# Do Gold and Crude Oil Act as Portfolio Diversifiers, Safe Haven Assets or Hedge Instruments Against Volatility in Stock Markets and Exchange Rates? Evidence from sub-Saharan Africa

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# Contents

# List of tables

# List of figures

# Abstract

This paper examines whether gold and crude oil are used as diversifying, hedging or as safe haven assets against stock markets and exchange rate volatility in selected African countries. We use daily data for South Africa, Kenya and Nigeria from 4th January 2005 to 31st December 2018 and apply different techniques, including the Dynamic Conditional Correlation and the Spillover Index to decipher the financial market characteristics of the two commodities during periods of market stress. The findings show that: (i) countries use gold and oil as diversifiers and safe haven assets rather than as a hedge instrument; (ii) the Nairobi Stock Exchange and Johannesburg Stock Exchange are the largest volatility contributors to other markets; (iii) while Nairobi stock exchange and gold are net transmitters of risk, and; (iv) currency markets are net receivers of risk transfer. We find heterogeneous results during periods of crisis. Specifically, during the period of COVID-19 pandemic, gold's attributes of portfolio diversifier and safe haven instrument increase, and acting as a hedge asset. Similarly, the Nigeria currency market and Johannesburg Stock Market are the largest net volatility transmitters while the Kenyan currency market and Nairobi Stock Exchange are net receivers of volatility. Our results highlight the significance of the characteristics of the two commodity assets for investors and financial markets.



**JEL Classification:** *E32 E40 E44 Q30 Q43*

**Keywords:** *Commodity prices, Exchange rate, Stock market, DCC-GARCH*

# 1. Introduction

Market turmoil presents the challenges of portfolio management, exacerbated by the dependence of various assets. In general, portfolio diversification permits investors to decrease the pitfalls of enduring large losses during periods of adverse economic shocks. Dornbusch et al. (2000) point out that even in the presence of sound macroeconomic fundamentals, different classes of assets tend to co-move emphatically[4]. Boyer et al. (2006) show that stock market crises spread through investor holdings of assets rather than induced by macroeconomic fundamentals. Therefore, economic uncertainties and expanded asset co-movement during crisis periods propels the quest to hold assets that do not move in pair while maintaining their value. Understanding the degree to which assets correlate helps to inform investors and financial experts on how to safeguard their asset value during episodes of market volatility. Central to this is the information on the behaviour and characteristics of different assets that follow a different path during periods of extreme market conditions (Śmiech and Papież, 2017). More importantly, the existence of uncertainties – economic, political or pandemics (such as the COVID-19) – has led investors and policy makers to identify protection assets with attributes of diversification, hedging and safe haven, to preserve erosion of their asset values.

We investigate these characteristics for gold and crude oil against stock markets and exchange rate movements for selected African countries. In particular, we aim to: (i) establish the dynamic linkages between gold, crude oil, stock markets and exchange rates; (ii) establish whether gold and crude oil acts as portfolio diversifier, hedge instruments and safe haven assets; and (iii) examine volatility spillover between gold, oil, stock markets and exchange rates. The theoretical framework for the relationship between gold, crude oil, stock market and exchange rate show that they have significant influence on macroeconomic fundamentals, and investors hold onto gold and oil price for their diversifier, hedge and safe haven properties.

The extant literature yields different empirical outcomes on the properties of the two commodity assets. In a sample of major advanced countries and emerging economies – Brazil, China and India, Baur and McDermott (2010) find that gold acts as a strong safe haven. This finding is corroborated by Chkili (2017) that gold is a weak hedge against stock markets. Contrastingly, Joy (2011) finds that gold acts as a hedge but has weak safe haven properties against currency markets, although it yields stabilizing impact against macroeconomic indicators such as inflation (see

Reboredo, 2013; Jain and Biswal, 2016). In instances of marked market turbulence, the currency properties of gold have been highlighted in the payments for oil (Tiwari and Sahadudheen, 2015). Joy (2011) and Reboredo (2012) also observe that exchange rate fluctuations influence investors to choose gold as a safe haven.

In addition, there is burgeoning empirical literature showing several techniques that have been used to examine investor behaviour in portfolio allocation during different market conditions. Baur and Lucey (2010) and Baur and McDermott (2010) use the distributed lag regression with quantiles to capture negative extreme market conditions. Hood and Malik (2013) and Gürgün and Ünalmış (2014) use a similar technique to classify the hedge and safe haven property of gold. In addition, Reboredo (2013) uses the copula framework while Beckmann et al. (2015) uses the Smooth Transition Regression (STR) while Joy (2011) uses DCC-MGARCH to uncover the market characteristics of gold and oil. Chkili (2017) uses a Markov switching GARCH model to assess the hedge and safe haven property. To the best of our knowledge, this is the first paper that uses this modelling framework in the context of Sub-Saharan Africa (SSA). The focus on SSA is motivated by several reasons. Firstly, Sub-Saharan Africa has an under-developed stock market, with market capitalization averaging 53% of GDP. Additionally, the level of stock market development varies significantly (see Appendix Figure 1) in SSA, with South Africa having the highest stock market development of 348% of GDP[5] while countries such as Algeria, Tanzania, Egypt and Seychelles have 0.2%, 10.0%, 11.0% and 72.0%, respectively. Allen et al. (2016) opine that the stock market in Africa remains low and dysfunctional relative to other regions. Secondly, several of SSA countries are resource-endowed, for example South Africa and Nigeria. However, low financial development continues to manifest due to lack of integration of commodity and financial markets (Mlachila and Ouedraogo, 2020).

The literature is replete with papers that focus on hedge, diversifier and safe haven characteristics, but much of the empirical work is for developed and mature emerging market economies. The literature for developing countries, and especially Africa, is scant and narrowly focussed. Our paper updates the analysis with new evidence and, in so doing, we make important contributions in several dimensions. Crucially, the novelty of this paper is that we focus on SSA, a region largely ignored in the literature despite its growing importance in the global economy.

Few studies in the literature focus on the inter-relation between exchange rate and oil prices in Africa. Among them, Pershin et al. (2016), Kin and Courage (2014) and Fowowe (2014) while Adjasi and Biekpe (2006), Alagidede (2009), Alagidede et al. (2011) and Mensah and Alagidede (2017) investigate the linkage between African stock markets. Other studies looking at the linkage between oil prices and stock markets in SSA include Adetunji et al. (2013) and Gil-Alana and Yaya (2014). Specifically, related to the focus of our paper, Gürgün and Ünalmış (2014), Li and Lucey (2017), and Wen and Cheng (2018) assess the safe haven and hedge characteristics of gold on financial assets in the context of emerging economies.

We depart from previous studies on SSA by broadening the search for diversifier, safe haven and hedge properties of the two commodity assets against movements in stock markets and exchange rate. Thus, to uncover empirical properties of gold and

crude oil as diversifier, hedge or safe haven assets against gyrations in stock markets and exchange rates, we focus on Kenya, Nigeria and South Africa, three of Africa's most dynamic financial markets and diverse investor base. Apart from having Africa's well-established stock market (see Appendix Figure 1), as of 2020, South Africa had 73% of gold deposits in SSA while Nigeria had 12% (World Gold Council, 2021) . Further, South Africa is the continent's largest gold exporter, and it has an integrated financial sector and a well-established stock market relative to other regional countries. South Africa financial sector is integrated at regional level with significant investments in other countries such as Namibia and Kenya, among others. Additionally, we consider Nigeria, the largest oil exporting country in Africa with a burgeoning stock market and growing investor interest[6]. Similarly, Nigeria's banking sector has a large regional presence across the continent. Kenya has a well-established and relatively sophisticated financial sector and, as a net importer of crude oil, suffers from price shocks. Further, these countries are considered for availability of high frequency data to aid in-depth analysis.

The other contributions are mostly methodological. First, we use a time varying dynamic conditional correlation among gold, crude oil, stock markets and exchange rates, thus extending the work of Ciner et al. (2013), and Jain and Biswal (2016). This approach is suitable for our analysis because it possesses several advantages such as: (i) it guarantees that the time-dependent conditional correlation matrix is positive definite at each point in time; and (ii) the number of parameters grows linearly, thus resulting to a relatively parsimonious model. Second, to test for characteristics of gold and oil prices against stock markets and exchange rates, we build on Baur and Lucey (2010) by first estimating the Dynamic Conditional Correlation and then extract the variance that is used in the quantile regression. The quantile based DCC framework helps to adequately capture gold and oil's characteristics during periods of market turmoil from a developing country context, an area ignored in existing analysis. Third, we examine the volatility spillover between gold, oil price, stock markets and exchange rates by implementing Diebold and Yilmaz (2012) Spillover Index (SI).

Our results confirm evidence of the diversifier property in gold and oil for stock markets and exchange rates found in previous studies. In addition, we observe heterogeneity in the strength of safe haven property. More importantly, the results show that gold is a strong safe haven asset while oil is a weak safe haven against stock markets and exchange rates, respectively. Interestingly, we do not find evidence of hedge property in either commodity against movements in stock markets and exchange rates. On risk transmission, we find gold as the net transmitter and South African exchange rate as the net receiver of volatility spillover in the whole sample period. However, we find that our results are sensitive to both time and event dynamics. In the aftermath of the global financial crisis, oil is a net transmitter while the Kenyan shilling was found to be a net receiver of volatility spillover[7].

The remainder of the paper is organized as follows. Section 2 presents a brief review of related literature. Section 3 describes the data and presents the methodology used in the empirical application. Section 4 presents the results and discussions. Section 5 provides the conclusion and policy recommendations.

# 2. Literature review

## Theoretical literature

The flow-oriented theory postulates a relationship between exchange rates and stock market returns. Dornbusch and Fischer (1980) postulate that movement in the domestic currency triggers changes in macroeconomic fundamentals through trade balance, which influences output and stock market prices. In particular, a depreciation of the domestic currency increases exports, thus improving trade balance and stimulating aggregate demand in the economy. Increase in exports results to increase in real output and stock market prices. Accordingly, the flow-oriented hypothesis argues in favour of a positive correlation between exchange rate and stock market prices.

The stock-oriented theory postulates that an increase in stock market prices through the wealth effect leads to a higher demand of local currencies. The increase in demand for domestic currencies results to appreciation of domestic currency. The stock-oriented theory argues that changes in stock market prices lead to changes in domestic currency to either depreciate or appreciate as a result of portfolio balance or capital mobility (Frankel, 1992). As such, the causal effect runs from stock market prices to exchange rates. The influence of stock market prices to exchange rate movement can either be direct or indirect. Directly, an increase in stock prices results to international investors revising their portfolio selection and buy more of domestic assets. In return, this leads to an increase in domestic currency values (Chkili and Nguyen, 2014). Indirectly, an increase in stock market prices results to investors' revision of the portfolio exposures, thus demand more of domestic assets. Increase in demand of domestic assets leads to increase in domestic interest rates, thus an increase in domestic currency values (Walid et al., 2011). The arbitrage hypothesis argues of a relationship between exchange rate movement and stock market returns.

## Empirical literature

The relationship between gold (oil) and stock market prices has received attention in the literature and is closely used to inform policy and investment decisions. In general, it has been viewed that investors assess the intensity of market risk before undertaking future investments. This has led to several commodity products (such as

gold) to be used as portfolio diversifiers, safe havens assets and hedges instruments during periods of market turmoil.

The correlation of commodity market and stock market (or exchange rate) has been a popular subject with academics, policy makers and investors alike. Empirical evidence suggests that during periods of market turmoil, investors mitigate risk by shifting their investments. To this end, Baur and Lucey (2010) and Baur and McDermott (2010) elucidate on the classification of assets as either safe haven assets, hedges instruments or diversifier portfolios. They define a portfolio to be a strong (or weak) hedge if it is negatively (or uncorrelated) correlated, on average, with another asset. An asset is a strong (or weak) safe haven when it is negatively (or uncorrelated) correlated with another asset during periods of stress or extreme market conditions. Moreover, an asset is a diversifier portfolio when it is positively correlated with another asset. When the hedging ability holds, on average, the portfolio can co-move even in periods of extreme market conditions. The safe haven effect holds when assets exhibit a negative relationship during bearish market periods. Baur and Lucey (2010) examine the role of gold as a hedge or safe haven to stock markets in the US, UK and Germany in a quantile regression model. The authors find that gold is a hedge instrument against stock markets in a selected group of countries. In addition, the authors find gold as a safe haven asset against stock markets during periods of market stress.

