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Modelling the heterogeneous relationship between the crude oil implied volatility index and African stocks in the coronavirus pandemic

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ABSTRACT

This paper revisited the crude oil – stock market nexus to examine how the oil implied volatility index (a forward-looking and more accurate measure for uncertainty in oil prices) affects stock returns in major Africa’s oil-importing (South Africa, Kenya, Mauritius, and Botswana) and oil-exporting (Nigeria, Egypt, Tunisia, and Morocco) countries during the COVID-19 pandemic. Quantile regression is employed to examine the heterogeneous relationship at different distributions of stock returns. The study documents evidence to support a negative relationship between the oil implied volatility shocks and stock returns in the selected stock markets, especially in downturns. Findings from this study also reveal that the oil implied volatility shocks can asymmetrically influence Africa’s stocks. Specifically, our empirical evidence reveals that positive shocks in the oil implied volatility index play a key role in most of Africa’s stock markets in market downturns while negative shocks play a moderate role during benign market conditions in some of Africa’s stock markets during the pandemic. More importantly, our findings divulge that investors can find an invaluable shelter with a portfolio of the selected African stocks and oil market securities in the time of the pandemic. The policy implications are further discussed.

1. Introduction

The consensus among academics and practitioners alike is that the global crude oil market and stock markets are often intertwined with economic activity. Exploring the nature and sources of the relationships has emerged as a promising area in academic research for decades. As a corollary to this, a burgeoning body of literature has examined the relationship between stocks and macroeconomic variables (see, Shi et al., 2021; Asafo-Adjei et al., 2020). Another strand of studies also explores the behaviours of macroeconomic variables to crude oil market volatilities (for example, see, Salisu et al., 2019; Balcilar et al., 2021; Ratti and Vespignani, 2016). As the extant literature continues to investigate these relationships with various econometric methods, a related promising area in the academic literature that has continued to arrest public debate is the linkage between oil prices and stock returns.

Theoretically, the discussion on how the oil market affects stock returns can emanate from the stock valuation model. Investors may value a stock by discounting all estimated future cash flows from the security (Huang et al., 1996). In this regard, oil prices can directly affect the earnings of a company (Xiao et al., 2019) and may also indirectly have an impact on the discount rate (Degiannakis et al., 2018), thereby influencing the value of the stock. The direct impact of oil price changes on stock markets may be observed from the fluctuations that occur in the profits of companies as a result of the oil price movements, but the impact depend on whether the company is a net oil-consumer or producer (Enwereuzoh et al., 2021). In periods of increasing oil prices, the production cost of an oil-consuming firm exhibits a direct relationship with oil price changes, which negatively affects expected earnings and dividends (Degiannakis et al., 2018). Similarly, the profit margins of an oil-producing company will also respond directly to changes in oil prices, with potential effects on the expected cash flows of the firm.

Aside from the direct channel, the oil market can indirectly influence stock returns with the stock valuation model via the discounting factor. The extant literature has shown that oil price fluctuations significantly affect economic activity, inflation, interest rate, monetary policy, and fiscal policy (see, Ratti and Vespignani, 2016; Olomola and Adejumo, 2006; Mork et al., 1994). Consequent to this, volatility in the oil market can be a predictor of global economic uncertainties (Xiao et al., 2019). Moreover, the discount rate is partly composed of inflation and interest rate (Huang et al., 1996). Since oil price changes may have a trickling
effect on these variables (Huang et al., 1996), the fluctuations in the oil market can have an impact on the borrowing rate (Degiannakis et al., 2018) and investors’ expectations (Xiao et al., 2019), which, in turn, affects the discount rate. Although the theoretical linkage between the stock market and the crude oil market is unambiguous, the empirical support for the nexus has been inconclusive.

Among the first to document that fluctuations in stock prices negatively affect stock market returns was the seminal paper of Jones and Kaul (1996). More importantly, their findings divulged that fluctuations in oil prices are a key factor influencing stock market returns. Their insights arguably provided the impetus for Sadorsky’s (1999) study and further studies in the area. In particular, Sadorsky (1999) also showed that the US stock market responds to oil price changes asymmetrically. Specifically, he found that positive changes in oil prices affected the stock returns negatively. However, the aforementioned relationship would not occur in stock markets that operate in oil-exporting economies (Degiannakis et al., 2013). In consequence of this, Arouri and Rault (2012) found that oil price shocks positively affected stock returns in most countries in the Gulf Cooperation Council. However, other studies also revealed that the relationship between the variables is not significant (see, Cong et al., 2008; Huang et al., 1996). Even though the empirical evidence on how the crude oil market influences stock returns is numerous, studies examining this phenomenon in Africa are relatively thin compared to studies in the developed economies and other emerging markets. The weak attention shown to African markets is quite startling given the critical role oil play in African economies and their contribution to the global oil and gas value chain.

According to the BP Statistical Analysis of World Energy report for 2020, Africa has the world’s third-highest reserve to output ratio, behind only the Middle East and South and Central America combined. The revenue produced from crude oil remains a key determinant of economic growth for countries that export oil in Africa. Africa’s oil-producing countries earned about USD 3.3 trillion in revenue between 2007 and 2017. This was more than seven times the amount of international aid the continent got over the same period. The regional outlook for the continent is also very intriguing. When oil production was disrupted by the Arab Spring, North Africa’s growth slowed (Robinson et al., 2000). In sharp contrast, increased oil production and exports in Libya were a major contributor to the region’s improved economic growth after 2016. Furthermore, excerpts from the African Economic Outlook (AEO) report for 2020 reveal that the continent grew by about 3.4% in 2019, with North Africa accounting for 44% of that increase. This growth was largely attributed to oil revenues. Similarly, oil-exporting economies in Sub-Saharan Africa (SSA) account for roughly half of the region’s GDP, with oil revenue accounting for up to 90% of total fiscal revenues. Nigeria is currently Africa’s biggest exporter and oil producer, with oil sales accounting for at least 8.4% of its GDP (Okoye et al., 2018). These underscore the extent to which African countries that export oil dependent on the commodity. This crude oil dependency behavior is also exhibited by oil-importing countries (OICs) in the continent.

Excerpts from the African Energy Commission’s (AFREC) report in 2020 indicate that fifty-one African countries were net importers of petroleum products in 2019. South Africa is Africa’s largest crude oil importer, with crude oil accounting for 8.5% of the country’s GDP. The report also indicated that South Africa derived 5% of its fuel needs from gas in 2018, 35% from coal, 50% from local oil refineries in 2018, and also imported nearly 80% of its crude oil. Hence, the dependence of Africa’s economy on its oil consumption is emphasized. Since energy policy remains vital in shaping economic outcomes in Africa (Gatsi and Appiah, 2020), the extent of Africa’s crude oil dependency can be consequential due to the enormous volatility in the crude oil market.

