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Oil price uncertainty, exchange rate volatility, and African stock markets: A nonparametric quantile-on-quantile analysis

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ABSTRACT

Given that crude oil is priced in U.S. dollars (USD) on the international market, exchange rate fluctuations can dampen or amplify the transmission effects from oil prices to stock markets, particularly in non-USD economies. Using quantile regression (QR) and nonparametric quantile-on-quantile (QQ) regression models, this study examines the impact of oil price uncertainty (*OVX*) on stock returns in African oil-importing and exporting countries, accounting for the moderating role of exchange rate volatility. Findings reveal that *OVX* exerts a heterogeneous and negative effect on African stock returns, with oil-importing nations experiencing more pronounced impacts than their oil-exporting counterparts. In addition, results indicate that *OVX* significantly affects African stock returns at moderate and high levels, but not at low levels, suggesting an asymmetry among the quantiles of *OVX*. Furthermore, the impact is found to be stronger during bearish market conditions than in bullish ones, emphasizing asymmetry across conditional quantiles of stock returns. Moreover, the joint variability of *OVX* and exchange rates has a substantially greater influence on African stock returns than *OVX* alone, regardless of the market state. This study offers important insights for investors, policymakers, and other stakeholders.

1. Introduction

Crude oil remains the predominant energy source driving the global economy, serving as a vital component in production and transportation processes. Accordingly, the relationship between crude oil prices and economic activity has been a focal point of interest among researchers worldwide. Studies by Hamilton (1983), Katircioglu et al. (2015), and Kilic and Cankaya (2020) provide evidence of the significant impact of crude oil prices on macroeconomic aggregates across various nations. As stock performance reflects overall economic conditions, the oil–stock connection has long attracted the attention of scholars, policymakers, and investors (Chang et al., 2023; Demirer et al., 2025; Fasanya et al., 2021).

Over recent decades, the crude oil market has experienced notable fluctuations, characterized by abrupt spikes and downturns in prices (Lu et al., 2020). Fig. 1 presents this trend, illustrating that crude oil prices have been relatively high—especially since 2005—with a greater degree of variation compared to earlier years. This observation points to increasing instability in the international oil market. Furthermore, the figure indicates that fluctuations in oil prices are frequently driven by market-related and external factors. Geopolitical conflicts, supply disruptions, production decisions by major oil producers such as the Organization of the Petroleum Exporting Countries, shifts in global demand patterns, financial crises, and the COVID-19 pandemic are among the key factors that can significantly disrupt the crude oil market and thus the stock market (Chen et al., 2025; Khan et al., 2023; Li et al., 2024; Yin et al., 2024).

Thus, instability in the crude oil market, driven by these factors, inherently introduces uncertainty about future oil prices. This rationale aligns with Xie et al. (2021), who reported that the extent and condition of oil price dynamics are captured by oil price uncertainty (*OVX*). Given oil's critical role in powering industry and transportation, such uncertainty can significantly affect the overall health of economies. Theoretically, heightened uncertainty impacts firms' inventory investments

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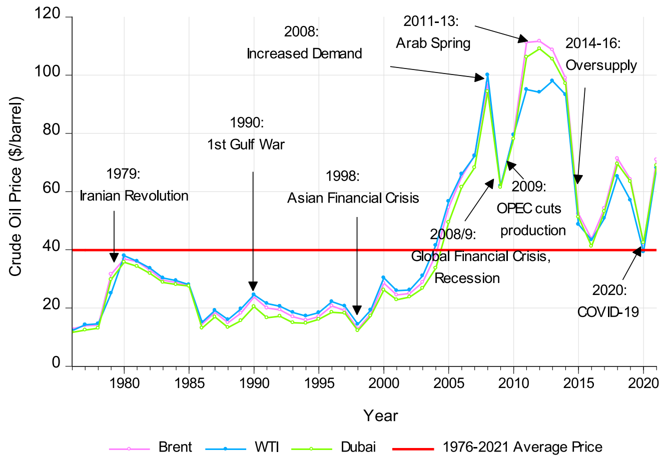

Fig. 1. Trend of crude oil prices (Brent, West Texas Intermediate, and Dubai), 1976–2021.

and capacity utilization, limiting cash flows and profits, which in turn affects stock performance (Degiannakis et al., 2018). Moreover, this uncertainty can influence the behavior of households and enterprises by altering investment decisions, consumer spending, and production planning—further affecting firms' cash flows and stock prices (Sreenu, 2022). Therefore, understanding how stocks react to *OVX* is essential for informed investment and risk management.

Because crude oil is traded globally in U.S. dollars (USD), and transactions involve buyers and sellers from different countries, the potential influence of foreign exchange rates (FOREX) on the oil–stock relationship cannot be overlooked. When the USD appreciates or depreciates, the cost of importing oil or the revenue from oil exports changes accordingly. These changes affect production costs and corporate profits, ultimately influencing stock prices. Kumar (2019) and Khan et al. (2025) asserted that exchange rates are closely linked to oil prices and significantly influence stock markets. Therefore, it is important to account for FOREX effects when analyzing the oil–stock connection. Notably, currencies in developing economies—particularly in Africa—have exhibited long-standing volatility against the USD. Accordingly, this study incorporates exchange rate volatility (*EXV*) as a moderating factor in the relationship between *OVX* and African stock markets.

In Africa, countries that either import or export oil remain highly dependent on this resource (Chekouri et al., 2017), making them vulnerable to fluctuations and uncertainty in global oil prices. In Nigeria, for example, ~86 % of export revenue is derived from oil and gas (Umechukwu & Olayungbo, 2022). Furthermore, weak economic diversification limits the ability of various African countries to quickly adapt to alternative energy or revenue sources when global oil market disruptions occur. You et al. (2017) found that *OVX* may exert greater effects on developing nations, particularly in Africa, due to underdeveloped monetary and financial frameworks. Therefore, focusing on Africa can offer new insights into the vulnerability of stock markets to *OVX*.

Against this background, this study examines the effects of *OVX* on stock returns in selected African net oil-importing and oil-exporting countries, considering the moderating influence of *EXV*. Specifically, this study addresses the following research questions: Do African stock returns under different market conditions (bullish, bearish, and normal) respond asymmetrically to varying levels of *OVX* (low, moderate, and high)? Does *OVX* exhibit heterogeneous impacts on stock returns across oil-importing and -exporting African countries? To what extent does the joint variability of *OVX* and exchange rates influence African stock returns across distinct market states? To answer these questions, this study employs the quantile regression (QR) model and the nonparametric quantile-on-quantile (QQ) regression method proposed by Sim and Zhou (2015), yielding the following key findings. First, *OVX* has heterogeneously negative effects on African stock returns, with oil importers more severely affected than exporters. Second, its impact is more pronounced during bearish conditions than bullish ones, revealing asymmetry across the conditional quantiles of stock returns. Furthermore, this effect is significant at moderate and high levels of *OVX* but insignificant at low levels. Third, its joint variability with exchange rate exerts a stronger influence on African stock returns than *OVX* alone, regardless of market conditions.

This study makes several notable contributions. First, it expands the existing literature by focusing on the context of African net oil-importing and oil-exporting economies, analyzing the effect of *OVX* on stock returns while considering *EXV* as a moderating factor. Whereas most previous studies have focused on developed and major emerging economies, African markets remain underexamined despite their heightened susceptibility to external shocks stemming from less mature financial systems and investment infrastructure. Second, to the best of our knowledge, this is among the first studies to explore the combined effects of *OVX* and *EXV* (*COVOX*) across low, moderate, and high levels on distinct stock return states (i.e., bullish, bearish, and normal). Most existing research considers these explanatory variables separately. Third, the findings offer practical insights for investors, policymakers, and other stakeholders by informing the design of robust investment strategies and policy responses. For example, the heightened impact of *OVX* —especially at moderate and high levels when combined with *EXV*—provides essential information for managing financial risk in African markets.

The rest of this article is organized as follows. Section 2 reviews the relevant literature, and Section 3 presents the data and methodology. Section 4 provides the preliminary analyses, and Section 5 discusses the empirical findings. Section 6 then concludes the study and offers policy implications and future research directions.

2. Literature review

The relationship between crude oil and stock markets has attracted scholarly interest for several decades, with one of the earliest studies conducted by Jones and Kaul (1996). However, findings in the literature are often contradictory, underscoring the complexity of the oil–stock relationship. Ciner (2001), Nandha and Faff (2008), and Sadorsky (1999) reported negative reactions of stock markets to oil price changes. Conversely, Ono (2011) and Sadorsky (2001) suggested positive effects. Meanwhile, Cong et al. (2008) found no significant relationship. Another strand of research emphasizes that oil supply and demand shocks influence the oil–stock connection (Güntner, 2014; Kilian & Park, 2009; Mokni, 2020). Although much of this research has focused on oil price changes and shocks, limited studies have examined *OVX*. Xie et al. (2021) argued that *OVX* reflects the intensity and dynamics of price fluctuations. Indeed, *OVX* can delay or alter investment, consumer spending, and production decisions (Jo, 2014; Phan et al., 2019), potentially influencing stock returns. Thus, *OVX* has garnered increasing attention in recent years.

Several studies in the existing literature have documented that *OVX* negatively influences stock returns. For example, Diaz et al. (2016) found a negative effect in Group of Seven (G7) countries. Similarly, Zhang et al. (2023) and Luo and Qin (2017) reported negative responses of Chinese stock markets to *OVX*. Sreenu (2022) and Alqahtani et al. (2019) observed similar effects in India and Gulf Cooperation Council (GCC) countries, respectively. However, some studies yielded opposing results. Bass (2017) reported a positive effect of *OVX* on Russian stock returns, while Alsalman (2016) found no significant effect on U.S. stock markets. Notably, most of these studies focus on developed and major emerging economies, with limited research on Africa. Among the few studies analyzing African markets, most examined oil price changes and shocks rather than *OVX* or *EXV* (Asafo-Adjei et al., 2024; Chen, Msofe, Wang, & Chen 2024; Enwereuzoh et al., 2021; Gourène & Mendy, 2018).

Aligning with Diaz et al. (2016), many studies use standard deviation (SD), generalized autoregressive conditional heteroskedasticity (GARCH)-based volatility, or realized volatility to proxy *OVX* (Sadorsky, 2008; Wang et al., 2017). However, these approaches rely on historical price data and fail to reflect forward-looking uncertainty. To address this limitation, the current study adopts the Chicago Board Options Exchange (CBOE) Crude Oil Volatility Index, consistent with recent studies by Liu et al. (2023) and Qiao et al. (2024). This index captures both historical fluctuations and market expectations of oil price volatility over the next 30 days.

Many prior studies have employed mean-based models (e.g., vector autoregression (VAR)), which assume a linear relationship between *OVX* and stock markets (Diaz et al., 2016; Dutta, 2017; Salisu et al., 2022). However, recent research has increasingly adopted nonlinear methods (Xie & Tang, 2022). Building on this perspective, Joo and Park (2021), Lee et al. (2024), and Xiao et al. (2018) showed that market conditions (i.e., bullish and bearish phases) affect how stock markets respond to *OVX*. Accordingly, this study employs a nonparametric QQ regression model to capture these varying behaviors across different market conditions.