Building on the previous empirical work, a number of studies have been undertaken to underscore the role of some assets to mitigate negative effects during periods of extreme market conditions. Using daily data in a wavelet technique, Bredin et al. (2015) investigate the role of gold as a hedge and safe haven asset against stock markets and bonds in the US, United Kingdom and Germany. They find evidence of hedging property of gold international stock and bond markets within a one-year period. However, during the 2008-2009 global financial crisis, gold acted as a safe haven asset against stock markets. Along the same line, Reboredo (2013) investigates the properties of gold as a hedge or safe haven against oil prices and exchange rates by using weekly data in a copula framework. Their findings show presence of gold as a safe haven asset against oil and exchange rates. However, the results show presence (or absence) of hedge property against exchange rates (or oil prices). Hood and Malik (2013) investigate the role of commodities to hedge or act as safe havens against stock markets in the US, using daily data in a quantile framework. They find evidence of hedge instrument and weak safe haven property of gold against stock markets while volatility index (VIX) exhibits strong safe haven (or hedge) property.

Further work has been undertaken by Beckmann et al. (2015) to examine gold's role as a hedge instrument or safe haven asset against stock markets in selected countries. Using monthly data from January 1972 to March 2012 in a Smooth Transition Regression (STR) framework, they find presence of hedge and safe haven characteristics of gold against stock markets. Using a Markov switching framework, Chkili (2017) investigates the role of gold as a hedge or safe haven using weekly data for Islamic stock markets. The findings show existence of both low and high volatility regimes, and gold acting both as a weak hedge instrument and a strong safe haven

asset among the stock markets of selected countries. Wang and Lee (2016) examine the hedging property of gold against exchange rates using weekly, monthly and quarterly data in a panel threshold model. The results reveal hedge effects of gold to exchange rates in weekly and monthly data. The findings also vary among groups of countries, with gold-consuming countries having higher hedge effects compared to gold-producing countries.

In line with other studies and using dual approaches such as the DCC GARCH and wavelet coherence models, Dar and Maitra (2017) examine the hedge and safe haven properties of gold for US, China and India. Using weekly data from November 1999 to October 2013, the authors find presence of weak hedge and safe haven properties of gold against stock markets. Further, in a broader analysis Ciner et al. (2013) investigate the hedge and safe haven ability between stock markets, oil price, exchange rates, gold and bonds in the US and UK. The study uses both DCC-GARCH and quantile techniques with daily data from January 1990 to June 2010. They find hedging characteristics in bonds against other assets, while gold acts both as hedge instruments and safe haven assets against exchange rates. The results also reveal evidence of safe haven property during extreme market conditions, for example during the Gulf war and the global financial crisis period.

In addition, they find presence of safe haven ability of oil against stock and bond markets, respectively. Along the same lines, Iqbal (2017) investigates the hedge and safe haven effects of gold against stock markets, inflation and exchange rates. Using both daily and monthly data in GARCH and quantile models for India, Pakistan and the US, they find heterogeneous results. The study finds that gold acts as a safe haven asset against exchange rates in India and Pakistan while in the US, gold exhibits hedge instrument and safe haven asset attributes against inflation. Relatedly, a number of empirical studies have addressed the role of oil price as a hedge or a safe haven and volatility to other sectors in the economy. For example, Lin et al. (2014) investigates risk transmission between oil prices and Ghana stock market using weekly data from January 2000 to December 2010 by using VAR-GARCH, VAR-AGARCH and DCC-GARCH models. They find presence of volatility between oil prices and stock markets to have a higher hedge effect while oil price exhibits more of a diversified portfolio characteristics.

In addition to determining the co-movement of assets and properties of diversifier portfolio, hedges instruments and safe haven assets, significant questions have always emerged on risk transmission during periods of market stress. In this regard, several techniques have been used in literature, such as Hafner and Herwartz (2006) causality-in-variance and Diebold and Yilmaz (2012) spillover index (SI). In the Hafner and Herwartz (2006), causality-in-variance framework is used in a Lagrange Multiplier (LM) framework and it involves several steps that include: (i) estimating the univariate GARCH model; (ii) extracting the residuals and the standardized residuals; and (iii) causality-in-variance by using the standardized residuals in an LM framework. Following this approach, a number of empirical work has emerged to test for volatility spillover under the causality technique. Nazlioglu et al. (2013) investigates volatility

transfer between oil and commodity (wheat, corn, soybeans and sugar) prices using daily data from 1st January 1986 to 22nd March 2011 by employing the causality-in-variance technique. The findings show no significant volatility spillover or risk transfer during pre-crisis period while in the post-crisis period, evidence of volatility spillover is found from oil to wheat, corn and soybeans, respectively.

To test for spillover, Diebold and Yilmaz (2012) posit that the direction of volatility is important to inform on policy and support investors in portfolio allocation. As an improvement on their earlier work, Diebold and Yilmaz (2012) develop a framework that helps to identify directional volatility (for example, from and to) among variables. Using the generalized vector autoregressive technique where the forecast error variance decomposition (FEVD) is invariant to the ordering of variables, they develop a spillover index. They examine their analysis by using daily data from January 1991 to January 2010 for US stock markets, bond prices, foreign exchange rates and commodity prices. They find evidence of volatility fluctuations and limited spillover before the global financial crisis. However, after the global financial crisis, the volatility spillover intensified from stock market to other assets.

In the same vein, Antonakakis and Kizys (2015) investigate the dynamic linkage between returns and volatility between commodities and exchange rates using weekly data from 6th January 1978 to 22nd July 2014. They find that exchange rates (British Pounds to US dollar and Swiz Franc to US dollar) and commodity prices (gold, silver and platinum) improve the forecasting ability of oil, palladium and other exchange rates. They also find that gold and Swiz Franc to US dollar exchange rate are the largest transmitters of volatility spillover. In addition, their findings show that volatility spillover varies and intensifies depending on global dynamics over time. Along the same line, Fasanya and Akinbowale (2019) investigate return and volatility spillover of crude oil prices and food prices in Nigeria using data from 1st January 1997 to 30th June 2017. They find evidence of interdependence between oil prices and food prices, with significant evidence of trend volatility spillover.

From the reviewed empirical literature, the role of gold and oil price is apparent in shielding stock markets and exchange rates, and this has not been investigated in Sub-Saharan Africa (SSA). As such, a gap exists that should be filled. Moreover, the literature on SSA does not show evidence that commodities (gold and oil), exchange rates and stock markets have been jointly evaluated. We believe that jointly evaluating these variables could reveal significant information on the regions, market behaviour to inform policy. Further, the use of a three-pronged approach of DCC-GARCH, quantile regression and the causality-in-variance will help mitigate the shortcomings of previous techniques used to assess commodity properties in developing countries. We also believe that the findings of this study will be widely applied to stock and financial markets of developing countries and influence academics and investor portfolio decisions. Additionally, the use of the Spillover Index (SI) could help offer information on the direction of risk transmission across existing markets. Table 1 summarizes the relevant empirical literature on the safe haven (hedge or diversifier) properties in a quantile for developing countries.

**Table 1: Previous research on hedge, safe haven and diversifier properties of gold and crude oil in developing countries**

| Studies | Objective | Period | Focus | Copula/Methodology | Findings |
|---|---|---|---|---|---|
| Gürgün and Ünalmış (2014) | The paper investigates the hedge and safe haven gold property against equity market | Daily data varies from 1st January 1980 to 31st December 2014 | Many developing countries, including (Kenya and South Africa) | GARCH and Baur and Lucey (2010) approach in quantile regression | Gold acts as both safe haven and hedge. Mixed results for major gold producers |
| Beckmann et al. (2015) | The paper examines hedge and safe haven gold property against stock markets | Monthly data from January 1970 to March 2012 | Both developed and developing countries, including Egypt and South Africa | Smooth Transition Regression | Gold serves as hedge and safe haven |
| Chkili (2016) | The paper investigates the time varying correlations between gold and stock markets, and hedge property of gold | Weekly data from January 2000 to July 2014 | Brazil, Russia, India, China and South Africa | Asymmetric Dynamic Conditional Correlation (A-DCC) | The dynamic conditional correlation switch between positive and negative values; Gold is a safe haven |
| Chkili (2017) | Investigates the hedge and safe haven property of gold against GCC stock markets | Weekly data from April 2003 to July 2015 | GCC countries plus US, Canada and UK | Markov switching GARCH model | High volatility consistent with major global events; Gold acts as a weak hedge and a strong safe haven |
| Bekiros et al. (2017) | Investigates hedging and safe haven gold property against stock markets | Daily data from 1st January 2000 to 31st July 2014 | Brazil, Russia, India, China and South Africa | Wavelet and GARCH-copula model | Presence of time scale co-movement between gold and stock market; Gold acts as a diversifier but not as a hedge or safe haven |
| Wen and Cheng (2018) | Investigates whether gold is a safe haven for emerging stock markets | Daily data varies from 3rd January 2000 to 6th July 2016 | Emerging countries including South Africa | Copula model | Both gold and US dollar act us safe havens for stock markets |

Note: Authors' compilation

# 3. Data description and empirical methodologies

This study uses daily data from January 2005 to December 2018 collected DataStream. As noted in Baur and Lucey (2010), daily return data are important in capturing investors behaviour to respond quickly to market stress and use gold's safe haven property to shield their investments. We make use of gold spot price measured in US$/ troy ounce and for crude oil prices, the US$/barrel of WTI prices. Exchange rates are expressed as units of local currency per US dollar for Kenya, Nigeria and South Africa. The stock market performance is denoted by all share index for Johannesburg Stock Exchange (JSE), Nairobi Stock Exchange (NSE) and Nigeria Stock Exchange (NIGSE). For all the data series, the daily returns are estimated and used in the analysis. We estimate the daily returns as $100 \times ln(^{p_t}/_{p_{t-1}})$ where $p_t$ is the daily closing price.

Movements in all variables are reported in Figure 1. Price series exhibit fluctuations over the period of our study. Crude oil price shows highly fluctuating movements between 2007 and 2008 during the global financial crisis and between 2013 and 2014 years, reflecting the 2014 oil price shock. The gold price shows an increasing trend, reaching the peak in 2011 and marked by a sharp fall during the 2014-2015 commodity price shock before rising again, but remained below the levels recorded prior to the price slump. The movement reflects investors' shift of funds into and out of gold as a safe haven asset during these periods. The JSE index has increased over time, with a slight fall in 2007 at the onset of the global financial crisis but has since generally been on the upward trend with marginal intra-period volatilities. The NIGSE and NSE20 have been more volatile, with the NSE20 depicting large humps and troughs than the NIGSE. All exchange rates have broadly depreciated against the US dollar, with the step-wise movements in the Nigerian naira reflecting periodic official devaluations.

