{14} \\
a_{21} & a_{22} & a_{23} & a_{24} \\
a_{31} & a_{32} & a_{33} & a_{34} \\
a_{41} & a_{42} & a_{43} & a_{44}
\end{pmatrix}
\]

\[
B = \begin{pmatrix}
b_{11} & b_{12} & b_{13} & b_{14} \\
b_{21} & b_{22} & b_{23} & b_{24} \\
b_{31} & b_{32} & b_{33} & b_{34} \\
b_{41} & b_{42} & b_{43} & b_{44}
\end{pmatrix}
\]

\[
C = \begin{pmatrix}
c_{11} & c_{12} & c_{13} & c_{14} \\
c_{21} & c_{22} & c_{23} & c_{24} \\
c_{31} & c_{32} & c_{33} & c_{34} \\
c_{41} & c_{42} & c_{43} & c_{44}
\end{pmatrix}
\]

\[ \Omega = \begin{pmatrix}
\Omega_{11} & 0 & 0 & 0 \\
\Omega_{21} & \Omega_{22} & 0 & 0 \\
\Omega_{31} & \Omega_{32} & \Omega_{33} & 0 \\
\Omega_{41} & \Omega_{42} & \Omega_{43} & \Omega_{44}
\end{pmatrix}
\]
Considering the conditional variance equation, it was noted by Salisu and Oloko (2015) that, due to the quadratic form of the conditional variance and co-variance matrices in the BEKK model, there is difficulty in providing a direct explanation of the estimated coefficients. Matrix A contains the coefficients of ARCH terms, which indicate the effects of short-term shocks spillover within and across markets. Similarly, matrix B consists of the coefficients of GARCH terms, which reflect the effect of long-term shock spillover within and across markets. Furthermore, matrix C contains coefficients that represent own-market and cross-market asymmetric effects, with those along the diagonal of the matrix indicating significance of own-market asymmetric effect, while those away from the diagonal reflecting significance of cross-market asymmetric effect. The rational for capturing asymmetric effect is to distinguish the potential differential impact of negative and positive shocks on the conditional volatility of a market. This idea that negative and positive shocks have differential effect on the conditional variance is captured by \( I_{(t)} = \text{diag}(I_{\text{stock}}, I_{\text{gold}}, I_{\text{crude}}, I_{\text{SPX volatility index}}) \) which is expressed as a function of independently and identically distributed error-term as follows:

\[
I_{(t)} = \begin{cases} 
0 \text{ if market at time } t \\
1 \text{ if market at time } t 
\end{cases}
\]

The minimum values of Akaike Information Criterion (AIC) and Schwartz Bayesian Criterion (SBC) are used to determine goodness of fit of the models. Similarly, in order to test for autocorrelation and ARCH effects, the Ljung-Box and McLeod-Li statistics are estimated, (with the null hypothesis of no autocorrelation for Ljung statistic and a null hypothesis of no Arch effect for McLeod-Li statistics). The null hypotheses of both the Ljung-Box and McLeod-Li statistics are not expected to be rejected for a robust model to be obtained.

In order to test for the stationarity and determine the significance of structural break in the return series, the frameworks provided by Perron (2006) and Narayan and Liu (2015) are employed. These frameworks are appropriate for ascertaining structural break endogenously from the dataset (Salisu and Oloko, 2015; and Salisu and Adeleke, 2016). The generalized regression for conducting the Perron (2006) unit root test can be written as follows;

\[
\begin{align*}
\gamma_{t} &= \mu \, + \, D_{T_{1}} \, U_{t} \, + \, \beta_{1} \, r_{T_{1}, t} \, + \, \beta_{2} \, D_{T_{1}} \, r_{T_{1}, t} \, + \, \varepsilon_{t} \\
&\quad + \sum_{i=1}^{c} \Delta \varepsilon_{t-i} \, + \, \varepsilon_{t-1} \quad \text{i.i.d.} \quad (0, \sigma_{\varepsilon}^{2})
\end{align*}
\]

Where D \( T_{1} = 1; \) D \( T_{1}^{*} = t - T_{1} \) if \( t \geq T_{1} \) and 0 otherwise; \( D_{T_{1}} = 1 \) if \( t = T_{1} \) and 0 otherwise. The procedure for the test is to compare the minimal value of the t-statistic for testing that \( \alpha = 1 \) against the alternative hypothesis that \( |\alpha| < 1 \) over all possible break dates in some pre-specified range for the break fraction \( \{c, 1-c\} \). The test regression is implemented following the Innovative Outlier (IO) framework which permits the adjustment to the new trend function to be gradual rather than being instantaneous as in the case of the Additive Outlier (AO) framework. The framework for conducting Narayan and Liu (NL) unit root test can be found in Narayan and Liu (2015) and Salisu and Adeleke (2016). Congruent upon the significance of the structural break in the return series, the mean equations of the multivariate GARCH model are modified by including dummy variables which capture the break dates identified in the foregoing.

4.2. Description and specification of the Quantile regression model

As opposed to the Ordinary Least Squares (OLS) regression which provide average estimate of the relationship between two variables, the Quantile regression (QR) approach developed by Koenker and Basset (1978), is a form of regression that describes the relationship between a set of regressors and the outcome variable at different points (lower, middle and higher quantiles or bearish and bullish conditions) in the conditional distribution of the outcome variable (Baur and Lucey, 2010; Mensi et al., 2014; and Iqbal, 2017). In line with Iqbal (2017), a random variable \( Y \) with probability distribution function \( F(y) = P(Y \leq y) \), the \( \tau \)th conditional quantile of \( Y \) given \( X = x \) is defined as the following inverse function:

\[
Q_{\tau}(y | x) = \{y : F(y | x) \geq \tau \}, 0 < \tau < 1.
\]

The ordinary least squares (OLS) is the conditional mean as a function of a number of variables defined as \( E(Y | x) = x^{\beta} \). However, quantile regression is specified as \( Q_{\tau}(y | x) = x^{\beta}() \), where \( \beta() \) is the vector of coefficients associated with variable \( x \) for the \( \tau \)th quantile.

Thus, the empirical models (OLS and QR regressions) capturing the effect of South Africa’s (or Nigeria’s) stock returns on gold returns, are specified with control variables (traceable to the theoretical discussion) as follows:

\[
R_{G, t} = \beta_0 + \beta_1 R_{stock, t-1} + \beta_2 R_{stock} + \beta_3 R_{crude} + \beta_4 R_{SPX volatility index} + \beta_5 R_{bond} + \epsilon_t
\]

(6)

\[
\eta_{\tau}(R_{stock}) = \eta_0 + \eta_1 R_{stock, t-1} + \eta_2 R_{stock} + \eta_3 R_{crude} + \eta_4 R_{SPX volatility index} + \epsilon_t
\]

(7)

Eq. (6) is the OLS regression model, while Eq. (7) is the quantile regression model. \( R_{G, t} \) is the returns on gold, \( R_{stock} \) is the returns on either South Africa’s or Nigeria’s stock, \( R_{bond} \) is the returns on oil, \( R_{SPX volatility index} \) is the returns on (or change in) SPX volatility index, \( R_{bond} \) is returns on either South Africa’s or Nigeria’s bond and \( \eta() \) is conditional quantile function of gold returns evaluated at \( \tau \in (0,1) \).

