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# Foreign exchange market and crude oil market-volatility spillover analysis

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**Abstract** The reality that governs financial markets in recent times is that fluctuations in one market could rub off the volatility of another market either by moving in the same direction as the mirrored market moving in the opposite direction. Hence, researchers have often proposed that volatility transmission be considered in volatility studies in financial markets. This study sought to determine the rates of volatility spillover and shocks between oil prices and exchange rates in oil production. Data for the study were measured quarterly. The quantile regression and asymmetric GARCH estimations formed analytical tools for the study in addition to regular descriptive, unit root and cointegration tests. We find that increased spillover syndrome in the crude oil market in past periods resulted in inverse adjustments of present volatility in crude oil markets with a magnitude of 0.1339. Whereas the spillover effect from the currency market to the oil market is weaker than its effect from the oil market to the currency market is, significant incidences of asymmetric volatility are found. The significant and inverse spillover of volatility from the currency market to the crude oil market reveals that oil-producing countries utilize the crude oil market as safe-haven securities, particularly during periods plagued with economic uncertainty. Leverage effects were significantly present in the oil-exporting countries researched. The presence of leverage effects is a reflection of the heightened sensitivity of the currencies of oil-producing countries to negative shocks, particularly those related to fluctuations in oil prices. These effects can result in increased exchange rate volatility and have implications for economic stability, policy formulation, and the need for diversification efforts. Managing exchange rate volatility and stabilizing oil prices in oil exporting jurisdictions requires a combination of sound economic policies, coordinated policy responses, effective risk management, and strategies to reduce dependency on oil exports.

**Keywords:** volatility spillover, exchange rate volatility, oil price volatility, VAR-GARCH, oil exporting countries, oil exporting countries

## 1. Introduction

Volatility is defined in economic theory as fluctuations in a financial or macroeconomic indicator across time. Volatility spillover implies that the fluctuations and variabilities in a certain market can cascade into another, resulting in either positive or negative consequences. In the crude oil and currency markets, rising oil prices can have a direct influence on economies, generating contraction in the economy, rising prices, depreciation of the currency, trade balance decline, and a deficit in the current account. Currency depreciation influences financial markets, causing capital withdrawals and a downward trend in the currency. Country peculiarities and exchange rate regimes also impact the oil price-exchange rate relationship. Countries with fluctuating exchange rates have more dependency, whereas net oil exporting countries have stronger dependence structures. The results also reveal volatility spillover and bidirectional risk transfer (Nandelenga & Simpasa, 2020).

Volatility spillover produces greater uncertainties, as forecasting only one market may become futile from changes in other markets, making it more difficult for monetary authorities to balance objectives such as limiting inflation and ensuring currency value stability. Even when the volatilities of other markets are considered, volatility spillover can have a distributional effect, affecting certain countries differently. Businesses that rely substantially on oil imports or exports may incur higher costs and more uncertainty as a result of volatility spillover. Financial market instability may be caused by heightened volatility, which affects asset prices, trade volumes, and investor mood. Businesses, investors, and governments face increased risk management issues as circumventing against swings becomes less effective in high-volatility periods.

In the current period of promoting sustainability and the increasing need for renewable energy sources, fluctuations in the renewable market may affect the demand for oil and its prices. The use of renewable energy, such as hydroelectric, wind and solar energy, can decrease the need for oil, resulting in decreased prices and increased energy self-sufficiency. The susceptibility of countries to supply interruptions and price fluctuations in the international oil market, regardless of their

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status as oil exporters, is worrisome. Renewable energy is also subject to price competition, as lower costs and increased efficiency make it more appealing, but supply variations could impact oil, thus potentially affecting local currencies. Environmental and policy factors, such as regulations and subsidies, can also affect oil prices and currency volatilities. Hence, it is imperative to observe the trends of crude oil prices in recent times and how these movements could spill into currency markets and vice versa.

Researchers and policymakers are interested in how volatility moves back and forth between oil price adjustments and currency returns. Nevertheless, empirical works are not in agreement on the pattern of causal relationships, as there is some proof of bidirectional causality. Some studies have also demonstrated that a spike in the actual petroleum price triggers an actual strengthening of the linked currency, whereas others indicate that a nominal gain of currencies causes a reduction in the oil price. The study seeks to provide empirical results on transmission to provide direct analysis work by the researcher, using quarterly oil price and currency data. The research aims to provide answers backed by empirical evidence to the following questions on the rates of volatility spillover and shocks between oil prices and exchange rates in oil-exporting countries. To what extent does the transfer of volatility between the oil and currency markets occur in countries that produce oil? This study sought to determine the rates of volatility spillover and shocks between the crude oil market and foreign exchange markets in oil-producing countries. The study of volatility transmission between exchange rates and crude oil markets offers benefits to investors and brokers. This study provides insights for making informed decisions in investment strategies, adjusting portfolios and trading strategies to reflect the impact of volatility transfer. This research helps financial regulators and policymakers analyze how turbulence in exchange rates and petroleum prices influences macroeconomic indicators and economic growth. This evidence is used to make decisions on adjusting interest rates and other tools of monetary policy, ultimately maintaining economic stability.

The importance of this study lies in the fact that government officials and energy policy makers can use it to develop healthier energy policies and laws. The findings of this research activates the need for governments can enhance energy security, control inflation, and minimize the economic repercussions of oil cost increases through strategies such as diversifying energy sources or providing incentives for renewable energy. Additionally, the research findings offer guidance on policy responses to currency, and oil price volatility can be beneficial for international organizations, particularly in developing countries reliant on oil exports. This can assist in controlling economic risks and advancing sustainable development, ultimately assisting countries and regions in confronting economic difficulties. The findings of the study add to the empirical literature on financial economics, the crude oil market, and financial markets,which is needed to test hypotheses related to volatility transmission between financial and energy markets, leading to a deeper understanding of market dynamics and more accurate forecasting of market returns. Next, a review of the literature, which is based on estimation methods as well as data sources and variable descriptions, is provided. Section four discusses and analyzes the research findings, and five conclusions are drawn.

## 2. Literature Review

The theory of contagion in volatility spillover is commonly utilized in financial economics to explain the disturbances and impacts on market turbulence and outcomes resulting from interconnected market relationships. The theory claimed that the condition in one market might be conveyed to other markets, resulting in excessive exposure to risk and volatility in the affected markets and the financial industry as a whole. The origin of the contagion hypothesis is attributed to Kaminsky, Reinhart & Lizondo, who researched contagion implications in Asia in 1998. Forbes and Rigobon (2002) argue that, to buttress *contagion* among markets was unreal; but rather, markets were *interdependent* on one another. This was after they reported that unconditional correlation remained significantly unchanged in their study of different financial crises, such as the U.S. Market crash in 1987.

The contagion hypothesis also described events that followed recent crises such as the Russian–Ukraine war, as well as how financial and economic problems in a single nation spread swiftly and fiercely to other countries around the world. The notion also implies that instability and fear in a single market might spur investors to migrate to other markets, resulting in larger instability shocks in other markets (Bekaert *et al*. 2013). With respect to this study, contagion theory explains how shocks in one market, such as crude oil, can spill over into other markets, such as exchange rates, through multiple channels, such as investor sentiment, trade and other financial linkages. Davidescu *et al.* (2023) stated that the proponents of the contagion theory assert that shocks originating from weak economies are diffused across other nations before they spread to the world's market arrangements.

Tiwari & Albulescu (2016) used the wavelet technique to perform asymmetric and Granger causality analyses on monthly petroleum price fluctuations and the rupee. They discovered that the Granger causal connection that existed between these variables was bidirectional in nature, showed a nonlinear association, and exhibited leverage effects. Olstad *et al*. (2021) evaluated the association between crude oil fluctuations in prices and currency instability in six nations from 1999 - 2016. They observed that oil price volatility significantly affects fluctuations in exchange rates and that fluctuations are transmitted from one market to the other.

In their study, García *et al.* (2018) used VAR to analyze the measurable cost of petroleum-affected currency exchanges in Mexico and Nigeria, a nation known for exporting oil, over the period from 1991--2017. Their research revealed a clear link between peso and prices in the oil market. Raji *et al.* (2018) explored the joint association between prices and exchange rate volatility in Nigeria, a nation that exports oil. Research has shown that changes in oil prices are associated with increased disruptions in exchange rates. When there is a sudden increase in these prices, the Mexican peso experiences growth due to increased revenue. In their study, Tiwari *et al.* (2019) applied the NGCo VaR method to analyze the effects of crude oil monetary values on real exchange rates in BRICS countries, revealing an adverse correlation between oil monetary values and currency value in India, Brazil and South Africa.

Nandelenga & Simpasa (2020) examine the relationships among exchange rates, crude oil prices, and volatility transfer in selected developing and low-income nations. They used daily data for nineteen years until 2018. The copula model indicates that Gaussian models well represent the dependency structure in the sampled nations. The findings indicate varying levels of reliance among net oil exporters and importers, depending on the currency rate and national categorization. The results revealed a symmetric dependency pattern across all the nations. Basher *et al*. (2016) utilized the Markov-Switching approach in mapping how shocks to energy markets impact real currency values in a number of chosen countries. According to the study, oil demand and the shocks that emerge from it have direct effects on the currency values of oil-exporting countries, causing their national currency to appreciate. However, the demand shocks that arose resulted in currency losses in countries that import oil.

Kathuria & Sabat (2020) utilized GARCH and EGARCH models along with daily statistics over a period of 20 years to examine how fluctuating oil prices impact the Indian currency. According to the study, oil price volatility has a negative influence on exchange rate volatility, with asymmetric impacts. In contrast, Huang *et al.* (2020) employed a pooled mean group (PMG) technique from 1997-2015. The results demonstrated an indirect influence of oil prices on the currency values of oil-importing countries; however, the link is not substantial in oil-producing economies. Olstad *et al.* (2021) applied a diagonal-BEKK model to examine how crude oil price volatility was linked to six currencies from 1999-2016. They found that fluctuations in oil prices positively impact the volatility of exchange rates, showing clear signs of the transfer of unstable trends across both markets. Bhatia (2021) employed empirical means to evaluate crude oil prices and their extending effects on BRICS nations' currencies for twelve years from 1999 via OLS and DCC GARCH models. During both traditional and pandemic times, there has been a continuous transfer of instability from energy items to the value of currencies in BRICS countries. The COVID-19 pandemic has aggravated the turbulence experienced in both markets.