**Figure 1: Plot of data series**

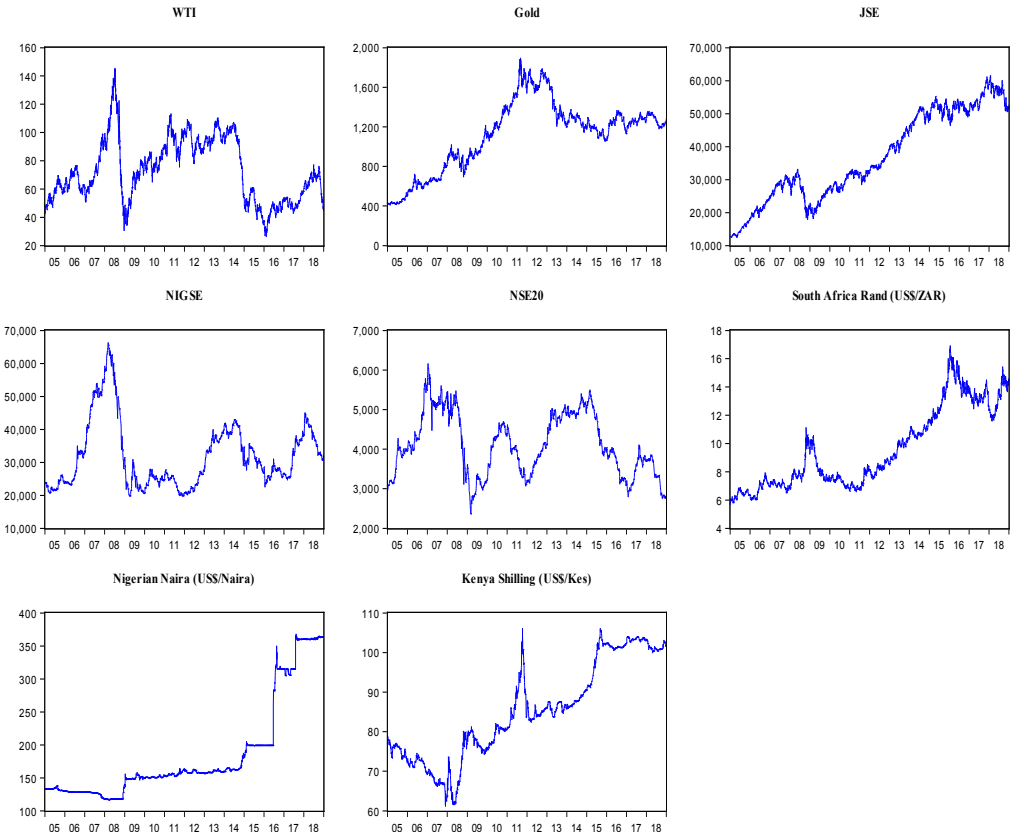



Table 2 highlights the descriptive statistics of the variables, expressed in logs. The means of all the variables are near zero, with the highest being JSE. Crude oil price exhibits the highest volatility (depicted by the standard deviation) followed by the JSE index, gold and the South African Rand while the Kenya Shilling to US dollar exhibits the lowest volatility. The Jarque-Bera test shows that the log returns of our variables are not normally distributed.

**Table 2: Descriptive statistics of variables**

| | WTI | GOLD | JSE | NIGSE | NSE20 | ZAR | NAIRA | KES |
|---|---|---|---|---|---|---|---|---|
| **Panel A: Whole sample period (January 2005 – July 2021)** | | | | | | | | |
| Mean (%) | 1.000 | 3.200 | 3.900 | 1.200 | -0.900 | 2.100 | 2.600 | 0.700 |
| Median | 0.031 | 0.018 | 0.039 | 0.000 | 0.000 | -0.005 | 0.000 | 0.000 |
| Maximum | 16.414 | 9.554 | 7.261 | 7.985 | 6.948 | 9.808 | 26.905 | 5.563 |
| Minimum | -13.610 | -8.913 | -10.227 | -5.044 | -5.234 | -6.391 | -7.631 | -4.088 |
| Std. Dev. | 2.265 | 1.121 | 1.204 | 1.004 | 0.780 | 1.034 | 0.699 | 0.424 |
| Skewness | -0.095 | -0.382 | -0.405 | 0.175 | 0.129 | 0.378 | 16.562 | 0.688 |
| Kurtosis | 8.224 | 9.662 | 8.897 | 7.151 | 11.930 | 7.075 | 577.485 | 29.123 |
| Jarque-Bera | 4,896.7 | 8,057.1 | 6,348.8 | 3,109.4 | 14,302.6 | 3,078.4 | | 122,630.7 |
| Probability | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| **Panel B: Pre-global financial crisis period** | | | | | | | | |
| Mean (%) | 9.082 | 5.683 | 7.426 | 7.416 | 3.874 | 3.678 | -1.288 | -1.088 |
| Median | 0.078 | 0.056 | 0.097 | 0.000 | 0.007 | 0.000 | 0.000 | 0.000 |
| Maximum | 8.408 | 4.592 | 5.149 | 3.828 | 4.613 | 3.427 | 2.614 | 5.563 |
| Minimum | -12.247 | -8.571 | -6.700 | -3.722 | -5.234 | -3.198 | -2.797 | -4.088 |
| Std. Dev. | 1.992 | 1.274 | 1.247 | 0.863 | 0.888 | 0.966 | 0.245 | 0.629 |
| Skewness | -0.128 | -0.865 | -0.330 | 0.230 | -0.384 | 0.296 | -2.699 | 0.658 |
| Kurtosis | 4.865 | 7.303 | 5.542 | 5.837 | 9.093 | 3.657 | 56.218 | 21.535 |
| Jarque-Bera | 142.396 | 864.227 | 277.174 | 331.740 | 1514.864 | 31.418 | 114929.7 | 13869.68 |
| Probability | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |

*continued next page*

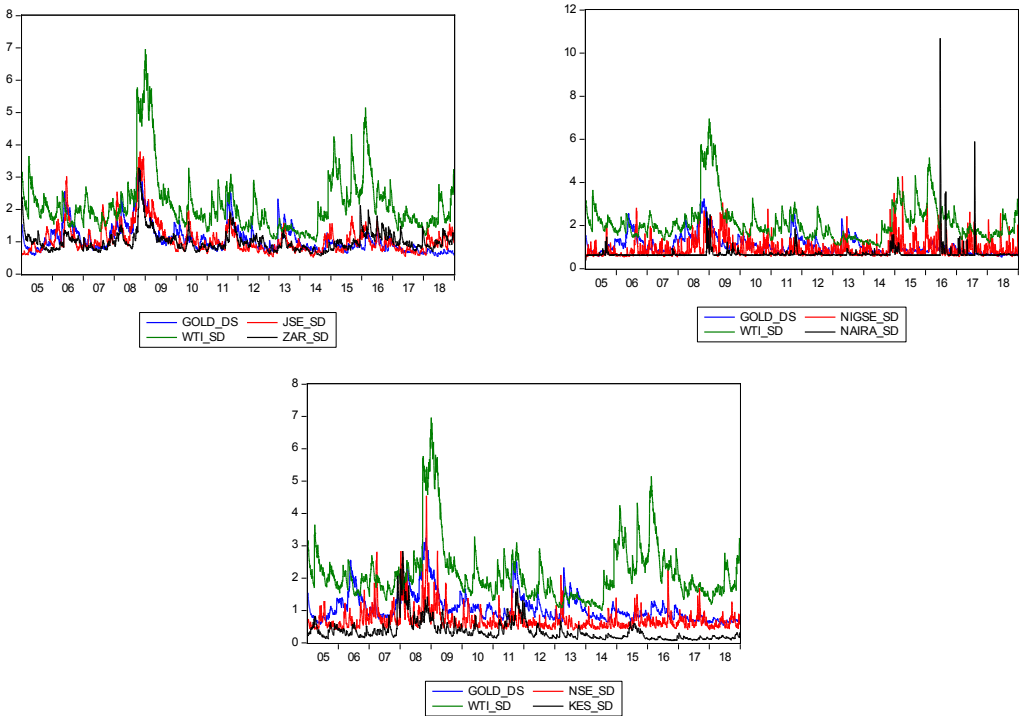
**Table 2 Continued**

| | WTI | GOLD | JSE | NIGSE | NSE20 | ZAR | NAIRA | KES |
|---|---|---|---|---|---|---|---|---|
| **Panel C: Post-global financial crisis period** | | | | | | | | |
| Mean (%) | -0.375 | 1.3096 | 3.7404 | 1.8061 | 0.0402 | 1.6267 | 3.5294 | 0.9394 |
| Median | 0.000 | 0.000 | 0.025 | 0.000 | 0.000 | -0.004 | 0.000 | 0.000 |
| Maximum | 11.289 | 5.071 | 4.233 | 7.985 | 3.876 | 5.202 | 26.905 | 3.285 |
| Minimum | -11.126 | -8.913 | -3.693 | -4.747 | -4.517 | -5.994 | -7.631 | -2.539 |
| Std, Dev, | 2.087 | 0.980 | 0.974 | 1.031 | 0.631 | 0.989 | 0.801 | 0.335 |
| Skewness | 0.032 | -0.589 | -0.133 | 0.229 | -0.095 | 0.157 | 17.819 | 0.524 |
| Kurtosis | 5.939 | 9.689 | 4.413 | 7.278 | 7.363 | 5.429 | 558.555 | 18.974 |
| Jarque-Bera | 916.418 | 4,889.514 | 219.077 | 1,962.81 | 2,021.822 | 635.947 | 32,850,563 | 27,165.41 |
| Probability | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| **Panel D: COVID-19 crisis period (January 2020 – July 2021)** | | | | | | | | |
| Mean (%) | 7.900 | 4.500 | 4.600 | 8.200 | -7.300 | 0.000 | 3.100 | 1.700 |
| Median | 0.265 | 0.146 | 0.152 | 0.027 | -0.019 | -0.097 | 0.003 | 0.018 |
| Maximum | 6.665 | 4.277 | 7.261 | 6.048 | 1.889 | 3.821 | 7.104 | 1.013 |
| Minimum | -13.610 | -4.881 | -10.227 | -5.044 | -5.138 | -2.703 | -3.497 | -1.433 |
| Std, Dev, | 2.206 | 1.106 | 1.620 | 0.998 | 0.797 | 1.006 | 0.756 | 0.226 |
| Skewness | -1.491 | -0.642 | -1.140 | 0.460 | -1.821 | 0.486 | 1.915 | -0.651 |
| Kurtosis | 10.472 | 6.405 | 11.480 | 10.302 | 10.896 | 3.603 | 26.188 | 10.822 |
| Jarque-Bera | 1076.1 | 220.1 | 1281.7 | 900.6 | 1256.8 | 21.8 | 9182.8 | 1045.3 |
| Probability | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |

Notes: Abbreviations: WTI, JSE, NIGSE and NSE denotes the Western Texas Intermediate (crude oil prices), Johannesburg Stock Exchange, Nigeria Stock Exchange and Nairobi Stock Exchange, respectively. The exchange rates are given as per the US dollar: ZAR. Naira and KES denote South Africa Rand, Nigeria Naira and Kenya Shilling, respectively. The number of observations varies as follows: whole sample (4,301), pre-crisis (964), post-crisis (2,544) and COVID-19 crisis period (399).

Figure 2 captures the volatility among variables in the selected countries and highlights the pattern of behaviour. For all the countries, we observe that prices of gold and crude oil are more volatile than financial asset returns. For the case of oil price, the intensity increases, stoked by the global financial crisis from 2008-2010 and the oil price crash of 2014-2016. During this period, global oil prices were on the upward trajectory. In contrast, exchange rates exhibit low volatility compared to gold and oil prices, thus confirming our findings in the SI of net receiver of volatility.

**Figure 2: Volatility of variables for selected countries (whole sample)**




Note: Abbreviations; JSE – Johannesburg Stock Exchange, NSE – Nairobi Stock Exchange, NIGSE – Nigeria Stock Exchange, WTI – Western Texas Intermediate oil prices, KES – Kenya Shilling/US dollar, ZAR – South African Rand/US dollar, Naira/US dollar.