Several factors including geopolitical tensions, financial crisis, and renewable energy policies influence fluctuations in oil prices at the global commodities market (Liu et al., 2020). A newfangled development, the coronavirus pandemic, is the recent factor that has affected global oil prices (Prabheesh et al., 2020). The social distancing measures, partial closures of businesses, and reduction of the oil workforce as a result of infection and quarantine measures have resulted in negative supply shocks and a reduction in oil consumption (Prabheesh et al., 2020). The shocks from the COVID-19 also occurred in tandem with unsuccessful negotiations between OPEC and its allies to regulate global oil production. These led to fluctuations in crude oil prices within the first and second quarter of 2020. For instance, crude oil prices at the international market reduced on January 2, 2020, from $61 to $36.98 on April 28, 2020. Due to the travel restrictions across the world, the COVID-19 has become crucial for oil companies as well as companies in the transportation and hospitality industries (Hung and Vo, 2021). Before the first case was reported in Africa, the economic impacts emanating from the pandemic were already being felt on its shores owing to the fall in demand of African export and tourist sector which translated into excessive depreciation of domestic currencies (Insaidoo et al., 2021).

In a similar vein, equity markets have greatly been affected in the COVID-19. Investor fear (VIX) has been in a record-breaking high since 2011 (Zhang et al., 2021). The well-known dark days of Africa’s stocks also occurred in the second week of March 2020. The Johannesburg stock market plunged by 9.72% with the Casablanca Stock Exchange recording its highest plunge (6.7%) in history (Zhang et al., 2021). About the same time, investors of the Nigerian Stock Exchange suffered losses amounting to about $2 billion as it ended with a plunge of 3.72%. The Nairobi Stock Exchange had to suspend trading after it witnessed a decline of about 15% following the announcement of the first COVID-19 infection in Kenya. Thus, the novel coronavirus has significantly affected the global economy, creating a crash on financial and commodity markets (Hung, 2021).

Hung (2020) aver that these uncertainties in the crude oil and global equity markets occasioned by the COVID-19 outbreak is a source of systemic risk and represent a two-edged challenge for policymakers due to its implications for firms’ production costs and profitability, employment rate, and the resultant deviations from macroeconomic policies to improve societal welfare. The pandemic has also triggered investors flight to safe haven assets in order to minimize investment losses (Cheema, Faff, & Szulczuk, 2020). While there is a clear consensus that developed equity markets offer little or no diversification benefits due to complete integration (Badshah, 2018), emerging and frontier markets are believed to be less integrated with developed markets and may offer support in times of crisis, making them more attractive to international investors. Moreover, financial innovation has resulted in the growth and creation of oil market securities which are useful for asset allocation and portfolio construction (Xiao et al., 2019). Hence, the relationship between the variables is also important for both international and local investors in the selected African economies (see, Asafo-Adjei et al., 2021). Predictably, these investors are relentless in their search of competing risks and rewards to satisfy their portfolio goals during the coronavirus pandemic. This is in line with the competitive market hypothesis developed by Owusu Junior et al. (2021).

The existing empirical results, however, cannot be relied upon to explain the nexus between crude oil volatility and stock market returns because the relationship varies across time (Singhal and Ghosh, 2016) and tends to alter during economic turbulence (see, Zhang et al., 2021; Hung, 2020; Zhang, 2017; Jammazi et al., 2017). Salsu et al. (2020) also proffer that markets may experience initial greater and persistent impacts of own and cross shocks during the pandemic than the period before. Corollary to this, how the volatilities in the crude oil market are affecting Africa’s stocks is unknown in the prevailing COVID-19 period. This paper attempts to fill the gap in the extant literature by examining
how the oil implied volatility affects stock returns in Africa. By providing empirical evidence from oil-importing and oil-exporting African countries, the contribution of this paper to the extant literature is dichotomous. First, although some attempts have been made in recent studies to empirically examine this phenomenon in Africa,¹ this paper presents first evidence on the heterogeneous between the crude oil market and stock returns in both oil-importing and oil-exporting countries in an era with the greatest economic uncertainty since the global financial crisis in 2007–2009 (Baker et al., 2020).

Second, the paper tests the response of Africa’s stock markets to asymmetric behaviors of the crude oil implied volatility index (OVX). Based on volatility derived from oil prices, some studies have revealed that positive and negative shocks affect Africa’s stock market returns differently (example, see, Enwereuzoh et al., 2021; Gouréne and Mendy, 2018; Okorie and Lin, 2020). On the one hand, these volatility series obtained from oil prices are historical and may not accurately capture future uncertainties in the crude oil market (Dutta et al., 2017). On the other hand, the OVX provides an accurate measure of uncertainty in the crude oil market as it captures both historical information of oil prices and investor sentiments about future expectations of oil price movements (Xiao et al., 2019; Xiao et al., 2018; Liu et al., 2013). Karim and Masih (2019) also show that the effect of the OVX is more persistent on stocks than realized volatility. Particularly, Xiao et al. (2019) and Xiao, Zhou, Wen, and Wen (2018) found that the asymmetric relationship with the Chinese stock market. However, there is little information on the impact of the OVX on African stocks (see, Dutta et al., 2017). Moreover, no known empirical discussion has examined the asymmetric relationship between the OVX and stock returns in Africa.

Employing changes in volatility indices rather than oil price changes present significant challenges since variations in volatility indices are much higher than the ones in oil price changes. As noted by Badshah et al. (2018) and Peng and Ng (2012), shocks from volatility indices are non-normal and asymmetrically distributed. Thus, it is likely large positive changes in investor fear in the crude oil market have been recorded due to the heightened uncertainties in crude oil prices. In the same vein, the coronavirus pandemic has triggered enormous heterogeneity in global equity markets (Ding et al., 2021) which will likely result in tail distribution of stock returns (Owusu Junior et al., 2021). This calls for an econometric tool that can enable a multifaceted analysis of the entire conditional distribution of the stock returns in response to the oil implied volatility shocks from the oil market. Accordingly, we employ a quantile regression method suggested by Koenker and Bassett (1978) to investigate the relationship between the variables. Baur (2013) acknowledges that the strength of the quantile regression lie in its ability to disentangle and present the structure and degree of the relationship between the variables in different market conditions.

Meanwhile, the quantile regression is also robust to outliers, skewness, and heteroscedasticity on the response variable (Koenker and Hallock, 2001) which are increasingly apparent in volatility indices, and may be exacerbated by the pandemic. Due to these intriguing properties, some finance and economic scholars in recent times have directed their attention towards how finance and economic variables behave at different market conditions (see, Badshah et al., 2018; Tweneboah et al., 2020; Owusu Junior and Tweneboah, 2020; Owusu Junior, Adam and Tweneboah, 2020; Xiao et al., 2019; Junior et al., 2020). However, these studies do not examine how crude oil volatility indices relate with stock markets in Africa in their quantile regression estimations.

In particular, although our paper fills an important gap in the extant literature, its practical implications for investment decisions are invaluable. The inherent heterogeneity in stock markets implies that the linkages between OVX and stock returns could vary across their conditional distributions. Badshah et al. (2018) argue that heterogeneity is persistent and more present during periods of higher crisis or volatile market conditions. Since the OVX plays a key role in portfolio optimization and risk management (Gong & Lin, 2017, 2018), and taking the COVID-19 pandemic into consideration, investors and policymakers may be interested in knowing the nature of the relationship between the variables at the lower-tails of the distribution because African stocks may serve as a safe haven to the oil market for investors (Baur and Lucey, 2010). Furthermore, asymmetric linkages are very blatant in the oil market and stock market dynamics since the cash flows of firms that are net oil consumers and those that are net-oil-producers respond differently to positive and negative shocks from the oil market (Salisu and Isah, 2017). Moreover, You et al. (2017) demonstrate that the heterogeneous response of investors to positive and negative oil market shocks can exacerbate the asymmetric impact of the oil market shocks on stock returns. In consequence of this, information on the heterogeneous nature of Africa’s stock markets response to asymmetric behaviors of the OVX is needed for investors in these markets to identify and implement appropriate risk management strategies that can protect themselves against dramatic variations in the stocks sensitive to oil prices (see, Hung and Vo, 2021).