Chowdhury & Garg (2022) utilized variations of ARCH models to identify the volatility transfer related to the prices of crude oil and the currency rates of Korea, Japan, India and China from 2017 to the COVID-19 core year. The study revealed that the pandemic strengthened the connections between crude oil prices and currency fluctuations due to heightened uncertainty and a considerable decrease in oil market value. During the crisis, identified connections became more robust, leading to currency rates becoming more fluid to oil price fluctuations during disruptive situations such as COVID-19. Adi *et al*. (2022) assessed the intertwining situation between oil prices and Nigerian exchange rate volatility from twelve years to 2020. They utilized a VAR-AGARCH model to consider volatility transfer impacts. The results of the study explain that past shocks and instability in the currency exchange and oil commodity markets play a significant role in current volatility and that the transfer is bidirectional.

Chen & Nan (2022) ventured into the link between crude oil prices, currency markets, and risk spillovers. It is based on WTI market values and exchange rates for other currencies. The research examined the variability of global petroleum prices and currency rates via Granger's test on linearity and nonlinearity, with an emphasis on the influence of each intrinsic mode function on volatility transmission. The study also investigated the risk spillover of both low- and high-frequency data, as well as currency values across countries. By employing a GARCH-VAR-Spillover method, Sánchez-García & Cruz-Rambaud (2023) assessed how oil price fluctuations affect financial markets, especially in times of economic and financial crisis. They analyze the volatility of WTI and Brent and their connection to significant financial markets during the period of 2000-2021. Research results suggest overall bidirectional volatility shocks and transference from oil to stock markets, with the United States being more susceptible to crisis sources than Europe. In the U.S., financial shocks lead to volatility being transmitted to the oil market, whereas economic shocks lead to volatility being transmitted to financial markets. This present research fills an empirical gap, as it uses the most recent quarterly data (up to 2024Q1) in the assessment of spillover between the oil and currency markets, unlike other studies in which data for 2024 were not included in their sample. In addition, the study covers not a single country but a cross-country analysis involving 10 different oil-producing nations.

## 3. Methodology

The research methodology is guided by the contagion theory of spillover, which is related largely to cross-volatility between the behavior of returns in the crude oil and currency markets. The theory holds that shocks in a market can spread to another owing to the interdependencies of different financial markets and economic stances, and this transmission could occur very rapidly and could be persistent (Claessens & Forbes, 2001). Contagion can occur through direct financial linkages, such as cross-market investments, portfolio holdings, and cross-border capital flows (Baele, Bekaert, Inghelbrecht & Wei, 2010). The reactions of investors to news or occurrences and other elements of market dynamics could also amplify contagion. The linkage between markets causes a chain reaction such that shocks in one market trigger turbulence in other interconnected markets. Apriori Expectation: There is significant spillover of volatility between crude oil markets and currency markets in both oil-importing and oil-exporting economies.

The vector autoregressive GARCH (VAR-GARCH) estimation was executed for this research. The VAR-GARCH is a multivariate approach to GARCH modeling in which the volatility of each variable in the VAR system is modeled via a GARCH process to determine volatility clustering, volatility persistence and spillovers among the study variables. The VAR-GARCH model has empirical relevance because it effectively accounts for conditional volatility by incorporating both GARCH and VAR. This further enhances the empirical standardized normality of the distributed errors of the regression. As a result, the assessment of the risk incentive that influences investors' selection of stock portfolios is adequately quantified. Additionally, the VAR-GARCH model hosts virtual variables into the GARCH model to measure asymmetry. Accordingly, the conditional mean equation of the VAR-GARCH model is as specified via the matrix representation of equation (1):

$$\begin{bmatrix} R_{1,t-1} \\ R_{2,t-1} \end{bmatrix} = \begin{bmatrix} \gamma_1 \\ \gamma_2 \end{bmatrix} + \begin{bmatrix} \gamma_{11} & \gamma_{12} \\ \gamma_{21} & \gamma_{22} \end{bmatrix} \begin{bmatrix} R_{1,t-1} \\ R_{2,t-1} \end{bmatrix} + \begin{bmatrix} \varepsilon_{1,t} \\ \varepsilon_{2,t} \end{bmatrix} \tag{1}$$

The corresponding conditional variance equation is as specified in equation (2):

$$\begin{bmatrix} \sigma^2_{11,t} & \sigma^2_{12,t} \\ \sigma^2_{21,t} & \sigma^2_{22,t} \end{bmatrix} = \begin{bmatrix} \varphi_{11} & \varphi_{12} \\ 0 & \varphi_{22} \end{bmatrix}^T \begin{bmatrix} \varphi_{11} & \varphi_{12} \\ 0 & \varphi_{22} \end{bmatrix} +$$

$$\begin{bmatrix} \mu^2{}_{1,t-1} & \mu_{1,t-1}\mu_{2,t-1} \\ \mu_{2,t-1}\mu_{1,t-1} & \mu^2{}_{2,t-1} \end{bmatrix}^T \begin{bmatrix} R_{1,t-1} \\ R_{2,t-1} \end{bmatrix} X \begin{bmatrix} s_{11} & s_{12} \\ s_{21} & s_{22} \end{bmatrix} +$$

$$\begin{bmatrix} d_{11} & d_{12} \\ d_{21} & d_{22} \end{bmatrix}^T \begin{bmatrix} \sigma^2_{11,t-1} & \sigma^2_{12,t-1} \\ \sigma^2_{21,t-1} & \sigma^2_{22,t-1} \end{bmatrix} \begin{bmatrix} d_{11} & d_{12} \\ d_{21} & d_{22} \end{bmatrix} \tag{2}$$

where $\sigma^2_{11}$ is the volatility (variance) of exchange rates, $\sigma^2_{12}$ is the covariance of exchange rates and oil prices of oil-producing countries, and $\sigma^2_{22}$ is the volatility (variance) of oil prices of oil-producing countries. The volatility spillover was ascertained on the basis of the following:

$$s_{21} \neq 0;\ s_{12} \neq 0 \tag{3}$$

The linear equation for conditional quantiles of an independent variable estimates the parameter vector given by equation (4) as:

$$\hat{\gamma}_t = {}^{argmin}_{\gamma_\vartheta} \sum_{t=1}^{T-j} \left( \vartheta . y^{(j)}_{t+j} < Z'{}_t \gamma_{\vartheta_t} |(y^{(j)}_{t+j} - Z'{}_t \gamma_\vartheta| + (1-\vartheta). y^{(j)}_{t+j} < z'{}_t \gamma_{\vartheta_t} |(y^{(j)}_{t+j} - Z'{}_t \gamma_\vartheta| \right) \tag{4}$$

where h is the forecast horizon; Z is the vector of constants and regressors, which include Frex, the foreign exchange rate; Frvol, the volatility of the foreign exchange rate; oilpvol, crude oil price volatility; oilprs, crude oil prices; and $\gamma$s are the estimated parameters for different quantiles, $e$ is error term. The exchange rates were calculated in LCU/US$ units and obtained from the market listings of https://www.investing.com. Similarly, crude oil prices in US$ were sourced from the market listings of https://www.investing.com. Quarterly indices cannot be derived directly from data sources. Hence, monthly series were retrieved and converted into quarterly (three-month average) series via spreadsheet pivot tables. The sample of oil producing countries in this research are Nigeria, Canada, Australia, Argentina, Saudi Arabia, UAE, Malaysia, Kuwait, China, and Tunisia. Africa's largest country is Nigeria. The organization in charge of managing Nigeria's oil sector is the Nigerian National Petroleum Company. Nigeria produced over 1.3 million barrels of oil per day in June 2024, while its proven oil reserves were 37.5 billion barrels. 5.65 million barrels of oil were produced daily in Canada in 2023 (OPEC, 2024). Compared to 2022, this represented an increase of almost 1.4%. Imperial Oil, Shell Canada, Suncor Energy, Tourmaline Oil, TC Energy, and Gibson Energy Inc. are some of the firms that manage Canada's oil industry. Companies such as Chevron Corporation, ExxonMobil Corporation, BP PLC, Shell PLC, and TotalEnergies SE are the leading international companies operating in the Australian oil and gas business. The major international companies in the Australian oil and gas market, such as ExxonMobil and Chevron Corporation, run the country's oil and gas sector. Australia produced 85,482 barrels of crude oil per day in December 2023, compared to 110,438 barrels per day in December 2022 (OPEC, 2022). Argentina produced 1,074 thousand barrels of oil per day in 2023, an increase of over 13% above the amount of petroleum produced in 2022. Crude oil output increased 8.7% year over year in 2023, exceeding our 6.2% year over year prediction, mostly as a result of better-than-expected Q423 results. A mix of foreign and state-owned businesses, such as YPF, Gas del Estado, Chevron, ConocoPhillips, ExxonMobil, Petronas, Shell, and Total, manage Argentina's oil sector.

As a member of OPEC+, Saudi Arabia consented to voluntary reductions in oil output, which started in April 2023. Saudi Aramco is in charge of the country's oil sector. Saudi Arabia unilaterally reduced OPEC+ production by an additional 1.0 million barrels per day in July 2023. 4.16 million barrels of oil were produced daily by the United Arab Emirates (OPEC, 2023). The United Arab Emirates produced 3,300,000 barrels of crude oil per day as of December 2023. Abu Dhabi National Oil firm (ADNOC), the country's national oil firm, has reportedly raised its ability to produce crude oil to 4.85 million barrels per day, with a goal of 5 million barrels per day by 2027. PETRONAS, a state-owned company, is in charge of managing the oil and gas sector in Malaysia. 660,000 barrels are produced in Malaysia on a daily basis. The commercial reserves of Malaysia are more than 17 billion barrels of oil equivalent (World Bank, 2024). Malaysia ranks fourth in the Asia-Pacific region for oil production and second in Southeast Asia. Kuwait's estimated 102 billion barrels of oil make it the sixth largest oil reserve in the world. This amounts to roughly 6 percent of the world's total oil reserves. Kuwait produced 2.9 million barrels of oil per day in 2023, or roughly 3% of global oil production. Ninety-four percent of Kuwait's export earnings come from oil sales. The Kuwait Petroleum Corporation is a government-owned company that manages the country's oil industry. China's oil production was 4.2 million barrels per day in 2023. It is now the Asia-Pacific region's biggest producer of oil. Several state-owned firms, such as Sinopec, the China National Petroleum Corporation, and the China National Offshore Oil Corporation, are in charge of managing China's oil sector. Since 2007, Tunisia's oil production has been decreasing; in 2022, it was 35.4 thousand barrels per day. Tende Energy and other businesses, along with the state-owned Enterprise Tunisienne d'Activités Pétrolières, are in charge of managing the country's oil sector.

