DYNAMICS OF CRUDE OIL PRICE, PRODUCTION AND EXPORTATION IN NIGERIA (2006 – 2024): A TIME-SERIES ANALYSIS

Ibeh, G. C. [1*], Ajaraogu, J. C. [1] and Onyenekwe, C. E. [2]

[1]*Department of Mathematics/Statistics, Federal Polytechnic Nekede, Owerri, Imo State, Nigeria*
[2]*Department of Statistics, Nnamdi Azikiwe University, Awka, Anambra State, Nigeria*
[*]*email: gibeh@fpno.edu.ng, +2348065955372*

ABSTRACT

This study examines the dynamic relationships between crude oil prices, domestic production, and exportation in Nigeria from January 2006 to December 2024 using advanced time-series methodologies. Monthly data sourced from the Central Bank of Nigeria was analyzed, encompassing crude oil prices (USD/barrel), production, and export volumes (million barrels/day). A missing data point for April 2023 was addressed using linear interpolation. Seasonal-Trend Decomposition using Loess (STL) revealed underlying trend structures, though statistical tests confirmed no significant seasonal effects across the variables. Stationarity was established through differencing, and a Vector Autoregressive (VAR) model with Granger causality testing found no significant lagged influence of price fluctuations on production. Volatility analysis using a Dynamic Conditional Correlation GARCH (DCC-GARCH) model identified strong persistence in crude oil price and production volatility but no short-term volatility spillovers. Comparative analysis across pre- and post-2014 and COVID-19 periods highlighted structural shifts in volatility patterns and a decline in output and export volumes. The study concludes with policy recommendations aimed at improving resilience in Nigeria's oil sector amidst external market shocks.

Keywords: Crude Oil Price, Volatility, Time Series Analysis, DCC-GARCH, Production, Exportation, Nigeria

1.0 Introduction

1.1 Background to the Study

Crude oil plays a central role in Nigeria's economy, serving as the primary source of government revenue and foreign exchange earnings. Since the discovery of crude oil in commercial quantities in Oloibiri, Bayelsa State in 1956, Nigeria has remained a major player in the global oil market. According to Central Bank of Nigeria (CBN) (2022), the petroleum sector accounts for over 85% of government revenue and more than 90% of the country's export earnings, making Nigeria highly dependent on oil fluctuations for economic stability. However, the volatility of crude oil prices has posed a persistent challenge, affecting production levels, export performance and overall economic growth.

Crude oil price movements are shaped by a combination of global and domestic factors, including demand–supply imbalances, geopolitical tensions, production quotas imposed by the Organization of the Petroleum Exporting Countries (OPEC), and speculative activities in international markets. Nigeria has experienced several episodes of pronounced oil price volatility, notably during the 2008 global financial crisis, the 2014 oil price collapse, and the 2020 COVID-19 pandemic-induced downturn. These episodes exerted significant pressure on

ISSN NUMBER: 1116-249X

crude oil production and exportation, with attendant consequences for government revenue and economic planning. In addition, domestic oil production has faced structural constraints in recent years, arising from aging oil fields, divestments by international oil companies, security challenges, and production limits imposed under OPEC agreements. Limited domestic refining capacity has further reinforced Nigeria's dependence on crude oil exports, while refined petroleum products are largely imported at considerable cost.

Despite the strategic importance of crude oil to Nigeria's economy, the country remains highly exposed to oil price fluctuations. Episodes such as the 2014 price collapse and the 2020 pandemic-induced downturn highlight how volatility in international oil markets can disrupt production planning, export performance, and fiscal stability. While several studies have examined oil price movements and related macroeconomic outcomes, empirical evidence on how oil price volatility transmits simultaneously to crude oil production and exportation in Nigeria remains limited, particularly across different economic regimes. This gap motivates the present study.

Specifically, the study analyzes seasonal patterns and trend movements in crude oil prices, domestic production, and exportation, evaluates lagged interdependencies, and assesses volatility transmission effects. A regime-based comparison is also conducted to determine whether oil sector dynamics differ between periods of relative stability and heightened volatility. Based on these objectives, the following hypotheses are tested:

H_{01}: There are no significant seasonal patterns in crude oil prices, production and exportation

H_{02}: There is no lagged relationship between crude oil price fluctuations and production/exportations dynamics

H_{03}: Crude oil price volatility does not significantly influence production and exportation levels

H_{04}: There is no significant difference in the behaviour of crude oil prices, production and exportation between stable periods and high-volatility periods

H_{05}: Changes in crude oil production significantly influence exportation trends under different price regimes.