Furthermore, the oil–stock relationship may vary between oil-importing and oil-exporting countries (Mokni, 2020). Syed and Bouri (2022) found that *OVX* has a stronger impact on stock return volatility in oil exporters than in importers and that emerging economies are generally more affected than developed ones. Using a global VAR (GVAR) model across 26 countries, Salisu et al. (2022) showed that oil exporters and developing nations exhibit greater sensitivity to *OVX* than developed or oil-importing countries. Therefore, this study compares the responses of selected African net oil-importing countries (i.e., South Africa, Tanzania, and Namibia) with those of net oil-exporting countries (i.e., Nigeria, Egypt, and Tunisia).

As crude oil is priced in USD on the international market, FOREX can hinder or amplify the effects of oil prices on stock returns, especially in countries with currencies other than the USD. Kumar (2019) and Chen et al. (2022) provided evidence of a strong connection between oil prices and exchange rates. Similarly, Chang and Chang (2023) and Delgado et al. (2018) identified a negative relationship between exchange rates and stock prices in China and Mexico. Moreover, Jain and Biswal (2016) demonstrated that declining oil prices in India reduce the value of the Indian rupee and negatively affect the stock market index. Therefore, this study incorporates *EXV* as a moderating variable in the oil–stock relationship in African economies.

Although numerous studies have examined the relationship between *OVX* and stock returns in developed and major emerging economies, small emerging markets—particularly in Africa—remain under-examined. These markets may be more vulnerable to *OVX* due to less mature financial systems and investor infrastructure (Syed & Bouri, 2022). Moreover, the joint effects of *OVX* and *EXV* on African stock markets across quantiles of both dependent and independent variables remain unexplored. This paper addresses these gaps by analyzing the quantile responses of African stock returns to *OVX* while considering *EXV*. It also investigates the joint impact of *OVX* and *EXV* on stock returns across different quantiles in both oil-importing and oil-exporting African nations.

3. Methodology

This section describes the econometric models, procedures, variables, and data used in this study. The QR model is first applied to assess the impact of *OVX* on African stock returns across different market states, while accounting for the moderating effect of *EXV*. Subsequently, the nonparametric QQ regression technique developed by Sim and Zhou (2015) is employed to analyze the influence of *OVX* at different levels (low, medium, and high) across various stock market conditions. These methods are more comprehensive and robust than the mean-based regression models used in most previous studies (Alsayed et al., 2020).

Because *EXV* is unobservable, the asymmetric Glosten–Jagannathan–Runkle (GJR)-GARCH model is applied to estimate the corresponding volatility series. Additionally, the dynamic conditional correlation (DCC)-GJR-GARCH model is used to construct the *COVOX* series. The study then examines how African stock returns respond to *COVOX*.

Before implementing the econometric models and procedures, several preliminary analyses were conducted, including exploratory data analysis (*EDA*), summary statistics and unit root tests, the Brock–Dechert–Scheinkman (BDS) test, and quantile plots. Fig. 2 provides a schematic overview of the entire empirical process adopted in this study.

3.1. GJR-GARCH

The asymmetric GJR-GARCH model with the autoregressive moving average mean equation is specified as

$$r_t = \sum_{i=1}^{k} \varphi_i r_{t-i} + \sum_{i=1}^{s} \gamma_i \eta_{t-i} + \eta_t, \tag{1}$$

$$\sigma_t^2 = \alpha + \lambda_1 \eta_{t-1}^2 + \lambda_2 l_{t-1} \eta_{t-1}^2 + \eta \sigma_{t-1}^2, \tag{2}$$

where r_t denotes the return series, and φ and γ correspond to the autoregression and moving average terms, respectively, with optimal lags, k and s. η_t represents the disturbance term, which is heteroscedastic over time. In Eq. (2), σ_t^2 indicates the conditional variance, α is the intercept, and λ_1 and β are the autoregressive conditional heteroskedasticity and GARCH parameters, respectively. λ_2 represents the asymmetric scale, and l_{t-1} is a dummy variable that allows for asymmetry, defined as

$$l_{t-1} = \begin{cases} 1, \eta_{t-1} < 0 \\ 0, otherwise \end{cases}, \tag{3}$$

where $\alpha > 0$, $\beta \geq 0$, $\lambda_1 + \lambda_2 \geq 0$, and $\lambda_1 + \beta + \frac{\lambda_2}{2} < 1$ must be satisfied to ensure stationarity and positive variance.

3.2. DCC-GARCH

In this study, the *COVOX* is generated using the DCC-GJR-GARCH model. Unlike many previous studies that rely on the univariate GARCH (1,1) model at the initial stage of building the multivariate DCC-GARCH framework, this paper applies the GJR-GARCH model to capture possible asymmetric effects, consistent with Chen, Msofe, and Wang (2024). The structure of the DCC-GARCH model is as follows:

$$r_t = \pi_t + \eta_t, \frac{\eta_t}{I_{t-1}} \sim N(0, H_t), \tag{4}$$

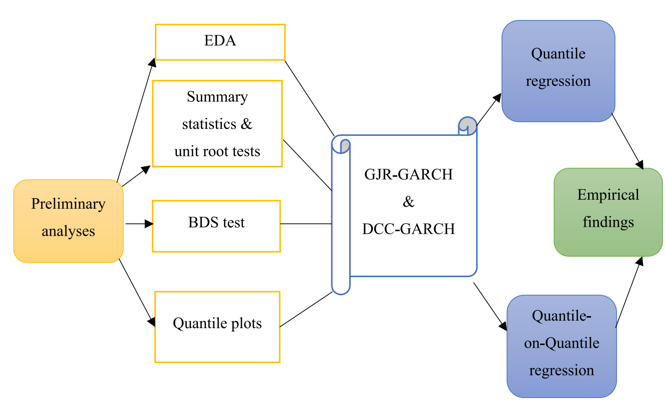

Fig. 2. Overview of the empirical process.

$$\eta_t = H_t^{\frac{1}{2}} z_t, z_t \sim N(0,1), \tag{5}$$

where r_t is the vector of returns for *OVX* and exchange rate series, π_t is the vector of expected the conditional r_t, η_t is the heteroscedastic error term conditional on the prior information set, I_{t-1}, $H_t^{\frac{1}{2}}$ is the dynamic conditional variance-covariance matrix, and z_t is the vector of standardized residuals. The time-varying conditional covariance matrix is represented as

$$H_t = M_t R_t M_t, \tag{6}$$

where M_t is a diagonal matrix such that $M_t = diag\left(\sqrt{h_t^{r_1}}, \sqrt{h_t^{r_2}}\right)$ is the diagonal matrix where $h_t^{r_1}$ and $h_t^{r_2}$ represent the time-varying conditional volatility *OVX* and exchange rate returns. $R_t = diag(G_t)^{\frac{-1}{2}} G_t diag(G_t)^{\frac{-1}{2}}$ is the conditional correlation matrix of returns, and G_t is the dynamic conditional correlation of standardized residuals given by

$$G_t = (1-\alpha-\beta)\overline{G} + \alpha z_{t-1} z_{t-1}^{'} + \beta G_{t-1}, \tag{7}$$

where $\overline{G} = Cov\left[z_t z_t^{'}\right] = E\left[z_t z_t^{'}\right]$ is the matrix of the unconditional correlation z_t. Coefficients α and β are DCC-GARCH parameters, which must satisfy $\alpha \geq 0$, $\beta \geq 0$, and $\alpha + \beta \prec 1$ to ensure positive unconditional variances. Moreover, G_t should be positive definite so that R_t can be positive definite.

3.3. QR

This study specifies two versions of the QR model. Eq. (8) estimates the impact of *OVX* on different quantiles of African stock returns, controlling for *EXV*. Eq. (9) then assesses how African stocks respond to *COVOX* at different quantiles.

$$Q^\tau(r_t) = \alpha_0^{(\tau)} + \alpha_1^{(\tau)} OVX_t + \alpha_2^{(\tau)} EXV_t + \alpha_3^{(\tau)} r_{t-1} + \varepsilon_t^{(\tau)}, \tag{8}$$

$$Q^\tau(r_t) = \alpha_0^{(\tau)} + \alpha_1^{(\tau)} COVOX_t + \alpha_2^{(\tau)} r_{t-1} + \varepsilon_t^{(\tau)}, \tag{9}$$

where τ denotes the quantile level such that $0 < \tau < 1$, r_t represents stock returns, OVX_t is the CBOE crude oil volatility index used to capture *OVX*, and EXV_t is the volatility in exchange rates estimated from the GJR-GARCH model in Eq. (2). $COVOX_t$ is the dynamic conditional covariance from the DCC-GARCH model. The disturbance term is ε_t, and the coefficients \beta and \gamma are estimated parameters.

3.4. QQ regression

Because *OVX* may vary in intensity, the nonparametric QQ method proposed by Sim and Zhou (2015) is used to evaluate the effects of low, medium, and high levels of uncertainty on African stock returns under different market states. The method offers two advantages. First, it estimates how quantiles of an independent variable affect the conditional quantiles of a dependent variable. Second, being nonparametric, it does not rely on restrictive assumptions inherent to parametric models.

Consider the following nonparametric QR models:

$$r_t = \beta^\tau(OVX_t) + \lambda_1^\tau r_{t-1} + \lambda_2^\tau EXV_t + \omega_t^\tau \tag{10}$$

$$r_t = \beta^\tau(COVOX_t) + \lambda^\tau r_{t-1} + \omega_t^\tau \tag{11}$$

where, τrepresents quantile of African stock returns, ω_t^τ denotes a disturbance term with the zero τ -quantile. The connecting function $\beta^\tau(\cdot)$ is presumed to be unknown since prior knowledge regarding the relationship between African stock returns and OVX_t or $COVOX_t$ is unavailable. The QQ technique involves disentangling the explanatory variables into different quantiles. From Eq. (10), to generate ϑ -quantile of explanatory variable OVX_t, the function $\beta^\tau(\cdot)$ is linearized at OVX^ϑ using a first-order Taylor function.

$$\beta^\tau(OVX_t) \approx \beta^\tau(OVX^\vartheta) + \beta^{\tau'}(OVX^\vartheta)(OVX_t - OVX^\vartheta) \tag{12}$$

where $\beta^\tau(OVX^\vartheta)$ and $\beta^{\tau'}(OVX^\vartheta)$ of Eq. (12) can be described as $\beta_0(\tau,\vartheta)$ and $\beta_1(\tau,\vartheta)$, respectively, since they are merely indexed in τ and ϑ. Thus, Eq. (12) can be expressed as follows:

$$\beta^\tau(OVX_t) \approx \beta_0(\tau,\vartheta) + \beta_1(\tau,\vartheta)(OVX_t - OVX^\vartheta) \tag{13}$$

Next, Eq. (10) can be rewritten as follows:

$$r_t = \underbrace{\beta_0(\tau,\vartheta) + \beta_1(\tau,\vartheta)(OVX_t - OVX^\vartheta) + \lambda_1(\tau) r_{t-1} + \lambda_2(\tau) EXV_t}_{(*)} + \omega_t^\tau \tag{14}$$

Similarly, Eq. (15) is obtained by reconstructing Eq. (11) to incorporate the ϑ -quantile of independent variable $COVOX_t$.

$$r_t = \underbrace{\beta_0(\tau,\vartheta) + \beta_1(\tau,\vartheta)(COVOX_t - COVOX^\vartheta) + \lambda(\tau) r_{t-1}}_{(*)} + \omega_t^\tau \tag{15}$$

In Eqs. (14) and (15), we denote $\lambda_1(\tau) \equiv \lambda_1^\tau$, $\lambda_2(\tau) \equiv \lambda_2^\tau$, and $\lambda(\tau) \equiv \lambda^\tau$. The portion marked by (*) describes the connectedness of the τ^{th} quantile of African stocks and the ϑ^{th} quantile of the *OVX* or *COVOX*.