## Dynamic conditional correlation-GARCH model

In this paper, we employ the DCC-GARCH model developed by Engle (2002) to investigate the time-varying correlations between the variables. In the first case, a Vector Autoregressive (VAR) is fitted to the data, standardized and classified in respect to their corresponding GARCH conditional standard deviations. This is later used by the DCC model to estimate the dynamic conditional correlations. The GARCH model is represented as follows:

$$y_t = \theta_0 + \varepsilon_t \tag{1}$$

where $\varepsilon_t$ is the standardized residuals found through the vector autoregressive (VAR) equations. The log of the volatility is given as a function of its lag and the lagged standardized residuals as follows:

$$log(\sigma_t^2) = \alpha_0 + \sum_{j=1}^{p} \beta_j log(\sigma_{t-j}^2) + \sum_{i=1}^{q} \alpha_i \varepsilon_{t-i}^2 \tag{2}$$

where $\beta's$ represents the persistence of volatility and $\alpha's$ the GARCH effect. Further, Engle (2002) defines the DCC process as follows:

$$Q_t = \bar{R} + \alpha(s_{t-1}s_{t-1}^{'}{}' - \bar{R}) + \beta(Q_{t-1} - \bar{R}) \tag{3}$$

$$\bar{R} = diag\{Q_t\}^{-\frac{1}{2}} Q_t diag\{Q_t\}^{-\frac{1}{2}} \tag{4}$$

The *R* in equation 3 is the time-varying correlation among the variables under investigation. Both the GARCH and DCC-GARCH are estimated using the Maximum Likelihood Estimator (MLE).

To investigate the diversifier, safe haven and hedge ability of gold and oil prices against stock markets and exchange rates, we follow Ratner and Chiu (2013) and more recently Bouri et al. (2017). After estimating the model, we extract the time-varying DCC and regress it against dummy variables for the bearish (0.1, 0.2, 0.3), normal (0.4, 0.5, 0.6) and bullish (0.7, 0.8, 0.9) markets, respectively[8].

$$R_t = m_0 + m_1 D(r_{stock}\, q_{10}) + m_2(r_{stock}\, q_{20}) + m_3(r_{stock}\, q_{30}) + \varepsilon_t \quad (5)$$

Where $R_t$ is the pairwise conditional correlation between gold (oil) and against stock markets (exchange rates), $r_{stock}$ is the stock market return and $\varepsilon_t$ is the error term, capturing the unobservable market effects. The same procedure is undertaken for estimation of the dynamic conditional correlation for oil price and exchange rates and the dummy variables.

## Volatility spillover analysis

To investigate the transmission of volatility between the variables (gold, oil, stock markets and exchange rates), we follow the Spillover Index (SI) technique developed by Diebold and Yilmaz, 2012[9]. As noted earlier, the SI uses the generalized vector autoregressive (GVAR), which is not affected by the ordering of variables. In the end, different spillovers are estimated, including Total spillovers, Directional spillovers and Net spillovers. The model is given as follows:

$$r_t = \rho r_{t-1} + \varepsilon_t \quad (6)$$

Where $r_t$ denotes return volatility, $\varepsilon_t$ is the error term and $\rho$ is the parameter. Thus, holding other factors constant, the GVAR H-step forecast error variance decomposition can be written as follows:

$$\theta_{jj}^{g} = \frac{\sigma_{jj}^{-1} \sum_{h=0}^{H-1} (e_i^{'} A_h \sum e_j)^2}{\sum_{h=0}^{H-1} (e_i^{'} A_h \sum A_h^{'} e_i)} \quad (7)$$

Where $\sigma_{jj}$ and $e_i$ denote the standard deviation and selector vector, respectively. Therefore, the total spillover is given as follows:

$$TS^{g}(H) = \frac{\sum_{i,j=1}^{N} \theta_{ij}^{g}(H)}{N} \times 100 \quad (8)$$

In our model, the Total spillovers captures the gold, oil prices, stock market and exchange rates for each of the three countries: South Africa, Kenya and Nigeria. The Directional spillovers are given as follows:

$$DS_i^{g}(H) = \frac{\sum_{i,j=1}^{N} \theta_{ij}^{g}(H)}{N} \times 100 \quad (9)$$

Lastly, the Net spillover is as a result of the difference between total volatility transmitted to and from other markets. As such, it offers significant information of each market's contribution to volatility in other markets.

## Causality in variance

The causality in variance is built on the Hafner and Herwartz (2006) framework which is based on the Lagrange Multiplier (LM) that overcomes the weakness of cross-correlation found in empirical tests proposed by Cheung and Ng (1996) and Hong (2001). Accordingly, the Hafner and Herwartz (2006) (here after HH) framework possesses features that makes its application (i) unaffected by oversizing of small and medium samples due to leptokurtic volatility, (ii) insensitive to ordering of lags and leads, and (iii) it is simple to implement. Owing to these important features, the HH model has gained wide application in empirical work, including by Bouri (2015) on causality between crude oil price and stock market indices, Nizlioglu et al. (2015) on causality between US stock markets and Islamic stock markets and Nouira et al. (2019) on volatility spillover between exchange rates and crude oil prices.

The application of the HH framework follows several steps. First, we estimate the GARCH (1,1) model to determine the innovations and the conditional variance (see Eqn. 2). We use the GARCH (1,1) due to its high performance relative to GARCH with other lag specifications. Second, determine the number of misspecifications $z_{j,t}$ and third, estimate the asymptotic distribution of variables using the LM test[10]. The HH framework used to estimate risk spillover is given as follows:

$$\lambda_{LM} = \frac{1}{4T}\left(\sum_{t=1}^{T}(\varsigma_{it}^2 - 1)\vartheta_{jt}\right)V(\gamma_i)^{-1}\left(\sum_{t=1}^{T}(\varsigma_{it}^2 - 1)\vartheta_{jt}\right) \xrightarrow{d} \chi^2 \tag{10}$$

# 4. Results and discussions

## Dynamic conditional correlation and quantile regression results

This section discusses the results of our estimation from the Dynamic Conditional Correlation (DCC), quantile regression and causality-in-variance models between the variables. We first transform our variables to logarithmic returns and conduct stationarity tests. As such, the Dickey and Fuller (1979) and Phillips and Perron (1988) tests for unit root are uzed. The optimal lag length selection is estimated using AIC and is found to be four. Our results are thus presented in turns.

First, the DCC model of Engle (2002) is estimated. The DCC model is a bivariate conditional correlation between gold (oil) prices and stock markets and exchange rates for each of the selected countries. To account for the robustness of the DCC model, diagnostic tests are conducted to check for serial correlation and heteroscedasticity to evaluate the aptness for usage of the model. The diagnostic results are not reported here but are available on request from the authors. After estimation, the time-varying dynamic conditional correlation are extracted from the DCC model and then regressed against a dummy variable in Baur and Lucey (2010) quantile framework. Before turning to the quantile regression, we report the results of the DCC model. Figure 3 reports the time varying correlations among the variables from DCC analysis. Although the dynamic correlations exhibit stability, significant outliers exist. We find that the dynamic conditional correlations for oil and gold for Gold-JSE, Gold-ZAR, WTI-JSE and WTI-ZAR are in positive zone with a high of between 0.43 and 0.62. Moreover, we observe markedly higher correlations between oil and stock markets (or exchange rates) from 2007 to 2013. This reflects higher demand in oil, thus increase in oil prices in a period where many countries experienced economic slowdown due to the global financial crisis. The positive correlation between oil prices and stock markets prices (exchange rates) signals improvement in international trade during the global financial crisis. In addition, during the same period, there was a significant increase in oil prices that were demand-related. The increase in oil demand indicates higher economic growth rates for both net oil exporters (Nigeria) and net importers (South Africa and Kenya). The former is an economy that depends on oil revenues to finance different sectors, while the later are economies that are dependent on exports to finance oil imports.

For example, Nigeria is an oil dependent economy, thus increased oil demand boasts exports and stock market investment. Increase in oil demand for oil importing countries, for example South Africa and Kenya, signals economic growth as these countries' exports enhance oil imports and boost exchange rates and investments in the stock markets. Further, we also observe that the dynamic conditional correlations between gold-stock markets, gold exchange rates, oil stock markets and oil exchange rates display short negative periods, signifying the shifting behaviour of investors from risky assets to safe havens. We also observe that in all dynamic conditional correlations, there is prolonged stay in positive zones as a display of investors diversifying their portfolios.

**Figure 3: DCC-GARCH conditional correlations**

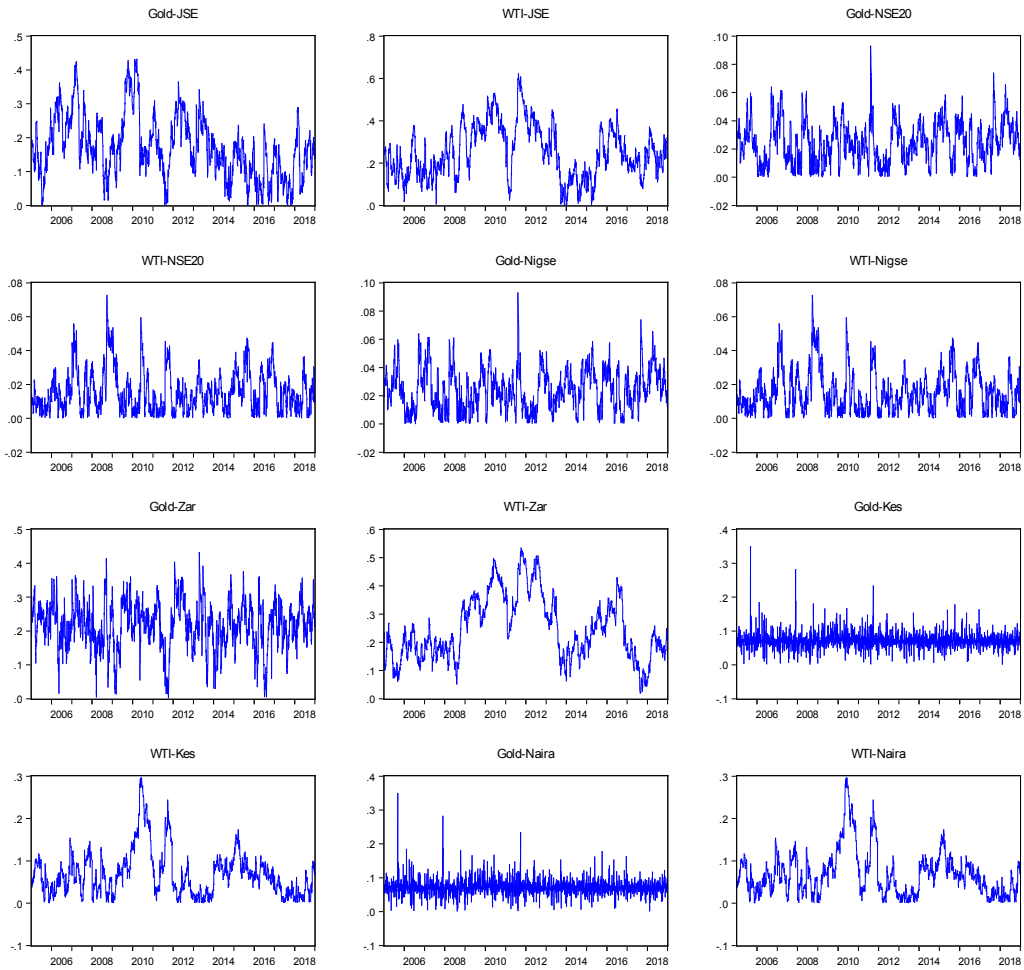



Table 3 reports the results diversifier, hedge or safe haven properties for gold and oil against stock markets and currency markets. From the results, we do not find hedge property in gold and oil against stock markets and exchange rates in South Africa,

Kenya and Nigeria, respectively. This result is in contrast to Iqbal (2017) and Baur and Lucey (2010) findings of hedge property in gold against stock markets. However, we find evidence from our analysis that gold and oil act as diversifier for stock markets in South Africa, Kenya and Nigeria in all market conditions, for example bearish, normal and bullish. Bekiros et al. (2017) document similar results of diversifier property of gold against stock markets among BRICS member countries. Our findings also show that diversification benefits of gold and oil vary across exchange rate and stock markets significantly. From Table 3, we find that JSE (0.3028) and NSE (0.0217) provide the highest and lowest benefits of diversification. This reflects the market size, as JSE is the largest stock exchange in Africa and among the top 20 in the world with many listed companies, thus offering higher room for diversification. Interestingly, both gold and oil are regarded as safe havens in South Africa, Kenya and Nigeria during extreme conditions for both bearish and bullish markets. Importantly, despite Gürgün and Ünalmış (2014) finding of a weak safe haven property of gold against JSE, this study documents strong safe haven property of gold and oil against Johannesburg Stock Exchange, Nairobi Stock Exchange and Nigeria Stock Exchange in the bearish market of 1% quantile level. In addition, gold (oil) is a strong (weak) safe haven against exchange rates in the selected countries. As noted in Baur and McDermott (2010), gold mitigates against the overall loss while exchange rate protects investors against market distress. During the normal and bullish market, we also find that the safe haven property varies across countries. It is important to note that while oil provides the highest benefit of safe haven to JSE in South Africa, Gold offers the highest benefit to exchange rates in Kenya (-0.0601) and Nigeria (-0.0544). We also observe that during bearish market conditions, oil acts as a safe haven against the NSE. For an oil importing country such as Kenya, these results are important as they signify preference in choices that investors make during extreme market conditions.