Furthermore, to ascertain the hedging or safe haven property of gold in terms of stock, the study develops a multivariate version of the Iqbal (2017)’s quantile regression model which is based on Baur and Lucey (2010) and Mensi et al. (2014) approaches. The following Eq. (8) is specified for hedging or safe haven property of gold in terms of either South Africa’s or Nigeria’s stock.

\[
Q_{\tau}(G/R_{Stock}) = \lambda_0 + \lambda_1 r_{stock} + \lambda_2 r_{stock} x + D(r_{stock} q10\%) + \lambda_3 r_{stock} x + D(r_{stock} q5\%) + \lambda_4 r_{stock} x + \lambda_5 r_{crude} + \lambda_6 r_{SPX volatility index} + \epsilon_t
\]

(8)

In Eq. (8), \( Q_{\tau}(G/R_{stock}) \) is the conditional quantile of gold returns and D \( (r_{stock} q10\%), D(r_{stock} q5\%), D(r_{stock} q1\%) \) represent the dummy variables that assume value 1 if South Africa’s stock return (or Nigeria’s stock return) is below the respective quantiles and zero elsewhere. A significantly negative \( \lambda_3 \) coefficient indicates that gold is a hedge for stock at the specified quantile. Sum of coefficients \( \lambda_1, \lambda_2, \lambda_3 \) and \( \lambda_4 \) is used to indicate the safe haven property of gold when stock market experiences the lowest 1% returns. If the sum of \( \lambda_1, \lambda_2, \lambda_3 \) and \( \lambda_4 \) is less than or equal to zero, then gold acts as a safe haven against stock at the 1% quantile. Sum of \( \lambda_3 \) through \( \lambda_7 \) indicates the safe haven property at 5% quantile, and sum of \( \lambda_1 \) and \( \lambda_2 \) indicates safe haven property at 10% quantile.

4.3. Variables description and sources of data

Since the high frequency stock data available on consistent basis over the study period for South Africa and Nigeria is monthly, then world gold price and the selected countries’ stock market indices which ranged from June 2002 to May 2017 were obtained from the World Bank database (Global Economic Monitor-GEM). Oil price data was obtained from Federal Reserve economic data (Federal Reserve Bank of St. Louis: https://fred.stlouisfed.org), while data on government bond and SPX (CBOE) volatility index were gathered from International Financial Statistics (IFS). The stock and gold returns were calculated from monthly time series of indices of stocks (South Africa and Nigeria) and gold price. The proxy for South Africa’s and Nigeria’s stock prices is

\footnote{Available daily data for these countries is inadequate for a robust analysis.}
The returns on stocks and gold were calculated using the formula;

\[ R = \ln \left( \frac{p_t}{p_{t-1}} \right) \]

where \( p_t \) is stock or gold price of present month while \( p_{t-1} \) represents stock or gold price of previous month.

5. Empirical results and discussions

5.1. Test of unit root with structural break and descriptive statistics

Results of the unit root test presented in Tables 2a and 2b show evidence of non-stationarity of the stock and gold price series. Meanwhile, the GARCH based unit root test in Table 2b reveals the presence of both ARCH and GARCH effects in all the series, justifying why it is germane to adopt a GARCH based model (VARMA-BEKK-AGARCH) for empirical analysis. Thus, when estimating the models, it is necessary to use the series in their differenced form (return form). Also, the results of the unit root tests reveal existence of structural breaks in the series (with the identified break dates).

Moreover, the result of the Narayan and Liu (2015) unit root test reinforced the significance of the structural break dates identified by the Perron (2006) unit root test. Based on the identification of the presence of structural breaks, it is pertinent to account for them in the methodologies (VARMA-BEKK-AGARCH and Quantile Regression) adopted in this study in order to ascertain their influence on the results.

The trends of the return series of the stock markets of the two countries and gold, as well as other control variables, are shown in Fig. 2a to c. All the return series show a large margin between the minimum and maximum values, suggesting the existence of a large variance (Table 2c). Based on the standard deviation, Nigeria's stock has the highest, followed by South Africa's stock and then gold. The high returns and risk associated with Nigeria's and South Africa's stock markets is a major characteristic of stock markets of developing economies. Furthermore, all the return series are negatively skewed, implying that there is a high tendency of the occurrence of extreme negative returns compared to extreme positive returns. Meanwhile, the kurtosis statistics reveal that all the return series (stocks and gold) are high peaked and fat tailed (leptokurtic), while the Jarque-Bera statistics rejects the null hypothesis of normality for stock returns of Nigeria and South Africa.

5.2. Results of the VARMA-BEKK-AGARCH MODEL

The estimated results of the VARMA-BEKK-AGARCH model reported in Table 3 show that there is returns spillover within the gold market and stock market of Nigeria with or without accounting for structural breaks. However, such spillover exists in South Africa's stock

\[ R_t = 100 \times \ln \left( \frac{p_t}{p_{t-1}} \right) \]

Note: Critical values are −5.28 and −4.62 for 1% and 5% levels of significance respectively.

Nigeria Stock Exchange (NSE) all share price index (NSEASI), and Johannesburg Stock Exchange (JSE) all share index (JSEALSHI) respectively, while gold price was measured in ounce per dollars. The returns on stocks and gold were calculated using the formula;

\[ R = \ln \left( \frac{p_t}{p_{t-1}} \right) \]

where \( p_t \) is stock or gold price of present month while \( p_{t-1} \) represents stock or gold price of previous month.

5. Empirical results and discussions

5.1. Test of unit root with structural break and descriptive statistics

Results of the unit root test presented in Tables 2a and 2b show evidence of non-stationarity of the stock and gold price series. Meanwhile, the GARCH based unit root test in Table 2b reveals the presence of both ARCH and GARCH effects in all the series, justifying why it is germane to adopt a GARCH based model (VARMA-BEKK-AGARCH) for empirical analysis. Thus, when estimating the models, it is necessary to use the series in their differenced form (return form). Also, the results of the unit root tests reveal existence of structural breaks in the series (with the identified break dates).

Moreover, the result of the Narayan and Liu (2015) unit root test reinforced the significance of the structural break dates identified by the Perron (2006) unit root test. Based on the identification of the presence of structural breaks, it is pertinent to account for them in the methodologies (VARMA-BEKK-AGARCH and Quantile Regression) adopted in this study in order to ascertain their influence on the results.