**4. Results**

Figure 1 shows the plotted exchange rate returns volatilities for ten oil-exporting countries, three of which, Argentina, the United Arab Emirates and Saudi Arabia, had more stable currencies than other currencies did. The other countries had varying intensities of fluctuations.

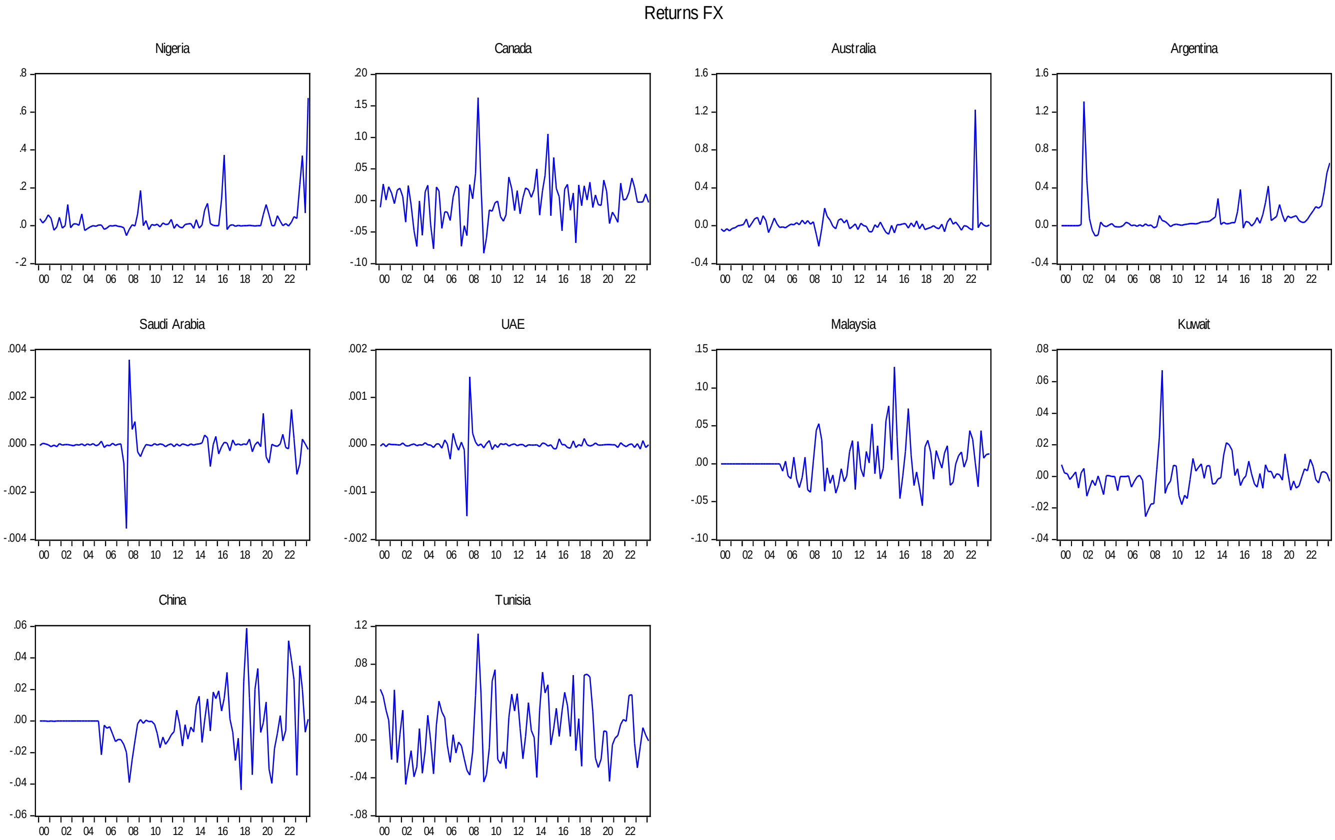


**Figure 1** Plots of exchange rate volatility of oil-exporting countries.

As shown in Table 1 below, the average change in crude oil quarterly prices was 0.0246 (2.46 percent), whereas the highest positive period shift in price was 37.6 percent. However, the most significant move in the crude oil price in market listing is reflected in the minimum value, -0.50955, which represents a decline in price by more than half of the market rate in the previous quarter. The leptokurtic distribution (kurtosis: 3.87 >3) implies that it has fatter tails and is thus more likely to contain extreme values, than a normal bell-shaped distribution.

**Table 1** Crude oil price volatility.

| Mean | Maximum | Minimum | Std. Dev. | Kurtosis | Skewness |
|---|---|---|---|---|---|
| 0.024631 | 0.376341 | -0.50955 | 0.152518 | 3.875176 | 2.1597 |

The mean currency returns on the global scale for Canadian dollar and the Chinese Yuan were negative, implying that the currencies rose in value against the dollar on average within the periods of study (Table 2). Argentinean Peso had the highest average volatility of 0.0824, and the UAE Dirham had the lowest volatility of 0.0000, indicating that it was the currency with the greatest stability of the selected countries in the group. The minimum values are indicative of declining currency values.

**Table 2** Descriptive results of the volatility of the exchange rate.

| Country | Mean | Max | Min. | Std. Deviation | Kurtosis |
|---|---|---|---|---|---|
| Argentina (ARS/USD) | 0.082446 | 1.312540 | -0.109026 | 0.17815 | 41.5291 |
| Australia (AUD/USD) | 0.014640 | 1.226392 | -0.217314 | 0.13440 | 6.3267 |
| Canada (CAD/USD) | -0.000187 | 0.162828 | -0.083380 | 0.03599 | 6.5134 |
| China (CNY/USD) | -0.001303 | 0.059021 | -0.043721 | 0.01729 | 5.5733 |
| Kuwait (KWD/USD) | 0.000177 | 0.067309 | -0.025644 | 0.01087 | 15.9426 |
| Malaysia (MYR/USD) | 0.002635 | 0.127828 | -0.055529 | 0.02784 | 6.6519 |
| Nigeria (NGN/USD) | 0.030952 | 0.674039 | -0.051734 | 0.09304 | 25.2483 |
| Saudi Arabia (SAR/USD) | -0.000001 | 0.003597 | -0.003540 | 0.00062 | 25.3855 |
| Tunisia (TND/USD) | 0.010166 | 0.112201 | -0.047143 | 0.03371 | 2.4547 |
| UAE (AED/USD) | -0.000002 | 0.001436 | -0.001507 | 0.00022 | 38.5012 |

A unit root indicates a stochastic trend that does not vanish over time, and its presence in a dataset could result in spurious regression and challenges in correctly interpreting the relationships between variables. The results of the five unit-root tests revealed that unit roots were not found in any of the two variables. This is revealed in Table 3.

The cointegration test results as reported in Table 4 below confirm that volatilities from exchange rates and crude oil prices across the groups are correlated in the long term such that, in a joint linear relationship, they produce stationary time series (p< 05). In effect, there are dynamic economic linkages between the variations in currency rates and crude oil prices. These variabilities could arise from the role of oil in global trade and its impact on overall economic activities.

**Table 3** Panel unit root test results.

| Method | Rex | | | |
|---|---|---|---|---|
| | Statistic (level) | Probability | Statistic (First difference) | Probability |
| Levin, Lin & Chu t* | -0.384 | 0.874 | -23.0651*** | 0.00 |
| Breitung t-stat | -0.291 | 0.486 | -4.09774*** | 0.00 |
| Im, Pesaran and Shin W-stat | -0.489 | 0.320 | -21.2492*** | 0.00 |
| ADF - Fisher Chi-square | 0.697 | 0.276 | 347.281*** | 0.00 |
| PP - Fisher Chi-square | 0.354 | 0.689 | 291.037*** | 0.00 |
| Method | Rcoil | | | |
| | Statistic (level) | Probability | Statistic (First difference) | Probability |
| Levin, Lin & Chu t* | -0.183 | 0.689 | -19.0458*** | 0.00 |
| Breitung t-stat | -0.122 | 0.721 | -17.1342*** | 0.00 |
| Im, Pesaran and Shin W-stat | -0.490 | 0.583 | -39.1058*** | 0.00 |
| ADF - Fisher Chi-square | 0.157 | 0.894 | 103.2871*** | 0.00 |
| PP - Fisher Chi-square | 0.236 | 0.126 | 179.7520*** | 0.00 |