Furthermore, we establish that the seriousness of the decrease in stock market and exchange rate prices scale up interest for safe haven assets. Importantly, we note that both gold and oil demand as safe haven increases as prices in stock market and exchange rates declines. Except for Naira and KES exchange rates, at 1% quantile all stock markets and ZAR exchange rate are negatively associated with gold and oil returns.

Since our paper includes the periods of global financial crisis 2008-2009, both the role of gold and oil prices on exchange rates and stock markets may vary from the normal period. As such, it is opportune to investigate before and after the financial crisis to determine the potential impact. During the pre-crisis period, we observe that both gold and oil exhibit the diversifier property against the stock market and exchange rates of the selected countries. We also find that gold acts as safe haven against all the stock markets and exchange rates for South Africa and Nigeria to a US dollar. The role of oil as a safe haven is established against all the three stock markets. We also observe no hedge property of gold and oil in the pre-crisis period. In the post-crisis period, our findings corroborate the pre-crisis results. However, the magnitude and intensity is much higher. In particular, we observe that gold and oil are diversifiers

against stock markets and exchange rates during the bearish market ranging from 0.021 to 0.322. We also find safe haven characteristics of gold and oil against all three stock markets during the bearish market ranging from -0.097 to -0.011 at 10% quantile. In addition, gold acts as safe haven against exchange rates for South Africa and Nigeria. Our results also show that during the normal and bullish periods, gold and oil also exhibit diversifier property against the stock markets and exchange rates.

Relatedly, we also consider the period of COVID-19 pandemic, which has influenced investor decisions globally. Specifically, we find that during the period of January 2020 to July 2021, the role of gold and oil prices to cushion stock markets and exchange rates intensified. We find that gold acts as portfolio diversifier for stock markets and exchange rates during the bearish market ranging from 0.41 to 0.67. Although these findings are similar to the pre- and post- global financial crisis periods, the magnitude has substantially increased, showing the market panic by investors to cushion themselves. Importantly, we also find that safe haven property of gold against stock markets and currency markets in the selected countries ranges from -0.2 to -0.73. These findings are in line with Akhtaruzzaman et al. (2021) that investors amplified their shift towards gold to cushion their investments during the COVID-19 pandemic in 2020. Interestingly, our findings during the COVID-19 period reveal the hedge asset property against stock markets and exchange rates in the selected countries.

**Table 3: Estimation results of the diversifier, safe haven and hedge properties of gold and oil prices (whole sample)**

| | Bearish market | | | | Normal market | | | | Bullish market | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $m_1$ | $m_2$ | $m_3$ | $m_0$ | $m_1$ | $m_2$ | $m_3$ | $m_0$ | $m_1$ | $m_2$ | $m_3$ | $m_0$ |
| Gold-JSE | -0.0624[b] | 0.0842 | 0.0054 | 0.2382[b] | 0.000 | -0.0642[b] | -0.0875 | 0.2338[b] | -0.0798[b] | -0.0696[b] | -0.0107 | 0.2436[b] |
| Gold-ZAR | -0.0954[b] | -0.0039 | -0.0483[b] | 0.2339[b] | 0.000 | -0.0898[b] | -0.0538[b] | 0.2374[b] | -0.0111 | -0.0856[b] | -0.049[b] | 0.2413[b] |
| WTI-JSE | -0.1451[b] | -0.0077 | -0.0553[b] | 0.3028[b] | -0.1674[b] | -0.0384 | -0.0057 | 0.2802[b] | -0.0394[b] | -0.0106 | -0.1673[b] | 0.2804[b] |
| WTI-ZAR | -0.0306 | -0.1522[b] | -0.0018 | 0.2675[b] | -0.0326[b] | -0.1527[b] | -0.0049 | 0.2681[b] | -0.0311 | -0.0044 | -0.1537 | 0.2684[b] |
| Gold-NSE | -0.0219[b] | -0.002 | -0.0028[b] | 0.0285[b] | -0.0078 | 0.000 | 0.0237[b] | 0.0314[b] | -0.0042[b] | -0.0048[b] | -0.0189[b] | 0.0299[b] |
| Gold-KES | -0.0601[b] | -0.0053 | -0.0025 | 0.0717[b] | -0.0601[b] | -0.0056 | -0.0061 | 0.0717[b] | -0.0069 | -0.0014 | -0.0572[b] | 0.0718[b] |
| WTI-NSE | -0.0037[b] | -0.0008 | -0.0165[b] | 0.0217[b] | -0.0167[b] | -0.0003 | -0.0033[b] | 0.0202[b] | -0.0077[b] | -0.0086[b] | -0.0153[b] | 0.0349[b] |
| WTI-KES | -0.0031 | -0.0665[b] | -0.0025 | 0.0736[b] | -0.0027 | -0.0021 | -0.0671[b] | 0.0718[b] | -0.0052 | -0.0055 | -0.0666[b] | 0.0819[b] |
| Gold-NIGSE | -0.0242[b] | -0.0022 | -0.0179[b] | 0.0446[b] | -0.0021 | -0.0017 | -0.0229[b] | 0.0267[b] | -0.0049[b] | -0.0158[b] | -0.0248[b] | 0.0502[b] |
| Gold-Naira | -0.0544[b] | -0.0127[b] | -0.0042 | 0.0722[b] | -0.0011 | 0.000 | -0.0703 | 0.0714[b] | -0.002 | 0.0695[b] | 0.000 | 0.0715[b] |
| WTI-NIGSE | -0.0128[b] | -0.0038[b] | -0.0095[b] | 0.0335[b] | -0.0146[b] | -0.0046[b] | -0.0073[b] | 0.0265[b] | -0.0156 | 0.000 | 0.000 | 0.0156[b] |
| WTI-Naira | -0.0013 | -0.0681[b] | -0.0014 | 0.0711[b] | -0.0691 | 0.000 | 0.000 | 0.0689[b] | -0.0011 | -0.0045 | -0.0684[b] | 0.0748[b] |

Note: Abbreviations: JSE – Johannesburg Stock Exchange, ZAR – South African Rand, WTI – Western Texas Intermediate oil prices, NSE – Nairobi Stock Exchange, KES – Kenya Shilling, NIGSE – Nigeria Stock Exchange, Naira – Nigeria Naira. All currencies are taken as exchange to US dollar. We choose nine quantiles divided into bearish (0.1, 0.2, 0.3), normal (0.4, 0.5, 0.6) and bullish (0.7, 0.8, 0.9) markets, respectively. [a,b] and [c] denote 1%, 5% and 10% significance levels, respectively.

**Table 4: Estimation results of the diversifier, safe haven and hedge properties of gold and oil prices**

| | Bearish market | | | | Normal market | | | | Bullish market | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $m_1$ | $m_2$ | $m_3$ | $m_0$ | $m_1$ | $m_2$ | $m_3$ | $m_0$ | $m_1$ | $m_2$ | $m_3$ | $m_0$ |
| **Panel A: Pre - Global financial crisis period** | | | | | | | | | | | | |
| Gold-JSE | -0.050[b] | 0.092[b] | 0.005 | 0.246[b] | 0.000 | -0.052[b] | -0.096[b] | 0.242[b] | -0.087[b] | -0.058[b] | -0.010 | 0.251[b] |
| Gold-ZAR | -0.092[b] | -0.005 | -0.042[b] | 0.233[b] | 0.000 | -0.087[b] | -0.035[b] | 0.235[b] | -0.011 | -0.084[b] | -0.030 | 0.240[b] |
| WTI-JSE | -0.075[b] | -0.007 | -0.027 | 0.231[b] | -0.094[b] | -0.029[b] | 0.000 | 0.207[b] | -0.025[b] | -0.010 | -0.093[b] | 0.207[b] |
| WTI-ZAR | -0.021 | -0.066[b] | -0.002 | 0.181[b] | -0.023[b] | -0.066[b] | -0.005 | 0.182[b] | -0.021 | -0.004 | -0.067[b] | 0.282[b] |
| Gold-NSE | -0.023[b] | -0.002 | -0.003[b] | 0.029[b] | -0.008 | 0.000 | -0.023[b] | 0.033[b] | -0.004[b] | -0.005[b] | -0.021[b] | 0.032[b] |
| Gold-Kes | -0.005 | -0.062 | -0.000 | 0.072[b] | -0.066[b] | 0.000 | 0.000 | 0.071[b] | -0.010 | 0.000 | -0.056[b] | 0.071[b] |
| WTI-NSE | -0.004[b] | -0.001 | -0.015[b] | 0.020[b] | -0.015[b] | 0.000 | -0.003 | 0.018[b] | -0.007[b] | -0.009[b] | -0.014[b] | 0.034[b] |
| WTI-Kes | -0.004 | -0.056[b] | -0.002 | 0.064[b] | -0.003 | 0.000 | -0.058[b] | 0.063[b] | -0.004 | -0.006 | -0.053[b] | 0.069[b] |
| Gold-NIGSE | -0.028[b] | -0.002 | -0.017[b] | 0.047[b] | -0.002 | -0.002 | -0.023[b] | 0.027[b] | -0.005[b] | -0.015[b] | -0.026[b] | 0.051[b] |
| Gold-Naira | -0.054[b] | -0.013 | -0.004 | 0.072[b] | 0.000 | 0.000 | -0.070[b] | 0.071[b] | -0.015 | 0.000 | 0.000 | 0.015[b] |
| WTI-NIGSE | -0.012[b] | -0.004[b] | -0.009[b] | 0.032[b] | -0.014[b] | -0.005[b] | -0.006[b] | 0.025[b] | 0.000 | 0.000 | 0.000 | 0.000 |
| WTI-Naira | -0.001 | -0.059[b] | -0.001 | 0.062[b] | 0.000 | 0.000 | 0.000 | 0.000 | -0.006 | 0.000 | -0.058b | 0.065[b] |