The trends of the return series of the stock markets of the two countries and gold, as well as other control variables, are shown in Fig. 2a to c. All the return series show a large margin between the minimum and maximum values, suggesting the existence of a large variance (Table 2c). Based on the standard deviation, Nigeria’s stock has the highest, followed by South Africa’s stock and then gold. The high returns and risk associated with Nigeria’s and South Africa’s stock markets is a major characteristic of stock markets of developing economies. Furthermore, all the return series are negatively skewed, implying that there is a high tendency of the occurrence of extreme negative returns compared to extreme positive returns. Meanwhile, the kurtosis statistics reveal that all the return series (stocks and gold) are high peaked and fat tailed (leptokurtic), while the Jarque-Bera statistics rejects the null hypothesis of normality for stock returns of Nigeria and South Africa.

5.2. Results of the VARMA-BEKK-AGARCH MODEL

The estimated results of the VARMA-BEKK-AGARCH model reported in Table 3 show that there is returns spillover within the gold market and stock market of Nigeria with or without accounting for structural breaks. However, such spillover exists in South Africa’s stock

\[ R_t = 100 \times \ln \left( \frac{p_t}{p_{t-1}} \right) \]

Table 2a
Results for unit root with structural break (with Perron, 2006).

<table>
<thead>
<tr>
<th>Variables</th>
<th>Break dates</th>
<th>T-statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gold price</td>
<td>01/07/2011</td>
<td>−12.6759</td>
</tr>
<tr>
<td>Nigeria stock index</td>
<td>01/11/2008</td>
<td>−8.33084</td>
</tr>
<tr>
<td>South Africa stock index</td>
<td>01/09/2008</td>
<td>−12.3950</td>
</tr>
<tr>
<td>Oil price</td>
<td>01/10/2008</td>
<td>−16.6940</td>
</tr>
<tr>
<td>SPX volatility index</td>
<td>01/10/2008</td>
<td>−17.3237</td>
</tr>
<tr>
<td>Treasury bill for Nigeria</td>
<td>01/10/2005</td>
<td>−11.8366</td>
</tr>
<tr>
<td>Treasury bill for South Africa</td>
<td>01/05/2008</td>
<td>−8.9540</td>
</tr>
</tbody>
</table>

Note: Critical values are −5.28 and −4.62 for 1% and 5% levels of significance respectively.

Table 2b
GARCH based unit root test with trend and two structural breaks (with Narayan and Liu (2015)).

<table>
<thead>
<tr>
<th>Variable</th>
<th>Constant</th>
<th>Lagged value of variable</th>
<th>D1 (Dummy for break 1)</th>
<th>D2 (Dummy for break 2)</th>
<th>TREND</th>
<th>C</th>
<th>A(ARCH effect)</th>
<th>B(GARCH effect)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gold price</td>
<td>1.729*** (1.214)</td>
<td>0.064 (0.048)</td>
<td>−28.867*** (12.013)</td>
<td>0.277*** (0.107)</td>
<td>19.875 (18.248)</td>
<td>0.337*** (0.105)</td>
<td>0.724*** (0.069)</td>
<td></td>
</tr>
<tr>
<td>Nigeria stock index</td>
<td>0.235 (1.475)</td>
<td>0.018*** (0.009)</td>
<td>−11.486** (2.920)</td>
<td>8.885 (12.016)</td>
<td>0.002 (0.019)</td>
<td>11.013** (4.662)</td>
<td>0.564*** (0.161)</td>
<td></td>
</tr>
<tr>
<td>South Africa stock index</td>
<td>2.783*** (0.818)</td>
<td>−0.059** (0.020)</td>
<td>2.914** (1.214)</td>
<td>−0.961 (1.304)</td>
<td>0.015 (0.013)</td>
<td>0.719 (0.585)</td>
<td>0.340*** (0.119)</td>
<td></td>
</tr>
<tr>
<td>Oil price</td>
<td>1.760*** (1.017)</td>
<td>−0.023*** (0.014)</td>
<td>1.701 (1.521)</td>
<td>1.091 (1.521)</td>
<td>0.014 (0.016)</td>
<td>7.491** (2.036)</td>
<td>0.416*** (0.184)</td>
<td></td>
</tr>
<tr>
<td>SPX index</td>
<td>2.483** (1.259)</td>
<td>−0.165*** (0.053)</td>
<td>−0.929 (1.139)</td>
<td>−1.181 (1.494)</td>
<td>0.014 (0.016)</td>
<td>7.491** (2.036)</td>
<td>0.416*** (0.184)</td>
<td></td>
</tr>
<tr>
<td>Treasury bill for Nigeria</td>
<td>0.626*** (0.339)</td>
<td>−0.059 (−0.059)</td>
<td>−0.133 (0.321)</td>
<td>0.021 (0.270)</td>
<td>0.0002 (0.003)</td>
<td>0.212* (0.074)</td>
<td>0.863* (0.001)</td>
<td></td>
</tr>
<tr>
<td>Treasury bill for South Africa</td>
<td>0.280* (0.074)</td>
<td>−0.060* (0.010)</td>
<td>−0.014 (0.034)</td>
<td>−0.326* (0.052)</td>
<td>0.003 (0.001)</td>
<td>0.587** (0.310)</td>
<td>0.454** (0.233)</td>
<td></td>
</tr>
</tbody>
</table>


Note: *, ** and *** represent 1%, 5% and 10% respectively. Figures in parenthesis are standard errors.

Full results that include control variables (oil price and SPX volatility index) can be produced upon request.
market only when structural break is not accounted for. This implies that past gold returns influence its present returns, while past stock returns also influence its present returns in both Nigeria’s and South Africa’s stock markets. Moreover, while there is evidence of cross-market return spillover from gold market to South Africa’s stock market, no such spillover is found in the case of Nigeria, regardless of structural break. Also, cross-market return spillover from stock market to gold market is observed only in South Africa, although with

