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The impact of oil and gold price fluctuations on the South African equity market: Volatility spillovers and financial policy implications☆

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ABSTRACT

This paper assesses the impact of gold and oil price fluctuations on the volatility of the South African stock market and its component indices or sectors – namely, the financial, industrial and resource sectors – to infer the link between the commodity and stock markets in South Africa. Use is made of the vector autoregressive asymmetric dynamic conditional correlation generalised autoregressive conditional heteroskedasticity (VAR-ADCC-GARCH) model to this end. Moreover, the paper assesses the magnitude of the optimal portfolio weight, hedge ratio and hedge effectiveness for portfolios constituted of a pair of assets, namely oil-stock and gold-stock pairs. The findings of the study show that there is significant volatility spillover between the gold and stock markets, and the oil and stock markets. This finding suggests the importance of the link between the commodity and stock markets, which is essential for portfolio management. With reference to portfolio optimization and the possibility of hedging when using the pairs of assets under study, the findings suggest the importance of combining gold and stocks as the best strategy to hedge against stocks risk, especially during financial crises.

1. Introduction

Over the past years, the South African stock market, an important emerging stock market in Africa, has shown significant growth, with market capitalisation increasing from 545.4 billion dollars in 2005 to 612.3 billion in 2012 and the turnover ratio increasing by 15.6 percentage points during the same period (World Bank, 2015). This growth has attracted several domestic and international investors searching for high yields (Zhang et al., 2013). However, despite having high yields, emerging markets, such as that of South Africa, are known to be vulnerable to shocks from developed markets. Several studies indicate how emerging markets have been exposed to the different crises, such as the dot-com bubble crisis from 2000 to 2001, the global financial crisis from 2007 to 2008 and the European debt crisis from 2010 to 2011 (see Heymans and da Camara, 2013). This vulnerability of emerging markets to external shocks has been a concern to policy makers, investors and asset managers, who seek different ways to minimise the risk thereof. For example, asset managers in search of high yields in emerging stock markets often seek effective methods to minimise risk exposure in these markets.

Studies suggest a number of ways to hedge risk exposure in stock markets. For example, Chkili (2016) and Khalifaoui et al. (2015) find that investment in oil and gold markets provides an opportunity to hedge against stock market exposure in developed economies. Chkili, Aloui and Nguyen (2014) study the volatility transmission and hedging strategies between US stock markets and crude oil prices and conclude that investors who seek to minimise portfolio risk should include oil and stock assets in their portfolio. Similar studies, for example Ewing and Malik (2016), Sadorsky (2012), Sadorsky (2014), Arouri et al., 2012 and Lin et al. (2014), also find that oil is an effective hedge for stock market exposure. Coudert and Raymond-Feingold (2011) show that, during periods of crises, stock prices are most likely to drop and investors tend to invest in safer assets, such as gold. Thus, it is expected that the gold market and stock market will co-move, and proper combination of instruments within the two markets should provide the best opportunity for hedging. Also relevant are the findings by Baur and Lucey (2010), who examine the constant and dynamic relationship between the stock markets, bonds and gold returns in the US, United Kingdom and Germany. The authors also explore whether gold plays hedging and safe haven roles against stock market exposure during financial crises. The authors find that gold can be a useful hedging tool as well as a safe haven insurance against stock market exposure. Similar studies conducted by

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Hood and Malik (2013) and Ciner et al. (2013) also suggest that gold has the characteristic of being a good hedge against stock market exposures.

Literature abounds on the volatility spillover between stock and commodity markets. For example, Abdelhedi and Boujebene-Abbes, 2020 assess the volatility spillover between Chinese stock market, investor’s sentiment and oil market during the turmoil period of 2014–2016 by making use of the dynamic conditional correlation generalised autoregressive conditional heterskedasticity (DCC-GARCH) and the wavelet decomposition technique. The authors find a bidirectional transmission of volatility spillover between oil market shocks and Chinese investors’ sentiment. Abdelhedi and Boujebene-Abbes (2020) finding implies that investors’ sentiment is the channel through which contagion is transmitted between oil and stock markets. Vardar et al. (2018) make use of a vector autoregressive Baba-Engle-Kraft-Krone (VAR-BEKK)-GARCH model to assess the shock transmission and volatility spillover effects among daily stock market indices of the US, UK, France, Germany, Japan, Turkey, China, South Korea, South Africa and India. The authors draw data from the five major commodity spot prices, namely crude oil, natural gas, platinum, silver and gold during the period 2005 and 2016. The results show bidirectional spillover effects between stock and the commodity returns.