*continued next page*

**Table 4 Continued**

| | Bearish market | | | | Normal market | | | | Bullish market | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $m_1$ | $m_2$ | $m_3$ | $m_0$ | $m_1$ | $m_2$ | $m_3$ | $m_0$ | $m_1$ | $m_2$ | $m_3$ | $m_0$ |
| **Panel B: Post - Global financial crisis** | | | | | | | | | | | | |
| Gold-JSE | -0.065[b] | -0.082[b] | -0.005 | 0.236[b] | 0.000 | -0.066[b] | -0.086[b] | 0.232[b] | -0.079[b] | -0.072[b] | -0.011 | 0.242[b] |
| Gold-ZAR | -0.097[b] | -0.004 | -0.051[b] | 0.235[b] | 0.000 | -0.046 | -0.005 | 0.304[b] | -0.011 | -0.087[b] | -0.051 | 0.242[b] |
| WTI-JSE | -0.164[b] | -0.008 | -0.064[b] | 0.322[b] | -0.192[b] | -0.091[b] | -0.055[b] | 0.239[b] | -0.044[b] | -0.011 | -0.192[b] | 0.305[b] |
| WTI-ZAR | -0.039 | -0.181[b] | 0.000 | 0.297[b] | -0.039 | -0.182[b] | -0.005 | 0.297[b] | -0.034 | -0.005 | -0.183[b] | 0.297[b] |
| Gold-NSE | -0.022[b] | -0.002 | -0.003 | 0.029[b] | 0.000 | 0.000 | -0.023[b] | 0.031[b] | -0.004[b] | -0.005[b] | -0.019[b] | 0.300[b] |
| Gold-KES | -0.005 | -0.002 | -0.060[b] | 0.021[b] | -0.016[b] | 0.000 | -0.003[b] | 0.019[b] | -0.006 | 0.001 | -0.058[b] | 0.072[b] |
| WTI-NSE | -0.004[b] | -0.001 | -0.015[b] | 0.072[b] | -0.060[b] | -0.006 | -0.005 | 0.072[b] | -0.008[b] | -0.008[b] | -0.013[b] | 0.033[b] |
| WTI-KES | -0.003 | -0.072[b] | -0.003 | 0.079[b] | -0.003 | -0.002 | -0.073[b] | 0.078[b] | -0.005 | -0.006 | -0.074[b] | 0.089[b] |
| Gold-NIGSE | -0.022b | -0.002 | -0.019[b] | 0.044[b] | 0.000 | 0.000 | -0.025[b] | 0.027[b] | -0.005[b] | -0.016[b] | -0.024[b] | 0.049[b] |
| Gold-Naira | -0.011b | -0.004[b] | -0.009[b] | 0.031[b] | -0.001 | 0.000 | -0.070[b] | 0.072[b] | -0.002 | 0.069 | 0.000 | 0.072[b] |
| WTI-NIGSE | -0.055b | -0.011 | -0.005 | 0.072[b] | -0.013[b] | -0.004[b] | -0.008[b] | 0.025[b] | 0.015[b] | 0.000 | 0.000 | 0.015 |
| WTI-Naira | -0.001 | -0.074[b] | -0.001 | 0.077[b] | -0.074 | 0.000 | 0.000 | 0.074 | -0.001 | 0.004 | -0.075[b] | 0.081[b] |

Note: Abbreviations and notations refer to Table 3

## Spillover index

To underscore our findings, we undertake more exercise to determine the risk transmission among variables. Table 5 reports the Spillover Index (SI) for the whole sample among gold, oil prices, stock market and exchange rates and helps to decompose returns into transmitters and receivers of spillovers. Table 6 shows the contributions to others (contributions from other markets), the net spillover and total spillover index . The results show that the total spillover index with average contribution of 2.8% due to un-anticipated changes to returns in a 10 step ahead forecast error variance decomposition. Further, our results show that NSE is the largest contributor to other variables (8.57%) and it receives only 0.57% from other variables. We also find that JSE is the second largest contributor to the FEVD, as it contributes 3.3% and receives 3.3%.

**Table 5: Estimates of volatility spillover (whole sample)**

| | Gold | WTI | JSE | NSE | NIGSE | Zar | Kes | Naira | From others |
|---|---|---|---|---|---|---|---|---|---|
| Gold | 98.232 | 0.335 | 0.328 | 0.075 | 0.115 | 0.179 | 0.137 | 0.598 | 1.767 |
| WTI | 0.574 | 98.222 | 0.448 | 0.268 | 0.078 | 0.034 | 0.188 | 0.185 | 1.775 |
| JSE | 0.639 | 1.137 | 96.661 | 0.238 | 0.068 | 0.044 | 0.016 | 1.196 | 3.338 |
| NSE | 0.075 | 0.043 | 0.072 | 99.422 | 0.021 | 0.337 | 0.007 | 0.019 | 0.574 |
| NIGSE | 0.051 | 0.486 | 0.316 | 0.34 | 98.705 | 0.087 | 0.006 | 0.009 | 1.295 |
| ZAR | 1.162 | 0.711 | 1.7 | 0.057 | 0.139 | 96.031 | 0.05 | 0.148 | 3.967 |
| KES | 0.233 | 0.677 | 0.184 | 7.58 | 0.061 | 0.119 | 91.129 | 0.0169 | 8.871 |
| Naira | 0.052 | 0.107 | 0.263 | 0.014 | 0.958 | 0.115 | 0.016 | 98.472 | 1.525 |
| Cont. to others | 2.786 | 2.785 | 3.311 | 8.572 | 1.440 | 0.915 | 0.420 | 2.172 | Total spillover |
| Cont. incl. own | 101.018 | 101.718 | 99.972 | 107.994 | 100.145 | 96.946 | 91.549 | 100.6439 | Index = 2.88% |
| Net spillovers | 1.019 | 1.01 | -0.027 | 7.998 | 0.145 | -3.052 | -8.451 | 0.6469 | |

Note: Abbreviation for the variables refer to Table 3. Cont. and incl. stand for contribution and including. Spillover indices are calculated from 10 step ahead of the variance decomposition. The FEVD is based on eight-variate VAR of order 1 based on Akaike Information Criterion.

To further determine the dynamic nature of our variables over time, we also divide our findings into net transmitters and net receivers of volatility spillover in the selected countries. As such, we find gold, JSE, NSE and NIGSE as net transmitters and oil prices, ZAR, KES and Naira as net receivers of spillover. Importantly, we find that NSE (7.9%) is the largest net transmitter of volatility in the selected countries. This

result supports other empirical findings on the role played by stock markets during periods of market turmoil. In particular, Baur (2012) argues that increase in stock market prices implies future uncertainty in other asset markets. This in return leads to increase in volatility and uncertainty in the stock market. For a country such as Kenya with a stock market still in development stages, volatility in the stock market negatively affects investment decisions. Moreover, we find exchange rate markets except for Nigeria exhibit net receiver characteristics. Specifically, we establish that the Kenya Shilling to US dollar is the largest net reciever at 8.45% compared to other currency markets.

Table 6 reports the Spillover Index (SI) for both the pre-crisis (Panel A) and post-crisis (Panel B) periods. We present results of the SI in turns. The pre-crisis period as reported in Panel A shows an average contribution of 8.86% total SI of unanticipated changes to returns in a 10-step ahead forecast error variance decomposition. Interestingly, the pre-crisis results show that NSE20 is the largest contributor to others (25.96%) followed by Kenya shilling to US dollar exchnage rate. In addition, we find gold (10.31%) and JSE (7.77%) as the third and fourth largest contributors to others while receiving 9.13% and 6.43%, respectively. Furthermore, we observe that NSE is largest net transmitter of volatility followed by oil prices.

**Table 6: Estimates of volatility spillover (pre-crisis)**

| | Gold | WTI | JSE | NSE | NIGSE | ZAR | KES | Naira | From others |
|---|---|---|---|---|---|---|---|---|---|
| **Panel A: Pre-crisis** | | | | | | | | | |
| Gold | 90.867 | 1.389 | 1.39 | 2.887 | 1.309 | 1.394 | 0.662 | 0.098 | 9.129 |
| WTI | 0.286 | 98.923 | 0.528 | 0.028 | 0.138 | 0.036 | 0.011 | 0.048 | 1.075 |
| JSE | 2.176 | 0.427 | 93.569 | 1.299 | 1.181 | 0.098 | 1.215 | 0.033 | 6.429 |
| NSE | 0.316 | 0.168 | 0.743 | 87.954 | 0.016 | 0.025 | 10.572 | 0.205 | 12.045 |
| NIGSE | 0.095 | 1.466 | 0.103 | 0.009 | 97.891 | 0.201 | 0.143 | 0.019 | 2.036 |
| ZAR | 7.211 | 1.626 | 2.267 | 5.848 | 2.326 | 80.599 | 0.091 | 0.031 | 19.4 |
| KES | 0.164 | 0.129 | 2.726 | 15.845 | 0.023 | 0.189 | 80.901 | 0.022 | 19.098 |
| Naira | 0.062 | 0.147 | 0.016 | 0.043 | 0.894 | 0.473 | 0.087 | 98.275 | 1.722 |
| Cont. to others | 10.31 | 5.352 | 7.773 | 25.959 | 5.887 | 2.416 | 12.781 | 0.456 | Total spillover |
| Cont. incl. own | 101.177 | 104.275 | 101.342 | 113.913 | 103.778 | 83.015 | 93.682 | 98.731 | Index = 8.86% |
| Net spillovers | 1.181 | 4.277 | 1.344 | 13.914 | 3.851 | -16.984 | -6.317 | -1.266 | |

*continued next page*

**Table 6 Continued**

| | Gold | WTI | JSE | NSE | NIGSE | ZAR | KES | Naira | From others |
|---|---|---|---|---|---|---|---|---|---|
| **Panel B: Post-crisis** | | | | | | | | | |
| Gold | 99.039 | 0.342 | 0.211 | 0.056 | 0.064 | 0.074 | 0.177 | 0.034 | 0.958 |
| WTI | 0.035 | 98.78 | 0.438 | 0.009 | 0.622 | 0.03 | 0.039 | 0.046 | 1.219 |
| JSE | 3.178 | 7.157 | 87.616 | 0.134 | 0.281 | 0.014 | 0.208 | 0.703 | 11.675 |
| NSE | 0.051 | 0.306 | 0.383 | 98.552 | 0.005 | 0.407 | 0.037 | 0.257 | 1.446 |
| NIGSE | 0.02 | 0.797 | 1.624 | 0.577 | 96.546 | 0.219 | 0.019 | 0.195 | 3.451 |
| ZAR | 1.731 | 2.638 | 2.553 | 0.013 | 0.139 | 91.739 | 0.006 | 1.179 | 8.259 |
| KES | 4.351 | 0.679 | 1.106 | 0.024 | 0.382 | 1.719 | 91.678 | 0.057 | 8.318 |
| Naira | 0.023 | 0.221 | 0.05 | 0.052 | 2.388 | 1.174 | 0.046 | 96.043 | 3.954 |
| Cont. to others | 9.389 | 12.14 | 6.365 | 0.865 | 3.881 | 3.637 | 0.532 | 2.471 | Total spillover |
| Cont. incl. own | 108.428 | 110.92 | 93.981 | 99.417 | 100.427 | 95.376 | 92.21 | 98.514 | Index = 4.91% |
| Net spillovers | 8.431 | 10.921 | -5.31 | -0.581 | 0.43 | -4.622 | -7.786 | -1.483 | |
| **Panel C: COVID-19 crisis** | | | | | | | | | |
| Gold | 92.394 | 0.229 | 1.156 | 0.180 | 0.267 | 5.240 | 0.321 | 0.211 | 7.604 |
| WTI | 4,045 | 85.716 | 5,212 | 2.575 | 1.642 | 0.349 | 0.051 | 0.409 | 14.283 |
| JSE | 0.527 | 4.359 | 92,511 | 1.891 | 0.151 | 0.160 | 0.172 | 0.225 | 7.485 |
| NSE | 0.389 | 0.191 | 0.833 | 90.388 | 0.371 | 0.16 | 0.175 | 7.491 | 9.610 |
| NIGSE | 0.629 | 3.071 | 1.272 | 0.309 | 93.354 | 0.531 | 0.582 | 0.251 | 6.645 |
| ZAR | 0.41 | 0.206 | 1.495 | 1.016 | 1.593 | 94.42 | 0.47 | 0.388 | 5.578 |
| KES | 0.861 | 3.667 | 0.443 | 0.343 | 0.365 | 0.411 | 93.832 | 0.077 | 6.167 |
| Naira | 0.733 | 0.222 | 0.215 | 0.258 | 0.663 | 0.574 | 0.149 | 97.186 | 2.814 |
| Cont. to others | 7.594 | 11.945 | 10.626 | 6.572 | 5.052 | 7.425 | 1.920 | 9.052 | Total spillover |
| Cont. incl. own | 99.988 | 97.661 | 103.137 | 96.96 | 98.406 | 101.845 | 95.752 | 106.238 | Index = 7.5% |
| Net spillovers | -0.010 | -2.338 | 3.141 | -3.038 | -1.593 | 1.847 | -4.247 | 6.238 | |

Note: Spillover indices are calculated from 10 step ahead of the variance decomposition. The FEVD is based on eight-variate VAR of order 1 based on Akaike Information Criterion

Panel B reports the SI for the post-crisis period. The findings show an average contribution of 4.91% total SI of unanticipated changes to returns in a 10 step ahead forecast error variance decomposition. Moreover, the results show that oil prices (12.14%) are the largest contributor to others followed by gold prices (9.38%) and JSE

(6.37%), respectively. Importantly, we observe that oil is the net transmitter of volatility (10.92%) followed by gold (8.43%). We observe that our results are senstive to time and event dynamics. In particular, we establish that oil is the main net transmitter in the post-global financial crisis. The JSE and NSE20 stock markets emerge as net receivers of volatility spillover compared to the whole sample and pre-crisis period. In addition, we observe the strength of gold and currency markets as net transmitter and net receivers stand in all sample periods.