The empirical evidence from the study supports a negative relationship between the oil implied volatility indices and stock market returns in the selected countries, which are more persistent at the lower quantiles. The findings of the study reveal that the relationship that persists at the lower quantiles is largely driven by positive changes in the OVX. In general, since we document that higher uncertainty is negatively correlated with stock returns in the sampled OECD’s and OIC’s, our study makes known that investors can find shelter in the pandemic with a portfolio of the selected Africa’s stocks and oil market securities. The next section of the paper presents a brief review of both the theoretical and empirical literature on the relationship between the oil market and stock market returns. Afterwards, the study presents the research methodology, the findings, conclusions, and some recommendations for policy and practice.

2. Literature review

Degiannakis et al. (2018) categorized the transmission mechanisms from the oil market to the stock market into the stock valuation, monetary, fiscal, output, and uncertainty channels. For simplicity purposes, we base our discussion on the stock valuation and monetary channels. The theoretical value of a stock, according to the equity valuation channel, is the discounted value of projected cash flows from the stock (Huang et al., 1996). Changes in oil prices will have varying effects on the cash flows of oil consumers and producers (Oberndorfer, 2009; Mohanty and Nandha, 2011). On the one hand, the cost of oil is a major component of an oil-consuming firm’s production costs, therefore, fluctuations in oil prices can affect its profits and, consequently, its potential cash flows (Degiannakis et al., 2018). On the other hand, the profit margins and cash flows of an oil-producing firm will also respond directly to volatilities in oil prices. Intuitively, the profit margins of an oil producer are expected to increase in benign market conditions, whereas the reverse holds for an oil-consuming firm.

The monetary channel also provides insights into changes in discount rates used in the valuation channel resulting from volatility in the oil market. Mohanty and Nandha (2011) show that the discount rate partially reflects interest rate and inflation. As noted earlier, rising costs of oil may result in an increment in the cost of production. However, these may be shifted to the final consumer, resulting in higher retail prices and ultimately, higher inflation. In response to the inflationary pressures, the Central banks will likely increase short-term interest (Basher and Sadowsky, 2006), thereby increasing the commercial borrowing rates (i.e. the discount rate). Moreover, the increase in borrowing rates also means that fewer viable investment projects (lower

¹ Enwereuzoh et al. (2021) analysed the relationship between crude oil shocks and African stocks with data spanning from January 2000 to July 2018. Asafo-Adjei et al. (2021) also investigated whether crude oil prices drive stock returns in oil producing countries in Africa.
net present values for projects) will be available for the firm, and consequently, lower cash flows.

On the empirical front, it is unclear how volatility in the oil market affects economic activity in African economies. Although it has widely been accepted in the literature that an oil price increase will positively affect the economies of net oil-exporting countries (OECs) with the reverse true for net oil-importing economies (IOGs), existing empirical findings have been quite startling. Gbato, Wang, Wesche Jr, and Tuttle (2017) documented evidence contrary to the aforementioned analogy when they found that an increase in oil price boosted Liberia’s economy. Similarly, Gerston et al. (2019) noted that the economies of oil-importing African countries such as The Gambia, Liberia, Sierra Leone, and Cape Verde, Sierra Leone reacted positively to a rise in global oil prices. Further, Gueye et al. (2019) showed that the impact of movements in oil prices does not just affect Sub-Saharan Africa countries differently but also affects the different sectors of the economies differently. Since the performance of the financial system of economies usually moves in tandem with economic activities in those economies, it is not surprising that inconclusive findings have been documented on the relationship between crude oil volatility and stock returns in Africa.

Gupta and Modise (2013) employed a structural vector autoregressive (SVAR) approach and found that for an economy that imports crude oil such as South Africa, its stock market responds asymmetrically to global movements in oil prices. Specifically, they showed that when economic activity is booming, South Africa’s stocks respond positively. Further, they also revealed that speculative demand shocks and oil supply shocks exhibit a negative relationship with oil price movements. However, Enwereuzoh et al. (2021) also used a structural VAR and a Markov regime-switching model and documented little evidence that oil-supply shocks affect stock returns of both oil-importing and oil-exporting economies. Previously, Uzo-Peters et al. (2018) had investigated this nexus with a VAR model and found that a negative relationship between positive oil price shocks and Nigerian oil and gas company stocks exist. This revelation was unusual and did not mimic how stock markets in countries that export crude oil responds to positive movements in oil prices in general, but it also confirms the differences in how Africa’s stocks respond to movements in oil prices. Finally, Dutta et al. (2017) also investigated the impact of oil implied volatility on Nigerian, Egyptian, South African, Tunisian, Moroccan, Kenyan, and Mauritius stocks. They showed that most of these stocks are vulnerable to uncertainty fluctuations from the OVX using a GARCH-jump model.

From the above-related discussions, the existing empirical evidence on how volatility in the oil market affects oil-importing and oil-exporting African stocks remains inconclusive. This is partly because the relationship varies over time (Dutta et al., 2017) and affects African economies differently (Gueye et al., 2019). Consequently, the emergence of the novel coronavirus pandemic calls for a deeper investigation into the crude oil-stock market nexus in Africa. A heterogeneous analysis is timely given the inherent heterogeneity in stock markets which tend to be pervasive in crisis periods and persistent in periods of high market volatility (Badshah et al., 2018), similar to conditions in the coronavirus pandemic. Similarly, Zhang (2017) shows that the relationship between the oil market and stock markets intensifies in periods of crisis. Moreover, the relationship could vary under different market conditions (Xiao et al., 2019). Accordingly, we present empirical evidence on how the selected African stocks react to implied volatility shocks from the oil market. The present study uses implied volatility shocks because real-time volatility obtained from the oil price series is historical and does not accurately measure uncertainty in the oil market (Xiao et al., 2019; Dutta et al., 2017). More importantly, the study also tests the response of the stock market to asymmetric movements of the indices, which is very crucial for investors in these stock markets for developing appropriate risk management strategies in the pandemic. We provide empirical findings from selected stock indices in oil-importing (Mauritius, Kenya, Botswana, and South Africa) and oil-exporting (Nigeria, Tunisia, Egypt, and Morocco) African economies to examine whether they exhibit similarities and differences in their response.