CretiJoets and Mignon (2013) assess the relationship between price returns for 25 commodities and stocks over the period 2001 to 2011, with a focus on energy raw materials. By making use of the dynamic conditional correlation (DCC) GARCH methodology, the authors find that the correlations between commodity and stock markets change through time and are highly volatile, particularly since the 2007–2008 financial crisis. This finding emphasises the links between commodity and stock markets, as well as the financialisation of commodity markets. Bashir and Sadorsky (2016), assess the extent of volatility spillovers of oil, gold, volatility index (VIX) and bonds in emerging stock markets. The authors also compare the hedge effectiveness of oil, gold, VIX and bonds against stock market exposure. Their findings show that oil provides a more effective hedge than gold when hedging against stock market risk.

There are many authors who have studied the role of gold and oil in portfolio diversification and hedging. However, there are only a few such studies on emerging markets, especially in the context of the African continent. Emerging stock markets in Africa, especially South Africa, are becoming important destinations for investors and asset managers looking to diversify their portfolio (see Bonga-Bonga, 2017). To fill the gap in the literature, this paper extends the study of Bashir and Sadorsky (2016) by assessing the extent of volatility spillover and the possibility of portfolio selection and hedging between the oil, gold and stock markets in South Africa. Furthermore, this paper adds to the existing literature on the link between stock and commodity markets by conducting the analysis at a disaggregated or sectoral level of stock markets rather than at an aggregate level. Indeed, one of the aims of this paper is to assess the extent of volatility spillover between oil returns and the returns of the resources sector of the stock exchange, for example, rather than the aggregate stock market. In so doing, this paper departs from the past empirical studies that have mainly focused on an aggregate regional, country-specific or global stock market levels (see Bhar and Nikolaou, 2009; Hammoudeh et al., 2013; Bashir and Sadorsky, 2016; Xu and Hamori, 2012). The findings of this paper provide insight to investors and policy makers to be more informed about which sector of the stock market provides a good mix of commodities and the possibility of diversification or hedging.

Thus, the contribution of this paper is threefold. Firstly, instead of focusing only on the impact of gold and oil volatility shocks on the aggregate stock market, this paper also analyses volatility spillovers between gold, oil and the South African stock market at aggregated and disaggregated levels. Secondly, the paper analyses the optimal weights, hedge ratios and effective portfolio weight for pairs of stock-oil and stock-gold portfolios. Lastly, this paper assesses which of the commodities – oil or gold – provides a better hedge against stock market exposure in South Africa. Based on the interaction between the commodity and stock markets in the context of emerging markets in general and South Africa in particular, our research provides beneficial and extensive information to portfolio managers and investors. Furthermore, this study may also serve as a reference for investors, policy makers, portfolio managers and researchers in terms of developing better and more effective trading strategies. The results of this paper emphasise the importance of combining stocks and commodities for portfolio optimization and effective hedging. Particularly, the empirical results show that gold is a safe haven asset that should be combined with any stock market component for better performance in portfolio optimization and hedging.

The remainder of this paper is organised as follows: Section 2 explains the methodology used in the paper. Section 3 presents the data used. Section 4 provides the estimation of the model and discuss the empirical results. Section 5 concludes the paper by highlighting and summarising the major findings of this paper.

2. Methodology

In this section the methodological approach in this paper is presented. We begin by explaining how to model time-varying volatility and correlations of the variables before analysing the optimal portfolio weights. We then give details on how to compute optimal hedge ratios followed by an assessment of hedge effectiveness.

This paper adopts an asymmetric dynamic conditional correlation model of Cappiello et al. (2006) to model conditional volatility, correlations, optimal weights and hedge ratios for oil-stock and gold-stock pairs. Recent literature shows that an asymmetric Dynamic Conditional Correlation (ADCC) model is by far the best model to estimate conditional correlation, variances and covariances among time series because it accounts for both the dynamic correlation and the asymmetric feature of stock market’ behavior (Ederington and Guan, 2010; Chkili, 2016).