For simplicity, Eq. (15) is used to elaborate the estimation procedure of parameters $\beta_0(\tau,\vartheta)$ and $\beta_1(\tau,\vartheta)$. To obtain estimates of $\widehat{\beta}_0(\tau,\vartheta)$ and $\widehat{\beta}_1(\tau,\vartheta)$, the following minimization problem is solved.

$$\min_{\widehat{\beta}_0,\widehat{\beta}_1} \sum_{j=1}^{m} \rho_\tau[r_t - \widehat{\beta}_0 - \widehat{\beta}_1(COVOX_t - COVOX^\vartheta]K\left(\frac{F_n(COVOX_t) - \vartheta}{h}\right) \tag{16}$$

where $\rho_\tau[\cdot]$ is the slanted absolute value function that yields estimates of the τ^{th}-conditional quantile of r_t. $K(\cdot)$ is the Gaussian kernel function that weights data points close to $COVOX^\vartheta$, depending on the smoothing parameter (bandwidth) h. The weights are distributed in reverse order from $COVOX_t$ to $COVOX^\vartheta$. The empirical distribution function is defined as follows:

$$F_n(COVOX_t) = \frac{1}{m}\sum_{s=1}^{m} I(COVOX_s < COVOX_t) \tag{17}$$

3.5. Data description

This study uses daily data on stock indices, exchange rates, and *OVX*, all obtained from Investing.com. The *OVX* index, published by the CBOE, serves as a reliable measure of uncertainty in oil prices (Sreenu, 2022), and it provides both historical fluctuations and market expectations of oil price volatility over the next 30 days. Higher *OVX* values indicate greater expected uncertainty, while lower values reflect more stable outlooks.

Exchange rate data are reported as USD against six African local currencies: South African rand, Tanzanian shilling, Namibian dollar, Nigerian naira, Egyptian pound, and Tunisian dinar. The selected African stock indices include Nigeria, South Africa, Namibia, Tunisia, Egypt, and Tanzania. South Africa, Namibia, and Tanzania are classified as net oil importers, whereas Nigeria, Tunisia, and Egypt are net oil exporters.

The dataset ends on December 31, 2021, with starting dates varying by country based on data availability: South Africa (August 17, 2011), Tanzania (April 3, 2013), Namibia (October 15, 2013), Nigeria (February 2, 2012), Egypt (January 4, 2012), and Tunisia (August 16, 2011). The dataset includes only trading days for each country. Returns for all variables are calculated using the following natural logarithmic difference:

$$r_t = (lnc_t - lnc_{t-1}) \times 100, \tag{18}$$

where r_t and c_t denote index returns and closing prices, respectively.

4. Preliminary analyses

4.1. Exploratory data analysis

As the dependent variable in this study (i.e., stock returns) are calculated using the log differences of their respective stock prices, this section begins by examining stock price trends in the selected African countries, illustrated by time series plots in Fig. 3, revealing an overall upward trend in stock prices for Egypt, Namibia, South Africa, and Tunisia. The upward trend indicates that the aggregate value of the stocks comprising each index has consistently risen over a specified time, reflecting positive stock performance and overall market growth in these countries. For Nigeria, upward and downward trends are observed, while Tanzania shows a rising trend from early 2013 to the end of 2014, followed by a persistent decline from 2015 to 2021. A downward trajectory in stock prices reflects a continuous decline in the collective value of index components over a given period, potentially signaling a downturn in the stock market, possibly due to reduced investor confidence or unfavorable economic conditions.

As this study investigates the effect of *OVX* on African stock returns, the behavior of both variables is examined in a common plot with time on the horizontal axis, as shown in Fig. 4. *OVX* remained relatively stable during 2011–2014 and 2016–2018, indicating calmer market conditions and reduced crude *OVX*. However, the index experienced significant fluctuations in other periods. Notably, a sharp spike in early 2020 reflects heightened *OVX* driven by exogenous shocks such as the COVID-19 pandemic. Meanwhile, stock returns display considerable volatility over time in most African countries. Remarkably, Namibia and Tanzania show relatively little variation compared with others.

Given that the study also examines the joint effect of *OVX* and exchange rates on African stock returns, this section further explores the temporal trends of these two variables, as depicted in Fig. 5. The figure

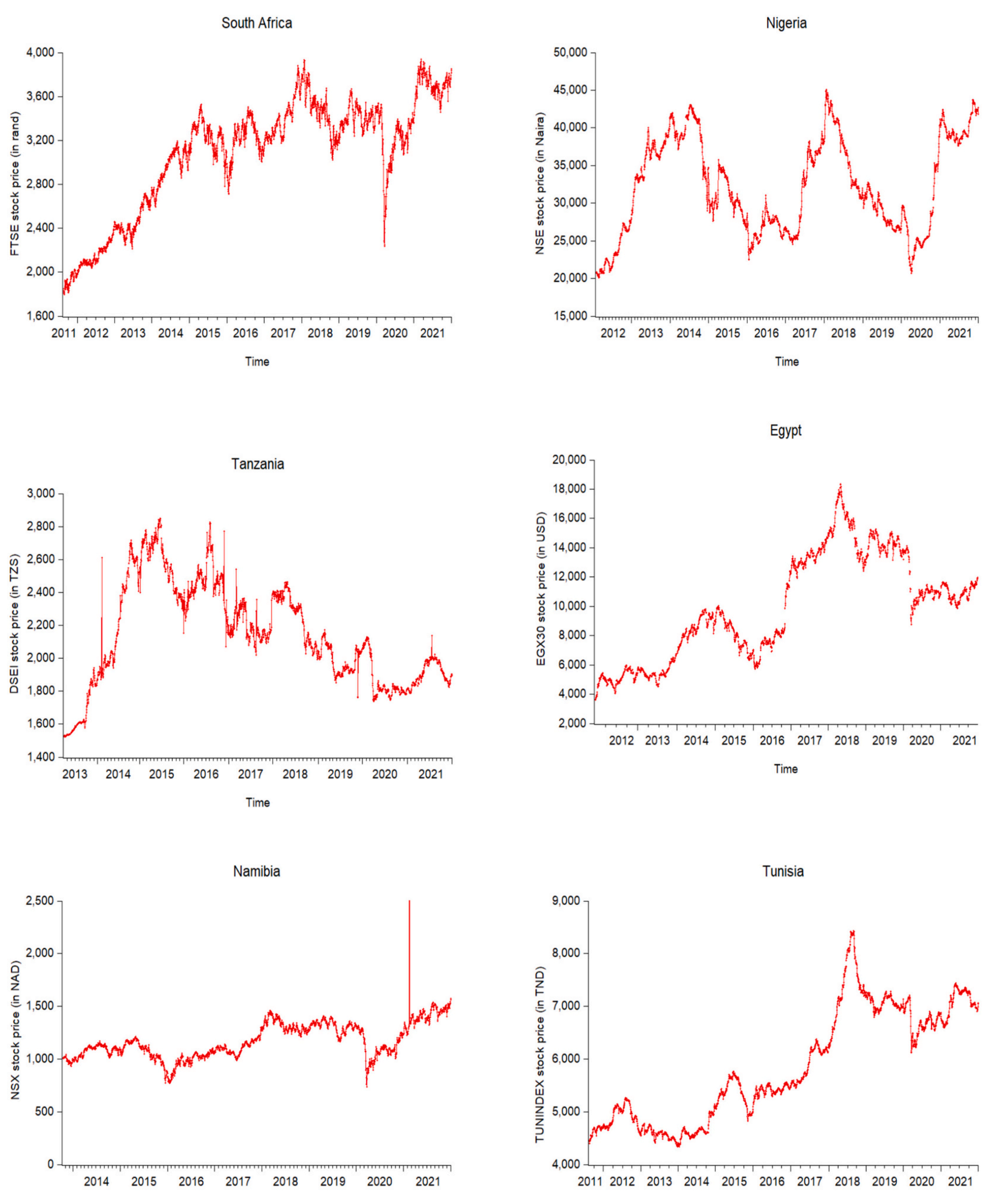

Fig. 3. Prices of African stock indices.

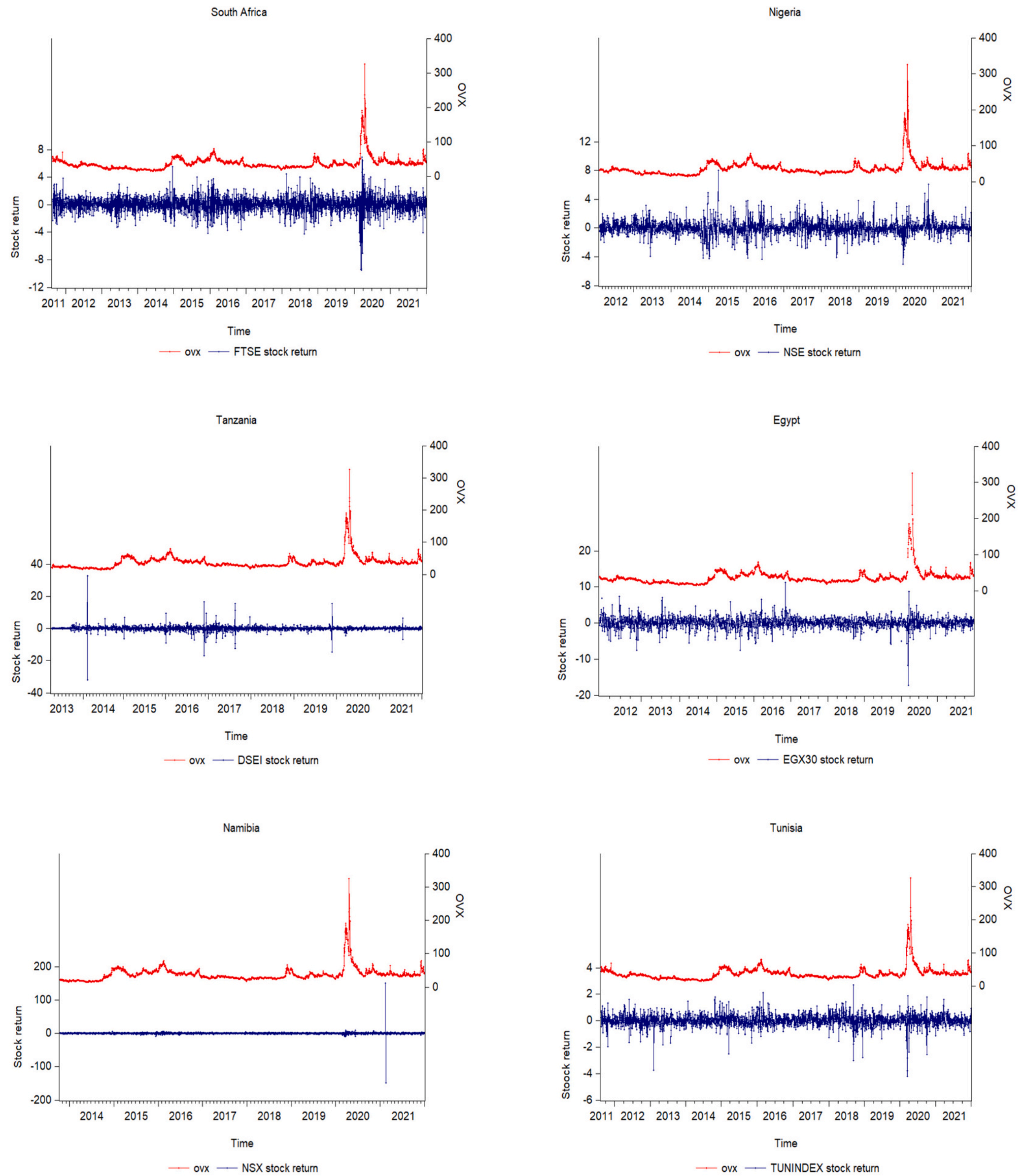

Fig. 4. Oil price uncertainty (*OVX*) and stock returns.

shows a steady upward trend in exchange rates, with fluctuations over time, suggesting persistent depreciation of African currencies relative to the USD. At various points, the trend in exchange rates aligns with movements in *OVX*, suggesting co-movement. For instance, both variables move in tandem from 2015 to 2021 in South Africa and Namibia, and from 2012 to 2015 in Nigeria and Egypt.