3. Materials and method

This paper aims to examine how the crude oil implied volatility shocks influence stock markets in oil-importing (Mauritius, Kenya, Botswana, and South Africa) or oil-exporting (Nigeria, Tunisia, Egypt, and Morocco) African economies. The study uses daily data spanning from January 8, 2020, to May 6, 2021. We obtained from the CBOE website the data coverage on crude oil implied volatility (OVX) and the implied volatility index of the US stock market (VIX). The data on stock indices were gathered from the EquityRT database. We proxy the stock markets of the oil-exporting countries (OECs), that is, Egypt, Nigeria, Morocco, and Tunisia with EGX 100, Nigerian All Share Index (ASI), Casablanca ASI, and TUNIS Tuniindex respectively. Likewise, the JSE/FTSE ASI, Mauritius SEMTRI-ASI Index, Nairobi ASI, and Botswana Domestic Company Index are proxies for the stock markets of South Africa, Mauritius, Botswana, and Kenya (the IOGs) respectively.

3.1. Estimation procedure

The study employs a quantile regression approach proposed by Koenker and Basset (1978) to enable a detailed presentation of the structure and degree of the relationship between the variables under different market conditions (Baur, 2013). The approach is also more robust to outliers, skewness, and heteroscedasticity on the response variable (Koenker and Hallock, 2001).

The value of $\epsilon_i$ conditional on the $\tau$-th quantile is assumed to be zero in quantile regression. Thus, the conditional quantile model of $\epsilon_i$ given $x_i$ can be estimated as follows:

$$Q_\tau(y_i|x_i) = \alpha(\tau) + x_i\phi(\tau)$$  \hspace{1cm} (1)

In the above equation, $0 < \tau < 1$. Also, $Q_\tau(y_i|x_i, \alpha)$ represents the $\tau$-th conditional quantile of $y_i$. $\phi(\tau)$ is the estimated parameters of the equation, and $a$ is the unobserved effect. $x$ represents all the independent variables in the model. The coefficients of the $\tau$-th quantile of the conditional distribution can be computed as follows:

$$\hat{\phi}(\tau) = \min_{\phi \in \mathbb{R}} \sum_{i=1}^{n} \rho(y_i - x_i\phi)Q_\tau(\phi(x))$$  \hspace{1cm} (2)

where $\rho(\tau(u) = u(\tau - I(u > 0))$ is the check function and $I(\cdot)$ is an indicator function ($I(y_i - x_i\phi < 0)$).

To estimate the influence of implied oil volatility shocks on stock returns, we estimate the quantile regression as follows:

$$Q_{stock \_ prov} = \alpha(\tau) + \phi(\tau)\Delta OVX$$  \hspace{1cm} (3)

In the above equation, $\Delta Stock \_ Price$, represents the change in stock price at time $t$ (stock returns), and $\Delta OVX$ is the change in the oil volatility index at time $t$ (oil volatility shocks). Further, some authors argue that the implied volatility index of the US stock market (VIX) exhibits a close relationship with the OVX and poses significant risk to other international markets (Badshah et al., 2018). In the light of this, some studies also control for the VIX in their analysis (Xiao et al., 2019). Therefore, we include the VIX and estimate the following quantile regression equation:

$$Q_{ stock \_ prov} = \alpha(\tau) + \phi(\tau)\Delta OVX + \gamma(\tau)\Delta VIX$$  \hspace{1cm} (4)

The $\Delta VIX$ represents the change in VIX at time $t$.

Finally, some empirical works have revealed an asymmetric linkage between the oil implied volatility shocks and some stock markets (Xiao et al., 2019; Xiao et al., 2018; You et al., 2017). Corollary to this, we group the OVX changes into positive and negative OVX shocks and test whether the positive and negative Oil shocks have an asymmetric relationship with African stocks. We define the positive and negative shocks, $\Delta OVX_+ = \max(0, \Delta OVX_t)$ and $\Delta OVX_- = \min(0, \Delta OVX_t)$ and estimate
the final regression equation as follows:

\[
\Delta \text{Oil Price}_t = \varphi_1(\tau)\Delta \text{OVX}_t^- + \varphi_2(\tau)\Delta \text{OVX}_t^+ \tag{5}
\]

Thus, the study examines the heterogeneous relationship between stock market returns and OVX in the selected importers and exporters of crude oil and control for the volatility in the US stock market (VIX) with Eq. (3). We employ Eq. (4) to examine how the selected stocks in Africa respond to positive and negative shocks separately under the quantile regression framework.

We also specify seven quantiles, in this case, \(\tau = (0.05, 0.10, 0.25, 0.5, 0.75, 0.90, 0.95)\) where the low quantiles \(\tau = (0.05, 0.10, 0.25)\) represent the bearish condition, the median, \(\tau = (0.5)\) is the normal condition and the upper quantiles \(\tau = (0.75, 0.90, 0.95)\) denote the bullish conditions.

3.2. Summary statistics

Fig. 1 illustrates the plots of stock market indices for the OICs and OECs as well as the series for the OVX and VIX. It can be observed that the variables have shown significant fluctuations during the COVID-19 pandemic. The plots show that the stock indices experienced the most significant drop in price during the first quarter of 2020 and few months within the second quarter of 2020. These were the periods when the OICs and OECs had started recording their first numbers of the COVID-19 cases and deaths. Concurrently, this period was also met with high investor fear and uncertainty from the crude oil market (OVX) and the US stock market (VIX). Further, the plots indicate that although the OVX and the VIX move in tandem, prices of the indices seem to respond in inverse direction to the movements of the volatility indices. Also, the plots reveal that even though stock prices declined sharply in the early phase of the pandemic, most of the stock indices have made a rebound with some markets recording higher stock prices for the indices as at May 2021 than prices that existed in January 2020. This implies that most the stock indices for the OICs and OECs have exhibited all forms of market conditions during the pandemic. This also confirms that stock markets exhibit more heterogeneity during periods of increasing uncertainty and crisis (Badshah et al., 2018), and the enormous stock price movements in international markets that have been triggered by the COVID-19 (Ding et al., 2021) also exist for the selected stock markets in Africa.

Fig. 2 also displays the ln-returns and the ln of the volatility shocks. Predictably, the variables exhibit persistence in amplitudes as we observe volatility clustering, consistent with stylized facts of financial time series.

The summary statistics on the stock returns of the countries, VIX and OVX are presented for the sampled periods in Table 1. The table shows that average stock returns during the pandemic have been low with the three OICs (Kenya, Mauritius, Botswana) and one OEC (Egypt) recording negative returns on average for the periods. The statistics also indicate that the stock returns are negatively skewed and present excess kurtosis. This suggests that large negative changes in stock prices have been witnessed in the stock markets of these countries during the pandemic. Further, the Augmented Dickey-Fuller (ADF) rejects the null hypothesis of unit root for all the stock indices.

The statistics also show that the VIX experienced larger changes on average compared to the OVX. Likewise, the table reports excess kurtosis for the volatility indices but positive skewness. This also implies that large positive changes in investors’ fear in the crude oil market and US stock markets have been common during the coronavirus pandemic. Again, the ADF test suggests that the volatility indices are stationary.

3.3. Pairwise correlation analysis

Table 2 reports the pairwise correlation between the stock returns of the oil-importing and oil-exporting African economies, as well as the implied volatility shocks of the crude oil market (ΔOVX) and the US stock market (ΔVIX).
stock market (ΔVIX). Except for the Nigerian market, it is blatant that the returns of the other African stocks exhibit a negative relationship with the ΔVIX and ΔOVX. Predictably, there exists a positive relationship between the ΔOVX and ΔVIX. However, this does not pose any concern for multicollinearity as the degree of the relationship between them does not exceed 0.9 as suggested by Kennedy (2008).