2.1. Asymmetric dynamic conditional correlation (ADCC) model

The ADCC formulated by Cappiello et al. (2006) follows a two-step estimation process. The first step is to estimate the conditional variances. To do so, we first obtain random error terms from the conditional mean model. We use a VAR model to account for autocorrelations and cross-autocorrelations in returns.

\[ \varepsilon_t = C_j + \sum_{h=1}^{H} \omega_h \varepsilon_{t-h} + \varepsilon_{it} \quad \varepsilon_{it} \sim N(0, \mu_{it}) \]  

where equation (9) represents the mean equation given as a VAR model with one lag. \( \varepsilon_t \) is a nx1 vector of daily returns of oil, gold and major sectors mentioned in the previous section, and it is calculated as \( \varepsilon_t = \log \left( \frac{P_t}{P_{t-1}} \right) \times 100 \), where \( P_t \) is the closing price of \( i \) at time \( t \). \( C_j \) is the long-term drift coefficient in the VAR equation. The parameter \( \omega_j \) for \( i = j \) indicates the effect of previous \( i \) returns on its own current returns. \( \omega_j \) for \( i \neq j \) indicates the effect of lagged \( j \) returns on current returns of \( i \). \( F_{t-1} \) is the market information available at time \( t-1 \). Lastly, \( \varepsilon_{it} \) represents the random error term for variable \( i \) at time \( t \).

Equation (10) shows that \( \varepsilon_{it} \) (error terms) is composed of \( \varepsilon_{it} \), which represents the standardised residuals with a joint normal distribution and the heteroscedastic residual, \( h_{it} \).

This paper uses the vector autoregressive moving average (VARMA)-GARCH (1, 1) developed by Ling and McAleer (2003) to model conditional variances and covariances. The method is useful when modeling volatility spillovers, because unlike a simple GARCH (1, 1) model, a VARMA-GARCH (1,1) has the ability to show how shocks in one variable
can affect the variances of the other variables (Sadorsky, 2012). A VARMA-GARCH (1, 1) is specified as follows:

$$h_{it} = \phi_i + \sum_{j=1}^{n} \alpha_j \varepsilon_{i,t-j}^2 + \sum_{j=1}^{n} \beta_j h_{j,t-j}$$

(3)

where $h_{it}$ is the conditional variance, $\phi_i$ denotes the constant term of the conditional variance equations for $i$. $\sum_{j=1}^{n} \alpha_j$ for $i = j$ denotes $i$’s own ARCH effect, which measures the short-run volatility persistence. $\sum_{j=1}^{n} \beta_j$ for $i = j$ denotes $i$’s own GARCH terms, which measure the long-run volatility persistence. For $i \neq j$, $\sum_{j=1}^{n} \alpha_j$ and $\sum_{j=1}^{n} \beta_j$ respectively denote the cross ARCH and GARCH terms, which measure the volatility spillovers from $j$ to $i$. $\varepsilon_{i,t}^2 D_{k-1}$ captures leverage effects (asymmetry), where $D_{k-1}$ is a dummy variable and equals one when $\varepsilon_{k-1}^2 < 0$ and 0 otherwise. The term $D_{k-1}$ allows bad news in the market ($\varepsilon_{k-1}^2 < 0$) to be followed by higher volatilities than good news ($\varepsilon_{k-1}^2 > 0$) of the same magnitude.

In the second step, we estimate conditional correlations based on the standardised residuals from step one, as follows:

$$H_t = D_t P_t D_t$$

(4)

where $H_t$ is an $n \times n$ conditional covariance matrix, $D_t$ is a diagonal matrix, and $P_t$ is the conditional correlation matrix.

$$P_t = \begin{bmatrix}
\frac{1}{\sqrt{Q_{ii}}} & 0 & \cdots & 0 \\
0 & \frac{1}{\sqrt{Q_{ij}}} & \cdots & 0 \\
\vdots & \ddots & \ddots & \vdots \\
0 & \cdots & \frac{1}{\sqrt{Q_{jn}}} & 0 \\
\end{bmatrix} * Q_t^{-1}$$

(5)

$$Q_{ij} = (1 - f_1 - f_2)Q_{0} + f_1 u_{i,t-1} u_{j,t-1} + f_2 Q_{ij}$$

(6)

where $Q_{0}$ is the unconditional variance between $i$ and $j$, and is a positive definite $n \times n$ matrix. $Q_{ij}$ is an $n \times n$ unconditional covariance matrix, $u_{i,t-1}$ represents standardised residuals and $f_1$ and $f_2$ are non-negative parameters, where $f_1 + f_2 < 1$. The time-varying conditional correlation coefficient is expressed as:

$$\rho_{ij} = \frac{q_{ij}}{\sqrt{q_{ii} q_{jj}}}$$

(7)

An asymmetric DCC model will be estimated using a Quasi-Maximum Likelihood Estimation (QMLE) with the Broyden-Fletcher-Goldfarb-Shanno (BFGS) algorithm and the T statistics being computed by a robust estimate of the covariance matrix.