**Table 4** Cointegration test results.

| No. of cointegration (r) | Fisher Trace test statistic | 5% critical value | Probability | Fisher Max-eigen statistic | 5% critical value | Probability |
|---|---|---|---|---|---|---|
| Nigeria | | | | | | |
| $r=0$ | 56.879*** | 40.872 | 0.001 | 32.471** | 24.589 | 0.006 |
| $r\leq 1$ | 35.198** | 32.489 | 0.007 | 25.879** | 17.314 | 0.058 |
| $r\leq 2$ | 20.548 | 29.187 | 0.679 | 9.389 | 11.289 | 0.594 |
| $r\leq 3$ | 13.129 | 21.389 | 0.875 | 6.094 | 8.099 | 0.878 |
| Canada | | | | | | |
| $r=0$ | 123.045*** | 110.879 | 0.000 | 90.342*** | 86.172 | 0.000 |
| $r\leq 1$ | 100.387*** | 98.367 | 0.000 | 68.149** | 52.103 | 0.006 |
| $r\leq 2$ | 78.093** | 50.211 | 0.005 | 42.509 | 43.129 | 0.234 |
| $r\leq 3$ | 45.986 | 49.762 | 0.457 | 19.487 | 23.156 | 0.672 |
| Australia | | | | | | |
| $r=0$ | 79.367** | 61.289 | 0.005 | 45.689** | 31.940 | 0.005 |
| $r\leq 1$ | 65.093** | 50.311 | 0.005 | 34.568** | 25.387 | 0.006 |
| $r\leq 2$ | 43.895 | 46.239 | 0.465 | 12.879 | 14.589 | 0.446 |
| $r\leq 3$ | 20.149 | 23.548 | 0.658 | 9.456 | 11.156 | 0.568 |
| Argentina | | | | | | |
| $r=0$ | 33.292** | 30.272 | 0.005 | 29.455** | 21.343 | 0.005 |
| $r\leq 1$ | 27.911** | 24.581 | 0.005 | 18.372 | 19.227 | 0.243 |
| $r\leq 2$ | 13.042 | 14.079 | 0.673 | 12.499 | 13.178 | 0.382 |
| $r\leq 3$ | 5.869 | 8.340 | 0.715 | 5.389 | 6.239 | 0.692 |
| Saudi Arabia | | | | | | |
| $r=0$ | 78.261*** | 60.197 | 0.000 | 53.879** | 42.491 | 0.005 |
| $r\leq 1$ | 56.892** | 50.285 | 0.001 | 46.589** | 33.128 | 0.007 |
| $r\leq 2$ | 43.587** | 41.389 | 0.006 | 21.079 | 24.561 | 0.274 |
| $r\leq 3$ | 31.129 | 35.623 | 0.248 | 9.421 | 7.093 | 0.596 |
| UAE | | | | | | |
| $r=0$ | 65.893*** | 49.863 | 0.005 | 33.589** | 24.123 | 0.005 |
| $r\leq 1$ | 45.613** | 35.100 | 0.006 | 15.116 | 17.392 | 0.467 |
| $r\leq 2$ | 22.109 | 28.412 | 0.210 | 12.169 | 14.523 | 0.558 |
| $r\leq 3$ | 10.179 | 17.089 | 0.524 | 4.198 | 6.489 | 0.672 |
| Malaysia | | | | | | |
| $r=0$ | 60.382*** | 36.897 | 0.005 | 29.603** | 27.091 | 0.005 |
| $r\leq 1$ | 35.896** | 23.123 | 0.006 | 12.109 | 13.581 | 0.356 |
| $r\leq 2$ | 16.450 | 17.415 | 0.494 | 9.481 | 11.987 | 0.284 |
| $r\leq 3$ | 5.679 | 8.390 | 0.643 | 2.103 | 5.482 | 0.351 |
| Kuwait | | | | | | |
| $r=0$ | 109.510*** | 90.187 | 0.005 | 87.365** | 54.389 | 0.005 |
| $r\leq 1$ | 98.367** | 67.322 | 0.005 | 56.093** | 31.017 | 0.005 |
| $r\leq 2$ | 65.130** | 47.209 | 0.005 | 24.587 | 26.119 | 0.293 |
| $r\leq 3$ | 25.389 | 31.389 | 0.387 | 12.199 | 13.598 | 0.486 |
| China | | | | | | |
| $r=0$ | 178.309*** | 128.409 | 0.000 | 101.387** | 98.467 | 0.005 |
| $r\leq 1$ | 112.380*** | 97.125 | 0.000 | 84.129** | 69.201 | 0.005 |
| $r\leq 2$ | 79.301** | 56.380 | 0.005 | 33.281 | 42.193 | 0.236 |
| $r\leq 3$ | 32.489 | 33.489 | 0.872 | 21.152 | 29.452 | 0.786 |
| Tunisia | | | | | | |
| $r=0$ | 51.223** | 53.280 | 0.006 | 21.087** | 16.489 | 0.005 |
| $r\leq 1$ | 35.119** | 31.198 | 0.006 | 10.149 | 12.154 | 0.375 |
| $r\leq 2$ | 13.134 | 29.467 | 0.347 | 4.589 | 9.271 | 0.394 |
| $r\leq 3$ | 12.159 | 16.094 | 0.595 | 1.312 | 2.289 | 0.589 |

In terms of the quantile regression estimates' significant coefficients, the seventieth percentile had a significant negative coefficient of -0.1293. This coefficient validates that if the top five grouping or 20 percent highest values of exchange rate fluctuations are isolated for testing in a regression model to predict crude oil prices, there is a corresponding 0.129% opposite movement in crude oil volatility for a percentage change in the isolated currency volatility values. A percentage increase in currency volatility resulted in a 0.0179% decrease in the volatility of petroleum prices. The constant value of 0.104 indicates that the rate of crude oil change would be a 10.4% quarterly increase if changes in the currencies of oil-producing countries do not exist.

The 90th percentile regression's quantile regression result has a p value of 0.0571 and a coefficient of -0.0571. The coefficient, which was determined to be substantial, supports the idea that the highest 10 percent of currency returns have a negative impact on the price of crude oil in economies that export. To put it another way, a percentage change in currency returns in the top 10% of the distribution would result in a 0.0571 percent drop in crude oil prices. The constant value for the same equation is 0.1918, which means that when currency fluctuations do not intervene or when exchange rate volatility is zero under comparable economic circumstances, the percentage change in crude oil volatility is 19.2 percent.

Insignificant parameters for exchange rate volatility were present in other equations from the 10th percentile through the other quantile and percentile equations as well as the median equation. All of the indicators were negative, though, which is in line with the way that changes in the currencies of nations that produce oil affect the price of crude oil globally. As greater levels of currency returns are studied, the quantile estimates show an overall growing pattern of impacts. With the exception of the fortieth percentile, constant values in every equation were significant. While the positive parameters of the other regression equations showed a tendency toward steady price increases, the constant values of the first three displayed a tendency toward declining crude oil prices. Additionally, the pattern is seen to rise steadily across all of the equations. All model quantiles showed negligible currency rates as a control variable.

**Table 5** Quantile regression estimates (response variable: oil price volatility).

| Variable | 0.1 | 0.2 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 |
|---|---|---|---|---|---|---|---|---|---|
| Frex | 0.00008 | 0.00001 | 0.00004 | 0.00001 | 0.00004 | 0.00003 | 0.00002 | 0.00001 | 0.00004 |
| | (0.00008) | 0.00007 | 0.00013 | 0.00011 | 0.00004 | 0.00004 | 0.00004 | 0.00013 | 0.00008 |
| Frvol | -0.3765 | -0.1720 | -0.1835 | -0.1791 | -0.0885 | -0.0953 | -0.1293** | -0.0179** | -0.0571** |
| | 0.4982 | 0.2960 | 0.1997 | 0.2024 | 0.0502 | 0.0498 | 0.0463 | 0.0409 | 0.0267 |
| C | -0.1650* | -0.0906** | -0.0429** | 0.0114 | 0.0368*** | 0.0639*** | 0.1038 | 0.104*** | 0.1918 |
| | 0.0115 | 0.0077 | 0.0088 | 0.0060 | 0.0051 | 0.0048 | 0.0056 | 0.0068 | 0.0074 |

Conversely, across all quantile process equations, Table 6's results demonstrate that the volatility of crude oil has a negative and considerable impact on the exchange rate fluctuations of oil-exporting nations. The tenth percentile has -0.0452 as the regression coefficient, demonstrates that oil volatility has a significant and negative impact on currency volatility when taken one after the other. According to the coefficient, a percentage change in the volatility of crude oil would be matched by a 0.0452 percent shift in the opposite direction in the currency movements of nations that produce oil. The constant value of -0.0213 also shows that if crude oil volatility does not change over time, oil-producing nations would typically have a quarterly currency volatility of 2 percent. A regression value of -0.030 indicated that oil price volatility has a negative and significant impact on currency volatility, according to the twentieth percentile or first quintile equation. A 0.03% decrease in the currency fluctuation rates of oil-producing countries follows a percentage increase in crude oil volatility, according to the correlation. If crude oil returns remained constant across time, petroleum-producing countries would have quarterly currency volatility of 0.9%, as indicated by the constant value of -0.009. With a regression value of -0.014, the thirtieth and fiftieth percentile regressions showed that currency volatility was negatively impacted by oil volatility, with the exception of the fiftieth quantile, where the value was undetectable. The above table's findings indicate that the currency fluctuation rates of oil-producing nations reduce by 0.015 percentage points for every percentage increase in crude oil price volatility.

Petroleum-producing nations would have negative quarterly currency volatility of 0.29% if crude oil volatility remained constant across time, as indicated by the value of the intercept in the 20$^{th}$ percentile equation. In contrast, the 60$^{th}$ percentile equation's intercept has a positive value of -0.0159, indicating that if the volatility in oil prices stays constant, currency volatility will drop by 0.0159%. There was a significant inverse relationship between oil price volatility and currency volatility, according to regression tests performed at the 40th percentile. Based on the results, a percentage rise in the volatility of crude oil prices is associated with a 0.001 percentage point decrease in the currency fluctuation rates of countries that produce a significant amount of oil. If crude oil price volatility remained constant across time, oil-producing economies would experience negative quarterly currency volatility of 0.003%, according to the intercept in the 40th percentile. The seventieth percentile revealed a substantial and noteworthy inverse association between currency and oil price volatility, with a regression coefficient of -0.03. According to this coefficient, there would be a corresponding 0.0299 percent rise in the currency fluctuations of countries that produce a significant amount of oil for every percentage change in the volatility of the price of crude oil. Oil-dependent economies would typically have positive quarterly currency volatility of 1 percent if crude oil price volatility remained unchanged throughout time, according to the constant term, which is indicated by 0.0101.

The 80th quantile's regression coefficient, which is -0.0607, shows a statistically significant negative correlation between currency rate volatility and oil price volatility. According to the quantile outcome, the currency fluctuation rates of nations that depend on oil production reduce by 0.061 percentage points for every percentage increase in crude oil price volatility. Oil-producing countries would witnessed quarterly currency volatility of 0.023 assuming crude oil volatility stayed constant across time, according to the constant term of 0.023. The equation for the 90th percentile values of crude oil price volatility showed a significant correlation: oil volatility had a significant and negative effect on currency rate variability, with a regression coefficient of -0.046. For every percentage rise in crude oil price volatility, the regression analysis showed that the currency fluctuation rates of oil-producing nations decreased by 0.046 percentage points. Furthermore, the constant term of -0.4531 suggests that oil-producing countries witnessed quarterly currency volatility of 4.53%, if crude oil price volatility stayed constant throughout time.

**Table 6** Quantile regression estimates (dependent variable: Frvol).

| Variable | 0.1 | 0.2 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 |
|---|---|---|---|---|---|---|---|---|---|
| oilpvol | -0.0399** | 0.0299** | -0.0140**** | 0.0101 | -0.0014 | -0.0159*** | -0.0320** | -0.0607** | -0.0460**** |
| | (0.0085) | (0.0071) | (0.0038) | (0.0028) | (0.0029) | (0.0043) | (0.0055) | (0.0082) | (0.0196) |
| oilprs | -0.0452*** | -0.9134*** | -0.3680** | -0.4210 | -0.5134** | -0.6166*** | -0.192** | -0.249** | -0.0178*** |
| | (0.000) | (0.0000) | (0.0002) | (0.4528) | (0.0029) | (0.0003) | (0.005) | (0.0082) | (0.0000) |
| C | -0.0213** | -0.0085* | -0.0022** | 0.1526*** | 0.01493 | 0.05429* | 0.0104* | 0.0230* | 0.4531*** |
| | (0.0018) | (0.0011 | (0.0004) | (0.0004) | (0.0004) | (0.0005) | (0.0014) | (0.0021) | (0.0033) |

The quantile process estimate charts for oil-exporting countries are labeled in Figure 2 below. Figure 2I shows the intercept and exchange rate volatility estimates per tenth-interval quantile in predicting variations in crude oil volatility. Figure 2II shows the intercept and crude oil returns estimates per tenth-interval quantile in predicting variations in exchange rate returns. The x-axis of the charts contains quantile labels, whereas the y-axis shows scale measurements of regression coefficients. As exchange rate volatility continues to increase, the rate of change in crude oil volatility increases as earlier established by Umoru et al., (2024).