2.0 Literature Review

2.1 Theoretical Framework

This study is anchored on relevant economic and econometric theories that provide insight into the interaction between crude oil price movements, production behaviour, and export performance in oil-dependent economies such as Nigeria.

2.1.1 Resource Curse Hypothesis

The resource curse theory provides an overarching context for interpreting the long-term economic instability often observed in oil-dependent economies like Nigeria. This theory supports the examination of oil price shocks and their effect on production and exportation behaviors, particularly in high-volatility periods.

2.1.2 Dutch Disease Theory

This theory offers insight into how oil revenue booms affect exchange rates and the broader economy by discouraging diversification and distorting trade patterns. It is particularly relevant for evaluating exportation patterns and regime-based production dynamics, especially in relation to price volatility.

Together, these theories provide a foundation for analyzing how oil price volatility interacts with production and exportation dynamics, particularly across periods of structural change

2.2 Empirical Review

Empirical studies on oil price dynamics have largely focused on volatility effects and macroeconomic transmission mechanisms. Chinanuife et al. (2021) applied the EGARCH model alongside cointegration techniques to examine quarterly data on oil prices and inflation volatility. The study revealed that negative oil price shocks significantly drive inflation volatility. However, seasonality in crude oil production and exportation patterns remains underexplored. Faruk (2020) examined the relationship between crude oil prices, domestic production, and exchange rates in Nigeria using ARDL and Granger causality techniques. The findings revealed a long-run relationship between oil prices and domestic production. Similarly, Usoro and Ekong (2022) identified bilateral causality between oil prices and production, suggesting feedback mechanisms that justify the use of lag-based multivariate models. Other studies have emphasized the broader macroeconomic implications of oil price volatility. Abdulkareem and Abdulhakeem (2016) identified oil price volatility as a major source of macroeconomic instability, while Ige and Obi (2018) confirmed its significant effects on exchange rates and government revenues. Kuhe et al. (2024) documented volatility clustering and asymmetric shocks in oil price returns using GARCH-type models. Adi et al. (2022) further demonstrated volatility spillovers from international oil prices to the USD/Naira exchange rate using a VAR-AGARCH framework, highlighting the transmission of external oil market shocks to Nigeria's domestic economy. Regime-specific analyses have also gained attention in recent literature. Obaka et al. (2022) showed that the impact of oil price volatility on economic performance varies across different historical periods, while Ayodele et al. (2024) demonstrated that investment outcomes in Nigeria's marginal oil fields differ substantially under alternative oil price recovery scenarios. These findings underscore the relevance of comparing oil sector behavior across stable and high-volatility regimes. Studies focusing directly on crude oil exportation remain limited. Yunusa (2020) examined the effect of exchange rate volatility on crude oil exports, implying the importance of considering joint effects of oil prices and production capacity. Sami and Taiwo (2023) reviewed the contribution of crude oil to economic growth but did not empirically model the transmission from production to exportation.

Collectively, these studies demonstrate the relevance of volatility modeling and lag-based analysis in understanding oil market behavior. Nonetheless, differences in methodological focus leave important aspects of seasonality, dynamic interdependence, and regime-specific effects insufficiently explored.

Overall, existing studies highlight the importance of volatility modeling and lag-based analysis in understanding oil market dynamics. However, differences in methodological focus leave important aspects of seasonality, dynamic interdependence, and regime-specific behavior

ISSN NUMBER: 1116-249X

insufficiently explored. In particular, few studies integrate seasonal decomposition, multivariate causality analysis, and volatility transmission modeling to examine the joint effects of oil price volatility on crude oil production and exportation in Nigeria. This study addresses this gap by combining STL decomposition, VAR modeling, and DCC-GARCH techniques to provide a comprehensive analysis of oil sector dynamics across different economic regimes.

3.0 METHODOLOGY

3.1 Research Design

In this study, a quantitative time-series econometric approach is adopted to explore the interactions existing among crude oil price, domestic crude oil production and crude oil exportation in Nigeria. The analysis is based on monthly observations from January, 2006 to December, 2024. To adequately capture both short-run dynamics and long-run volatility behaviour, the methodological framework combines seasonal decomposition, stationarity testing, multivariate time-series modelling, causality analysis, and volatility transmission modelling.