### 2.2. Optimal portfolio weights

To construct an optimal portfolio that minimizes risk without lowering expected returns, we use the approach of Kroner and Ng (1998) to construct optimal portfolio weights of a two-asset portfolio as follows:

$$w_{SO,ij} = \frac{h_{ij} - h_{ij}^*}{h_{ij}^* - 2 h_{ij} + h_{ij}^*}$$

(8)

$$w_{SO,ij} = \begin{cases} 
0, & \text{if } w_{ij} < 0 \\
q_{ij}, & \text{if } 0 \leq w_{ij} \leq 1 \\
1, & \text{if } w_{ij} > 1 
\end{cases}$$

(9)

where $w_{ij}$ refers to the weight of $j$ in a portfolio of the two assets defined above at time $t$ and weight of $j$ in the considered portfolio is obtained by $(1 - w_{ij})$.

#### 2.3. Optimal hedge ratios

Alternatively, in order to minimise risk, we follow Kroner and Sultan (1993) regarding risk minimizing hedge ratios of a two-asset portfolio. We typically seek the amount of the short position taken in $j$ in order to minimise the risk of a long position in $i$. The optimal hedge ratio is as follows:

$$\tau_{ij} = \frac{h_{ij}^*}{h_{ij}}$$

(10)

where $\tau_{ij}$ represents the optimal hedge ratio, $h_{ij}$ and $h_{ij}^*$ is the conditional variance of asset $i$, conditional variance of asset $j$, respectively. $h_{ij}^*$ denotes the conditional covariance of asset $i$ and $j$.

#### 2.4. Measuring the performance of a hedged portfolio

Most studies use the hedge effectiveness index given by Ederington (1979) to analyse the performance of a hedged portfolio (Chkili, 2016; Basher and Sadorsky, 2016). We also apply this hedge effectiveness index in our analysis below. The hedge effectiveness index is a comparison of risk between a hedged and an unhedged portfolio. A hedged portfolio comprises a long position in the underlying stock and a short position in futures’ contracts. An unhedged portfolio consists of only a long position in the underlying stock.

A hedge effectiveness (HE) index computes the percentage of the variance that is eliminated from an unhedged portfolio by hedging, and is calculated as follows:

$$HE = \frac{\text{Variance}_{U} - \text{Variance}_{H}}{\text{Variance}_{U}}$$

(11)

where $\text{Variance}_{H}$ and $\text{Variance}_{U}$ denote hedged and unhedged variances respectively.

This method compares the variance of the hedged portfolio to that of an un-hedged portfolio. Hence, a higher hedge effectiveness implies that a higher variance (risk) is eliminated by the hedging strategy.

### 3. Data

The data used in this paper includes daily closing values of: FTSE/JSE All Share Index (JSE), FTSE/JSE Financials (FIN), FTSE/JSE Industrials Index (IND), FTSE/JSE Resources (RES), nearby futures’ contract of gold (GOLD) and nearby futures’ contract of Brent crude oil (OIL). The prices of all commodities are expressed in US dollars. The sample period is from January 3, 2006 to April 23, 2020. The choice of the period is meant to capture the effects of the global financial crisis, the European debt crisis and other late crises, such as the early 2020 COVID-19 global pandemic crisis. We make use of daily data in order to capture the intensity and speed of the dynamic transmission between commodity and stock markets’ returns. Data on FTSE/JSE and its setorial indices is obtained from Inet BFA, while OIL and GOLD data is from Bloomberg. In total, our analysis includes 3732 observations. Continuously compounded daily returns are obtained from stock indices and futures prices of commodities ($P_f$) as $100\times \ln \left( \frac{P_f}{P_{f-1}} \right)$.