Table 2c
Descriptive statistics.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>SPX</td>
<td>19.61</td>
<td>16.91</td>
<td>59.89</td>
<td>10.41</td>
<td>8.46</td>
<td>1.91</td>
<td>7.5</td>
<td>261.32</td>
<td>0</td>
<td>3529.63</td>
<td>3529.63</td>
<td>180</td>
</tr>
<tr>
<td>OP</td>
<td>70.9</td>
<td>64.74</td>
<td>133.87</td>
<td>24.13</td>
<td>30.08</td>
<td>0.24</td>
<td>1.81</td>
<td>1239</td>
<td>0</td>
<td>12762.4</td>
<td>161966.11</td>
<td>180</td>
</tr>
<tr>
<td>TBN</td>
<td>9.87</td>
<td>9.95</td>
<td>20.72</td>
<td>1.04</td>
<td>4.06</td>
<td>−0.17</td>
<td>2.27</td>
<td>48</td>
<td>0.09</td>
<td>1777.37</td>
<td>29477.18</td>
<td>180</td>
</tr>
<tr>
<td>RSPX</td>
<td>−0.5</td>
<td>−1.65</td>
<td>85.26</td>
<td>−48.6</td>
<td>19.95</td>
<td>0.61</td>
<td>4.64</td>
<td>317.17</td>
<td>0</td>
<td>−89.2</td>
<td>70874.22</td>
<td>179</td>
</tr>
<tr>
<td>ROP</td>
<td>0.47</td>
<td>1.42</td>
<td>18.66</td>
<td>−31.35</td>
<td>8.97</td>
<td>−0.91</td>
<td>4.29</td>
<td>57.14</td>
<td>0</td>
<td>74.59</td>
<td>14310.34</td>
<td>179</td>
</tr>
<tr>
<td>RTBN</td>
<td>−0.2391</td>
<td>−0.345</td>
<td>117.8341</td>
<td>−80.664</td>
<td>19.973</td>
<td>0.91081</td>
<td>13.513</td>
<td>849.106</td>
<td>0</td>
<td>−42.815</td>
<td>71009.34</td>
<td>179</td>
</tr>
<tr>
<td>RTBS</td>
<td>−0.24</td>
<td>0</td>
<td>7.45</td>
<td>14.51</td>
<td>3.15</td>
<td>−1.23</td>
<td>7.16</td>
<td>174.31</td>
<td>0</td>
<td>−43.16</td>
<td>1768.34</td>
<td>179</td>
</tr>
<tr>
<td>TBS</td>
<td>7.44</td>
<td>7.06</td>
<td>12.74</td>
<td>4.93</td>
<td>2.06</td>
<td>1.01</td>
<td>3.12</td>
<td>3078</td>
<td>0</td>
<td>1339.02</td>
<td>76049.18</td>
<td>180</td>
</tr>
<tr>
<td>GOLD</td>
<td>974.23</td>
<td>1081.09</td>
<td>1772.14</td>
<td>310.26</td>
<td>436.416</td>
<td>−0.01</td>
<td>1.78</td>
<td>11.08</td>
<td>0.003</td>
<td>175360.9</td>
<td>34092151</td>
<td>3965.64</td>
</tr>
<tr>
<td>NG</td>
<td>134.39</td>
<td>115.13</td>
<td>379.72</td>
<td>55.003</td>
<td>68.24</td>
<td>1.73</td>
<td>5.73</td>
<td>146</td>
<td>0</td>
<td>24190.21</td>
<td>833666.1</td>
<td>3240.57</td>
</tr>
<tr>
<td>SA</td>
<td>89.48</td>
<td>98.46</td>
<td>130.69</td>
<td>24.02</td>
<td>30.83</td>
<td>−0.74</td>
<td>2.28</td>
<td>20.18</td>
<td>0</td>
<td>16106.8</td>
<td>170142.1</td>
<td>3786.35</td>
</tr>
<tr>
<td>RGOLD</td>
<td>0.76</td>
<td>0.61</td>
<td>11.19</td>
<td>−12.48</td>
<td>4.01</td>
<td>−0.07</td>
<td>3.35</td>
<td>1.03</td>
<td>0.10</td>
<td>135.57</td>
<td>2860.25</td>
<td>–</td>
</tr>
<tr>
<td>RNG</td>
<td>−0.09</td>
<td>0.21</td>
<td>21.19</td>
<td>−28.02</td>
<td>7.22</td>
<td>−0.64</td>
<td>4.77</td>
<td>35.55</td>
<td>0.00</td>
<td>−16.66</td>
<td>9285.32</td>
<td>–</td>
</tr>
<tr>
<td>RSA</td>
<td>0.766351</td>
<td>1.870899</td>
<td>15.18429</td>
<td>−38.44545</td>
<td>6.103853</td>
<td>−1.68291</td>
<td>11.39265</td>
<td>609.8327</td>
<td>0.000000</td>
<td>137176.8</td>
<td>6631.749</td>
<td>–</td>
</tr>
</tbody>
</table>
Furthermore, there is shock spillover within gold market and Nigeria’s as well as South Africa’s stock markets. However, while cross-market shock spillover is observed from each country’s stock market to gold market with or without accounting for structural breaks, shock spillover from gold market stock market exists for Nigeria when structural break is recognized and for South Africa when such break is not considered. This result is supported by Arouri et al. (2015) where evidence of significant volatility cross-effects between world gold price and Chinese stock was reported, and Mensi et al. (2017) where similar findings exist for USA, Japan, Europe and Asia. Moreover, there is short-term shock spillover within gold market and both countries’ stock markets, whether structural break is accounted for or not. Thus, past short-term shocks induces present short-term shocks in both Nigeria’s and South Africa’s stock markets. Also, with or without accounting for structural break, there is short-term cross-market shock spillover only from South Africa’s stock market to gold market. The reverse of such shock spillover (from gold market to stock market) is also present in the same country but in the absence of structural break.

In contrast, while there is long-term shock spillover within the gold market only in the presence of structural break, past stock returns affect present returns in both countries in the long term irrespective of structural break. In addition, long term shock spillover from each country’s stock market to gold market is noticed whether or not structural break is considered. The reverse of such shock spillover is valid only for South Africa, in the absence of structural break. A major distinguishing feature of this novel methodology is its capacity to account for cross-market asymmetric shock spillover, which captures whether (or not) a positive or a negative shock in one market will translate to either a positive or negative shock in another market. Accounting for break, there is cross-market asymmetric shock spillover within gold market when either Nigeria’s or South Africa’s stock market is the source. Also, this shock spillover exists within the two countries’ stock markets. Moreover, cross-market asymmetric shock spillover is found from gold market to South Africa’s stock market and Nigeria’s stock market with break and without break respectively. Furthermore, cross-market asymmetric shock spillover is observed from Nigeria’s stock market and South Africa’s stock market to gold market, with and without accounting for breaks respectively. This implies that there is partial bi-directional cross-market asymmetric shock spillover from each country’s stock market to gold market. The foregoing results have implications for optimal portfolio allocation and hedging effectiveness which are to be discussed below.

5.3. Portfolio management

The significant volatility spillovers between two markets implies that investors’ assets in both markets are volatile and susceptible to risk and uncertainty. Among the prominent strategies for avoiding risk in volatile assets are optimal portfolio allocation (or diversification) and hedging. Two important hedging methods adopted in this study are optimal portfolio weight (OPW) and optimal hedging ratio (OHR).