3.2 Data Description and Source

The data used in this study are secondary monthly observations sourced from the Central Bank of Nigeria (CBN) online Statistical Bulletin. In the dataset, crude oil price is measured in United States dollars per barrel (USD/bbl), while domestic crude oil production and exportation are measured in million barrels per day (mb/d).

3.3 Treatment of Missing Observation

Since the missing value occurs once in the series, a linear interpolation method was applied to obtain an estimate for the missing observation. Linear interpolation is given as:

$$Y_t = \frac{Y_{t-1} + Y_{t+1}}{2} \qquad (1)$$

where Y_t represents the missing observation, while Y_{t-1} and Y_{t+1} are the observations recorded immediately before and after the missing period. This method relies on the assumption that the series follows a relatively smooth pattern between consecutive observations. A brief visual and descriptive assessment was also conducted to confirm that the interpolation did not materially alter the data pattern.

3.4 Seasonal-Trend Decomposition using Loess (STL)

STL is used to investigate the underlying trend and potential seasonal patterns in the time series data. Using STL, each time series was decomposed into trend, seasonal and residual components. The additive STL decomposition is represented as:

$$Y_t = T_t + S_t + R_t \qquad (2)$$

where the observed series (Y_t) is expressed as the sum of trend (T_t), seasonal (S_t) and residual (R_t) components. The STL method employs locally weighted regression to estimate the individual components. This method is especially useful for economic time series that experience changes in structure over time. After decomposition, a formal statistical test was conducted to check the significance of the seasonal component. Specifically, the Kruskal-Wallis rank-based test was applied to evaluate whether monthly observations differ significantly. The null hypothesis for this test assumed that no seasonal variation exists.

3.5 Stationarity Testing (Augmented Dickey-Fuller Test)

The Augmented Dickey-Fuller test was applied to assess the stationarity of the series. The test is implemented using the following regression equation:

ISSN NUMBER: 1116-249X

$$\Delta Y_t = \alpha + \beta t + \gamma Y_{t-1} + \sum_{i=1}^{p} \delta_i \Delta Y_{t-i} + \varepsilon_t \qquad (3)$$

where ΔY_t denotes the first-differenced series, t is a time series trend, p represents the lag order, and ε_t is the error term. Under the null hypothesis, the series is non-stationary, while the alternative hypothesis is that the series is stationary. The null hypothesis is rejected if the ADF test statistic is more negative than the critical value. The test proceeded from level form to differenced series until stationarity was achieved. This procedure ensured that all variables included in subsequent analyses met the stationarity requirements of time-series modeling.

3.6 Vector Autoregressive (VAR) Model Specification

The dynamic relationships among the variables were analyzed using a VAR model. In VAR modeling, all variables are treated as endogenous variables and are expressed as functions of their own past values and the past values of other variables. Generally, the VAR(p) model is specified as:

$$\mathbf{Y_t} = \mathbf{c} + \sum_{\mathbf{i=1}}^{\mathbf{p}} \mathbf{A_i Y_{t-i}} + \boldsymbol{\varepsilon}_\mathbf{t} \qquad (4)$$

where $\mathbf{Y_t}$ denotes the vector of endogenous variables, $\mathbf{c}$ is a vector of intercepts, $\mathbf{A_i}$ are coefficient matrices, p represents the lag order, and $\boldsymbol{\varepsilon}_\mathbf{t}$ is the error vector.

Information criteria viz Akaike, Schwarz Bayesian and Hannan-Quinn were adopted to select the optimal lag length. The VAR model was tested for stability to confirm that the roots satisfy the unit circle condition. The estimated VAR model formed the basis for subsequent causality and dynamic analysis. However, due to perfect collinearity between crude oil production and exportation, the VAR analysis was restricted to crude oil price and production to avoid multicollinearity bias.

3.7 Granger Causality Test

The Granger causality test was employed to determine the directional causal relationships among the variables. The test is formally represented by the following equations:

$$Y_t = \alpha_0 + \sum_{i=1}^{p} \alpha_i Y_{t-i} + \sum_{i=1}^{p} \beta_i X_{t-i} + \varepsilon_t \qquad (5)$$

$$X_t = \gamma_0 + \sum_{i=1}^{p} \gamma_i X_{t-i} + \sum_{i=1}^{p} \delta_i Y_{t-i} + u_t \qquad (6)$$

where X_t and Y_t denote any two variables under consideration, p is the lag order, and ε_t and u_t are error terms.