1. Note: we use the futures contract of gold and oil and not their spot prices, because the basic concept of hedging is to build a hedged portfolio that will minimise risk by combining futures’ and spots’ positions. Therefore, since this paper aims to analyse the hedge effectiveness of oil and gold against stock market exposure, using future prices will be more appropriate to determine optimal hedge ratios.

2. All the data is denominated in US dollars in order to align our study with other international studies.
4. Estimation and discussion of results

Fig. 1 displays the squared returns of each variable, which represent their unconditional volatilities or variances. While all variables depict high volatilities during main economic and financial crises, such as the 2008–2009 global financial crisis, the 2010–2011 European debt crisis and the current COVID-19 global pandemic crisis, OIL displays high volatilities during COVID-19 global pandemic crisis.

The price of Brent crude oil dropped spectacularly from a high of $71.45 on 6 January to a low of 18.72 on April 12, 2020 due to the low demand of oil caused by lockdown measures adopted by many countries to fight the pandemic. Moreover, Table 1 shows the correlation between the different variables’ unconditional volatilities. The table indicates the extent of volatility connection among stocks and commodities. The results show high correlations between stocks’ volatilities, especially the market (JSE) and sectoral stocks’ volatilities. For example the correlation between the market (JSE) and resources sector (RES) is 0.94191.

Table 1
Correlation of unconditional volatilities of the different variables.

|         | JSE   | FIN   | IND   | RES   | OIL   | GOLD  |
|---------|-------|-------|-------|-------|-------|-------|
| JSE     | 1     | 0.83041| 0.89921| 0.94191| 0.22420| 0.20252|
| FIN     | 1     | 0.84664| 0.68775| 0.22114| 0.18421|
| IND     | 1     | 0.79285| 0.19142| 0.16955|
| RES     | 1     | 0.28090| 0.21579|
| OIL     | 1     | 0.09610|
| GOLD    | 1     | 1     |

Note: unconditional volatilities are obtained by the square of returns of each variable.

There is a low correlation between stocks and commodities. For example, volatility correlation between JSE and GOLD is 0.20252. The volatility correlation between RES and commodities (OIL and GOLD) is relatively higher compared to other stocks.

While the results of the correlation of unconditional volatilities

Fig. 1. Unconditional volatilities of the main variables.
between the different variables are important in showing the extent of risk association between variables, they are uninformative on how risks are transmitted between the different variables. For example, investors are willing to know whether there is unilateral or bilateral risk transmission or spillover between JSE and OIL. To do so, the paper makes use of the VAR-ADCC-GARCH model. The advantage of using a family of GARCH model resides in accounting for heteroscedasticity in returns series when using high frequency data.

4.1. Results for the VAR-ADCC-GARCH model estimation

It is important to recall that the aim of this paper is to assess the extent of volatility spillover between the stock and commodity markets and its implications for portfolio optimization and hedging ration. Moreover, the paper emphasises the importance of disaggregating stock market when assessing the link between stock and commodity markets. It is in this context that four VAR-ADCC-GARCH models are estimated with each model combining a specific stock (either JSE, IND, RES or FIN) and the two commodities (OIL and GOLD). For example, model 1 combines JSE (aggregate stock), OIL and GOLD; model 2 has FIN, OIL and GOLD; model 3 joins IND, OIL and GOLD while model 4 contains RES, OIL and GOLD. The parameters of the model are obtained from the quasi-maximum likelihood estimation of Equations (1)–(7) above.

Table 2 provides the quasi-maximum likelihood estimation of the four VAR-ADCC-GARCH models. VAR model of order 1 (VAR (1)) is used to estimate the mean equations. The order is determined by the Akaike Information Criteria (AIC). Asymmetric effects are accounted for in the volatility equations. The importance of accounting for the asymmetric effect in the conditional volatility of GARCH models due to leverage effects is well documented in the literature (see Bonga-Bonga and Nleya, 2018). Table 2 reports the estimation of the parameters of all the four models as per Equations (1)–(7). Given the aim of this paper in assessing volatility spillover between stocks and commodities, our focus is on coefficients $\alpha_{ij}$ as in Equation (3). The coefficients $\alpha_{ij}$ indicates how...
previous volatility shocks from $j$ affect $i$ in each model. For example, model 1 with the order of variables as JSE-OIL-GOLD means that JSE is represented with subscript 1, OIL and GOLD are represented with subscripts 2 and 3, respectively. The coefficient $\alpha_{12}$ in model 1 indicates how previous volatility shocks from OIL affect the current conditional volatility of JSE.