The OPW is used to determine the optimal amount to invest in gold and stock, while the OHR is meant to ascertain the rate at which $1 worth of asset (with a long position) in one market could be hedged by taking asset (with a short position) in the other market so as to minimize risk and maximize returns. Following Arouri et al. (2015) and Saliisu and Oloko (2015), optimal weight of holding two assets—stock and gold at time $t$ ($W_{opt}$) can be expressed as;

$$w_{opt,t} = \begin{cases} v_{t}^{S} - \beta^{S} \sigma_{t}^{S} & \text{if } w_{opt,t} < 0 \\ 0 & \text{if } 0 \leq w_{opt,t} \leq 1 \\ 1 & \text{if } w_{opt,t} > 1 \end{cases}$$

and,

$$w_{opt,t} = \frac{\alpha_{t}^{S} - \alpha_{t}^{G}}{\beta^{S} \sigma_{t}^{S} + \sigma_{t}^{G}}$$

Table 3

<table>
<thead>
<tr>
<th>Mean Equation</th>
<th>With break (SA)</th>
<th>With break (NG)</th>
<th>Without break (SA)</th>
<th>Without break (NG)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\theta_1$</td>
<td>1.293***(0.018)</td>
<td>0.513 (0.324)</td>
<td>0.430 (0.250)</td>
<td>0.722***(0.253)</td>
</tr>
<tr>
<td>$\theta_2$</td>
<td>0.180 (0.033)</td>
<td>0.117**(0.05)</td>
<td>0.141 (0.070)</td>
<td>0.164***(0.066)</td>
</tr>
<tr>
<td>$\theta_3$</td>
<td>0.020 (0.010)</td>
<td>-0.010 (0.04)</td>
<td>0.174***(0.001)</td>
<td>-0.046 (0.088)</td>
</tr>
<tr>
<td>$\theta_4$</td>
<td>0.016***(0.000)</td>
<td>-0.029 (0.03)</td>
<td>0.072 (0.066)</td>
<td>-0.048 (0.034)</td>
</tr>
<tr>
<td>$\theta_5$</td>
<td>0.152 (0.010)</td>
<td>0.369**(0.06)</td>
<td>0.165***(0.075)</td>
<td>0.396**(0.058)</td>
</tr>
<tr>
<td>$\theta_6$</td>
<td>0.003***(0.000)</td>
<td>-0.002***(0.00)</td>
<td>0.002***(0.000)</td>
<td>0.047***(0.000)</td>
</tr>
<tr>
<td>$\theta_7$</td>
<td>0.001**(0.000)</td>
<td>-0.004**(0.00)</td>
<td>-0.017**(0.000)</td>
<td>0.003(0.000)</td>
</tr>
<tr>
<td>$\theta_8$</td>
<td>0.016**(0.000)</td>
<td>-0.001**(0.00)</td>
<td>-0.003**(0.000)</td>
<td>0.001***(0.000)</td>
</tr>
<tr>
<td>$\theta_9$</td>
<td>0.003***(0.000)</td>
<td>-0.004**(0.00)</td>
<td>0.001***(0.000)</td>
<td>0.021**(0.000)</td>
</tr>
<tr>
<td>$\theta_{10}$</td>
<td>2.066**(0.281)</td>
<td>1.300**(0.465)</td>
<td>1.210**(0.305)</td>
<td>0.450(0.406)</td>
</tr>
<tr>
<td>$\theta_{11}$</td>
<td>-2.450**(0.141)</td>
<td>-1.404**(0.425)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>$\theta_{12}$</td>
<td>0.001**(0.000)</td>
<td>1.167(0.982)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>$\theta_{13}$</td>
<td>0.450**(0.277)</td>
<td>0.295(0.404)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>$\theta_{14}$</td>
<td>0.903**(0.327)</td>
<td>1.568(0.314)</td>
<td>0.523(0.327)</td>
<td>1.794**(0.403)</td>
</tr>
</tbody>
</table>

Variance Equation

| C11 | 0.745**(0.363) | 1.568(0.314) | 0.523(0.327) | 1.794**(0.403) |
| C12 | 1.498**(0.390) | 0.664(0.379) | 1.280**(0.452) | 1.084(0.895) |
| C22 | 0.072***(0.462) | -0.009(0.671) | -0.000(2.142) | 0.692(4.423) |
| A1 | 0.223***(0.118) | 0.218***(0.08) | 0.554***(0.074) | -0.185***(0.089) |
| A2 | 0.070(0.125) | 0.178(0.101) | 0.400**(0.127) | -0.177(0.137) |
| B1 | -0.248**(0.118) | -0.067(0.043) | -0.169**(0.065) | 0.025(0.055) |
| B2 | -0.228**(0.127) | 0.056(0.061) | -0.392**(0.100) | 0.204**(0.117) |
| C1 | 0.697**(0.078) | 0.744**(0.063) | 0.116(0.102) | -0.643**(0.112) |
| C2 | 0.417**(0.068) | 0.049(0.111) | -0.936**(0.108) | -0.211(0.250) |
| D1 | 0.222***(0.102) | 0.053(0.038) | 0.583***(0.064) | -0.286**(0.096) |
| D2 | 0.277**(0.133) | 0.887**(0.036) | 0.726**(0.092) | 0.733**(0.088) |
| E1 | -0.248**(0.145) | 0.374**(0.138) | -0.841(0.135) | 0.053(0.152) |
| E2 | -1.166**(0.218) | -0.239(0.166) | 0.176(0.207) | 3.831**(0.202) |
| F1 | 0.165**(0.122) | -0.197**(0.073) | 0.394**(0.105) | 0.026(0.092) |
| F2 | 0.198(0.135) | -0.222**(0.099) | 0.394**(0.185) | 0.393**(0.175) |
Table 4
Computed optimal weights and hedging ratios for asset management.

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Gold-stock (South Africa)</th>
<th>Gold-stock (Nigeria)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Portfolio mix indicator</td>
<td>Without break</td>
<td>With break</td>
</tr>
<tr>
<td>Optimal weight</td>
<td>0.146</td>
<td>0.175</td>
</tr>
<tr>
<td>Optimal hedging ratio</td>
<td>1.018</td>
<td>0.871</td>
</tr>
</tbody>
</table>

Where \(W_{\text{opt}}\) implies the weight of stock in one-dollar asset worth of gold-stock portfolio at time \(t\), \(h_{\text{opt},t}\) is the conditional covariance between stock and gold returns at time \(t\), and the optimal weight of gold in one-dollar worth of gold-stock portfolio will be \(1 - W_{\text{opt},t}\). The sensitivity of the results to structural break is also explored.