The RESET test was used in Table 7 to assess and verify whether the model was appropriately described in terms of specification. The p-value was 0.01 and the results of the QLR L-statistic and QLR Lambda-statistic were 7.2929 and 7.2742, respectively. Additionally, the QLR L-statistic and QLR Lambda-statistic values, which are 3.6235 and 3.6189, respectively, with a p-value of 0.05, were obtained via the Ramsey RESET test once more. According to this result, the general model structure seems to be sufficiently described for comprehending the relationships within the dataset utilized in estimation, even though some nonlinear correlations may exist.

The Quantile Slope Equality Test (QSET) and Symmetries Quantile Test are two further diagnostics from Table 7, both of which are evaluated using the Wald statistics. A high chi-square statistic of 116.80 with a p-value of 0.00 is shown by the QSET, suggesting significant differences in impact of crude oil prices on currency return volatility at varying percentiles. This noteworthy finding suggests differences in the relationships by demonstrating that there is asymmetry in the quantile slopes. On the contrary, with a p-value of 0.12 and a Chi-Square statistic of 22.648 for the Quantile Slope Equality Test in Table 7 when crude oil price variability serves as the response variable, the results at the usual significance level of 0.05 suggest a more stable and consistent link between the variables. In effect, the slope estimates do not differ substantially between quantiles.

VAR-GARCH estimations**-** For the VAR specification, a lag specification was necessary to determine the most suitable lag for the estimations. Using the AIC as the information criterion, the dataset had lag 3 as the most appropriate lag for the estimation of the variability of crude oil prices and lag 2 as the most suitable lag for currency rate volatility. The results are contained in Table 8 below. Note that ** indicated the chosen lag order at 0.05 level.

ARCH effects- To satisfy the conditions for GARCH estimation, the residuals were tested for the presence of ARCH effects. The test results for the ARCH effects reported in Table 9 below confirm that the data series possess ARCH effects, as denoted by the significant p value of 0.00, which is less than 0.05. Hence, GARCH estimations were deemed sufficient for modeling return volatility; where ***, **, and * denotes significance at 0.01, 0.05, and 0.10 levels respeticlvely.

Volatility graphs of the exchange rate volatility are presented in Figure 3I while charts showing correlations between the volatility of oil prices and exchange rate volatility are presented in Figure 3II respectively. For Nigeria, currency fluctuations were fairly transient from 2000 before a small spike between 2008 and 2011 and an increase in rates in 2016. Similar volatility movement intensities did not cluster around one another, indicating that volatility was not persistent in Nigeria. Currency values in Saudi Arabia, Argentina, and the United Arab Emirates also fluctuated very little. In contrast, Tunisia had the highest persistence and volatility spikes, as evidenced by the clustering of larger surge and tiny volatilities, which suggests that future values may be predicted more accurately from historical data. According to their own charts, Australia, Canada, China, and Malaysia also experienced differing levels of volatility. Additionally, it is noted that, albeit unevenly, every nation had times of abnormal surges throughout this time.

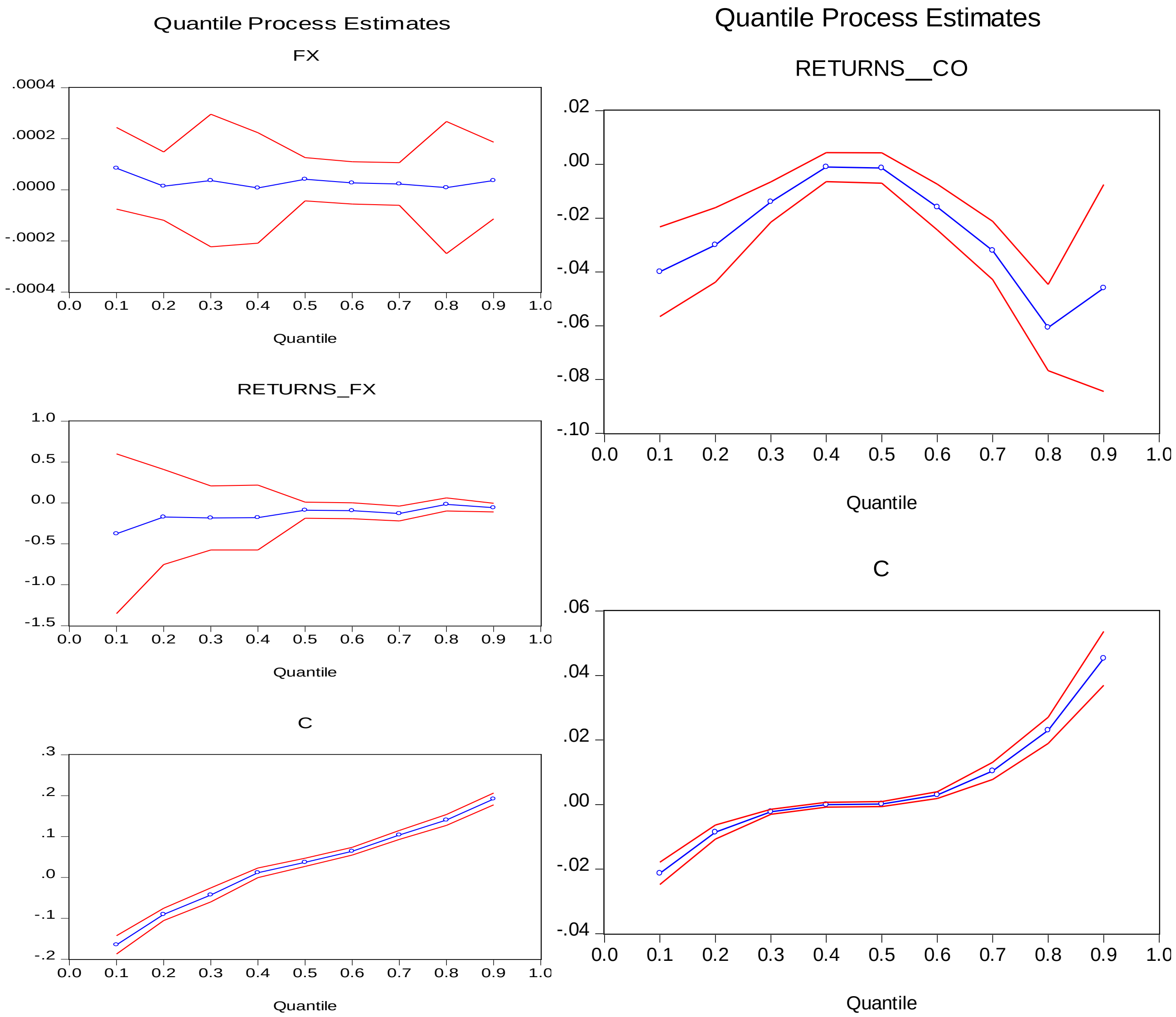


**Figure 2** Plot of quantile process estimates of oil exporters.

**Table 7** Estimation diagnostics.

| Test | Statistic | Frex: Rcoil Value (pvalue) |
|---|---|---|
| Stability Test: | QLR L-statistic | 7.2929 (0.01) |
| Ramsey Reset Test | QLR Lambda-statistic | 7.2742 (0.01) |
| Quantile Slope Equality Test: | | |
| Wald Test | Chi-Sq. Statistic | 116.80 (0.00) |
| Symmetries Quantile Test: | | |
| Wald Test | Chi-Sq. Statistic | 143.27 (0.00) |
| Test | Statistic | Rcoil: RFrex Value (p-value) |
| Stability Test: | QLR L-statistic | 3.6235 (0.05) |
| Ramsey Reset Test | QLR Lambda-statistic | 3.6189 (0.05) |
| Quantile Slope Equality Test: | | |
| Wald Test | Chi-Sq. Statistic | 22.648 (0.12) |
| Symmetries Quantile Test: | | |
| Wald Test | Chi-Sq. Statistic | 25.287 (0.01) |

**Table 8** Lag selection criteria for AGARCH model estimation.

| Endogenous Variable: Frvol | | | | |
|---|---|---|---|---|
| Statistic | Lag 0 | Lag 1 | Lag 2 | Lag 3 |
| LogL | 986.2816 | 1039.065 | 1042.002 | 1042.840 |
| LR | NA | 105.3394 | 5.856095 | 1.667840 |
| FPE | 0.007036 | 0.006294 | 0.006268 | 0.006270 |
| AIC | -2.118885 | -2.230247 | -2.234414 | -2.234064** |
| SC | -2.113686 | -2.219849 | -2.218816 | -2.213268** |
| HQ | -2.116902 | -2.226281 | -2.228465 | -2.226132** |
| Endogenous Variable: Oilpvol | | | | |
| Statistic | Lag 0 | Lag 1 | Lag 2 | Lag 3 |
| LogL | 190.367 | 250.367 | 345.278 | 534.192 |
| LR | NA | 6.0927 | 13.289 | 9.7615 |
| FPE | 0.1752 | 0.3546 | 0.1873** | 0.0957 |
| AIC | -0.3567 | -0.3254 | -0.3512** | -0.2906 |
| SC | -0.2679 | -0.2802 | -0.2246** | -0.6219 |
| HQ | -0.66752 | -0.67289 | -0.69234 | -0.72994** |