The results reported in Table 2 show that volatility shocks to oil has moderate effect on the aggregate stock market (JSE), whereby a 1% volatility shock to OIL increases conditional volatility of the JSE in the following period by 0.009%. However, the same shock increases industrial (IND) and resource (RES) stocks by 0.013% and 0.018%, respectively and the coefficients are statistically significant at 1% level. Moreover, while the effect of the volatility shocks to GOLD is not statistically significant on JSE, the same shocks increase IND by 0.078% with 1% level of significance. These outcomes show the importance of disaggregating stock market when assessing its reaction to volatility shocks to commodities. In general, the results reported in Table 2 show that industrial and resource stocks are affected more by past volatility shocks to commodities while financial stocks are mostly insulated from these shocks. This outcome should be expected given that most listed firms in the resource and industrial sectors derive their profit and retained earnings, which affect their share prices from the price of commodities such as OIL and GOLD. Also, most firms listed in the industrial sector of stock exchanges use commodities as their inputs.

Another coefficient used for testing volatility spillover is $\beta_{ij}$. While $\alpha_{ij}$ measures the short-term persistence of past volatility shocks, $\beta_{ij}$ measures the long-term persistence of past conditional volatility, i.e., how previous volatilities from $j$ persist when transmitted to $i$. The results presented in Table 2 show evidence of the persistence of own previous volatility shocks. This is substantiated by the estimated coefficients $\beta_{ii}$ that are positive and statistically significant at 1% level. For example, the coefficient $\beta_{11}$, show that past conditional volatilities of JSE persist in its future, given the high magnitude of the coefficient at 0.927. This coefficient is statistically significant at 1%. Cross-volatility persistence is mostly observed from OIL to sectoral stocks (see $\beta_{12}$).

The validity of our VAR-ADCC-GARCH model is proven by the statistical significance of the estimates of the dynamic conditional correlation parameters $f_1$ and $f_2$ in Table 2. Moreover, the statistical significance of coefficients $\gamma$ provide evidence of asymmetric behaviour in stock and commodity markets. In order to provide more evidence on the validity of our results, Table 3 presents the diagnostic tests of the estimated models, especially the Ljung-Box Portmanteau test of up to 20 lags (Q20) for no serial correlation in the standardised and squared standardised residuals. The results reported in Table 3 show that the null

![Fig. 2. Conditional correlations between stocks and commodities.](image-url)
hypotheses of no serial correlation are not rejected at the 1% level for all the models.

4.2. Time-varying conditional correlations

Given the aim of the paper to analyse the magnitude of hedge ratios and effective portfolio weights for pairs of stock-oil and stock-gold portfolios, it is imperative to begin by examining the time-varying correlations for these pairs from the estimations of the VAR-ADCC-GARCH model based on Equation (7). Fig. 2 below displays the dynamic conditional correlation of the following stock-commodity combination: JSE-OIL, FIN-OIL, IND-OIL, JSE-GOLDL, FIN-GOLD and IND-GOLD pairs. The common feature of the graphs (Fig. 2) is that the correlations of stock-GOLD are all negative during important global crises, such as the 2008 global financial crisis, the 2010–2011 European debt crisis, the 2014 Russian financial crisis, the 2016 Chinese financial crisis and the COVID-19 financial crisis. The observed negative correlations between stocks and GOLD observed during the crisis periods are due to the role of GOLD as a store of value. Studies have shown that investors and asset managers tend to purchase gold and gold related instruments as a store of value and as a diversification tool to protect against stock and currency shocks during period of political and economic uncertainties (see Kios and Sariannidis, 2010). The correlation between stocks and OIL is mostly positive and increase during crisis periods. The positive correlation is certainly because the value of both stocks and oil decrease during crisis periods. However, it is important to note a significant negative correlation between stocks and OIL at the outset of the 2008 global financial crisis. This is certainly due to the lagged effect in the change of oil price compared to stock prices during the 2008 global financial crisis. Bhar and Malliaris (2011) show that oil price increased substantially prior to the 2008 global financial crisis. It may have taken for this price to adjust during the crisis. The correlation between resources stocks (RES) and commodities are mainly positive, especially with OIL. This might be because the performance of resources’ stocks should be linked, to some extent, to the behaviour of the commodity market.