4.2. Summary statistics and stationarity tests

Table 1 indicates that all African countries exhibit positive mean values for both stock and exchange rate returns. A positive mean stock return implies that, on average, stock values increased during the study period. Likewise, a positive mean exchange rate return suggests average depreciation of African currencies against the USD. The SD values indicate that stock returns in Namibia and exchange rate returns in Egypt exhibit the highest variability among the countries analyzed. *OVX* displays greater volatility compared to both stock and exchange rate returns.

Stock returns in South Africa, Egypt, and Tunisia, as well as exchange rate returns in Tunisia, are negatively skewed. Positive skewness is observed in the remaining countries. Additionally, all variables have positive kurtosis values greater than three, which exceeds the kurtosis of a normal distribution. These results suggest asymmetry and non-normality across all variables. The Jarque–Bera test confirms that none of the series follow a normal distribution, thus justifying the use of QR and QQ models.

To assess stationarity, the augmented Dickey–Fuller test and the Zivot and Andrews (2002) structural break unit root test are employed. Both tests incorporate trend and constant terms in their unit root models. The results indicate that all series are stationary at the 1 % significance level.

4.3. BDS test

The BDS test is applied to evaluate the nonlinear dependence in the return series. As shown in Table 2, all series exhibit nonlinearity, confirmed by the rejection of the null hypothesis. This finding supports the earlier observation of non-normality in stock, exchange rate, and

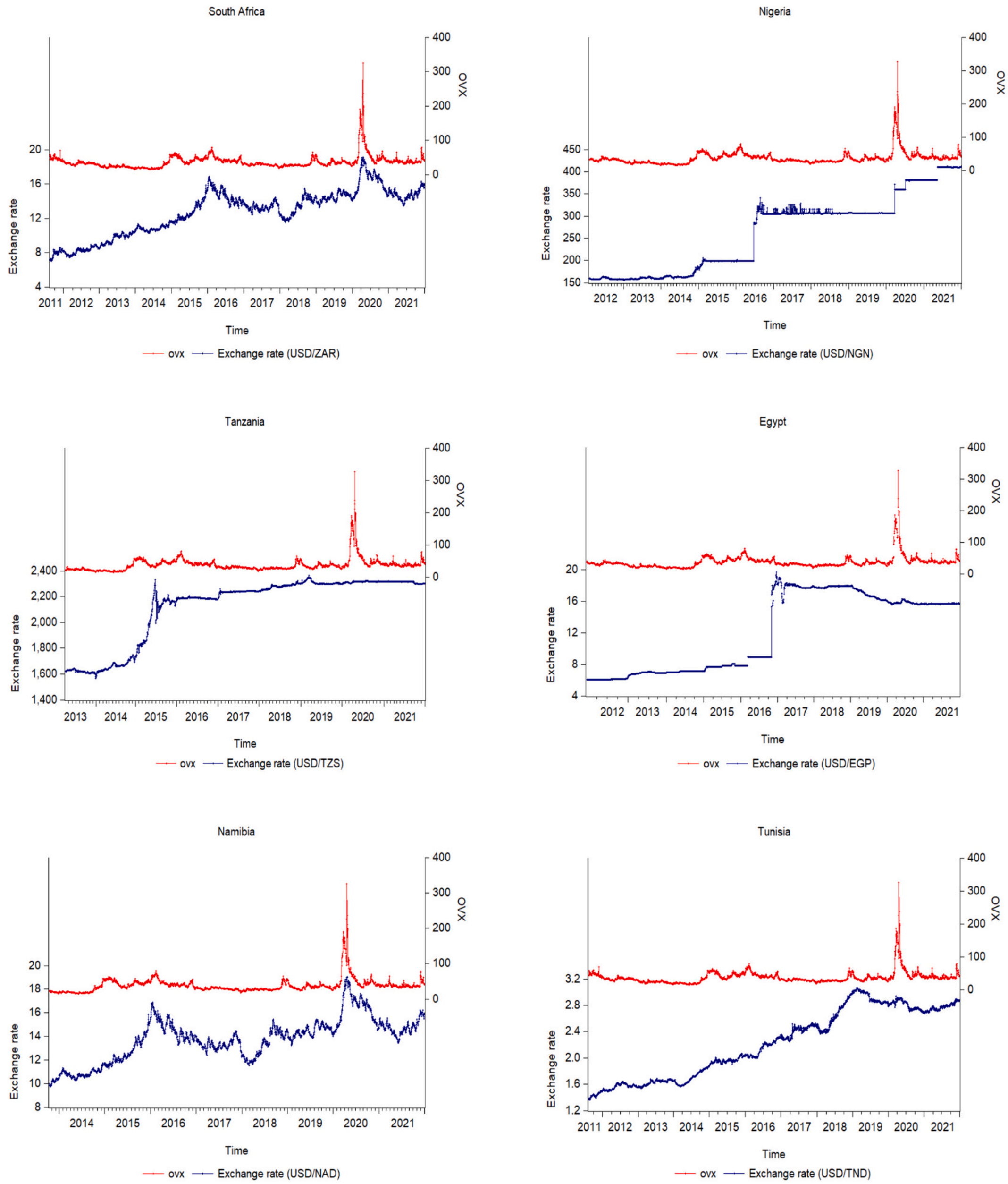

Fig. 5. *OVX* and exchange rates.

Table 1
Summary statistics and stationarity tests.

	Mean	Standard Deviation	Kurtosis	Skewness	Jarque–Bera	Zivot–Andrews	Augmented Dickey–Fuller
Panel A: Stock Returns							
South Africa	0.0275	1.1637	10.3308	−0.6494	6173.2***	−37.8***	−52.5***
Tanzania	0.0102	1.7305	137.9384	0.2978	1,623,611***	−44.0***	−29.0***
Namibia	0.0229	4.9071	843.0106	0.6902	60,242,285***	−50.4***	−22.6***
Nigeria	0.0290	0.9881	8.5916	0.3392	32,41.3***	−29.5***	−35.9***
Egypt	0.0589	1.5769	15.0034	−0.8315	12,237.2***	−28.8***	−37.8***
Tunisia	0.0189	0.4563	13.4978	−1.0512	12,279.1***	−31.0***	−39.9***
Panel B: Exchange Rate Returns							
South Africa	0.0003	0.0099	4.6899	0.3175	362.96***	−36.7***	−51.6***
Tanzania	0.0223	0.3944	233.1861	4.5990	4,732,095***	−34.5***	−6.8***
Namibia	0.0233	0.9646	4.2331	0.2523	151.5555***	−26.8***	−44.8***
Nigeria	0.0407	1.2547	277.2703	10.4128	7,729,713***	−40.9***	−62.7***
Egypt	0.0496	1.3354	1347.8150	33.8373	151,000,000***	−27.0***	−25.7***
Tunisia	0.0351	0.6325	28.4834	−1.0298	70,021.7***	−48.0***	−47.8***
OVX	−0.0012	6.0718	33.1174	1.7840	102,441.40***	−39.8***	−39.5***

Note: *** Signifies that null hypothesis is rejected at 1 % significance level.

Table 2
Brock, Dechert, and Scheinkman test results.

	$m = 2$	$m = 3$	$m = 4$	$m = 5$	$m = 6$
Panel A: Stock Returns					
South Africa	0.0137***	0.0291***	0.0410***	0.0485***	0.0512***
Tanzania	0.0286***	0.0524***	0.0709***	0.0817***	0.0862***
Namibia	0.0205***	0.0395***	0.0502***	0.0562***	0.0570***
Nigeria	0.0341***	0.0600***	0.0748***	0.0804***	0.0810***
Egypt	0.0170***	0.0322***	0.0425***	0.0478***	0.0493***
Tunisia	0.0288***	0.0519***	0.0644***	0.0694***	0.0685***
Panel B: Exchange Rate Returns					
South Africa	0.0073***	0.0159***	0.0214***	0.0249***	0.0268***
Tanzania	0.0799***	0.1506***	0.2012***	0.2316***	0.2479***
Namibia	0.0088***	0.0157***	0.0198***	0.0224***	0.0237***
Nigeria	0.0826***	0.1500***	0.1940***	0.2218***	0.2382***
Egypt	0.0639***	0.1161***	0.1532***	0.1789***	0.1939***
Tunisia	0.0296***	0.0500***	0.0629***	0.0684***	0.0700***
OVX	0.0188***	0.0349***	0.0447***	0.0499***	0.0510***

Note: *** Signifies that null hypothesis is rejected at 1 % significance level. *m* denotes the dimension, which specifies number of sequential data values included in the test set.

OVX return series, further validating the adoption of QR and nonparametric QQ methods for this study.

4.4. Quantile plots

The quantile plots in Fig. 6 demonstrate that the lower quantiles (below 0.5) and upper quantiles (above 0.5) correspond to declining and rising returns of African stocks, respectively. The median quantile (0.5) reflects a neutral condition. It is commonly known that a bullish market state is characterized by increasing prices and positive asset returns, while declining prices and negative asset returns reflect a bearish market state. Accordingly, this study uses the upper quantiles to represent a bullish market, the lower quantiles to signify a bearish market, and the median quantile to indicate normal market conditions, aligning with (Khalfaoui et al., 2023).

5. Findings and discussion

5.1. QR results

Table 3, Panel A, presents the effects of *OVX* on African stock returns across various conditional quantiles. The results show that *OVX* negatively influences stock returns in all countries and across all quantiles, regardless of whether the country is a net oil importer or exporter. However, in some cases, the effects are statistically insignificant at certain quantiles. These results align with findings by Luo and Qin (2017) and Diaz et al. (2016), who reported adverse effects of *OVX* on stock markets in China and G7 countries. One plausible explanation is that heightened uncertainty reduces companies' inventory investment and capacity utilization, thereby lowering revenues and profits and negatively affecting stock performance (Degiannakis et al., 2018).