Panel C reports the SI for the COVID-19 pandemic period from January 2020 to 31st July 2021. The findings show an average contribution of 7.5% total SI of unanticipated changes to returns in a 10 step ahead forecast error variance decomposition. Similarly, our results show that oil prices (11.94%) are the largest contributor to others followed by JSE (10.63%) and Nigeria exchange rate (9%), respectively. We also observe that Nigeria currency to the US dollar is the largest transmitter of volatility followed by the JSE (3.1%). Interestingly, our findings establish that Kenya exchange rate to US dollar (4.3%) is the largest net receiver followed by NSE (3%).

These findings show that our variables in the selected countries are senstive to time and event dynamics. In particular, we establish that the exchange rate markets, oil prices and stock markets are both net transmitters and net receivers in the COVID-19 period. These findings are in contrast with the post global financial crisis where the JSE and NSE stock markets emerge as net receivers of volatility spillover compared to the whole sample and pre-crisis period. Further, our findings also establish variation in total volatility spillover. While the whole sample shows low total volatility at 2.8%, the pre-global financial crisis and COVID-19 period show increase in volatility spillover of 8.8% and 7.5%, respectively.

## Causality-in-variance

So far, we have used the dynamic conditional correlation and the spillover index to examine time-varying contemporaneous relationship and to determine the behaviour of assets during different market periods. In the next step, we also examine risk transfer between variables to shed light on the level and direction. To this end, causality-in-variance by Hafner and Herwartz (2006) is conducted. However, before proceeding with causality tests, as noted by Francis et al. (2010), it is important to perform the non-linearity test popularly known as Brock, Dechert and Scheinkman (BDS) test. Accordingly, following Broock et al. (1996), we conduct the non-linear dependence test. The results from the non-linear dependence test are reported in Table 7. We find presence of nonlinearities in the return series as BDS test results are all statistically significant. These results confirm the aptness for the use of nonlinear causality tests.

**Table 7: Estimates of the BDS tests for return series**

| | Gold | WTI | JSE | NSE20 | NIGSE | ZAR | KES | NAIRA |
|---|---|---|---|---|---|---|---|---|
| $m_2$ | 11.220[b] | 12.799[b] | 12.654[b] | 24.477[b] | 27.186[b] | 5.891[b] | 24.293[b] | 23.718[b] |
| | (0.002) | (0.002) | (0.001) | (0.001) | (0.001) | (0.001) | (0.002) | (0.002) |
| $m_3$ | 13.824[b] | 15.794[b] | 17.422[b] | 27.178[b] | 29.388[b] | 8.536[b] | 29.001[b] | 28.984[b] |
| | (0.002) | (0.002) | (0.002) | (0.003) | (0.002) | (0.002) | (0.003) | (0.004) |
| $m_4$ | 15.777[b] | 18.364[b] | 20.936[b] | 28.074[b] | 30.922[b] | 10.118[b] | 32.410[b] | 32.455[b] |
| | (0.003) | (0.003) | (0.003) | (0.002) | (0.003) | (0.002) | (0.004) | (0.004) |
| $m_5$ | 17.583[b] | 20.074[b] | 23.583[b] | 29.207[b] | 32.545[b] | 11.757[b] | 35.751[b] | 36.455[b] |
| | (0.003) | (0.003) | (0.003) | (0.003) | (0.003) | (0.003) | (0.004) | (0.004) |
| $m_6$ | 19.410[b] | 22.109[b] | 25.920[b] | 30.373[b] | 34.261[b] | 13.069[b] | 39.631[b] | 40.654[b] |
| | (0.003) | (0.003) | (0.002) | (0.003) | (0.003) | (0.003) | (0.004) | (0.004) |

Note: *m* denotes for embedded dimensions, BDS values are the z-statistics and standard errors in brackets, *b* denotes significance at 5% level.

Subsequent to the causality tests, we also undertake the GARCH analysis to extract the volatility that will be used to assess the causal effect between the variables. In this regard, Table 8 reports the volatility results of AR (1)-GARCH (1,1) model. In testing for volatility, we make the following assumptions: (i) intercept is positive ($\omega > 0$); (ii) the ARCH effect ($\alpha \geq 0$); (iii) GARCH parameter ($\beta \geq 0$) are positive or equal to zero; and (iv) the persistence parameter is less than one ($\alpha + \beta < 1$). The optimal lag is selected following Akaike Information Criterion (AIC) procedure for each of the fitted univariate GARCH following different specifications. The results support the stability conditions of the GARCH model estimates. Our results exhibit a positive coefficient in the variance, which indicates the volatility process. The findings show that the estimated volatility process is influenced by past conditional variance ranging between 0.6868 and 0.9484. However, volatility process for oil, gold and South African Rand to US dollar exhibit similar pattern that differs from other variables. In addition, we find that the degree of persistence shows high level of volatility shocks among the variables.

Having confirmed the presence of non-linearities in the return series and extracted volatility or variance from the GARCH process, we now undertake the causality-in-variance test. Table 9 reports results of HH causality in variance test results. The causality tests are conducted to identify risk transmission from the commodity market (oil and gold prices) to both the stock market and exchange rate markets, respectively. Overall, our risk transfer causality results are insignificant in majority of the countries in the whole sample, pre- and post-global financial crisis. However, we find unidirectional nonlinear causality for risk transfer. The results show risk transfer from stock market to both the oil market and gold prices for Kenya and Nigeria. Interestingly, we also find that volatility transfer varies across countries, with Kenya exhibiting a higher risk transfer to both oil prices (15.323) and gold market (15.845), respectively. Interestingly, during the COVID-19 period, we establish bi-directional causality in commodity market, stock markets and exchange rate markets.

**Table 8: Parameter estimates for marginal models**

| | WTI | Gold | JSE | NSE20 | NIGSE | ZAR | KES | Naira |
|---|---|---|---|---|---|---|---|---|
| **Panel A: Conditional mean equation** | | | | | | | | |
| mu | 0.0281 | 0.0230 | 0.0593[b] | 0.0109 | 0.0070 | 0.0217 | 0.0062 | -0.0009 |
| *AR*1 | -0.0338[b] | -0.0050 | -0.0083 | 0.2855[b] | 0.3157[b] | 0.0109 | -0.0089 | -0.1872[b] |
| *AR*2 | 0.0069 | -0.0215 | -0.0411[b] | 0.1287[b] | 0.0176 | -0.0098 | -0.0343b | -0.0696[b] |
| **Panel B: Conditional variance equation** | | | | | | | | |
| *Omega* | 0.0266[b] | 0.0083[b] | 0.0145[b] | 0.0481[b] | 0.0852[b] | 0.0111[b] | 0.0011[b] | 0.0006[b] |
| *Alpha* | 0.0536[b] | 0.0452[b] | 0.0884[b] | 0.1891[b] | 0.3060[b] | 0.0466[b] | 0.1499[b] | 0.3122[b] |
| *Beta* | 0.9423[b] | 0.9484[b] | 0.9017[b] | 0.7101[b] | 0.6570[b] | 0.9429[b] | 0.849b | 0.6868[b] |
| *Skew* | 0.9383[b] | 0.9894[b] | 0.8718[b] | 0.9957[b] | 1.0526[b] | 1.1191[b] | 1.0232[b] | 0.9928[b] |
| *Shape* | 6.9332[b] | 5.8438[b] | 11.02515[b] | 5.7497[b] | 4.0813[b] | 9.4337[b] | 3.8077[b] | 3.2164[b] |
| $\alpha + \beta$ | 0.9959 | 0.9916 | 0.9901 | 0.8992 | 0.9629 | 0.9896 | 0.9989 | 0.9990 |
| *Q* (5) *P* − value | 0.986 | 0.3049 | 0.4262 | 0.747 | 0.372 | 0.8185 | 0.471 | 0.993 |
| *Qsq* (5) *P* − *value* | 0.1476 | 0.8821 | 0.7144 | 0.9968 | 0.0862 | 0.0036 | 0.5702 | 0.998 |
| *ARCH* − *LM* | 0.4579 | 0.6876 | 0.9986 | 0.9539 | 0.0989 | 0.1258 | 0.4989 | 0.9783 |

Note: Abbreviations refer to Table 3. [a, b] and [c] denote 1%, 5% and 10% significance levels, respectively

From the literature, empirical findings on the causal effect of risk transmission between oil price and exchange rate and stock market is mixed. Bal and Rath (2015) find a bi-directional causality between oil price and exchange rates. Granger et al. (2000) find that exchange rates have a causal effect on stock market in Korea, while other Asian economies causality runs from stock market to exchange rate. Bouri et al. (2017) find that volatility spillover or risk transfer emanates from the oil market to stock market in China. However, there is no risk transfer after the 2013 oil market reforms.