**Table 9** ARCH effects test results.

| Nigeria | F-Stat | Obs*R-squared | Canada | F-Stat | Obs*R-squared |
|---|---|---|---|---|---|
| Oilprvol | 56.505*** | 100.139*** | Oilprvol | 124.587*** | 110.287*** |
| | (0.000) | (0.000) | | (0.000) | (0.000) |
| Frvol | 28.528** | 100.456*** | Frvol | 567.312** | 525.834*** |
| | (0.000) | (0.00) | | (0.000) | (0.00) |
| Australia | F-Stat | Obs*R-squared | Argentina | F-Stat | Obs*R-squared |
| Oilprvol | 156.217*** | 150.287*** | Oilprvol | 26.389** | 23.947** |
| | (0.000) | (0.000) | | (0.005) | (0.005) |
| Frvol | 345.131*** | 341.009*** | Frvol | 140.791*** | 137.112*** |
| | (0.000) | (0.000) | | (0.000) | (0.000) |
| Saudi Arabia | F-Stat | Obs*R-squared | UAE | F-Stat | Obs*R-squared |
| Oilprvol | 149.256*** | 146.879*** | Oilprvol | 23.487** | 22.371** |
| | (0.000) | (0.000) | | (0.005) | (0.005) |
| Frvol | 112.467*** | 109.674*** | Frvol | 156.289*** | 123.891** |
| | (0.000) | (0.000) | | (0.000) | (0.000) |
| Malaysia | F-Stat | Obs*R-squared | Kuwait | F-Stat | Obs*R-squared |
| Oilprvol | 47.289** | 43.079** | Oilprvol | 28.146** | 25.793** |
| | (0.003) | (0.004) | | (0.005) | (0.005) |
| Frvol | 119.327*** | 106.113*** | Frvol | 26.519** | 25.168** |
| | (0.000) | (0.000) | | (0.005) | (0.005) |
| China | F-Stat | Obs*R-squared | Tunisia | F-Stat | Obs*R-squared |
| Oilprvol | 67.281** | 66.223** | Oilprvol | 35.298** | 34.231** |
| | (0.001) | (0.004) | | (0.003) | (0.003) |
| Frvol | 89.322*** | 86.271*** | Frvol | 897.376*** | 893.762** |
| | (0.000) | (0.000) | | (0.000) | (0.001) |

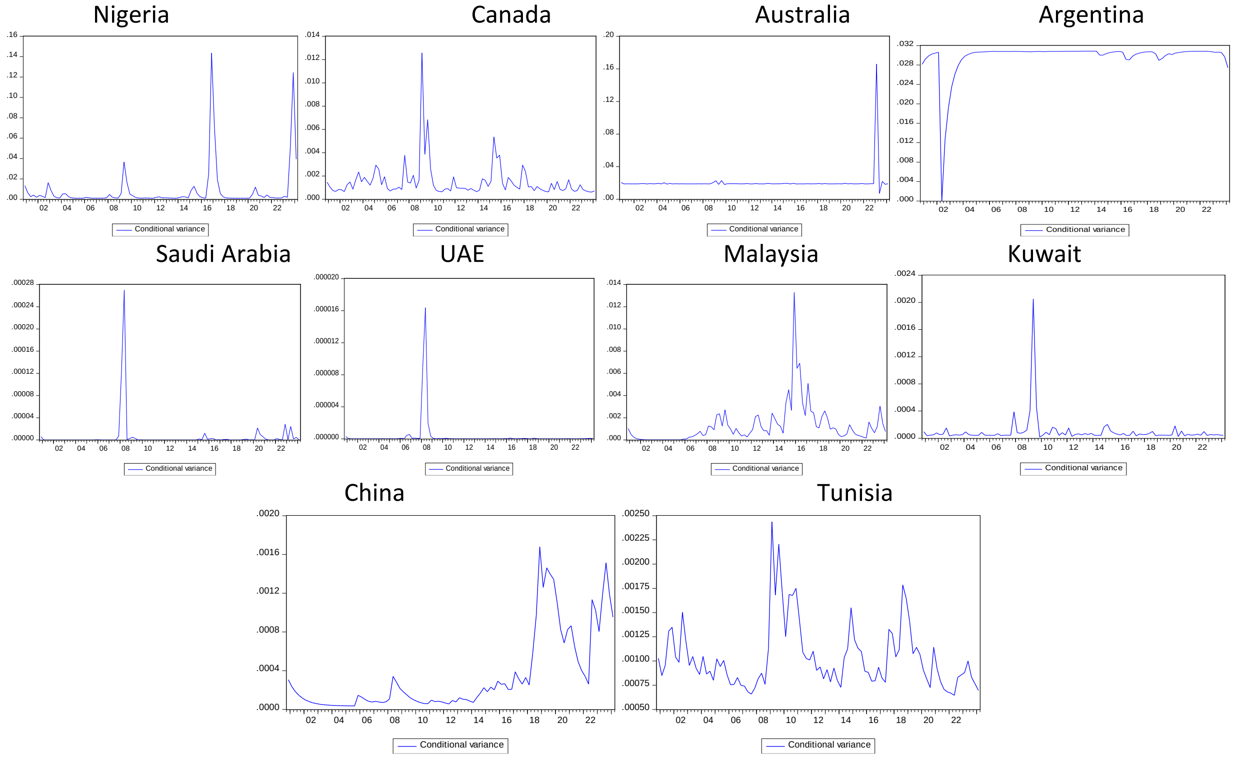


**Figure 3I** Charts of exchange rate volatility in oil-exporting countries.

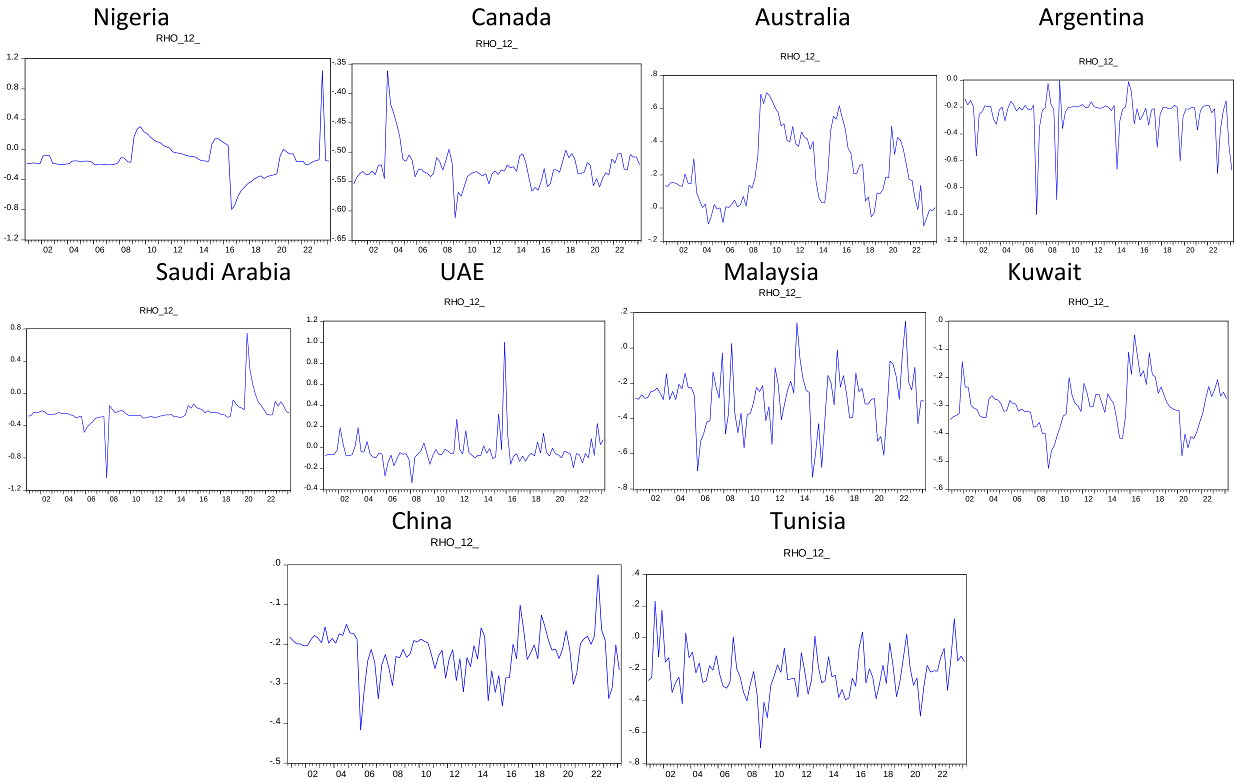


**Figure 3II** Charts showing correlations between the volatility of oil prices and exchange rate volatility in oil- exporting countries.

## 5. Discussion

According to the results of Table 10, the ARCH term for exchange rate fluctuation, given by the estimate 0.5490, is a measure of the magnitude of the effect of past squared errors of exchange rate volatility on its own current fluctuation. These values, which are found to be significant, confirm the extent to which shocks from earlier volatilities of these prices affect the present state of volatility. The volatility of the oil price has an arch effects of 0.2234 and 0.0339 for Nigeria; 0.0152 and 0.0243 for Canada; 0.0041 and 0.00197 for Australia; 0.0271 and 0.0298 for Argentina; 0.1093 and 0.0123 for Saudi Arabia; 0.0182 and 0.0309 for UAE; 0.0556 and -0.1123 for Malaysia; 0.0134 and -0.0167 for Kuwait; 0.0276 and 0.0184 for China; and 0.1005 and -0.1093 for Tunisia. The GARCH coefficients for oil price volatility and currency rate volatility are 0.6593 and 0.3547 for Nigeria; 0.0361 and -0.00199 for Canada; 0.1977 and 0.1243 for Australia; 0.0273 and 0.2168 for Argentina; 0.0256 and 0.7919 for Saudi Arabia; 0.0279 and 0.0135 for UAE; -0.0192 and 0.1035 for Malaysia; -0.2339 and -0.0193 for Kuwait; and -0.0013 and -0.1029 for China; and 0.0193 and 0.0517 for Tunisia respetively. There is presence of persistence of volatility.

This suggests that the effects of volatility shocks resulting from earlier currency fluctuations for oil-producing nations diminish as soon as volatility starts. Since of the ongoing volatility, there is a somewhat higher chance that market players can forecast returns in the near future for the price of crude oil, but not in the long run since dispersion takes time. At a significance level of 0.05, the impact of leverage for exchange rates had a notable positive value of -0.3851. The finding suggests that currency exchange rate shocks that are negative have a bigger impact on future volatility than positive shocks of the same size. This implies that unexpected shocks regarding currency exchange rates cause a greater reaction in in volatility than when investors have access to positive news.