An expression for the optimal hedge ratio between stock and gold is provided as follows;

\[
\rho_{\text{opt},t} = \frac{h_{\text{opt},t}}{r_{t}}
\]

From the result in Table 4, without break, the optimal weight of gold in one dollar worth asset of gold-South Africa stock is 0.146, implying that the optimal weight of South Africa’s stock is 0.854 (= 1 – 0.146). This means that if one dollar is to be spent optimally between gold and South Africa’s stock, about 15% of the one dollar should be spent on gold and the rest 85% on stock. In contrast, when break is accounted for, the optimal weight of gold in one dollar worth asset of gold-South Africa’s stock increased to 0.175. In the same vein, without accounting for structural break, the optimal weight of gold in a one dollar worth asset of gold-Nigeria stock is 0.357, which signifies that the optimal weight of Nigeria’s stock is 0.64. This further means that if one dollar is to be spent optimally between gold and Nigeria’s stock, about 36% of the one dollar should be spent on gold and the remaining 64% on Nigeria’s stock. Meanwhile, when break is accounted for, the optimal weight of gold in one dollar worth of gold-Nigeria stock fell to 0.265.

Furthermore, the optimal hedging ratio reveals how a long position of one dollar in gold market can be hedged by a short position of certain dollar in South Africa’s and Nigeria’s stock markets. The optimal hedging ratio for gold-Nigeria stock is 0.398 (0.143) without structural break (with structural break). This means that a one dollar long position of gold can be hedged by taking a short position in Nigeria’s stock for 39.8 cents (14.3 cents) without break (with break). It can be seen clearly that ignoring structural breaks can underestimate the computed optimal weights and optimal hedging ratio. However, the optimal hedging ratio for gold-South Africa’s stock is about 1.018 without structural break and 0.87 with structural break. This implies that a one dollar long position of gold can be shorted by $1 (87 cents) of South Africa’s stock without break (with break), which is about 1:1. The hedging ratios for Nigeria are low compared to South Africa, suggesting that hedging associated with gold market and Nigeria’s stock market would be more effective than that of South Africa. This submission is consistent with the explanation of Arouiri et al. (2015) that low ratio signifies hedging effectiveness and thus, they found gold to be capable of being used to effectively hedge stock risk exposures in China. These diverse results between the countries may be attributed to the role of gold in the respective economies. Gold plays a major role in the economic activities in South Africa (which ranks among the top 10 world producers of gold), unlike Nigeria (which ranks among the 100 world gold producers and top 10 world oil producers) where oil is the engine of growth. Thus, gold make be (highly) positively related with South Africa’s stock but either correlated little or negatively related with Nigeria’s stock.

5.4. Results of the Quantile regression model

According to the OLS results reported in Table 5, when structural break is not considered, estimated stock market coefficients for Nigeria and South Africa are positive but insignificant, while the lagged values of gold are negative and significant. However, when structural break is accounted for, estimated stock market coefficient is significant (positive) only for South Africa, while lagged value of gold is significant (positive) for both countries. Thus, while gold responds instantaneously to South Africa’s stock (with break), it reacts to its past returns with or without break. In essence, the OLS result with lagged variable reveals that there is a connection between past and present returns on gold.

The quantile regression results portray a clearer picture of the significance of the relationship (Table 6). The results show that South Africa’s stock influences gold instantaneously only in quantiles up to 55%, in the absence of structural break, but no instantaneous response of gold to stock returns is observed at all quantiles in Nigeria. Also, while past gold returns influence its present returns for South Africa in all quantiles, it influences the returns only up to quantiles 0.65% in Nigeria. When structural break is considered, gold responds to stock returns in both countries instantaneously in all quantiles except at 95%. Also, while gold responds to lagged values of stock returns up to quantiles 0.75 in Nigeria, it responds only at quantiles 0.75 in the case of South Africa. In both countries, gold responds to its past returns. The implications of the above relationship between gold and the stocks are analysed for portfolio selection and hedging effectiveness in the subsequent discussions.

The results shown in Table 6 reveal hedge or safe haven property of gold for the stocks. It should be stated that, for gold to be a hedge against stock it is expected that the slope coefficients (\(\beta_1\) and \(\lambda_1\)) be negative and statistically significant (Iqbal, 2016). In the case of Nigeria, the slope coefficient \(\beta_1\) is significant negative at all quantiles, indicating that gold is a clear hedge against the country’s stock. However, in the case of South Africa, although the slope coefficient \(\lambda_1\) is significant, it is positive at all quantiles, suggesting that gold is not a hedge against the country’s stock but it could forecast stock returns. Furthermore, at all quantiles up to 45%, gold is a safe haven for Nigeria’s stock, but not for South Africa’s stock at all quantiles. It therefore implies that gold may be a clear safe haven only when the Nigerian stock market is bearish. The finding for South Africa is largely consistent with that of Basher and Sadorsky (2016) where gold does not provide a hedge or safe haven for stock among 23 emerging market countries, and Baur and McDermott (2010) where similar findings are reported for Australia, Canada, Japan and the BRIC countries. For Nigeria, the finding is in line with Gürgün and Ünalmas (2014) where gold is found to be both a hedge and safe haven for developing market stocks.

The slope equality test results, presented in Table 7, are the test proposed by Koenker and Bassett (1982). The following null hypothesis are tested;

\[
\beta_{0.15} = \beta_{0.25}, \beta_{0.25} = \beta_{0.35}, \beta_{0.35} = \beta_{0.45}, \beta_{0.45} = \beta_{0.55}, \beta_{0.55} = \beta_{0.65}, \beta_{0.65} = \beta_{0.75}, \beta_{0.75} = \beta_{0.85}, \beta_{0.85} = \beta_{0.95}, \text{ i in Eq. (6) to (9).}
\]

According to the slope test results, the null hypothesis of equality of slope is rejected at 85th and 95th quantiles at 5% level of significance for returns on South Africa stock. Furthermore, the null hypothesis of equality of slope is also rejected at 75th and 85th quantiles at 5% level of significance for the lagged returns on South Africa stock. All other results accept the null hypothesis of equality of slopes between the quantiles under consideration. Similarly, all results for Nigerian stock accept this hypothesis.

\(^{8}\) Full results that include control variables (oil price, bonds and SPX volatility index) can be produced upon request.
Table 5
OLS and Quantile regression results with lagged values.

Source: Computed.