4.3. Optimal portfolio weights results

In this subsection, optimal portfolio weights or the distribution of weight for a portfolio constituted of pairs of stock-oil and stock-gold are calculated from the estimated VAR-ADCC-GARCH models based on Equations (8) and (9). Fig. 3 below illustrates the time-varying optimal portfolio weights for specific pairs of stock-oil and stock-gold portfolios. For example JSE/GOLD reflect the proportion or weight of JSE in a portfolio made of JSE and GOLD. The total weights sum to unit. Fig. 3 reflect the outcome of the dynamic correlation between stocks and commodities displayed in Fig. 2. The results show that during periods of financial crisis, the weight attributed to stocks decreases compared to commodities. Moreover, regarding the two commodities, the average weight for stock/Gold is always below 0.5, reflecting the investors’ preference for GOLD to stocks in an optimal portfolio. Studies show that more addition of gold to a stock portfolio increases its risk-adjusted returns and that gold can serve as a safe haven against stock and

| PORTFOLIO | MEAN | STANDARD DEVIATION | MINIMUM | MAXIMUM |
|-----------|------|---------------------|---------|---------|
| JSE/OIL   | 0.61 | 0.19                | 0.03    | 1.00    |
| JSE/GOLD  | 0.25 | 0.12                | 0.00    | 0.68    |
| FIN/OIL   | 0.56 | 0.11                | 0.00    | 1.00    |
| FIN/GOLD  | 0.25 | 0.01                | 0.02    | 0.61    |
| IND/OIL   | 0.60 | 0.16                | 0.00    | 1.00    |
| IND/GOLD  | 0.24 | 0.10                | 0.00    | 0.61    |
| RES/OIL   | 0.45 | 0.18                | 0.00    | 1.00    |
| RES/GOLD  | 0.12 | 0.08                | 0.00    | 0.45    |
Another important observation in Fig. 3 is that although resources’ stocks (RES) are mostly seen as a mirror of GOLD, there are periods when investors prefer to hold only GOLD without any resource stock, especially during major global financial crisis. These results are confirmed in Table 4 that provides the summary statistics of portfolio weight between stocks and commodities. Table 4 show that the mean portfolio weight of all stocks/GOLD is below 0.25 reflecting investors’ preference to hold more gold than stocks. The lowest weight is for RES/GOLD showing that investors prefer more gold commodity than resource-based financial asset.

### 4.4 Hedge ratios results

In order to assess whether commodities such as oil and gold can be used successfully to hedge against stocks, this subsection constructs optimal hedge ratios for specific pairs of stock-oil and stock-gold based on the estimation of Equation (10). Fig. 4 shows the time-varying hedge ratios for specific pairs of stock-oil and stock-gold portfolios. It can be noted that the hedge ratios fluctuate significantly over time showing the disadvantage of using a static hedge ratio for policy recommendation on hedging. A positive stock/commodity hedge ratio describes the number of futures contract that must be sold (short) in the commodity market if investors take a long position in the stock market. A negative hedge ratio occurs when investors take either long or short positions in both stock and commodity markets (see Bonga-Bonga and Umoetok, 2016).

The display in Fig. 4 reflects the outcome of dynamic correlation and portfolio optimization weights reported in Figs. 2 and 3, respectively. Whenever stock/commodity pairs are negatively correlated the hedge ratios are also negative. This implies that during global financial crises, investors prefer either to long or short both stock and commodities. This situation occurs more often for stock/GOLD hedging than for stock/OIL. However, the most important insight is to identify which combination of stock/commodity provides the best hedging opportunity. To this end, we make use of hedging effectiveness. Given that Hedging effectiveness is quantified in terms of the reduction in volatility of the hedged portfolio, we compare the change in volatility of an unhedged portfolio (a portfolio made of stocks only) and a hedged portfolio (a portfolio that combines stock and commodity). Table 5 provides the mean values of hedging effectiveness for different combinations of stock/commodity hedging strategies.