4. Empirical results

The study presents the quantile regression results on the relationship between oil volatility shocks and stock returns of the oil-importing and oil-exporting African economies.
4.1. Quantile regression estimates of the impact of crude oil volatility shocks on stock returns

We examine the effect of oil implied volatility shocks on stock market returns in the selected oil-exporting and oil-importing African countries during the COVID-19 pandemic using quantile regression. The study estimates the heterogeneous relationships based on equation (4) for the OECs and OICs and present their results in Table 3 and Table 4 respectively.

From Table 3, we can observe that the oil implied volatility shocks (the OVX changes) exhibit a significant negative impact on stock returns in Egypt, Tunisia, and Morocco during market downturns in the pandemic (0.05, 0.1, and 0.25 quantiles). Also, the OVX changes have a significant negative influence on stock returns in Tunisia and Egypt at the median of the return distribution (0.5 quantiles). Again, we can also observe that stock returns in Egypt were negatively affected by the OVX changes in the upper quantiles where return series had peaked (0.9, and 0.95 quantiles). Similarly, the OVX changes negatively affected stock returns in Tunisia at the 0.95 quantiles and Morocco at 0.75 and 0.9 quantiles. OVX shocks further exhibited a negative effect on the Nigerian stock index, but only at the 0.05 and 0.25 quantiles. Overall, we find that even if the relationship is not always significant across all the conditional distributions of stock returns, all the significant relationships were negative. More importantly, we also document that the relationship is common to all the OECs at the extreme lower quantiles.

In Table 4, it is also obvious that the shocks from the crude oil market have had a significant negative impact on stock returns in Kenya at all tails of the distribution (i.e. 0.05, 0.1, 0.25, 0.5, 0.75, 0.9, and 0.95). Similar results are also recorded for South Africa except for the 0.95 quantiles. In Mauritius and Botswana, changes in the OVX negatively affected stock returns at the lower tails of the distribution (0.05 and 0.1), with the significant negative relationship persisting in the case of Mauritius at 0.25 and 0.75 quantiles. The gleanings from the above results on the nexus in the OICs can be summarized as follows: firstly, the OVX changes negatively impact stock returns at the lower tails and the median (average) of the distribution can also be interpreted within the context of diversification, safe haven and hedge expounded in the work of Baur and Lucey (2010). In the time of the pandemic, investors and policymakers are very interested in knowing the relationship between the two markets at the lower tails of the distribution as investors are interested in finding safe havens in crisis periods (Badshah et al., 2018). The negative relationship documented between the variables indicates at the lower quantiles indicates that the selected African stocks can serve as a safe haven to the crude oil market for investors (Baur and Lucey, 2010). However, such benefits are not available to investors who seek to spread investment risks across the selected OECs and OICs. Moreover, we find that stock markets in Egypt and Tunisia as well as South Africa and Kenya can be a hedge to the oil market in the period of the pandemic. This finding is similar to the results of Ciner et al. (2010), Hung and Vo (2021), and Asafo-Adjei et al. (2021) who revealed that oil remains a useful addition worth considering in portfolio optimization decisions.

Lastly, the study finds evidence of a negative relationship in most of the stock markets at conditions when the stocks are performing better in the pandemic (Egypt, Morocco, Tunisia, South Africa, and Mauritius) and all the upper quantiles in Kenya. Although the stock markets may be doing well in these conditions, economic activity in the period of the pandemic may not be strong enough to counteract the effects of the oil countries to oil implied volatility shocks (ΔOVX) differs, it is a common feature that crude oil implied volatility shocks negatively impacted stock market returns in the African countries during downturns. This is intriguing but not startling as Zhu et al. (2016) and Xiao et al. (2018) show that the effect of crude oil price volatility on stocks is particularly present in bearish conditions. Similarly, Balcilar et al. (2019) revealed that stock markets in emerging and developing countries are particularly sensitive to volatility from the oil market in downturns. The results provide an important insight into the heterogeneous relationship between the crude oil market and stock market. That is, greater uncertainty in the crude oil market will result in lower earnings and consequently lower returns for the stock markets, especially in market downturns. This may be because, in bearish market conditions, the economies of these African countries weaken, rendering companies in the countries more vulnerable to oil market volatility. Thus, the negative effects of volatility in the crude oil market can be easily transmitted to these countries’ stock markets. This is in line with the findings of Salisu et al. (2020).

In addition, since the derivative markets for oil have matured and are enriched with securities, investors may be willing to trade in both markets. Thus, the negative relationship that have been recorded for the lower tails and the median (average) of the distribution can also be interpreted within the context of diversification, safe haven and hedge expounded in the work of Baur and Lucey (2010). In the time of the pandemic, investors and policymakers are very interested in knowing the relationship between the two markets at the lower tails of the distribution as investors are interested in finding safe havens in crisis periods (Badshah et al., 2018). The negative relationship documented between the variables indicates at the lower quantiles indicates that the selected African stocks can serve as a safe haven to the crude oil market for investors (Baur and Lucey, 2010). However, such benefits are not available to investors who seek to spread investment risks across the selected OECs and OICs. Moreover, we find that stock markets in Egypt and Tunisia as well as South Africa and Kenya can be a hedge to the oil market in the period of the pandemic. This finding is similar to the results of Ciner et al. (2010), Hung and Vo (2021), and Asafo-Adjei et al. (2021) who revealed that oil remains a useful addition worth considering in portfolio optimization decisions.

Lastly, the study finds evidence of a negative relationship in most of the stock markets at conditions when the stocks are performing better in the pandemic (Egypt, Morocco, Tunisia, South Africa, and Mauritius) and all the upper quantiles in Kenya. Although the stock markets may be doing well in these conditions, economic activity in the period of the pandemic may not be strong enough to counteract the effects of the oil

Table 3
Oil-exporting African countries (OECs).

| Stock Returns | 0.05 | 0.10 | 0.25 | 0.50 | 0.75 | 0.90 | 0.95 |
|---------------|------|------|------|------|------|------|------|
| Egypt         |      |      |      |      |      |      |      |
| ΔOVX          | 0.000384 | 0.007581*** | 0.01806 *** | 0.02499*** |
| ΔVIX          | -0.011687*** | -0.02168*** | -0.01450*** | -0.03159 |
| Nigeria       |      |      |      |      |      |      |      |
| Constant      | -0.01976*** | -0.01293*** | -0.00377*** | 0.00075*** | 0.00701*** | 0.016086*** | 0.02099*** |
| ΔOVX          | -0.01567*** | -0.01902*** | 0.00187 | 0.00273 | 0.000589 | -0.01348 | -0.02099 |
| ΔVIX          | 0.007024 | -0.00609 | -0.00194 | -0.002092 | 0.00254 | 0.00997 | -0.02882 |
| Tunisia       |      |      |      |      |      |      |      |
| Constant      | -0.01103*** | -0.00929*** | -0.00347*** | 0.00096*** | 0.00475*** | 0.01048*** | 0.01492*** |
| ΔOVX          | -0.00999*** | -0.01288*** | -0.00606*** | -0.00498*** | 0.00628 | 0.00766 | -0.00108*** |
| ΔVIX          | 0.00580 | 0.00571 | 0.000572 | 0.000377 | -0.00553 | -0.01643 | 0.00966 |
| Morocco       |      |      |      |      |      |      |      |
| Constant      | -0.0198*** | -0.00903*** | -0.00386*** | 0.001049*** | 0.006434*** | 0.01272*** | 0.01842*** |
| ΔOVX          | -0.05274*** | -0.02929*** | -0.01973*** | -0.0158 | -0.00449*** | -0.00470*** | -0.01056 |
| ΔVIX          | -0.04933 | 0.00274 | 0.00186 | 0.001495 | -0.00724 | -0.01206*** | -0.0090 |

Note that ΔOVX and ΔVIX represent implied volatility shocks from the crude oil index and the US stock index respectively. Also, *** and ** represent 1%, 5% and 10% significance level.
market shocks in the pandemic.