<table>
<thead>
<tr>
<th>Model type</th>
<th>Constants</th>
<th>Slope coefficients (Nigeria)</th>
<th>Slope coefficients (South Africa)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NG</td>
<td>SA</td>
<td>LNG</td>
</tr>
<tr>
<td>Results without structural break</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OLS</td>
<td>123.23 (23.76)</td>
<td>129.44 (44.67)</td>
<td>0.25 (5.23)</td>
</tr>
<tr>
<td>0.15</td>
<td>-147.21 (196.77)</td>
<td>383.04*** (128.45)</td>
<td>0.24 (4.11)</td>
</tr>
<tr>
<td>0.25</td>
<td>44.67 (224.18)</td>
<td>392.15** (164.47)</td>
<td>0.93 (3.52)</td>
</tr>
<tr>
<td>0.35</td>
<td>198.29 (152.13)</td>
<td>331.79** (147.10)</td>
<td>-1.44 (3.05)</td>
</tr>
<tr>
<td>0.45</td>
<td>192.64 (140.84)</td>
<td>378.97*** (111.92)</td>
<td>-1.70 (3.00)</td>
</tr>
<tr>
<td>0.55</td>
<td>352.64 (140.84)</td>
<td>364.02** (174.95)</td>
<td>-2.83 (2.97)</td>
</tr>
<tr>
<td>0.65</td>
<td>704.15*** (245.38)</td>
<td>340.33 (238.63)</td>
<td>-4.04 (3.05)</td>
</tr>
<tr>
<td>0.75</td>
<td>876.82*** (158.51)</td>
<td>195.41 (335.70)</td>
<td>-4.76** (2.25)</td>
</tr>
<tr>
<td>0.85</td>
<td>1062.76*** (189.18)</td>
<td>573.79 (393.24)</td>
<td>-3.93 (2.19)</td>
</tr>
<tr>
<td>0.95</td>
<td>1170.70*** (108.40)</td>
<td>814.85 (547.01)</td>
<td>-1.30 (2.71)</td>
</tr>
<tr>
<td>Results with structural break</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.15</td>
<td>234.08*** (80.79)</td>
<td>98.81** (43.98)</td>
<td>1.01 (1.09)</td>
</tr>
<tr>
<td>0.25</td>
<td>117.80 (114.69)</td>
<td>62.72 (44.81)</td>
<td>2.94** (1.36)</td>
</tr>
<tr>
<td>0.35</td>
<td>43.52 (79.87)</td>
<td>42.84 (35.98)</td>
<td>2.81*** (0.82)</td>
</tr>
<tr>
<td>0.45</td>
<td>57.26 (68.18)</td>
<td>98.04 (41.42)</td>
<td>2.52*** (0.91)</td>
</tr>
<tr>
<td>0.55</td>
<td>61.39 (73.75)</td>
<td>121.40*** (45.55)</td>
<td>2.42*** (0.68)</td>
</tr>
<tr>
<td>0.65</td>
<td>80.49 (63.94)</td>
<td>183.26*** (42.05)</td>
<td>3.20*** (0.75)</td>
</tr>
<tr>
<td>0.75</td>
<td>103.25 (69.91)</td>
<td>203.24*** (41.04)</td>
<td>2.17*** (0.71)</td>
</tr>
<tr>
<td>0.85</td>
<td>136.97*** (42.57)</td>
<td>128.83*** (54.97)</td>
<td>1.76 (1.03)</td>
</tr>
<tr>
<td>0.95</td>
<td>193.08*** (30.54)</td>
<td>107.37*** (43.66)</td>
<td>0.01 (1.09)</td>
</tr>
</tbody>
</table>

Note: *, ** and *** represent 1%, 5% and 10% respectively. Figures in parenthesis are standard errors.
Table 6
Hedge or safe haven property of gold for stocks.

<table>
<thead>
<tr>
<th>Source: Computed by the Authors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quantile Constant (Nigeria) Constant (South Africa) Slope Coefficients (Nigeria) Slope Coefficients (South Africa)</td>
</tr>
<tr>
<td>Level β0 λ1 β1 ∑β21% ∑β35% ∑β3(10%) λ 1 ∑λ21% ∑λ35% ∑λ410%</td>
</tr>
<tr>
<td>0.15 -51.89 (165.51) 365.00*** (107.56) -8.36*** (1.44) 0.45 (1.39) 2.14 (1.40) -1.32 (1.21) 23.02*** (3.44) 2.90 (3.45) 7.09***(2.14) 6.78 (3.89)</td>
</tr>
<tr>
<td>0.25 152.80 (257.77) 339.63** (152.88) -6.66*** (1.35) 1.78 (0.67) 1.78 (2.43) 2.54 (2.89) 22.20*** (3.05) 3.09 (3.55) 6.87 (5.54) 6.90 (4.99)</td>
</tr>
<tr>
<td>0.35 163.30 (150.15) 342.60** (170.01) -6.79*** (1.24) 1.45 (1.77) 1.79 (2.11) 2.34 (2.17) 19.62** (2.91) 7.09 (6.77) 6.999 (4.99) 4.99 (4.87)</td>
</tr>
<tr>
<td>0.45 296.18 (204.21) 348.06** (139.51) -7.93*** (2.79) 1.44 (2.67) 3.54 (2.54) 2.88 (3.10) 6.87 (4.88) 4.87 (4.38) 6.76** (3.87)</td>
</tr>
<tr>
<td>0.55 686.09*** (230.18) 367.21*** (121.84) -11.46*** (2.88) 2.88 (3.33) 4.88 (5.54) 4.65 (4.90) 14.25*** (2.69) 5.98 (4.88) 4.88 (3.84)</td>
</tr>
<tr>
<td>0.65 843.51*** (157.15) 359.38** (138.59) -13.57*** (1.50) 5.78 (5.67) 6.98 (6.78) 3.76 (4.67) 19.68*** (3.14) 4.76 (6.98) 8.77* (4.56)</td>
</tr>
<tr>
<td>0.75 899.17*** (189.50) 211.07(206.59) -14.64*** (1.56) 3.54 (4.76) 3.89 (6.56) 3.87 (4.87) 22.69*** (3.01) 6.05 (4.65) 5.76 (3.54)</td>
</tr>
<tr>
<td>0.85 951.59 (215.82) 218.12(134.51) -14.52*** (1.75) 6.89 (7.90) 4.66 (3.89) 4.89 (4.31) 23.596*** (2.63) 4.76 (6.98) 5.87 (5.43)</td>
</tr>
<tr>
<td>0.95 1078.49 (162.40) 230.19(178.43) -15.64*** (2.25) 6.87 (6.09) 4.98 (4.84) 7.98 (9.99) 25.74*** (4.42) 7.98 (7.77) 5.88 (4.45)</td>
</tr>
</tbody>
</table>

In Nigeria, the hedging effectiveness is poor in the former and good in the latter. In South Africa, the hedging effectiveness is good in both countries in almost all quantiles. Implications are also drawn for portfolio diversification and hedging effectiveness.