Notably, in line with the observed negative coefficient and supporting evidence that crisis conditions intensify volatility spillovers across markets, studies like Kyriazis and Corbet (2024) also show that exchange rate fluctuations can inversely affect interconnected currencies and amplify spillovers during crises. Shang and Hamori's (2023) study, which demonstrated that extreme quantiles during crises, like the Russian-Ukrainian conflict, have a significant impact on currency correlations and spillovers, is consistent with this finding. It reflects the role of currency and oil price volatility during market distress in economies that export oil. Additionally, Umar and Bossman's (2023) research on asymmetry in oil shocks and exchange rates, which shows that sharp swings in oil prices have a significant effect on exchange rates for nations that export oil, supports our research findings. Mensi, Maitra, Selmi, and Vo (2023) further support the observed inverse relationship between oil price volatility and currency stability in oil-dependent economies by highlighting the sensitivity of spillovers between asset classes, such as gold and stock returns, to market shocks and the need for investors in correlated markets to exercise caution.

The findings also queued up with the findings of Belloumi, Aljazea, and Alshehry (2023), who demonstrated a similar relationship between oil prices and more general economic factors by showing that an increase in oil prices in Saudi Arabia causes higher inflation in the short and long term, while currency appreciation also has an inflationary effect in the short term. Similar tendency was seen by Youssef and Mokni (2023) in oil-exporting nations, who pointed out that rising oil prices cause investors to react collectively to changes in oil prices in stock markets such as China and Russia. Additionally, Kumar, Kumar, and Singh (2023) discovered that the Indian stock market is positively impacted by crude oil prices, whereas the exchange rate has a short-term negative impact, highlighting the complex association between oil prices and emerging economies' financial markets and economic results. Significant volatility spillover effects are also seen in both markets, in view of the statistical significance of the coefficient estimates given by -0.0371 and -0.1339 for Nigeria; -0.0199 and -0.0145 for Canada; 0.1977 and 0.1243 for Australia; 0.0273 and 0.2168 for Argentina; 0.0256 and 0.7919 for Saudi Arabia; 0.01691 and 0.0135 for UAE; -0.0192 and 0.1035 for Malaysia; -0.0148 and -0.0152 for Kuwait; -0.0013 and -0.1029 for China; and 0.0143 and 0.0517 for Tunisia respectively.

Shocks from previous volatility in the currency markets of oil-exporting economies have a strong and inverse impact on existing volatility in the crude oil markets, as confirmed by the coefficients -0.0379 and 0.1339. The spillover measure for the crude oil market verifies that higher levels of market volatility in previous eras would result in inverse adjustments of current volatility. Additionally, there is less of a spillover effect from oil markets to currency markets than there is from oil markets to the currency markets of nations that export oil. The shape parameter is weak as confirmed by the shape parameter of -0.4407. Note that ***, ** and * all denotes significance at 0.01, 0.05, and 0.10 levels respectively. The convoluted bidirectional relationship between oil prices and exchange rates in both oil-importing and oil-exporting countries was also highlighted by Wu et al. (2023). They demonstrated that during crises like the global financial crisis and the COVID-19 pandemic, there is "dark causality," where oscillatory trends rather than purely positive or negative trends are seen. This intricate connection emphasizes how important it is for investors to consider the various factors that influence currency markets and oil prices. Additionally, Okorie and Lin (2024) examined how global shocks, such as the COVID-19 pandemic and changes in the price of crude oil, impact the stability and economic activity of nations that rely heavily on oil, such as Nigeria, and how fiscal policies are occasionally employed to moderate these effects.

### *5.1. Policy implications*

Cointegration between the variables of the study suggests that changes in exchange rates and oil prices are not independent of each other in the long run. Consequently, while volatilities in exchange rates and oil prices may exhibit short-term fluctuations, there is an underlying equilibrium relationship that tends to bring them back together over time. Variations in oil prices have an impact on a nation's trade balance and exchange rates, which has implications for private sector importers, exporters, and multinational firms as well as, on the stability of the overall economic magnitude. Investors are not left out. The long-term nexus of the fluctuations of both currencies and crude oil listings or pricing implies that certain variations in exchange rates and oil prices are likely to be correlated, affecting the risk and return characteristics of a diversified portfolio. For example, global tensions causing a notable rise in petroleum prices exert direct effects on the economies of oil-exporting countries, resulting in economic shrinkage, currency devaluation, inflation, trade imbalance, and current account shortfalls. The repercussions of these downturns in the economy have wider consequences for financial institutions and markets internationally, and worldwide economic growth.

**Table 10** AGARCH estimates with exchange rate volatility as the dependent variable.

| Nigeria | | |
|---|---|---|
| Variable | Coefficients | Standard Error |
| Mean(Frvol) | -0.0064*** | 0.00006 |
| Mean(Oilprvol) | 0.0724*** | 0.00086 |
| C(1) | 0.0007*** | 0.00001 |
| C(2) | 0.0108*** | 0.00024 |
| A(1,1) | 0.5490*** | 0.0081 |
| A(1,2) | 0.0177*** | 0.00027 |
| A(2,1) | 0.2234*** | 0.00071 |
| A(2,2) | 0.0339* | 0.00060 |
| B(1,1) | 0.6593** | 0.0052 |
| B(1,2) | -0.0371*** | 0.00046 |
| B(2,1) | -0.1339** | 0.00050 |
| B(2,2) | 0.3547*** | 0.00064 |
| D(1) | 0.3851*** | 0.0285 |
| D(2) | 0.2728** | 0.0052 |
| F(2,1) | -0.4407*** | 0.00303 |
| Log Likelihood: 2174.85 | | |
| Canada | | |
| Variable | Coefficients | Standard Error |
| Mean(Frvol) | 0.0154 | 0.0106 |
| Mean(Oilprvol) | 0.0142 | 0.3821 |
| C(1) | 0.0581 | 0.8724 |
| C(2) | 0.0133 | 0.9352 |
| A(1,1) | 0.0461** | 0.0049 |
| A(1,2) | 0.0235 | 0.0001 |
| A(2,1) | 0.0152*** | 0.0001 |
| A(2,2) | 0.0243*** | 0.0004 |
| B(1,1) | 0.0361*** | 0.0001 |
| B(1,2) | -0.0199*** | 0.0002 |
| B(2,1) | -0.0145*** | 0.0001 |
| B(2,2) | 0.0124 | 0.0003 |
| D(1) | -0.0185** | 0.0019 |
| D(2) | 0.0196*** | 0.0001 |
| F(2,1) | 0.0134*** | 0.0003 |
| Log Likelihood: 3254.189 | | |
| Australasia | | |
| Variable | Coefficients | Standard Error |
| Mean(Frvol) | 0.1462 | 0.0234 |
| Mean(Oilprvol) | 0.0183 | 0.0292 |
| C(1) | 0.1573 | 0.0013 |
| C(2) | 0.0123 | 0.0004 |
| A(1,1) | 0.0019*** | 0.0005 |
| A(1,2) | 0.0041*** | 0.0006 |
| A(2,1) | 0.0197*** | 0.0087 |
| A(2,2) | 0.0028*** | 0.0092 |
| B(1,1) | 0.0195 | 0.0003 |

| | | |
|---|---|---|
| B(1,2) | 0.1977*** | 0.0005 |
| B(2,1) | 0.1243** | 0.0003 |
| B(2,2) | 0.0516*** | 0.0001 |
| D(1) | 0.1862 | 0.0015 |
| D(2) | 0.1263*** | 0.0002 |
| F(2,1) | 0.1973*** | 0.0001 |
| Log Likelihood: 2835.9 | | |
| | Argentina | |
| Variable | Coefficients | Standard Error |
| Mean(Frvol) | 0.0356 | 0.0001 |
| Mean(Oilprvol) | 0.0245 | 0.0013 |
| C(1) | 0.0576** | 0.0042 |
| C(2) | 0.0452 | 0.0018 |
| A(1,1) | 0.0231 | 0.0001 |
| A(1,2) | 0.0271 | 0.0001 |
| A(2,1) | 0.0298*** | 0.0002 |
| A(2,2) | 0.0172** | 0.0003 |
| B(1,1) | 0.0185 | 0.0005 |
| B(1,2) | 0.0273*** | 0.0001 |
| B(2,1) | 0.2168*** | 0.0004 |
| B(2,2) | 0.2745*** | 0.0001 |
| D(1) | 0.0413*** | 0.0019 |
| D(2) | 0.0178** | 0.0053 |
| F(2,1) | 0.1632** | 0.0005 |
| Log Likelihood: 3671.02 | | |
| | Saudi Arabia | |
| Variable | Coefficients | Standard Error |
| Mean(Frvol) | 0.2971 | 0.0009 |
| Mean(Oilprvol) | 0.0163*** | 0.0001 |
| C(1) | 0.1130 | 0.0005 |
| C(2) | 0.0173 | 0.0082 |
| A(1,1) | 0.2456*** | 0.0004 |
| A(1,2) | 0.1093** | 0.0025 |
| A(2,1) | 0.0123** | 0.0022 |
| A(2,2) | 0.0148*** | 0.0001 |
| B(1,1) | 0.0538*** | 0.0009 |
| B(1,2) | 0.0256*** | 0.0010 |
| B(2,1) | 0.7919*** | 0.0001 |
| B(2,2) | 0.9187 | 0.0032 |
| D(1) | 0.1304*** | 0.0007 |
| D(2) | 0.0152*** | 0.0002 |
| F(2,1) | 0.1032*** | 0.0001 |
| Log Likelihood: 3671.02 | | |
| | UAE | |
| Variable | Coefficients | Standard Error |
| Mean(Frvol) | 0.389 | 0.0005 |
| Mean(Oilprvol) | 0.0287 | 0.0028 |
| C(1) | 0.1310 | 0.0017 |
| C(2) | 0.1934 | 0.0066 |
| A(1,1) | 0.0387*** | 0.0031 |
| A(1,2) | 0.0182*** | 0.0062 |
| A(2,1) | 0.0309*** | 0.0006 |
| A(2,2) | 0.1873 | 0.0091 |
| B(1,1) | 0.0534** | 0.0028 |
| B(1,2) | 0.0169*** | 0.0001 |