Regarding magnitude, Table 3 shows that the negative impact of *OVX* is more pronounced in lower quantiles (bearish conditions) than in upper quantiles (bullish conditions), particularly for South Africa, Namibia, and Egypt, where the coefficients are mostly statistically significant. This result implies asymmetric effects, where *OVX* has a greater impact during bearish market conditions. This is consistent with Xiao et al. (2018), who found that *OVX* has a stronger negative impact on sectoral stocks in China during bearish periods. Several reasons may explain this amplified effect in bearish markets. First, these periods are typically associated with economic weakness, causing lower firm profitability and reduced expected returns. Second, during bearish market conditions, investors often become more risk-averse, reacting more strongly to negative information and adjusting portfolios to minimize losses (Ahmed, 2020).

With respect to a country's net oil position, the results also indicate that stock markets in African oil-importing countries are more sensitive to *OVX* than those in oil-exporting countries. This points to a

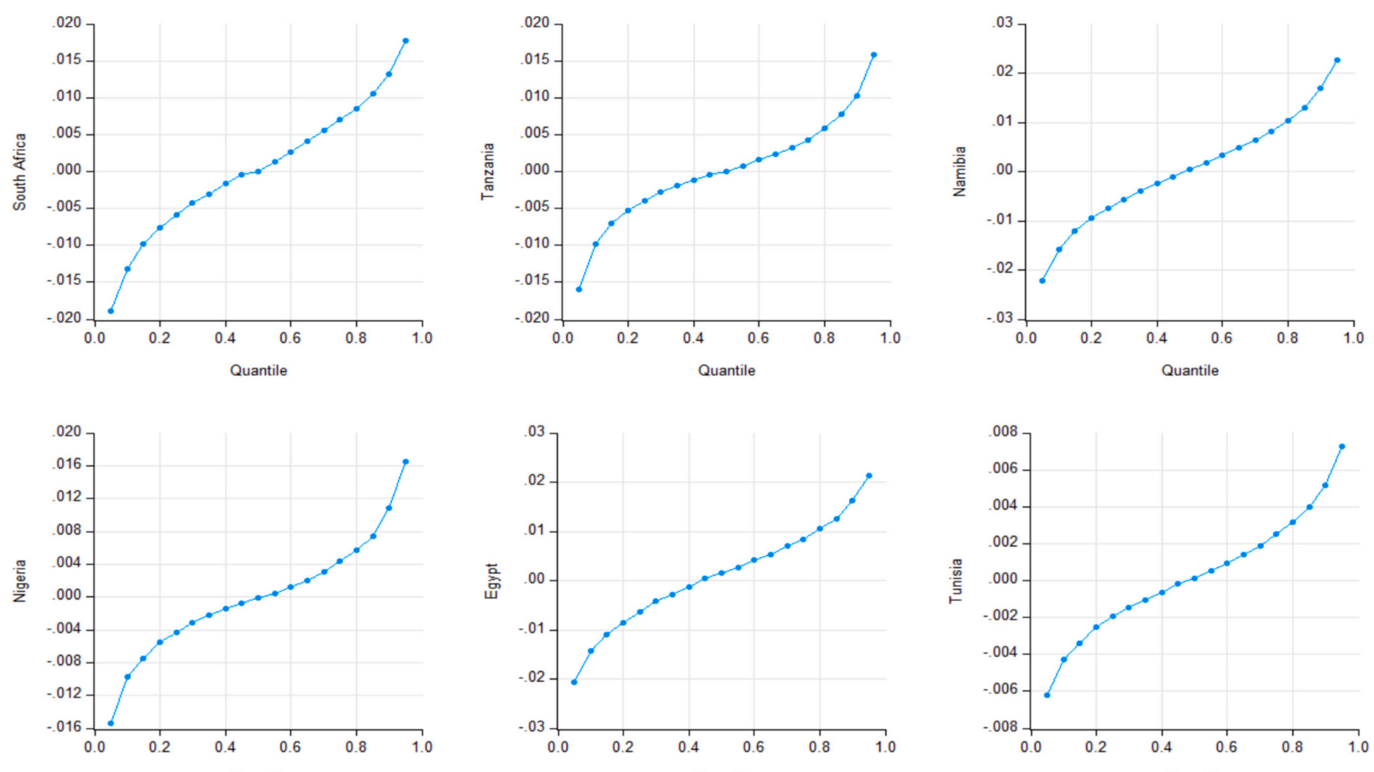

Fig. 6. Quantile plots of African stock returns.

Table 3
Impact of oil price uncertainty (***OVX***) and exchange rate volatility (***EXV***) on quantiles of African stock returns.

Panel A: *OVX*

	South Africa		Tanzania		Namibia		Nigeria		Egypt		Tunisia	
Quantile	*OVX*	*p − val*	*OVX*	*p − val*	*OVX*	*p − val*	*OVX*	*p − val*	*OVX*	*p − val*	*OVX*	*p − val*
0.1	−0.0588***	0.0000	−0.0083*	0.0504	−0.0682***	0.0000	0.0002	0.9733	−0.0257***	0.0000	−0.0011	0.5829
0.2	−0.0530***	0.0000	0.0003	0.8970	−0.0553***	0.0000	−0.0057	0.2048	−0.0189***	0.0008	−0.0009	0.6028
0.3	−0.0387***	0.0000	−0.0010	0.6532	−0.0482***	0.0000	−0.0027	0.4768	−0.0235***	0.0008	−0.0004	0.7908
0.4	−0.0313***	0.0000	−0.0024	0.2336	−0.0429***	0.0000	−0.0050	0.1126	−0.0185***	0.0084	−0.0010	0.4873
0.5	−0.0250***	0.0000	−0.0032*	0.0997	−0.0394***	0.0000	−0.0017	0.4404	−0.0196***	0.0070	0.0006	0.6026
0.6	−0.0298***	0.0000	−0.0039*	0.0595	−0.0368***	0.0000	−0.0016	0.4302	−0.0149*	0.0697	−0.0010	0.4366
0.7	−0.0329***	0.0000	−0.0041	0.1591	−0.0369***	0.0000	−0.0039*	0.0664	−0.0118	0.1498	−0.0020	0.1412
0.8	−0.0268***	0.0000	−0.0098***	0.0061	−0.0417***	0.0000	−0.0020	0.3756	−0.0108	0.2299	−0.0016	0.5440
0.9	−0.0269***	0.0000	−0.0106*	0.0932	−0.0426***	0.0000	0.0024	0.6232	−0.0083	0.4464	0.0023	0.6480

Panel B: *EXV*

	South Africa		**Tanzania**		**Namibia**		**Nigeria**		**Egypt**		**Tunisia**	
Quantile	*EXV*	*p − val*	*EXV*	*p − val*	*EXV*	*p − val*	*EXV*	*p − val*	*EXV*	*p − val*	*EXV*	*p − val*
0.1	−0.5298***	0.0000	−0.0409***	0.0000	−0.6692***	0.0000	−0.0161**	0.0346	0.0324	0.1299	0.0227	0.3784
0.2	−0.2640***	0.0009	−0.0216***	0.0000	−0.3746***	0.0013	−0.0159***	0.0006	0.0147*	0.0754	0.0368**	0.0113
0.3	−0.1057	0.1239	−0.0071*	0.0911	−0.1860*	0.0969	−0.0109***	0.0005	0.0030	0.6841	0.0356***	0.0060
0.4	0.0026	0.9690	−0.0060*	0.0705	−0.0857	0.4104	−0.0058**	0.0328	0.0001	0.9870	0.0391***	0.0113
0.5	0.0853	0.1773	−0.0015	0.6386	0.0245	0.8026	−0.0004	0.8692	−0.0105	0.1175	0.0422***	0.0016
0.6	0.1535**	0.0225	0.0001	0.9630	0.2595**	0.0175	0.0026	0.3660	−0.0097	0.1097	0.0538***	0.0000
0.7	0.2118***	0.0019	0.0063*	0.0767	0.4827***	0.0000	0.0001	0.9729	−0.0134**	0.0305	0.0533***	0.0008
0.8	0.3429***	0.0000	0.0139***	0.0036	0.6732***	0.0000	0.0013	0.8124	−0.0161**	0.0184	0.0544***	0.0057
0.9	0.5232***	0.0000	0.0328***	0.0001	1.0004***	0.0000	0.0115*	0.0724	−0.0165	0.1574	0.0926***	0.0010

Note: ***, **, & * denote statistical significance at 1 %, 5 %, and 10 % levels, respectively.

heterogeneous effect. Specifically, Panel A of Table 3 shows that oil-importing countries (i.e., South Africa, Tanzania, and Namibia) exhibit statistically significant effects across all market conditions. In contrast, oil exporters show mostly insignificant results, apart from Egypt, where stock returns are significantly affected in the median and lower quantiles but not in the upper quantiles. Moreover, the significant coefficients for oil importers such as South Africa and Namibia are relatively larger in magnitude than those for exporters like Egypt, indicating stronger effects of *OVX* in oil-importing economies.

Regarding exchange rates, Panel B of Table 3 shows that, in South Africa, Tanzania, and Namibia, *OVX* negatively affects stock returns during bearish markets but has a positive impact in bullish markets. In Nigeria, *EXV* has a significant negative effect in bearish markets, while the effect is insignificant in bullish conditions. Significant effects are also observed in the bullish market for Egypt and across all market conditions for Tunisia. These findings align with Ali et al. (2020), who identified significant effects of *EXV* on stock returns in Pakistan under both bear and bull conditions.

Importantly, this study includes *EXV* to evaluate the quantile-specific impact of *OVX* on stock returns in African oil-importing and exporting countries. As crude oil is predominantly traded in USD on the global market, and African countries rely on local currencies, a stronger USD raises oil import costs, increases production expenses, and reduces firm profitability, thereby depressing stock prices. Conversely, a weaker USD lowers oil import costs and supports profits. For oil-exporting economies, the impact is the opposite: a stronger USD reduces local currency revenues from oil exports, whereas a weaker USD boosts those revenues. Thus, the significant coefficients of *EXV* in Panel B of Table 3 confirm its moderating role in the relationship between *OVX* and African stock returns.

Table 4 presents the results of the combined effects of *OVX* and *EXV* on African stock returns across various conditional quantiles. As

Table 4
Joint impact of ***OVX*** and exchange rate (***COVOX***) on African stock returns.