4.2. Control variable in the study

The study also controlled for the volatility index of the US stock markets (VIX). The results in Tables 3 and 4 show that except for Mauritius, Tunisia, and Nigeria, the other five stock markets were affected negatively by the VIX changes. Moreover, such impacts can occur at any tails of the distribution for South Africa, Kenya, Egypt, and Botswana but may occur only in some upper tails for Morocco. Our findings confirm that the VIX significantly affect international markets (Xiao et al., 2019; Badshah et al., 2018). Further, the results reveal that stock markets in most of the OICs, except Mauritius, can serve as safe haven to the US stocks in the pandemic. In addition, the results also imply that Egypt, South Africa, Kenya and Botswana can hedge the US stock market in the pandemic.

4.3. Quantile regression estimates for testing asymmetric effects of the crude oil volatility shocks

Having confirmed that the OVX changes negatively affect the stock market returns of most of the countries, especially in poor market conditions, the study further tests the response of the stock markets to asymmetric movements of the oil market in the coronavirus pandemic using equation (5). Results of the test are shown in Table 5 and Table 6 for countries that export and import crude oil respectively.

Table 5 shows that in downturns (where stock performance are low, i.e. lower tails of the distribution), the stock index in Egypt responds negatively to positive changes of the OVX. Stock returns of the indices in Nigeria and Morocco also respond likewise in the 0.05 and 0.1 quantiles, while positive OVX changes only have a significant negative effect on the Tunindex in Tunisia at 0.5 quantiles. It can also be observed that under normal market conditions (median tails), the only oil-exporting country that responds to the OVX positive changes is Egypt and it does so negatively. For negative changes in the OVX, the study documents that it has no significant effect on stock returns in the OECs at the lower quantiles. However, we find glimpses of its effect in upper tails of the return distributions but only limited to Egypt and Morocco at 0.9 and 0.75, 0.95 quantiles respectively.

As regards the OICs, the results in Table 6 indicate that Kenya, South Africa, and Mauritius are negatively affected by positive changes in the OVX in downturns and median quantiles. In sharp contrast, we find no evidence for Botswana at all market conditions. It is also interesting to note that just like their counterpart OECs, most of the stock indices are affected by negative changes in the OVX under extreme and normal market conditions. In the upper tails of the distribution where the stocks tend to perform better, the impact of a negative OVX change is significant and negatively affects South Africa at the 0.75 quantiles - Kenya, and Mauritania at the 0.9 quantiles.

Even though the markets respond differently to mostly positive

| Table 4 |
| Oil-importing African countries. |
| Stock Returns | 0.05 | 0.10 | 0.25 | 0.50 | 0.75 | 0.90 | 0.95 |
| South Africa | | | | | | | |
| 0.0402*** | -0.0234*** | -0.00902*** | 0.00186*** | 0.01357*** | 0.0277*** | 0.0425*** | 0.0850*** |
| ΔOVX | -0.0954*** | -0.0820*** | -0.0467*** | -0.0354*** | -0.0304*** | -0.0526*** | -0.0551 | 0.0354*** |
| ΔVIX | -0.0673*** | -0.0645*** | -0.0773*** | -0.0764*** | -0.0489*** | -0.0547*** | -0.0850*** | 0.0511 |
| Kenya | | | | | | | |
| -0.032*** | -0.0157*** | 0.000776*** | 0.00058 | 0.00758*** | 0.0181*** | 0.0249*** | 0.0373*** |
| ΔOVX | -0.0691*** | -0.0335*** | -0.0450*** | -0.0238*** | -0.0294*** | -0.0404*** | -0.0373*** | 0.0316 |
| ΔVIX | -0.0972*** | -0.0336*** | -0.0104*** | -0.0117*** | -0.0217** | -0.0145*** | -0.0425*** | 0.0316 |
| Mauritius | | | | | | | |
| -0.0177*** | -0.0808*** | 0.0032*** | 0.0002 | 0.00309*** | 0.0072*** | 0.00922*** | 0.00922*** |
| ΔOVX | -0.0546** | -0.0235*** | -0.0214*** | -0.0174 | -0.018*** | -0.010 | -0.0147** | 0.0104 |
| ΔVIX | 0.0387 | 0.012 | 0.0048 | 0.00183 | 0.00029 | -0.0118 | -0.0175 | 0.0098 |
| Botswana | | | | | | | |
| -0.0131*** | -0.0104*** | 0.0041*** | 0.0003 | 0.0041*** | 0.0073 | 0.0098 | 0.0098 |
| ΔOVX | -0.0167*** | -0.0108*** | -0.0068*** | -0.00086 | -0.0047 | -0.0078 | -0.0104 | 0.0078 |
| ΔVIX | 0.0180 | 0.0085 | 0.0119*** | 0.00113*** | -0.0147*** | -0.0143*** | -0.0134 | 0.0078 |

Note that ΔOVX and ΔVIX represent implied volatility shocks from the crude oil index and the US stock index respectively. Also, *** represents 1%, 5% and 10% significance level.
changes in the OVX and sometimes negative changes in the OVX, the empirical results presented in Tables 5 and 6 highlights two deep insights into the phenomenon. First, positive OVX changes negatively affect African stocks at the lower conditional distributions of stock returns. Second, in the upper tails of the distribution, the negative OVX changes have significant effects on the stock returns of both the oil-importing and oil-exporting African countries. These findings are quite intuitive. Crude oil shocks can undermine economic activities (Diaz et al., 2016; Jo, 2014). As a consequence of this, higher levels of uncertainty in the crude oil market (positive changes in the OVX) may transmit negative signals about future economic conditions, which can worsen bearish market conditions and aggrivate volatility in the earnings of firms (Xiao et al., 2019). Also, an increase in uncertainty from the crude oil market may be interpreted by investors as unfavorable news, as they may expect a deteriorating economic activity. Accordingly, investors may react massively to bad news in conditions where stock performance is low (lower quantiles). For instance, investors tend to be irrational in turbulent market conditions and tend to focus on bad news (positive OVX shocks) more (Maheu and McCurdy, 2000; Yang and Luo, 2014). Moreover, because African stock markets are immature, this behavior could be exhibited by investors in these African stock markets and could be exacerbated by the coronavirus pandemic.