6. Summary of findings and policy implications

This study analyses the nexus between gold, and Nigeria’s as well as South Africa’s stocks using multivariate VARMA-BEKK-AGARCH model and Quantile regression approach with monthly data ranging from June 2002 to May 2017. Results of the VARMA-BEKK-AGARCH model reveal return spillover within the gold market and stock markets of Nigeria with or without accounting for structural breaks, while such spillover is present in South Africa when break is not assumed. Evidence of cross-market return spillover from gold to stock is found in South Africa but not in Nigeria while cross-market return spillover from stock to gold is identified in South Africa. Moreover, shock spillover within gold and Nigeria’s and South Africa’s stock markets, as well as cross-market shock spillover from each country's stock market to gold market is evident. Shock spillover from gold market to stock market can only be concluded for Nigeria when structural break is assumed and South Africa when such break is not considered. There is also strong confirmation that short-term shock spillover within gold market and both countries’ stock markets and short-term cross-market shock spillover only from South Africa’s stock market to gold market.

Estimates further suggest that past stock returns strongly influence present returns in both countries in the long term with similar findings within gold market only valid in the presence of break. Also, strong long term shock spillover from each country’s stock market to gold is reported with reverse shock spillover only true for South Africa. Also, findings indicate cross-market asymmetric shock spillover within gold market and the countries’ stock markets. In addition, partial bi-directional cross-market asymmetric shock spillover between each country’s stock market and gold market is noticed. The foregoing results are complemented with that of the quantile regression analysis. Thus, findings show instantaneously influence of South Africa’s stock on gold in the low to intermediate quantiles where structural break is not considered, while no evidence of instantaneous response of gold to stock returns is found for Nigeria at all quantiles. In the presence of structural break, there is instantaneous gold response to stock returns in both countries in almost all quantiles. Implications are also drawn for portfolio diversification and hedging effectiveness.

Based on the computed results from the VARMA-BEKK-AGARCH model, the optimal weight of gold in one dollar worth asset of gold-South Africa’s stock increased from 0.146 without accounting for structural break to about 0.175 with and without break respectively. Also, shock spillover within gold market to stock market can only be concluded for Nigeria when structural break is assumed and South Africa when such break is not considered. There is also strong confirmation that short-term shock spillover within gold market and both countries’ stock markets and short-term cross-market shock spillover only from South Africa’s stock market to gold market.

This study analyses the nexus between gold, and Nigeria’s as well as South Africa’s stocks using multivariate VARMA-BEKK-AGARCH model and Quantile regression approach with monthly data ranging from June 2002 to May 2017. Results of the VARMA-BEKK-AGARCH model reveal return spillover within the gold market and stock markets of Nigeria with or without accounting for structural breaks, while such spillover is present in South Africa when break is not assumed. Evidence of cross-market return spillover from gold to stock is found in South Africa but not in Nigeria while cross-market return spillover from stock to gold is identified in South Africa. Moreover, shock spillover within gold and Nigeria’s and South Africa’s stock markets, as well as cross-market shock spillover from each country's stock market to gold market is evident. Shock spillover from gold market to stock market can only be concluded for Nigeria when structural break is assumed and South Africa when such break is not considered. There is also strong confirmation that short-term shock spillover within gold market and both countries’ stock markets and short-term cross-market shock spillover only from South Africa’s stock market to gold market.
the latter. This finding is also confirmed by the quantile regression analysis where gold is found to be a clear hedge against the stock only in Nigeria. Furthermore, while gold is a safe haven for Nigeria’s stock only at low quantiles, there is no evidence of its safe haven property for South Africa’s stock at any quantile. It therefore implies that gold may be a clear safe haven only when the Nigerian stock market experiences bearish condition.

The foregoing analysis could be useful to investors, policy analysts and policy makers. Thus, in the case of Nigeria (unlike South Africa) adding gold asset to a well-diversified portfolio of stocks may improve and policy makers. Thus, in the case of Nigeria (unlike South Africa) beac clear safehaven only when the Nigerian stock market experiences bearish condition. It therefore impliesthat gold may in Nigeria. Furthermore, while gold is a safe haven for Nigeria’s stock only at low quantiles, there is no evidence of its safe haven property for South Africa’s stock at any quantile. It therefore implies that gold may be a clear safe haven only when the Nigerian stock market experiences bearish condition.

Acknowledgements

We thank the Editor and the anonymous reviewers for their valuable comments and suggestions.

References

Bai, Z.D., Wong, W.K., Zhang, B.Z., 2010. Multivariate linear and nonlinear causality comments and suggestions to effectively hedge stock risk exposures. The risk-adjusted performance, which suggests that gold could be used to effectively hedge stock risk exposures.

We thank the Editor and the anonymous reviewers for their valuable comments and suggestions.

References

Bai, Z.D., Wong, W.K., Zhang, B.Z., 2010. Multivariate linear and nonlinear causality comments and suggestions to effectively hedge stock risk exposures. The risk-adjusted performance, which suggests that gold could be used to effectively hedge stock risk exposures.

We thank the Editor and the anonymous reviewers for their valuable comments and suggestions.

References

Bai, Z.D., Wong, W.K., Zhang, B.Z., 2010. Multivariate linear and nonlinear causality comments and suggestions to effectively hedge stock risk exposures. The risk-adjusted performance, which suggests that gold could be used to effectively hedge stock risk exposures.

We thank the Editor and the anonymous reviewers for their valuable comments and suggestions.

References

Bai, Z.D., Wong, W.K., Zhang, B.Z., 2010. Multivariate linear and nonlinear causality comments and suggestions to effectively hedge stock risk exposures. The risk-adjusted performance, which suggests that gold could be used to effectively hedge stock risk exposures.

We thank the Editor and the anonymous reviewers for their valuable comments and suggestions.

References

Bai, Z.D., Wong, W.K., Zhang, B.Z., 2010. Multivariate linear and nonlinear causality comments and suggestions to effectively hedge stock risk exposures. The risk-adjusted performance, which suggests that gold could be used to effectively hedge stock risk exposures.

We thank the Editor and the anonymous reviewers for their valuable comments and suggestions.

References

Bai, Z.D., Wong, W.K., Zhang, B.Z., 2010. Multivariate linear and nonlinear causality comments and suggestions to effectively hedge stock risk exposures. The risk-adjusted performance, which suggests that gold could be used to effectively hedge stock risk exposures.

We thank the Editor and the anonymous reviewers for their valuable comments and suggestions.

References

Bai, Z.D., Wong, W.K., Zhang, B.Z., 2010. Multivariate linear and nonlinear causality comments and suggestions to effectively hedge stock risk exposures. The risk-adjusted performance, which suggests that gold could be used to effectively hedge stock risk exposures.

We thank the Editor and the anonymous reviewers for their valuable comments and suggestions.

References

Bai, Z.D., Wong, W.K., Zhang, B.Z., 2010. Multivariate linear and nonlinear causality comments and suggestions to effectively hedge stock risk exposures. The risk-adjusted performance, which suggests that gold could be used to effectively hedge stock risk exposures.

We thank the Editor and the anonymous reviewers for their valuable comments and suggestions.

References