	South Africa		Tanzania		Namibia	
Quantile	*COVOX*	*p − val*	*COVOX*	*p − val*	*COVOX*	*p − val*
0.1	−0.4715***	0.0001	−0.1002***	0.0060	−0.7345***	0.0010
0.2	−0.1947**	0.0225	−0.1717***	0.0091	−0.3675**	0.0132
0.3	−0.0721	0.2097	−0.1608***	0.0048	−0.2180	0.1015
0.4	0.0075	0.7970	−0.0857	0.2402	−0.0590	0.6185
0.5	0.0516	0.1793	−0.0679	0.1739	0.0427	0.6739
0.6	0.1053***	0.0098	−0.1007**	0.0370	0.1546***	0.0014
0.7	0.1793***	0.0000	0.0045	0.9411	0.2559**	0.0415
0.8	0.2805***	0.0026	0.0159	0.8733	0.5132***	0.0004
0.9	0.4711***	0.0000	−0.0470	0.8580	0.7479***	0.0000
	Nigeria		**Egypt**		**Tunisia**	
Quantile	*COVOX*	*p − val*	*COVOX*	*p − val*	*COVOX*	*p − val*
0.1	0.1288	0.6494	0.1900*	0.0726	0.1953***	0.0076
0.2	0.1052***	0.0000	0.1653*	0.0915	0.1285**	0.0175
0.3	0.1150***	0.0027	0.1109	0.3903	0.0841**	0.0286
0.4	0.0824**	0.0304	0.1625**	0.0275	0.0801***	0.0045
0.5	0.0330	0.6267	0.2237***	0.0003	0.0872***	0.0013
0.6	0.0098	0.9290	0.1970***	0.0008	0.0702*	0.0627
0.7	−0.0712	0.2928	0.4454	0.5559	0.0440	0.2984
0.8	−0.1730***	0.0000	0.4769***	0.0000	0.0138	0.7609
0.9	−0.1404***	0.0000	0.4617	0.2913	−0.0385*	0.0540

Note: ***, **, & * denote 1 %, 5 %, and 10 % levels of significance, respectively.

previously noted, this study uses *COVOX* generated via the DCC-GARCH model, to capture the simultaneous variation in *EXV* and *OVX*. *COVOX* reflects the degree to which fluctuations in *OVX* and *EXV* move together.

The findings in Table 4 indicate significant negative responses of stock returns in oil-importing countries (i.e., Namibia, Tanzania, and South Africa) to *COVOX* in the lower quantiles (bearish states). This outcome may be explained by the fact that African net oil importers rely heavily on stable oil prices and exchange rates to maintain predictable import costs and manageable production expenses. When oil prices and exchange rates become simultaneously volatile, import costs can rise unpredictably, adding substantial financial pressure on firms already operating under bearish market conditions. In such environments, firms face reduced pricing power and compressed profit margins, limiting their ability to pass higher input costs on to consumers without suppressing demand. This dual uncertainty disrupts operational stability and exacerbates economic vulnerabilities, intensifying the negative reaction of oil-importing stock markets during bearish periods.

Furthermore, when compared with the results in Table 3, where *OVX* alone negatively affects stock returns under bearish conditions, it becomes clear that *COVOX* exerts a more substantial impact. This is evidenced by the larger coefficient magnitudes in Table 4, suggesting that integrating *EXV* with *OVX* significantly amplifies the adverse effects on stock returns during bearish market conditions. For investors and other stakeholders, this insight is particularly important for evaluating risk exposure in oil-importing economies during economic downturns.

In contrast, Table 4 also reveals significant positive effects of *COVOX* on stock returns in the upper quantiles (bullish states) for South Africa and Namibia. This finding implies that, under bullish market conditions, the joint movement of *OVX* and *EXV* positively influences stock performance in these countries. A bullish state is typically characterized by economic expansion, investor optimism, and strong confidence, all of which enhance market resilience to external shocks. In such conditions, investors may interpret volatility in oil prices and exchange rates as less threatening, instead viewing it as a signal of heightened economic activity. For example, in oil-importing countries, a depreciation in the local currency, caused by increased demand for oil imports, may be offset by strong macroeconomic fundamentals. Under such scenarios, growth expectations can absorb the effects of higher oil costs, leaving stock markets largely unaffected or even positively influenced by the broader economic outlook. This finding is particularly useful for investors seeking to identify opportunities in oil-importing nations when economic conditions are favorable. Indeed, the results for oil-importing countries indicate asymmetric responses across bullish and bearish market states, particularly in the direction of stock returns in response to *COVOX*.

In the case of oil exporters, the *COVOX* coefficients for Nigeria and Tunisia are significantly positive under bearish conditions but turn negative under bullish ones. In a bearish market, a positive *COVOX* coefficient suggests that simultaneous increases in *OVX* and *EXV* may bolster stock returns. During such periods, heightened *EXV* can increase the local currency value of oil export revenues, because oil is priced in USD. This co-movement may stabilize the economy by enhancing export revenue, which investors may interpret as a cushion against economic decline, thereby supporting stock prices.

However, during bullish conditions, the negative *COVOX* coefficient suggests a different interpretation. In an environment of heightened investor confidence and expanding markets, co-movements in *OVX* and *EXV* may be perceived as sources of potential instability. Increased *EXV* may raise concerns about macroeconomic imbalances, while increased *OVX* introduces additional unpredictability in future revenue streams. Consequently, investors may view the combined volatility of oil prices and exchange rates as a threat to continued growth, thus negatively affecting stock valuations in oil-exporting countries.

Taken together, the results in Table 4 suggest that the responses of African stock returns to *COVOX* differ based on the country's oil trade status (importer vs. exporter) and the prevailing market condition (bearish vs. bullish). These findings provide comprehensive insight into the asymmetric and heterogeneous nature of stock return behavior in African economies, depending on the simultaneous variability of *OVX* and *EXV*. This nuanced understanding equips policymakers and investors with valuable information for crafting informed policies and strategic decisions tailored to their economic context and market conditions.

Fig. 7 presents QR plots of the effects of *COVOX* on stock returns in African oil-importing and exporting countries. The blue line represents the estimated QR coefficients, with the associated confidence interval shown by the shaded gray area. For comparison, ordinary least squares (OLS) regression estimates are included, represented by a horizontal maroon line, and flanked by dotted lines showing their corresponding 95 % confidence intervals. Apart from Egypt and Tunisia, the OLS results indicate an insignificant impact of *COVOX* on African stocks, as the confidence interval includes zero. However, QR reveals significant responses of stock returns to *COVOX* across both low and high quantiles, validating the use of quantile-based models over mean-based models such as OLS for this analysis. Additionally, Fig. 7 illustrates that *COVOX* has a positive effect on African oil importers' stock returns in upper quantiles (bullish states), whereas the effects are negative in lower quantiles (bearish states), consistent with Table 4. For oil exporters, the opposite pattern is observed, except in the case of Egypt.

5.2. QQ regression results

The left vertical axis of Fig. 8 shows the slope coefficient β_1, which describes the intensity and direction of the impact of *OVX* across different quantiles on the conditional quantiles of African stock returns. The corresponding color scale of β_1 is displayed on the right vertical axis. It is important to note that the coefficient is derived from the QQ regression method, in which *EXV* is included as a control variable. *OVX* is the main explanatory variable, with its middle, lower, and upper quantiles representing moderate, low, and high levels, respectively. For stock returns, the lower and upper quantiles correspond to bearish and bullish market states, respectively, while middle quantiles represent normal conditions.

The findings in Fig. 8 show that in oil-importing nations (i.e., South Africa and Tanzania), moderate and high levels of *OVX* negatively affect stock returns during bearish states but have positive effects under bullish conditions. Similar results are observed in Namibia, except that only the upper quantiles of *OVX* reveal significant effects. For oil exporters (i.e., Nigeria, Egypt, and Tunisia), stocks display significant responses when *OVX* reaches moderate and high levels, particularly under bearish and bullish conditions. However, when *OVX* is low, its effect on stock returns is insignificant for oil importers and exporters. These results provide valuable insight into how elevated *OVX* (moderate and high), influences African stock returns across various market states.

In oil-importing African economies, the finding that elevated *OVX* negatively affects stock returns during bearish market conditions highlights their economic vulnerability to oil price volatility. Uncertainty in crude oil prices increases production costs and reduces consumer purchasing power, exacerbating stock market declines. Faced with uncertain input costs and narrowing profit margins, investors may become more risk-averse, leading to sell-offs and further depressing stock prices. Meanwhile, during bullish conditions, moderate and high *OVX* levels appear to positively influence stock returns. This counterintuitive result may reflect investor interpretation of oil price volatility as a signal of strong global demand during periods of economic expansion. In such cases, investor optimism may override concerns about volatility, as firms benefit from favorable economic conditions, thus supporting stock prices.

In oil-exporting nations, the significant impact of moderate and high *OVX* across market states carries critical implications. As these economies depend heavily on oil exports, elevated *OVX* threatens revenue stability and market confidence. During bearish conditions, the negative

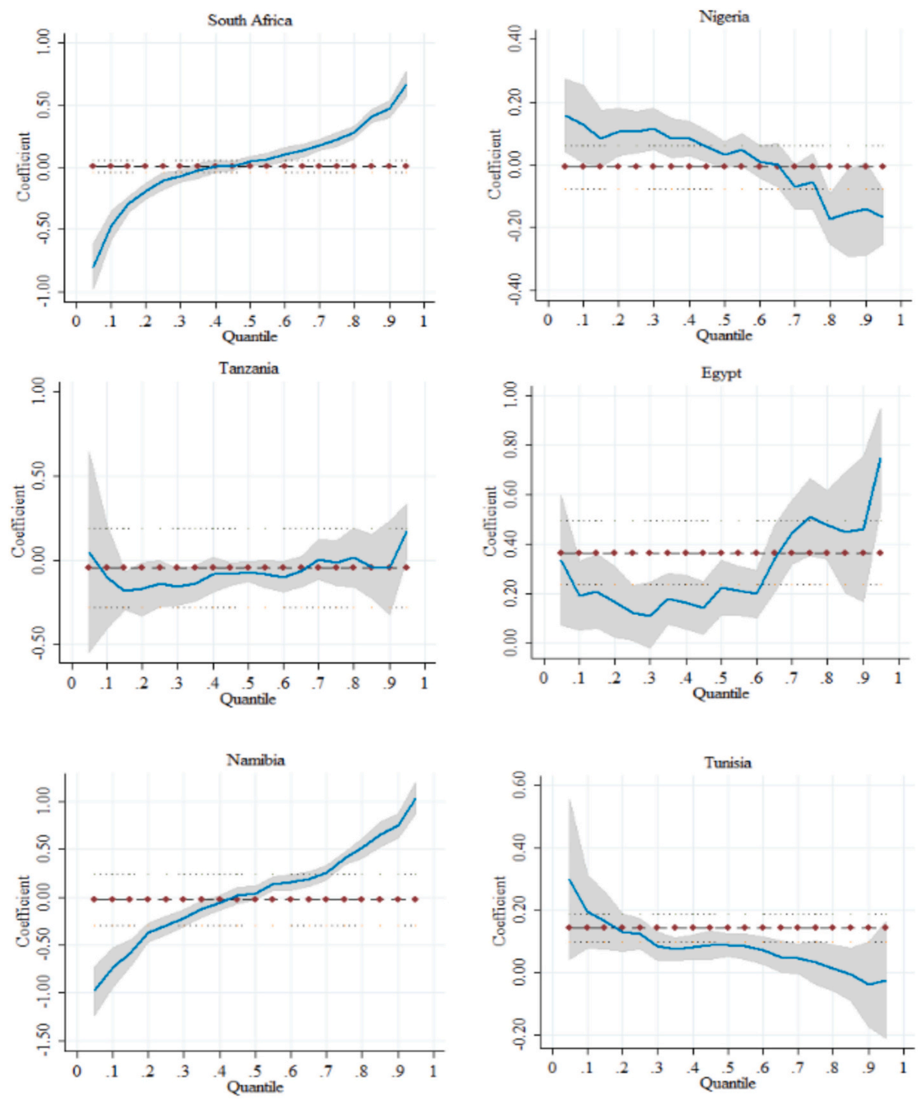

Fig. 7. Joint effects of *OVX* and exchange rate on African stock returns.

effect on stock returns suggests that volatility in oil prices disrupts government revenue planning and investor confidence, discouraging both domestic and international investment. The resulting fiscal stress can constrain public spending and dampen market sentiment. Conversely, in bullish markets, the positive stock response to high *OVX* may be driven by expectations of increased export revenues amid rising global demand, which can reinforce investor confidence and boost stock valuations even amid volatility.