| Stock Returns | 0.05 | 0.10 | 0.25 | 0.50 | 0.75 | 0.90 | 0.95 |
|---------------|------|------|------|------|------|------|------|
| South Africa  | O VX | O VX | O VX | O VX | O VX | O VX | O VX |
| ΔOVX_t         | -0.21710*** | -0.14261*** | -0.16079*** | -0.03626*** | -0.04785 | -0.06108 | -0.06533 |
| ΔOVX_t         | -0.06934 | -0.05803 | -0.03415 | -0.04368 | -0.07168*** | -0.09945 | -0.17790 |
| Kenya          | O VX | O VX | O VX | O VX | O VX | O VX | O VX |
| ΔOVX_t         | -0.21540*** | -0.14503*** | -0.12904*** | -0.06184*** | -0.03435 | -0.04084 | -0.05283 |
| ΔOVX_t         | -0.02116 | -0.02665 | -0.01352 | -0.00114 | -0.03940 | -0.09845*** | -0.10340 |
| Mauritius      | O VX | O VX | O VX | O VX | O VX | O VX | O VX |
| ΔOVX_t         | -0.09374*** | -0.08627*** | -0.04911*** | -0.03216*** | -0.03103 | -0.01563 | -0.00493 |
| ΔOVX_t         | -0.00150 | 0.00997 | 0.01454 | 0.00578 | -0.01549 | -0.01126*** | -0.02929 |
| Botswana       | O VX | O VX | O VX | O VX | O VX | O VX | O VX |
| ΔOVX_t         | 0.00856 | 0.00714 | -0.00532 | -0.00443 | 0.00294 | 0.00663 | -0.01240 |
| ΔOVX_t         | -0.00277 | 0.00521 | 0.00305 | 0.00336 | -0.00772 | -0.01265 | -0.04141 |

Note that ΔOVX and ΔVIX represent implied volatility shocks from the crude oil index and the US stock index respectively. Also, ***, ** and * represent 1%, 5% and 10% significance level.

Table 6
Oil-importing African countries.

|       | Egypt        | Nigeria       | Morocco       | Tunisia       |
|-------|--------------|---------------|---------------|---------------|
|       | O VX         | VIX           | O VX+         | O VX-         |
|       | O VX         | VIX           | O VX+         | O VX-         |
|       | O VX         | VIX           | O VX+         | O VX-         |
|       | O VX         | VIX           | O VX+         | O VX-         |

Figure SEQ Figure 3. Plots of coefficients for OECs.
In the upper quantiles, our findings show no trace of a significant influence from positive OVX changes. However, we find few traces of the relationship between negative OVX changes in some of the stock markets (South Africa, Kenya, Mauritius, Morocco, and Egypt) at some of the upper quantiles (0.75 and 0.9). This may be because since the performance of the markets tend to be high in these quantiles, investors may be inclined to pay attention to good news (negative OVX changes), although this good news from the oil market may rarely occur (as evidenced by few glimpses at the upper quantiles) in the time of the pandemic. However, the negative relationship may be attributed to the fact that investors may be skeptical about the good news especially in the phase of the pandemic. These findings corroborate with the findings of Enwereuzoh et al. (2021) and Balcilar et al. (2019).

4.4. Summary of results

The study plots the coefficients of the quantile regression estimates in Figs. 3 and 4. The OVX coefficients are shown in blue, the positive shocks (OVX+) are in ash while the negative shocks (OVX−) are in yellow. The diagram illustrates the negative relationship that is being
Fig. 5. Plots of causality-in-mean tests results.
exhibited between the OVX (in blue) and the Stock returns in the selected OECs and OICs at the lower quantiles and the median quantiles. The plots also confirm that this relationship at the lower quantiles is largely driven by positive shocks in the OVX (in ash). However, the negative shocks (in yellow) play a moderate role in the upper tails of the distribution.

4.4.1. Robustness

Following the studies of Adekoya and Oliyide (2021) and Adebayo and Acheampong (2021), we employ the non-linear causality (causality-in-quantiles) test of Jeong et al. (2012) which was later improved by Balcilar et al. (2017). The results, as shown in Fig. 5, are in line with the findings already documented from the quantile regression estimates. Specifically, the results underscore the causal role played by the volatility indices (especially the crude oil implied volatility shocks, ΔOVX) in the selected OECs and OICs stock markets, the significance/impetus of which are more pronounced at the lower quantiles and diminishes at the upper tails of the distribution. In consequence, we document overwhelming similarities and conclude that our findings are robust to a new method that accounts for non-linearities in the relationships.

5. Conclusion and policy implications

Recently, interest in using the OVX to measure uncertainty in the crude oil market has heightened. This increased interest stems from the fact that the OVX not only takes into consideration historical movements in oil prices but also tracks investor sentiments and takes into account the expectations of investors about global crude oil prices. Therefore, the OVX is regarded as a more accurate measure uncertainty in the crude oil market. However, the empirical evidence linking the relationship between the OVX and African stocks is relatively thin. To shed more light on the already inconclusive empirical findings on the crude oil-stock nexus, the present study examined the heterogeneous relationship between the implied oil volatility index and stock market returns in Africa using a quantile regression approach in the period where Africa’s stocks are exhibiting enormous heterogeneity. Further, the study investigated
the inherent asymmetric response of the stock market returns to shocks in the OVX.

The study clustered the African stock markets into crude oil-exporting (Morocco, Nigeria, Egypt, and Tunisia) and OICs (South Africa, Kenya, Mauritius, and Botswana) and employed daily data that captures episodes of the COVID-19 pandemic. With data spanning from January 8, 2020, to May 6, 2021, our findings reveal that the impacts of shocks in the oil implied volatility index (OVX changes) on stock market returns are significantly negative for the oil-importing and oil-exporting African stock markets. Our results also indicate that the negative changes at the lower quantiles are driven by positive changes in the OVX. This result is robust since the analysis controlled for the VIX, which is deemed to be linked to the OVX and a source of risk for international markets. Concerning the asymmetric impacts, our study documents a negative relationship between positive changes in the OVX and stock returns of most of the stock markets at lower quantiles, we also record similar results for negative OVX shocks for some stocks in the upper quantile.

Given the current uncertainty arising from the COVID-19 which exposes the crude oil market to volatilities, we recommend that investors in these oil-exporting and oil-importing African countries take full advantage of volatility indices and react quickly to changes in the index during downturns in stock performance. More importantly, these investors must pay close attention to positive changes in the OVX in such market conditions. In the time of increasing uncertainty in the crude oil market as a result of the COVID-19, the similarities in the responses of the selected stocks to the implied volatility shocks from the crude oil market signify that investors cannot minimize losses by spreading investment risk across the OECs and OICs. Notwithstanding, investors in these markets can seek shelter in the period of the pandemic with a portfolio of oil securities and the African stocks. In response to the asymmetric linkages between most of the African stocks and the shocks from the OVX, policymakers in these African countries must develop a rapid response mechanism to deal with the uncertainty caused by volatilities in the crude oil market, which is exacerbated by the coronavirus pandemic. Moreover, since the implied volatility index also captures investor sentiments, policymakers must also adopt strategies to mitigate the fear of investors especially in turbulent market conditions and more importantly, amid this coronavirus pandemic. This could be achieved by reducing policy inconsistencies and implementing monetary and fiscal policy that would reduce the impact of the pandemic.