The results reported in Table 5 show that exposure to gold to hedge against RES, FIN, IND and JSE stocks reduces each of the hedged portfolio volatilities. Compared to unhedged portfolios, the hedged portfolios volatilities of RES-GOLD, FIN-GOLD, IND-GOLD and JSE-GOLD are reduced by 2.50%, 1.56%, 2.04% and 3.45%, respectively. The results confirm the findings of previous studies that adding gold to a portfolio of stocks helps improve hedging against stock risks (see Shahzad et al., 2020 and Ghazali et al., 2020). The largest volatility reduction occurs by combining the market index (JSE) and GOLD, rather than sectoral indices with GOLD. However, the results reported in Table 5 show that adding OIL to stocks for hedging purpose worsens the effectiveness of hedging compared to the unhedged portfolio, except for resources stocks (RES). RES-OIL hedged portfolio volatility is reduced by 4.83% compared to unhedged portfolio. Given that resources stocks

![Fig. 4. Hedger ratio in a portfolio of stock and futures commodity.](image)

| OIL   | GOLD   |
|-------|--------|
| JSE   | 21.26% | −3.45% |
| FIN   | 13.54% | −1.56% |
| IND   | 26.60% | −2.04% |
| RES   | −6.83% | −2.50% |

Note: negative numbers denote a decrease in volatilities from the unhedged portfolio.
often mirror the performance of the commodity market, the portfolio RES-OIL as well as RES-GOLD should mimic a spot-futures portfolio of the same instrument. Studies show that proper combination spot-futures of the same instrument is the best way for hedging (see Bonga-Bonga and Umoetok, 2016). Several studies support our findings by suggesting that the inclusion of GOLD in a portfolio increases its hedging performance (see Aroui et al., 2012) and Chkhili (2016). However, our findings are contrary to those of Bashier and Sadorsky (2016) who assess the hedging effectiveness of the stock market, oil, gold, VIX and bonds in emerging markets (including South Africa) and conclude that oil is a more effective hedge instrument against stock market exposure than to gold, VIX and bonds. We attribute this difference to the fact that Bashier and Sadorsky (2016) do not disaggregate the stock markets to assess the role of each of the sector in volatility spillover, portfolio optimization and hedging with the commodity market. Our findings in Table 5 show that OIL provides the best opportunity for hedging stocks in the resources sector only in the stock exchange market in South Africa. It is possible that the aggregate stock markets considered by Bashier and Sadorsky (2016) are dominated by the resources sector. For policy implications, our results support the fact that gold is a safe haven asset that should be combined with any stock market component for better performance in portfolio optimization and hedging. This reality is supported by the fact that gold prices tend to move in the opposite direction to stock market prices during periods of crisis.

5. Conclusion

This paper investigated the impact of commodities (oil and gold) price fluctuations on the South African stock market. More precisely, the study assessed the extent of volatility spillover between the oil and gold markets and the stock exchange in South Africa. To do so, the paper analysed the time-varying correlations and volatility transmission between oil, gold and the South African stock market returns, using the VAR-ADCC-GARCH model. Our findings show that there is mostly a unidirectional volatility transmission from the commodities market (oil and gold) to South African stock markets, which is because South Africa is a small country that does not have much influence on global commodity prices. Furthermore, when assessing the dynamic correlation between commodities (oil and gold) and the stock market, the paper finds that the correlations of stock-gold are all negative during important global crises. The observed negative correlations between stocks and gold during the crisis periods are due to the role of gold as a store of value.

The study further examined optimal portfolio weights, hedge ratios and hedge effectiveness across different portfolios constituted of asset pairs such as oil-stock and gold-stock. Our results confirm the findings of previous studies that adding gold to a portfolio of stocks helps improve hedging against stock risks’ exposure. However, our findings are contrary to those of Bashier and Sadorsky (2016) who concluded that oil is a more effective hedge instrument against stock market exposure than gold. We attributed this difference to the fact that Bashier and Sadorsky (2016) do not disaggregate the stock markets to assess the role of each of the sector in volatility spillover, portfolio optimization and hedging with the commodity market.

Our results have a number of policy implications for investors, policy makers, portfolio managers and researchers. Investors should be aware that gold is a safe haven asset that should be combined with any stock market component for better performance in portfolio optimization and hedging. This reality is supported by the fact that gold prices tend to move in the opposite direction to stock market prices during periods of crisis. Moreover, portfolio managers need to be informed that oil is an optimal hedging instrument for mitigating risk in the industrial sector of stock exchange, not in the aggregate stock market. It is in that context that this study support that the link between the stock and commodity markets be conducted at a disaggregated level.

CRediT authorship contribution statement

Kgotso Morema: Conceptualization, Formal analysis. Lumengo Bonga-Bonga: Conceptualization, Formal analysis.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.resourpol.2020.101740.

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