Fig. 9 illustrates the β_1 slope coefficient, representing the size and direction of the effect of *COVOX* on African stock returns. Based on the magnitude of β_1, the combined effects of *OVX* and *EXV* on stock returns are greater than the effect of *OVX* alone, as shown in Fig. 8. This difference can be attributed to the compounding nature of the two variables, which together amplify economic pressure and market risk. When both factors fluctuate simultaneously, they create greater challenges for firms and investors by affecting production costs, revenue streams, and overall financial stability.

EXV directly affects the import and export costs of oil, both crucial to African economies. In oil-importing countries, a volatile exchange rate introduces additional uncertainty in import costs, intensifying the unpredictability created by oil price fluctuations. This combination can worsen trade imbalances, raise inflationary pressures, and erode corporate profit margins. The resultant decline in purchasing power and financial constraints can significantly depress stock returns. In oil-exporting economies, *OVX* and *EXV* jointly affect revenue predictability and fiscal stability. High *EXV* creates unpredictable conversion rates for export revenues, affecting government budgets and corporate revenues. Thus, investor sentiment becomes increasingly risk-averse, reacting more strongly to the compounded uncertainty than to oil price volatility alone.

In South Africa and Namibia, the results in Fig. 9 indicate that high levels of *COVOX* strongly reduce stock returns under bearish market conditions. Meanwhile, under bullish markets, the reaction of stocks is significantly positive but relatively less intense compared to the bearish market. The observation that significant impacts occur only at elevated *COVOX* levels suggests the presence of threshold effects, which are more clearly identified using QQ regression than traditional QR. Under bearish conditions, elevated *COVOX* magnifies perceived risks and pressures on corporate costs, leading to cautious investor behavior and market withdrawals. However, during bullish periods, strong demand and market optimism may mitigate the negative impact, and investors might interpret elevated *COVOX* as a sign of economic vitality. In Tanzania, moderate and high levels of *COVOX* significantly affect stock returns, with greater magnitude than observed in South Africa and Namibia—especially during bearish conditions—indicating that Tanzanian stock returns are more vulnerable to joint fluctuations in *OVX* and

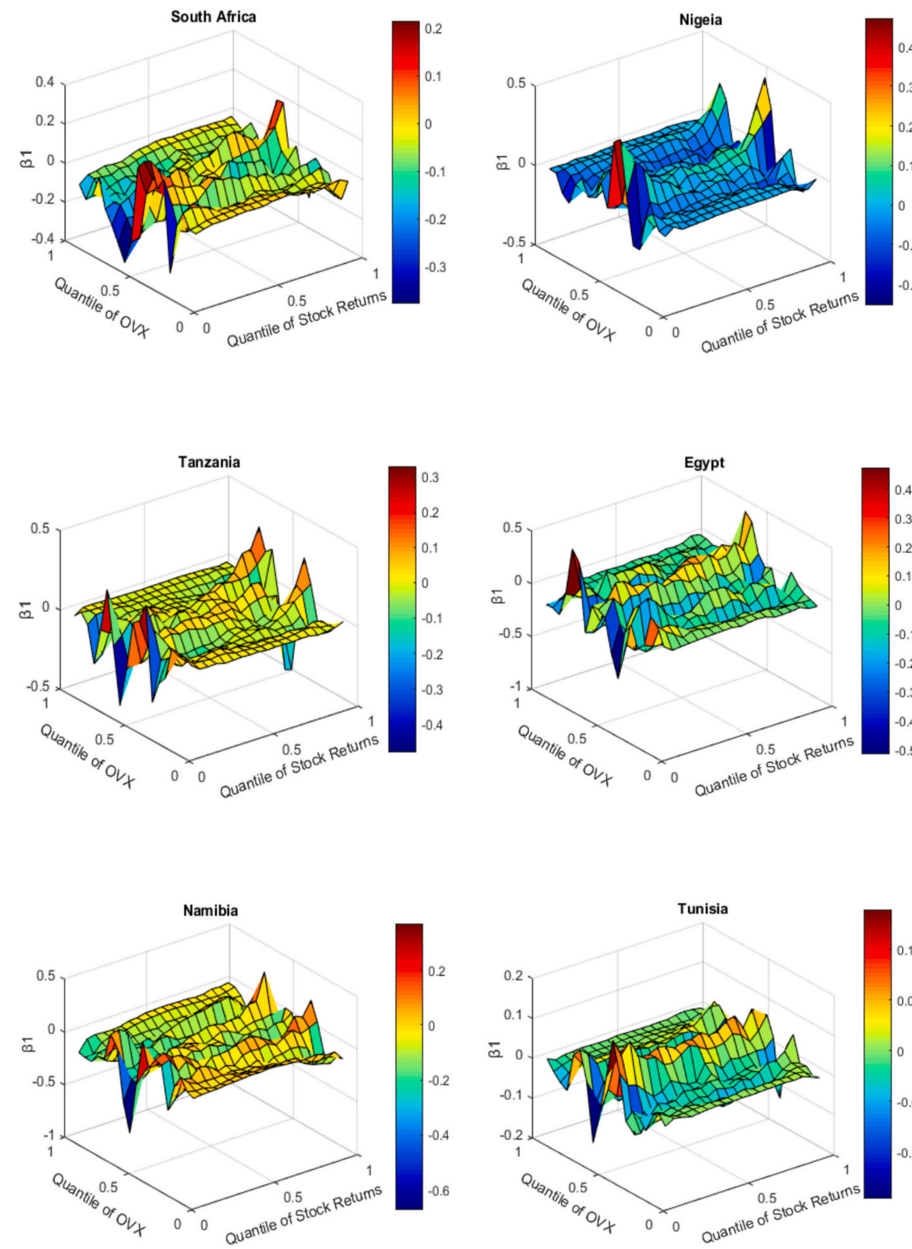

Fig. 8. Impacts of *OVX* on African stock returns.

EXV.

For oil exporters (i.e., Nigeria, Egypt, and Tunisia), *COVOX* has a notably strong negative impact on stock returns during bearish conditions. This could be due to these economies heavy reliance on oil exports; therefore, high *OVX* disrupts expectations of export earnings, making it difficult for governments and firms to plan budgets, manage expenditures, and forecast future cash flows and thus stocks. As oil is traded in USD, currency fluctuations can affect real income from oil exports. A depreciating local currency raises the cost of foreign debt and intensifies inflationary pressures, often leading to tighter monetary policy. In already weak markets, these factors deepen investor pessimism, leading to further declines in stock valuations. Among oil exporters, Nigeria appears most vulnerable to high *COVOX*, especially under bearish conditions. Nonetheless, high *COVOX* exerts a small but significantly positive impact on stock returns in oil exporters during bullish states.

Across all selected African oil-importing and exporting countries, Figs. 8 and 9 demonstrate asymmetries in the effects of both explanatory and dependent variables. In Fig. 8, the quantiles of *OVX* reveal significant impacts only at moderate and high levels, whereas low *OVX* has negligible effects. A similar pattern is evident in Fig. 9 for *COVOX*. Based on the magnitude of \beta (\tau, \theta) in both figures, African stock returns are more sensitive to *OVX* and *COVOX* under bearish market conditions than under bullish or normal states, with *COVOX* exerting a stronger influence than *OVX*.

5.3. Comparative discussion: Africa versus Asia, Europe, and America

5.3.1. Africa vs. Asia

Building on this study's findings and relevant empirical literature, this section explores how the relationship between *OVX* and African stock markets compares with that in developed and major emerging markets in Asia, Europe, and America. African stock markets are generally less mature, with lower market capitalizations, reduced trading volumes, and underdeveloped financial policy frameworks relative to those in more advanced economies. These structural

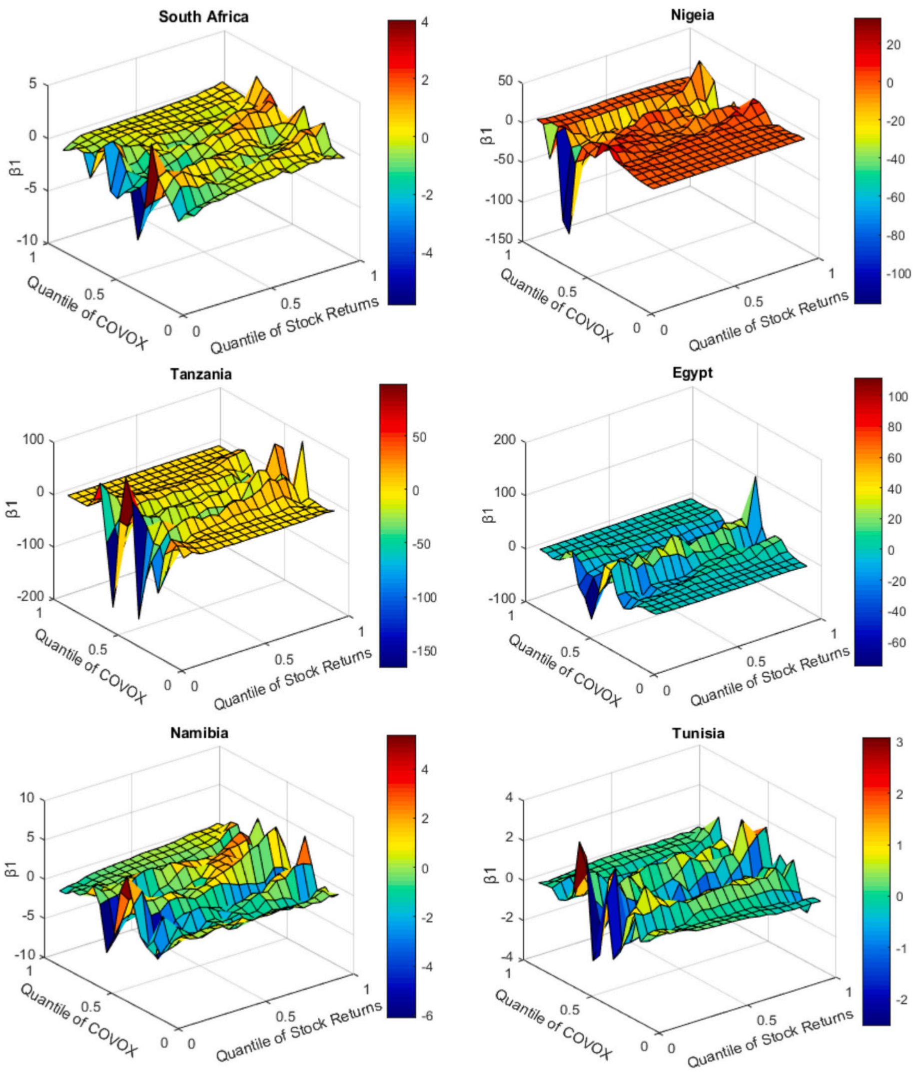

Fig. 9. Joint impacts of oil price uncertainty and exchange rate (*COVOX*) on African stock returns.

limitations underscore the importance of comparative analysis to understand variations in sensitivity to *OVX*.