CRediT authorship contribution statement

Ebeenezer Boateng: Conceptualization, Methodology, Data curation, Formal analysis Writing-Original Draft Formal; Writing-Review & Editing. Anoky M. Adam: Supervision, Writing- Review & Editing. Peterson Owusu Junior: Supervision, Writing-Review & Editing.

Data availability statement

The data on stock returns were obtained from the EquityRT. This data is under license and not freely available. The data can be obtained from their https://equityrt.com/.

Also, the data on the implied volatility index (OVX) and the volatility index of the US stock market were freely obtained from the CBOE official website https://www.cboe.com/data/

Declaration of competing interest

The authors whose names have been listed immediately below certify that they have no affiliations with or involvement in any organization or entity with financial interest (such as honoraria; educational grants; participation in speakers’ bureaus; membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements), or non-financial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript.

References

Adeloye, T.S., Acheampong, A.O., 2021. Modelling the globalization-CO2 emission nexus in Australia: evidence from quantile-on-quantile approach. Environ. Sci. Pollut. Control Ser. 1–16.

Adeloye, O.B., Oliyide, J.A., 2021. How COVID-19 drives connectedness among commodity and financial markets: evidence from VYP-VAR and causality-in-quantiles techniques. Resour. Pol. 70, 101898.

Arouni, M.E.H., Rauth, C., 2012. Oil prices and stock markets in GCC countries: empirical evidence from panel analysis. Int. J. Finance Econ. 17 (3), 242–253.

Asafa-Adjie, E., Adam, A.M., Darkwa, P., 2021. Can crude oil price return drive stock returns of oil producing countries in Africa? Evidence from bivariate and multiple wavelet. Macroeconomics and Finance in Emerging Market Economies 1–19.

Asafa-Adjie, E., Ayagpong, D., Ageyi, S.K., Frimpong, S., Djimnatey, R., Adam, A.M., 2020. Economic policy uncertainty and stock returns of Africa: a wavelet coherence analysis. Discrete Dynam Nat. Sci. 2020 https://doi.org/10.1155/2020/8846507.

Badshah, I., Bekiros, S., Lucey, B.M., Uddin, G.S., 2018. Asymmetric linkages among the fear index and emerging market volatility indices. Emerg. Mark. Rev. 37, 17–31.

Baker, S.R., Bloom, N., Davis, S.J., Terry, S.J., 2020. Covid-induced Economic Uncertainty (No. W26983). National Bureau of Economic Research.

Balcilar, M., Bekiros, S., Gupta, R., 2017. The role of news-based uncertainty indices in predicting oil markets: a hybrid nonparametric quantile causality method. Empir. Econ. 53 (3), 879–894.

Balcilar, M., Demirer, R., Hammoudeh, S., 2019. Quantile relationship between oil and stock returns: evidence from emerging and frontier stock markets. Energy Pol. 134, 119931.

Balcilar, M., Rosaud, D., Usman, O., Wohar, M.E., 2021. Moving out of the linear rut: a period-specific and regime-dependent exchange rate and oil price pass-through in the BRICS countries. Energy Econ. 98, 105249.

Basher, S.A., Sadosky, P., 2006. Oil price risk and emerging stock markets. Global Finance J. 17 (2), 224–251.

Baur, D.G., 2013. The structure and degree of dependence: A quantile regression approach. J. Bank. Finance 37 (3), 786–798.

Baur, D.G., Lucey, B.M., 2010. Is gold a hedge or a safe haven? An analysis of stocks, volatility, and gold. Financ. Res. Rev. 17, 217–229.

Ciner, C., Gurdgiev, C., Lucey, B.M., 2010. Hedges and Safe Havens: an Examination of Stocks, Bonds, Oil and the Dollar. IIES.

Cong, R.G., Wei, Y.M., Jiao, J.L., Fan, Y., 2008. Relationships between oil price shocks and stock market: an empirical analysis from China. Energy Pol. 36 (9), 3544–3550.

Degiannakis, S., Filis, G., Arora, V., 2018. Oil prices and stock returns: a review of the theory and empirical evidence. Energy J. 39 (5).

Degiannakis, S., Filis, G., Kleyr, R., 2013. Oil Price Shocks and Stock Market Volatility: Evidence from European Data. No. 1613.

Diaz, E.M., Molero, J.C., de Gracia, F.P., 2016. Oil price volatility and stock returns in the G7 economies. Energy Econ. 54, 417–430.

Ding, W., Levine, R., Lin, C., Xie, W., 2021. Corporate immunity to the COVID-19 pandemic. J. Finance Econ. 141 (2), 802–830.

Dutta, A., Nikkihen, J., Rothovius, T., 2017. Impact of oil price uncertainty on Middle East and African stock markets. Energy 123, 189–197.

Enverouzah, P.A., Odei-Mensah, J., Junior, P.O., 2021. Crude oil shocks and African stock markets. Res. Int. Bus. Financ. 55, 101346.

Gati, J.G., Apiah, M.O., 2020. Population growth, income growth and savings in Ghana. J. Econ. Dev. 22 (2), 281–296.

Ghati, A.P., Wang, Z., Wensh, J., P.K., Tundel, J.Y.R., 2017. The impacts of oil price shocks on small oil-importing economies: time series evidence for Liberia. Energy 139, 975–990.

Gershon, O., Ezenwuo, N.E., Obashobin, R., 2019. Implications of oil price shocks on net oil-importing African countries. Heliyon 5 (8), e02208.

Gong, X., Lin, B., 2017. Forecasting the good and bad uncertainties of crude oil prices using a HAR framework. Energy Econ. 67, 315–327.

Gong, X., Liu, B., 2018. The incremental information content of investor fear gauge for volatility forecasting in the crude oil futures market. Energy Econ. 74, 370–386.

Goureine, G.A.Z., Mendy, P., 2018. Oil prices and African stock markets co-movement: a time and frequency analysis. Journal of African Trade 5 (1–2), 55–67.

Guye, G.A., Mbelu, A., Sy, M.A.N., 2019. Coping with falling oil prices: the different fortunes of African banks. Int. Monetary Fund 2019 (129). https://doi.org/10.5089/ 978149831795.001.

Gupta, R., Modirzadeh, M.P., 2013. Does the source of oil price shocks matter for South African stock returns? A structural VAR approach. Energy Econ. 40, 825–831.

Hang, K.D., Mandal, R.W., Stoil, J.P., 1996. Energy shocks and financial markets. J. Futures Mark. 16 (1), 1986–1986, 1.

Hung, N.T., 2020. Dynamic spillover effects between oil prices and stock markets: new empirical results from pre and during COVID-19 outbreak. Aims Energy 9 (5), 819–834.

Hung, N.T., 2021. Oil prices and agricultural commodity markets: evidence from pre and during COVID-19 outbreak. Resour. Pol. 73, 102236.

Hung, N.T., Vo, X.V., 2021. Directional spillover effects and time-frequency nexus between oil, gold and stock markets: evidence from pre and during COVID-19 outbreak. Int. Rev. Finance. Anal. 76, 101730.