## Table 9: Estimates of causality-in-variance

| Oil and gold to stock and exchange rate market | | | | Stock and exchange rate markets to oil and gold markets | | | |
|---|---|---|---|---|---|---|---|
| $H_0$ | $\chi^2$ | $H_0$ | $\chi^2$ | $H_0$ | $\chi^2$ | $H_0$ | $\chi^2$ |
| **Panel A: Whole sample period** | | | | | | | |
| WTI ⇏ ZAR | 0.034 | Gold ⇏ ZAR | 0.801 | ZAR ⇏ WTI | 0.745 | ZAR ⇏ Gold | 0.727 |
| WTI ⇏ KES | 0.362 | Gold ⇏ KES | 2.555 | KES ⇏ WTI | 9.922[b] | KES ⇏ Gold | 10.202[b] |
| WTI ⇏ Naira | 0.449 | Gold ⇏ Naira | 2.650 | Naira ⇏ WTI | 0.165 | Naira ⇏ Gold | 0.139 |
| WTI ⇏ JSE | 0.065 | Gold ⇏ JSE | 1.259 | JSE ⇏ WTI | 1.862 | JSE ⇏ Gold | 1.336 |
| WTI ⇏ NSE | 0.435 | Gold ⇏ NSE | 2.785 | NSE ⇏WTI | 15.323[b] | NSE ⇏ Gold | 15.845[b] |
| WTI ⇏ NIGSE | 0.324 | Gold ⇏ NIGSE | 2.702 | NIGSE ⇏ WTI | 9.905[b] | NIGSE ⇏ Gold | 10.570[b] |
| **Panel B: Pre-crisis period** | | | | | | | |
| $H_0$ | $\chi^2$ | $H_0$ | $\chi^2$ | $H_0$ | $\chi^2$ | $H_0$ | $\chi^2$ |
| WTI ⇏ ZAR | 0.150 | Gold ⇏ ZAR | 1.881 | ZAR ⇏ WTI | 1.698 | ZAR ⇏ Gold | 0.271 |
| WTI ⇏ KES | 0.032 | Gold ⇏ KES | 1.395 | KES ⇏ WTI | 12.025[b] | KES ⇏ Gold | 11.883[b] |
| WTI ⇏ Naira | 0.031 | Gold ⇏ Naira | 1.616 | Naira ⇏ WTI | 0.271 | Naira ⇏ Gold | 0.273 |
| WTI ⇏ JSE | 0.717 | Gold ⇏ JSE | 1.531 | JSE ⇏ WTI | 1.385 | JSE ⇏ Gold | 0.869 |
| WTI ⇏ NSE | 0.027 | Gold ⇏ NSE | 1.606 | NSE ⇏ WTI | 3.225 | NSE ⇏ Gold | 3.114 |
| WTI ⇏ NIGSE | 0.043 | Gold ⇏ NIGSE | 1.601 | NIGSE ⇏ WTI | 20.043[b] | NIGSE ⇏ Gold | 19.772[b] |
| **Panel C: Post-crisis period** | | | | | | | |
| $H_0$ | $\chi^2$ | $H_0$ | $\chi^2$ | $H_0$ | $\chi^2$ | $H_0$ | $\chi^2$ |
| WTI ⇏ ZAR | 0.135 | Gold ⇏ ZAR | 0.105 | ZAR ⇏ WTI | 0.129 | ZAR ⇏ Gold | 1.352 |
| WTI ⇏ KES | 0.513 | Gold ⇏ KES | 2.254 | KES ⇏ WTI | 7.353[b] | KES ⇏ Gold | 7.753[b] |
| WTI ⇏ Naira | 0.690 | Gold ⇏ Naira | 1.965 | Naira ⇏ WTI | 0.059 | Naira ⇏ Gold | 0.046 |
| WTI ⇏ JSE | 1.359 | Gold ⇏ JSE | 1.505 | JSE ⇏ WTI | 2.352 | JSE ⇏ Gold | 1.046 |
| WTI ⇏ NSE | 0.692 | Gold ⇏ NSE | 2.152 | NSE ⇏ WTI | 0.696 | NSE ⇏ Gold | 0.568 |
| WTI ⇏ NIGSE | 0.429 | Gold ⇏ NIGSE | 2.026 | NIGSE ⇏WTI | 0.331 | NIGSE ⇏ Gold | 0.153 |
| **Panel D: COVID-19 crisis period** | | | | | | | |
| $H_0$ | $\chi^2$ | $H_0$ | $\chi^2$ | $H_0$ | $\chi^2$ | $H_0$ | $\chi^2$ |
| WTI ⇏ ZAR | 0.177[a] | Gold ⇏ ZAR | 0.128[a] | ZAR ⇏ WTI | 0.064[a] | ZAR ⇏ Gold | 0.058[a] |
| WTI ⇏ KES | 0.117[a] | Gold ⇏ KES | 0.123[a] | KES ⇏ WTI | 0.065[a] | KES ⇏ Gold | 0.059[a] |
| WTI ⇏ Naira | -0.028 | Gold ⇏ Naira | 0.006 | Naira ⇏ WTI | -0.023 | Naira ⇏ Gold | 0.043 |
| WTI ⇏ JSE | 0.120[a] | Gold ⇏ JSE | 0.160[a] | JSE ⇏ WTI | 0.068[a] | JSE ⇏ Gold | 0.075[b] |
| WTI ⇏ NSE | 0.031[b] | Gold ⇏ NSE | 0.035[b] | NSE ⇏ WTI | 0.062[b] | NSE ⇏ Gold | 0.057[a] |
| WTI ⇏ NIGSE | 0.000 | Gold ⇏ NIGSE | -0.000 | NIGSE ⇏ WTI | 2.540 | NIGSE ⇏ Gold | -2.582 |

Note: Abbreviations refer to Table 3. $H_0$ and $\chi^2$ refers to Null hypothesis and Chi square, [a, b] and [c] denotes at 1%, 5% and 10% significance levels, respectively

# 5. Conclusion and policy recommendations

## Conclusion

In this paper, we investigate the ability of gold and oil as a hedge (negative correlation on average) or ability to act as a safe haven (negative correlation during extreme periods) or diversifier (positive correlation) against stock market and exchange rates in South Africa, Kenya and Nigeria. We also examine the spillover or risk transfer between oil prices and gold with stock market and exchange rates. Using daily data from 1st January 2005 to 31st July 2021, we find evidence that gold and oil act as diversifiers against stock markets and exchange rates in South Africa, Kenya and Nigeria. We also find that gold and oil serve as safe havens in South African, Kenya and Nigeria during extreme conditions in both bearish and bullish markets. As such, gold serves as a strong safe haven for exchange rates while oil is a weak safe haven. In addition, during the normal and bullish market periods, the safe haven property varies across countries. In particular, we also observe that during bearish market conditions, oil acts as a safe haven against the Nairobi Stock Exchange.

On the risk transmission, we find interesting results of risk transfer from stock markets to oil and gold markets in Kenya and Nigeria. Surprisingly, we find no risk transfer to South African exchange rate and stock markets, respectively. Performing the spillover index, we establish interesting results. In the whole sample, we observe that, JSE and gold are the largest contributors to volatility spillover. At the same time, our findings show that gold and oil are the largest net transmitters and net receivers, respectively. To capture time and event dynamics, we split our sample into pre and post-crisis periods. In the pre-crisis period, we find evidence of NSE as the largest contibutor and also the largest net transmitter of spillover, while South African Rand to US Dollar is the largest net receiver of volatility spillover. In the post-crisis, we observe that oil is the largest contributor and the net transmitter of volatility spillover. During this period, Kenya/US dollar and JSE are the largest net receivers of volatility spillover. From our findings on spillover, one thing stands out from the results, the currency market in the selected countries are net receiver of volatility. To ascertain our results, we undertake further analysis of causality in variance and establish spillover or causality from currency and stock markets to both oil and gold markets, respectively.

## Policy recommendations

Our findings in this study offer important policy implications for investors, academics and policy makers especially in emerging and developing countries.

(i) The findings clearly show that oil and gold are important diversifier products against stock and exchange rate markets in the selected countries. More important, the currency market has also exhibited net receipt property on volatility spillover. Therefore, given the weak nature of currencies in Africa relative to the US dollar and the stock markets, it will be important for investors to diversify their portfolio allocations. At the same time, governments in the selected countries could develop regulatory procedures that support faster investments and remove bottlenecks in business investments.

(ii) The results show evidence of safe haven property in gold and oil. These results are also confirmed in the ability of gold and oil as net transmitters of volatility. Importantly, this shows that when markets are in turmoil, investors shift their investments towards gold and oil, thus increase prices in this particular assets. As such, for commodity countries, e.g. South Africa (gold) and Nigeria (oil), it will be important to strengthen the supply side factors. Thus, the mining sector strikes in South Africa should be mitigated or minimized. In addition, the Nile Delta conflicts should be addressed to strengthen oil flow in Nigeria.

(iii) Further, the results reveal that the currency market in selected countries are net receivers of volatility spillover. Given the nature of net transmission from oil and gold, to achieve exchange rate stability, policy makers should pay clear attention to changes in oil and gold markets.

(iv) Finally, policy makers need to pay considerable attention on stock markets in selected countries as they seem to significantly contribute to spillover. It is important that policy makers pay attention to changes in these markets for macroeconomic stability.

Our results could assist investors in portfolio allocation diversification. Similarly, financial institutions could use our results to predict the future trend of oil and gold and improve their diversification and safe haven performance.

# Notes

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4. Boyer et al . (2006) investigates the spread of crises among stock markets and finds evidence that the crises spread through investor holdings instead of macroeconomic fundamentals.

5. According to the World Bank (2021), market capitalization is defined as the product of share price and the number of shares outstanding in the stock market.

6. In this paper, we argue that in the commodity market of gold and crude oil, prices are determined through demand and supply. As such, countries such as those considered in this paper (Kenya, Nigeria and South Africa) are price takers.

7. Aït-Sahalia et al. (2012) provides a detailed explanation of the global financial crisis and accordingly indicates that it begun from 15th September, 2008 to 31st March, 2009. Therefore, in this paper, we define the pre-crisis period as from 4th January, 2005 to 14th September, 2008 and the post-crisis from 1st April, 2009 to 31st December, 2018.

8. In this paper, we acknowledge that market stress varies across countries. However, we argue that changes in global markets may have similar effects across countries. For example, a reduction in oil prices may positively influence consumption of oil uniformly in net oil- importing countries. We also argue that change in US dollar will influence other countries' currencies. Therefore, when the US dollar strengthens in the global market, the local currencies of South Africa, Kenya and Nigeria will depreciate. However, we acknowledge that the magnitude may vary between countries. This is also evident when countries experience uncertainties such as the global financial crisis and COVID-19 pandemic, when investors across countries will want to shield their investments in either gold or crude oil.

7. For detailed steps and explanation of the Spillover Index, refer to Diebold and Yilmaz (2012).

8. For details on application of the HH test refer to Hafner and Herwartz (2006).

9. The total spillover is determined by taking the ratio of the sums of contributions from others to contributions, including own, while net transmitters and net receiver are denoted by the positive and negative of net spillovers, respectively.

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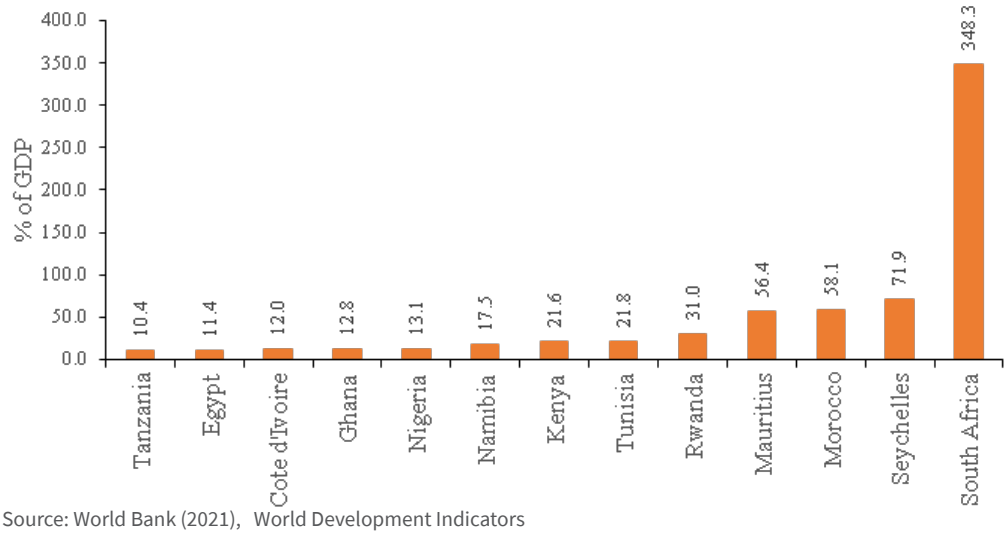
# Appendix

## Appendix Table 1: Unit root tests

| | Levels | | 1st difference | |
|---|---|---|---|---|
| | ADF | PP | ADF | PP |
| $Gold_t$ | -1.514 | -1.4818 | -61.7183 | -61.7313 |
| $WTI_t$ | -2.2968 | -2.4309 | -63.8244 | -63.8244 |
| $JSE_t$ | -2.8894 | -2.5444 | -60.3512 | -60.0223 |
| $NIGSE_t$ | -1.6874 | -1.5862 | -38.0664 | -37.5813 |
| $NSE20_t$ | -2.3534 | -2.0549 | -30.8964 | -39.4351 |
| $ZARUS\$_t$ | -2.5055 | -2.4526 | -58.1337 | -58.1867 |
| $NairaUS\$_t$ | -1.0433 | -1.0934 | -28.2072 | -56.2968 |
| $KESUS\$_t$ | -2.8373 | -2.9955 | -45.3885 | -56.8689 |

Notes: Abbreviations: WTI, JSE, NIGSE, NSE20, ZARUS$, NairaUS$, KESUS$ ADF and PP denote crude oil prices. Johannesburg Stock Exchange All share. Nigeria Stock Exchange All share. Nairobi Stock Exchange and exchange rates for Rand. Nigerian Naira and Kenya shillings to US dollar, respectively

## Appendix Figure 1: Market capitalization in Africa




Source: World Bank (2021), World Development Indicators
Notes: All data for each country for 2020 except for Rwanda and Seychelles

# Mission

To strengthen local capacity for conducting independent, rigorous inquiry into the problems facing the management of economies in sub-Saharan Africa.

The mission rests on two basic premises: that development is more likely to occur where there is sustained sound management of the economy, and that such management is more likely to happen where there is an active, well-informed group of locally based professional economists to conduct policy-relevant research.

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