The current study finds that African stock returns respond negatively to *OVX*. This result is consistent with several studies in Asia. For example, Luo and Qin (2017) and Zhang et al. (2023) documented adverse effects of *OVX* on Chinese stock returns. Likewise, Joo and Park (2017) reported time-varying negative impacts of *OVX* on stock markets in Japan, South Korea, and Hong Kong. Alqahtani et al. (2019) also found negative effects on stock returns in Asian GCC countries, including the United Arab Emirates, Oman, Kuwait, Bahrain, and Qatar. These findings suggest a common pattern: both African and Asian stock markets exhibit negative responses to *OVX*.

This similarity in responses between African and Asian stock markets to *OVX* likely stems from shared structural and economic vulnerabilities. Emerging and developing economies in both regions depend heavily on oil, either as a major import or primary export. For oil-importing countries, uncertainty in oil prices creates instability in production costs and transportation expenses, squeezing profit margins and depressing stock performance. However, in oil-exporting economies, volatile oil prices destabilize government revenues, eroding fiscal confidence and investor confidence and thus leading to negative stock market reactions.

Xiao et al. (2018) found that *OVX* had significant and negative effects on Chinese stocks at low and median quantiles. Similarly, Sreenu (2022) observed negative effects at the median and lower quantiles for Indian stock returns. This study reveals that African stock returns are significantly affected in the median and lower quantiles (normal and bearish market conditions) and the upper quantiles (bullish states), particularly in oil-importing countries, i.e., South Africa, Tanzania, and Namibia. This broader sensitivity indicates that African markets may be more exposed to *OVX* across varying market conditions compared to their Asian counterparts.

However, with regard to the strength, the sensitivity of African stocks, as represented by this study, and that of Asian stocks (China and India), as documented by Xiao et al. (2018) and Sreenu (2022), are all stronger in the bearish state than in the bullish and normal states. The intensity of negative responses in both African and Asian stock markets is strongest during bearish conditions; this pattern reflects a shared vulnerability to external shocks. In bearish markets, when investor confidence is already low and liquidity is limited, *OVX* intensifies pessimism, triggering sharper declines in stock returns. Thus, while the scope of sensitivity may differ, the overall trend aligns: African and Asian emerging markets exhibit heightened vulnerability to *OVX* during economic downturns.

5.3.2. Africa vs. Europe and America

Consistent with the findings of this study, which indicate that African stock markets respond negatively to *OVX*, Diaz et al. (2016) found similar adverse effects in major European and American economies, including the U.S., Germany, France, the U.K., and Italy. This observation is further supported by Joo and Park (2021), who documented the negative impact of *OVX* on stock markets in Europe (i.e., Germany, Spain, France, the Netherlands, and Italy), the U.S., and Asia (i.e., China, Japan, South Korea, and India). However, the present study also reveals that stock markets in African oil-importing countries (i.e., South Africa, Tanzania, and Namibia) are more sensitive to *OVX* than those in oil-exporting countries (i.e., Nigeria, Tunisia, and Egypt). This result contrasts with the findings of Diaz et al. (2016), who reported that oil-importing countries such as the U.S. and the U.K. were less reactive than oil-exporting Canada.

Nevertheless, some studies in Europe and America present contrasting results compared to the African context observed in this research. For instance, although the current study reveals a negative response of African stocks to *OVX*, Bass (2017) found that *OVX* positively influences the Russian stock market, a major oil exporter. Similarly, Alsalman (2016) concluded that U.S. stock returns show no discernible response to *OVX*. Therefore, while many studies from Europe and America align with the African findings, others diverge, highlighting the complexity of the relationship between *OVX* and stock markets across regions.

6. Conclusions, policy implications, limitations, and areas for future research

The dynamics of crude oil markets generate uncertainty regarding future oil prices, potentially affecting investment decisions, firm profitability and thus stock market performance. This study applied QR and an innovative nonparametric QQ regression approach to examine the effects of *OVX* on African stock returns across various market states. Moreover, the analysis accounted for the moderating effect of *EXV* (USD/local currencies), given that crude oil is globally priced in USD. Furthermore, this study applied the DCC-GARCH model to construct *COVOX* to investigate the joint variability's impact of *OVX* and exchange rates on African stock returns.

Based on the empirical findings, this study reached several conclusions. First, *OVX* negatively affects African stock returns, with a more pronounced impact on oil importers than exporters, suggesting heterogeneous effects. Second, *OVX* and *COVOX* exhibit asymmetric effects across African stock return quantiles. The results show that moderate and high levels significantly impact stock returns, while low levels have no significant effect. Moreover, asymmetry is observed across stock return quantiles, with greater sensitivity to *OVX* and *COVOX* under bearish conditions than in bullish ones. Third, the influence of *COVOX* on African stock returns is stronger than that of *OVX* alone, regardless of the market state. This suggests that the combined variability of *OVX* and exchange rate exerts a more intensified impact on stock markets.

This study offers valuable implications for investors, policymakers, and other stakeholders. First, the observed sensitivity of African stock returns to *OVX*—especially in bearish markets—highlights the need for investors to adopt targeted risk management strategies during downturns. Such strategies may include robust hedging mechanisms or the use of financial instruments designed to mitigate the effects of *OVX* on stock returns. Second, investors should consider diversifying portfolios by including stocks from both oil-importing and oil-exporting African countries. This diversification helps to offset the high sensitivity of oil-importing stocks to *OVX* with the relative stability found in oil-exporting markets, thereby reducing overall investment risk. Additionally, policymakers should promote diversification of energy sources by supporting investments in renewable energy technologies. Reducing dependency on imported oil or oil-export-based revenues can enhance economic resilience.

Third, policymakers should implement measures aimed at stabilizing exchange rates through sound monetary and fiscal policy. A more stable local currency against the USD could provide a buffer against the adverse effects of *OVX*. Finally, both investors and policymakers should develop forward-looking strategies and robust investment frameworks that account for the intensified risks stemming from the joint variability of oil prices and exchange rates, as highlighted by the significant effects of *COVOX*.

Despite its contributions, this study has certain limitations that shape the generalizability of its findings. First, the analysis used aggregate (all-share) stock indices for the selected African countries. Consequently, it may not have fully captured sector-specific dynamics or the behaviors of individual companies that are particularly sensitive to oil price fluctuations. Second, due to data constraints, this study focused on six African countries—three oil-importing (South Africa, Tanzania, and Namibia) and three oil-exporting (Nigeria, Egypt, and Tunisia). This limited sample may not represent the full diversity of African stock markets, especially those in countries with distinct economic structures or varying levels of energy dependence.

Based on the limitations, this study suggests several avenues for future research. First, future studies could explore sector-specific or firm-level analyses, particularly in industries most exposed to oil market fluctuations or involved in emerging clean energy sectors. Such analyses would address the dynamics overlooked by aggregate stock indices. Examining the responses of individual companies or specific sectors, such as energy, manufacturing, and financial services, would provide more detailed insights into how *OVX* affects various segments of the African stock markets. Second, future research should aim to expand the sample to include more African oil-importing and oil-exporting countries as more comprehensive and reliable data becomes available. This would allow for a broader exploration of cross-country heterogeneity within the African context.

Third, future studies could investigate the economic transmission channels through which *OVX* influences African stock markets. Incorporating macroeconomic variables, such as inflation, interest rates, discount rates, and firm-level cash flows, into the analysis would clarify the mechanisms driving the observed relationships. Finally, future studies could assess the role of policy interventions, regulatory frameworks, and institutional quality in influencing the relationship between *OVX* and African stock markets. Understanding how governance and policy measures influence market stability and mediate the effects of *OVX* would offer actionable insights for policymakers and other stakeholders and strengthen resilience in African stock markets.

Notably, this study does not include economic transmission channels or policy variables due to the unavailability of high-frequency daily data, which are essential for such analysis. As more granular data become available, future research should address this gap, enabling a deeper and more nuanced examination of the relationship between *OVX* and stock market behavior in Africa. This will enhance the relevance of findings for researchers, investors, policymakers, and other stakeholders.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A

Table A.1
List of abbreviations.

ADF	Augmented Dickey–Fuller
AR	Autoregressive
ARCH	Autoregressive Conditional Heteroscedasticity
ARMA	Autoregressive Moving Average
BDS	Brock, Dechert, and Scheinkman
CBOE	Chicago Board Options Exchange
COVID-19	Coronavirus Disease of 2019
COVOX	Covariance of Oil Price Uncertainty and Exchange Rate
DCC	Dynamic Conditional Correlation
DSE	Dar es Salaam Stock Exchange
EDA	Exploratory Data Analysis
EGP	Egyptian Pound
EGX	Egyptian Exchange
EXV	Exchange Rate Volatility
FOREX	Foreign Exchange Rates
FTSE	Financial Times Stock Exchange for South Africa
GARCH	Generalized Autoregressive Conditional Heteroscedasticity
GCC	Gulf Cooperation Council
GJR	Glosten, Jagannathan, and Runkle
GVAR	Global Vector Autoregressive
JB	Jarque–Bera
JSE	Johannesburg Stock Exchange
MA	Moving Average
NAD	Namibian Dollar
NSE	Nigeria Stock Exchange
NSX	Namibia Stock Exchange
OLS	Ordinary Least Square
OVX	Oil Price Uncertainty
QQ	Quantile-on-Quantile Regression
QR	Quantile Regression
SD	Standard Deviation
TND	Tunisian Dinar
TZA	Tanzanian Shilling
UAE	United Arab Emirates
USD	United States Dollar
WTI	West Texas Intermediate
ZA	Zivot and Andrews Unit Root Test
ZAR	South African Rand

Data availability

No

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Glossary

Term: Description
Oil price uncertainty (OVX): Unpredictability or volatility in future oil prices over time. The CBOE Crude Oil Volatility Index is used in this study to proxy OVX since it measures market expectations of crude oil price volatility over the next 30 days.
Stock market return: The growth rate of a stock market index over a given period, calculated as the logarithmic difference in stock prices.
Exchange rate volatility (EXV): The variation in exchange rates between the US dollar and African local currencies, estimated using the GJR-GARCH model.
COVOX: A measure of the joint variability between oil price uncertainty and exchange rates, calculated as the covariance between the two variables.
Bearish market state: A market condition characterized by declining stock prices, typically associated with pessimism, low investor confidence, and negative economic expectations.
Bullish market state: A market condition characterized by rising stock prices, generally driven by investor optimism, strong confidence, and positive economic outlooks.
Asymmetric responses/impacts: Uneven effects of changes in explanatory variables (OVX/COVOX) on African stock returns across different quantiles.
Heterogeneous effects: Differential impacts of OVX/COVOX on stock markets in African oil-importing and oil-exporting countries.
Quantile Regression (QR): A statistical technique that extends ordinary least squares (OLS) by estimating the effects of explanatory variables at various conditional quantiles of the dependent variable, rather than only at the mean.
Quantile-on-Quantile (QQ) Regression: A statistical technique that examines the relationship between quantiles of an independent variable and quantiles of a dependent variable