| | | |
|---|---|---|
| B(2,1) | 0.0135*** | 0.0001 |
| B(2,2) | 0.0289 | 0.0001 |
| D(1) | 0.1546 | 0.0002 |
| D(2) | 0.3289 | 0.0003 |
| F(2,1) | 0.5368*** | 0.0042 |
| Log Likelihood: 3671.02 | | |
| | Malaysia | |
| Variable | Coefficients | Standard Error |
| Mean(Frvol) | 0.1672 | 0.0005 |
| Mean(Oilprvol) | 0.1793 | 0.0027 |
| C(1) | -0.0152 | 0.0014 |
| C(2) | 0.2921 | 0.0025 |
| A(1,1) | 0.3891*** | 0.0001 |
| A(1,2) | 0.0556** | 0.0001 |
| A(2,1) | -0.1123*** | 0.0012 |
| A(2,2) | 0.1573 | 0.2569 |
| B(1,1) | -0.9172*** | 0.0001 |
| B(1,2) | -0.0192*** | 0.0001 |
| B(2,1) | 0.1035** | 0.0009 |
| B(2,2) | -0.1522** | 0.0005 |
| D(1) | 0.1573 | 0.0003 |
| D(2) | -0.0189** | 0.0005 |
| F(2,1) | -0.1037*** | 0.0001 |
| Log Likelihood: 4251.893 | | |
| | Kuwait | |
| Variable | Coefficients | Standard Error |
| Mean(Frvol) | 0.1209*** | 0.0001 |
| Mean(Oilprvol) | 0.1399** | 0.0039 |
| C(1) | -0.1580*** | 0.0001 |
| C(2) | 0.1277** | 0.0067 |
| A(1,1) | 0.2378 | 0.0871 |
| A(1,2) | 0.0134 | 0.0672 |
| A(2,1) | -0.0167*** | 0.0003 |
| A(2,2) | 0.0059*** | 0.0001 |
| B(1,1) | -0.2339*** | 0.0001 |
| B(1,2) | -0.0148** | 0.0025 |
| B(2,1) | -0.0152*** | 0.0001 |
| B(2,2) | 0.0197 | 0.0226 |
| D(1) | 0.1026** | 0.0035 |
| D(2) | 0.0032 | 0.1672 |
| F(2,1) | -0.0192*** | 0.0001 |
| Log Likelihood: 2234.809 | | |
| | China | |
| Variable | Coefficients | Standard Error |
| Mean(Frvol) | 0.7610** | 0.0051 |
| Mean(Oilprvol) | 0.9240*** | 0.0002 |
| C(1) | -0.0150 | 0.0026 |
| C(2) | 0.0256 | 0.0010 |
| A(1,1) | 0.2083** | 0.0002 |
| A(1,2) | 0.0276** | 0.0028 |
| A(2,1) | 0.0184** | 0.0005 |
| A(2,2) | -0.0249*** | 0.0003 |
| B(1,1) | -0.0152 | 0.0023 |
| B(1,2) | -0.0013*** | 0.0001 |
| B(2,1) | -0.1029*** | 0.0001 |

| | | |
|---|---|---|
| B(2,2) | -0.1044 | 0.3573 |
| D(1) | 0.5472*** | 0.0001 |
| D(2) | -0.1087*** | 0.0001 |
| F(2,1) | 0.1654*** | 0.0001 |
| Log Likelihood: 4952.891 | | |
| | Tunisia | |
| Variable | Coefficients | Standard Error |
| Mean(Frvol) | -0.0985** | 0.0005 |
| Mean(Oilprvol) | 0.1304 | 0.2834 |
| C(1) | 0.2600*** | 0.00001 |
| C(2) | 0.0017 | 0.8723 |
| A(1,1) | 0.1809*** | 0.0001 |
| A(1,2) | 0.1005 | 0.2784 |
| A(2,1) | -0.1093** | 0.0055 |
| A(2,2) | 0.0167** | 0.0053 |
| B(1,1) | 0.0226** | 0.0052 |
| B(1,2) | 0.0143*** | 0.0003 |
| B(2,1) | 0.0517*** | 0.0001 |
| B(2,2) | 0.0103 | 0.3824 |
| D(1) | -0.1725*** | 0.0001 |
| D(2) | 0.1309** | 0.0058 |
| F(2,1) | 0.1793** | 0.0052 |
| Log Likelihood: 2713.289 | | |

The quantile results reveal the none significance of currency adjustments of oil-exporting economies in determining crude oil prices in most quantiles. Significance is only found in the 70$^{th}$ and 90$^{th}$ percentiles, and this significance is found to be negative. This implies that crude oil prices are influenced by other global factors other than the currencies of oil-exporting countries. Factors such as supply and demand dynamics and the quotas of oil-supply organizations such as OPEC have broader effects on the set prices of crude oil. Other geopolitical events, such as the Russian–Ukraine war and economic conditions, may also account for the weak impact of currency adjustments on oil prices. The few times where currency volatility impacts crude oil volatility, the study revealed that increased fluctuations in currency markets are linked to lower adjustments in crude oil prices.

Crude oil price fluctuations were found to be significant predictors of the volatility of local currencies in oil-exporting economies. The significance found was also of an inverse nature, indicating that greater fluctuations in crude oil market are associated with lower fluctuations in currency market. This indeed validates previous research findings that volatility in oil prices has a direct influence on revenue and foreign exchange earnings. Higher oil prices impact the trade balance, through increased export income, whereas decreasing prices cause currency depreciation. Specifically, increased oil prices for oil-exporting countries increase their demand for assets denominated in local currency, which increases the countries' exchange rate. This opens a conduit for volatility spillover. In addition to making the domestic economy more vulnerable to external shocks, reliance on oil exports also causes instability in government revenue, the execution of fiscal policy, and a decline in general economic stability. Many oil-producing nations rely substantially on oil exports as a major source of revenue. When crude oil prices decline, the revenue generated from oil exports decreases. This reduction in income can lead to trade imbalances, reduced foreign exchange reserves, and fiscal challenges, which, in turn, can contribute to currency depreciation. A decrease in oil costs can lead to deteriorating terms of trade for oil-producing countries. This means that the value of their exports (oil) relative to their imports decreases. This can affect financial assets' trade dynamics in the international currency market, putting downward pressure on the currency's value. The negative impact of lower oil volatility on the balance of payments can affect the currency's exchange rate, as a decrease in oil export earnings can lead to current account deficits. Deficits could necessitate borrowing or resort to foreign exchange reserves weakening currency value. Oil-producing countries with foreign external debts taken during periods of high oil prices may find it challenging to service these debts in periods of less volatility, causing currency volatility to change adversely by a greater magnitude from credit rating downgrades and currency depreciation. Reduced crude oil profits may cause a decrease in investor confidence regarding the economic future of oil-producing countries, leading to capital flight as investors withdraw their funds, further weakening the currency.

Oil-exporting countries experienced a comparable spillover from oil markets to currency markets. Additional clarifications indicate that oil-producing nations heavily depend on oil exports, which are influenced by alterations in crude oil prices, as evidenced by the research of Chowdhury & Garg (2022). Higher prices in crude oil trade arrangements can result in higher export revenue, strengthening respective currencies, whereas lower prices may result in currency devaluation. During times of low oil prices, the central banks of these countries adjust their monetary policies by lowering interest rates or becoming involved in currency markets to maintain currency stability. An optimistic investor outlook on increasing oil prices could increase confidence in the currencies of oil-exporting nations. Increased volatility in crude oil markets often indicates greater perceived risk in global markets, leading investors to look for more secure assets. Variations in crude oil costs can also impact the trade balances of oil-exporting countries, potentially resulting in trade surpluses, boosting the local currency, and reducing market volatility. When market volatility spikes, investors may move their investments from currencies to crude oil markets as safe-haven assets, causing less volatility in crude oil markets. In other cases, when a currency depreciates, it can increase the purchasing power of countries using that currency, which may lead to increased demand for commodities such as crude oil. This increased demand can stabilize or even decrease volatility in crude oil markets.

Oil exporting countries that are heavily reliant on oil exports might face increased vulnerability due to price volatility. Oil-producing countries rely largely on oil export income to finance US dollar-denominated economies. The volatility of oil prices has a positive influence on revenue and foreign exchange earnings. Changes in oil prices can have an impact on the trade balance, with higher prices resulting in greater export income and currency strength, whereas decreasing prices cause currency depreciation. Specifically, increased oil prices for oil-exporting countries increase their demand for assets nominated in local currency, which increases the country’s exchange rate. This opens a conduit for volatility spillover. The dependence on oil exports also exposes the domestic economy to external shocks, causing volatility in government income, fiscal policies, and general economic stability. The overall state of the world economy, which affects currency markets, central banking, and policymakers' responses to volatility in the oil price, is a reflection of the variabilities in oil prices.

## 6. Conclusion

Attempt was made by researchers to empirically examine the spillover of volatility between the foreign exchange market and the crude oil market in oil-producing countries. These countries include Nigeria, Canada, Australia, Argentina, Saudi Arabia, UAE, Malaysia, Kuwait, China, and Tunisia. The research findings indicate that volatility does not persist in the currency market of oil-exporting nations. Currency movements have cascading effects that reverberate through various aspects of the oil sector, affecting production costs, investment decisions, trade dynamics, and ultimately, the supply and demand balance that influences petroleum prices. The negative impact of currency volatilitis of oil-producing nations on crude oil price adjustments underscores the multifaceted nature of the global energy scenery. The interactions of currency markets and energy markets are highlighted by the inverse impact of foreign exchange variability on crude oil price fluctuations in oil exporting economies. Currency instability can add more unpredictability to the already intricate elements affecting crude oil prices, impacting the balance between supply and demand and ultimately impacting the overall global economy. Ultimately, fluctuations in crude oil prices have significant policy upshots for governments, industries, and economies. Policymakers should find a medium between addressing immediate price shocks and implementing strategies to improve energy security, and economic stability. Effective policy development should consider the interdependences among energy markets, financial systems, and broader economic dynamics. The study also revealed significant spillover effects of fluctuations from currency trade arrangements to oil markets and vice versa across oil importing and oil exporting systems. A negative spillover effect was observed from the currency market to the crude oil market.

The study identified an inverse spillover from petroleum market to currency market in countries of oil–exporting region. The occurrence of volatility was found to be asymmetric in the currency markets of all oil-producing countries. Asymmetric effects in oil-producing countries revealed that negative shocks to one asset tend to have a stronger effect on the fluctuations of other assets in the system than favorable shocks of the same size do. International cooperation is essential due to the worldwide scope of energy markets. Nations can collaborate to address price fluctuations by sharing information, coordinating policy actions, and working together to stabilize the cost of oil. Research interests could arise from the limitations of this study by focusing on volatility spillover stemming from indirect transmission factors that could influence the transmission from oil trade arrangements to exchange rate markets or vice versa. There can also be a crude oil exchange rate volatility spillover study focusing on nonoil sectors, such as tourism, technology and manufacturing can enhance economic resilience of countries that both import and export crude oil to understand the dynamics of spillover in such countries.

## Ethical Considerations

With regards to the materials utilized and data collection, this study complied with ethical standards.

## Conflict of Interest

The authors hereby affirm that this work contains no conflicts of interest of any kind.

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