The null hypothesis states that past values of X_t do not Granger-cause Y_t. The null hypothesis is rejected when the lagged values of X_t are jointly significant. The joint significance of the lagged values was tested using an F-statistic. The rejection of the null hypothesis implies that there is Granger causality.

3.8 Volatility Modeling Using Dynamic Conditional Correlation Generalized Autoregressive Conditional Heteroskedasticity (DCC-GARCH)

A DCC-GARCH model was used to capture volatility transmission and time-varying correlations among the variables. Volatility persistence in economic time series motivates the application of GARCH models. The volatility of each series was modeled using a GARCH (1,1) specification.

ISSN NUMBER: 1116-249X

$$r_t = \mu + h_t^{1/2} z_t \quad (7)$$

$$h_t = w + \alpha\varepsilon_{t-1}^2 + \beta h_{t-1} \quad (8)$$

where h_t is the conditional variance and z_t denotes the standardized residual.

The GARCH (1,1) specification was adopted due to its parsimony and its effectiveness in capturing volatility persistence in economic and commodity price series.

The standardized residuals obtained from the univariate GARCH models formed the basis for estimating dynamic conditional correlation (DCC). Within the DCC model, the conditional covariance matrix is specified as:

$$H_t = D_t R_t D_t \quad (9)$$

where D_t is a diagonal matrix of conditional standard deviations and R_t denotes the conditional correlation matrix.

The dynamics of conditional correlations are modeled using the following DCC process:

$$Q_t = (1 - a - b)\bar{Q} + a z_{t-1} z'_{t-1} + b Q_{t-1} \quad (10)$$

The coefficients a and b reflect short-run shock effects and long-run correlation persistence. The DCC-GARCH model provides insight into time-varying volatility and correlation behaviour. Model adequacy was further assessed using information criteria.

3.9 Regime-Based Comparative Analysis

To account for potential structural differences as a result of different economic conditions, a regime-based comparative analysis was conducted. The classification of regimes was guided by notable structural and institutional changes affecting the oil industry. Regime comparisons were supported using descriptive statistics, variance equality tests, and regime-specific volatility models. Key regime-defining events include periods of global oil price volatility, domestic production challenges and policy reforms. The models were estimated separately for each regime to facilitate comparative analysis. Comparative assessment was made based on differences in estimated coefficients, causality patterns and volatility behaviour across regimes. The comparison provides insights into how variable interactions change across economic conditions. The regime-based results provide additional context for interpreting the main findings.

3.10 Diagnostic and Robustness Checks

The estimated models were subjected to diagnostic checks to ensure their adequacy, consistency and reliability. Serial correlation diagnostics were also conducted to ensure that model residuals are not autocorrelated. Residual normality checks were also conducted as part of the diagnostics analysis. These diagnostics checks help ensure that the empirical results are not driven by model misspecification. Additional diagnostic tests, including variance equality and parameter stability tests, were applied where appropriate.

4.0 Results and Discussion

4.1 Results

4.1.1 Data overview and Preprocessing

To analyze the long-term trends and seasonal variations in crude oil prices, production and exportation, it is essential to first preprocess the dataset. This involves examining the structure of the data, handling missing values, and ensuring that the date format is correctly set. Since the

ISSN NUMBER: 1116-249X

dataset contains separate year and month columns, a new date column was created to represent the full date in year-month-day format.

Time-Series Plots for Crude Oil Price, Production, and Exportation

To visualize the historical patterns of crude oil price, domestic production, and exportation, the following time-series plots are generated:

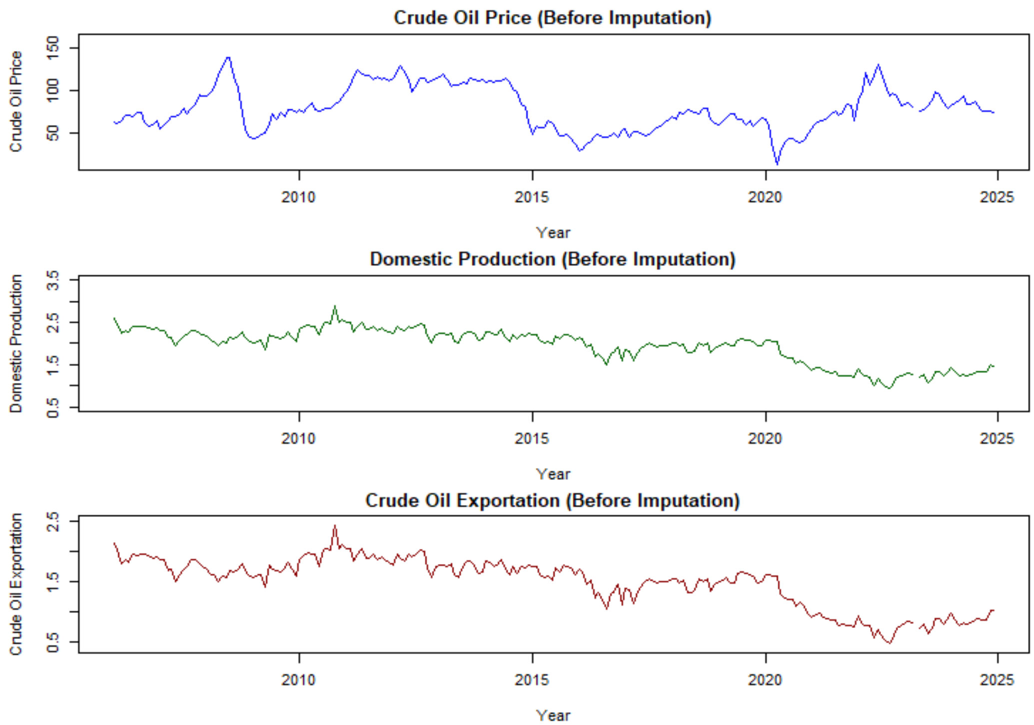

Figure 1: Time Series Plots of Crude Oil Price, Domestic Production, and Exportation with Missing Data (Jan 2006 – Dec 2024)

Crude Oil Price Over Time

The time series plot of crude oil prices from January 2006 to December 2024 reveals substantial fluctuations, indicative of the volatility inherent in the global oil market. Periods of pronounced price escalation are observed around 2008–2009 and 2021–2022, whereas a significant price collapse is evident around 2020, coinciding with the onset of the COVID-19 pandemic and associated economic disruptions. These price dynamics likely reflect the influence of geopolitical tensions, supply chain interruptions, shifts in global demand, and macroeconomic conditions. Overall, the observed trends provide critical insight into the responsiveness of crude oil prices to external shocks and broader market forces.

Domestic Crude Oil Production Over Time

The domestic crude oil production series demonstrates relative stability across the observed period, with only moderate fluctuations. A gradual decline becomes apparent following 2015, suggesting potential impacts of evolving market conditions, regulatory interventions, or operational challenges within the sector. The slight resurgence in production towards the end of the study period may point to adjustments in market strategy or technological improvements.

These trends underscore the complex interplay between production capacity, policy frameworks, and international market pressures.

Crude Oil Exportation Over Time

Crude oil exportation exhibits a broadly similar trend to production, albeit with a more pronounced decline following 2015. This divergence suggests that while production remained relatively steady, a greater proportion of crude oil may have been redirected towards domestic consumption or strategic reserves. Additionally, export volumes appear sensitive to shifts in international trade policies, demand patterns, and potential trade restrictions. The exportation dynamics presented in the plot thus reflect both internal market adaptations and external global economic developments.

4.1.2 Missing Data Imputation

Imputation Methodology

To address the missing data point for April 2023 in the crude oil price, domestic production, and exportation time series, linear interpolation was applied. This technique estimates the missing value by computing the average of the immediately preceding (March 2023) and following (May 2023) observations. Linear interpolation was selected due to its simplicity, transparency, and suitability for handling isolated missing values where temporal continuity and smooth trends are assumed.

Impact Assessment

To assess the effect of the interpolation on the dataset's integrity, a visual comparison between the original (containing the missing data) and the imputed time series was conducted. Furthermore, we evaluated the magnitude of the interpolation's impact by calculating both the absolute and relative differences between the interpolated values and their neighboring monthly observations.

Table 1: Interpolated Value for April 2023 and Corresponding Monthly Changes

Indicator	March	April (interpolated)	May	Abs. Change	% Difference from Average
Crude Oil Price (USD)	81.10	79.01	76.91	0.60	0.76
Dom Crude Oil Production(mb/d)	1.27	1.23	1.19	0.04	3.25
Crude Oil Exportation(mb/d)	0.82	0.78	0.74	0.04	5.13

ISSN NUMBER: 1116-249X

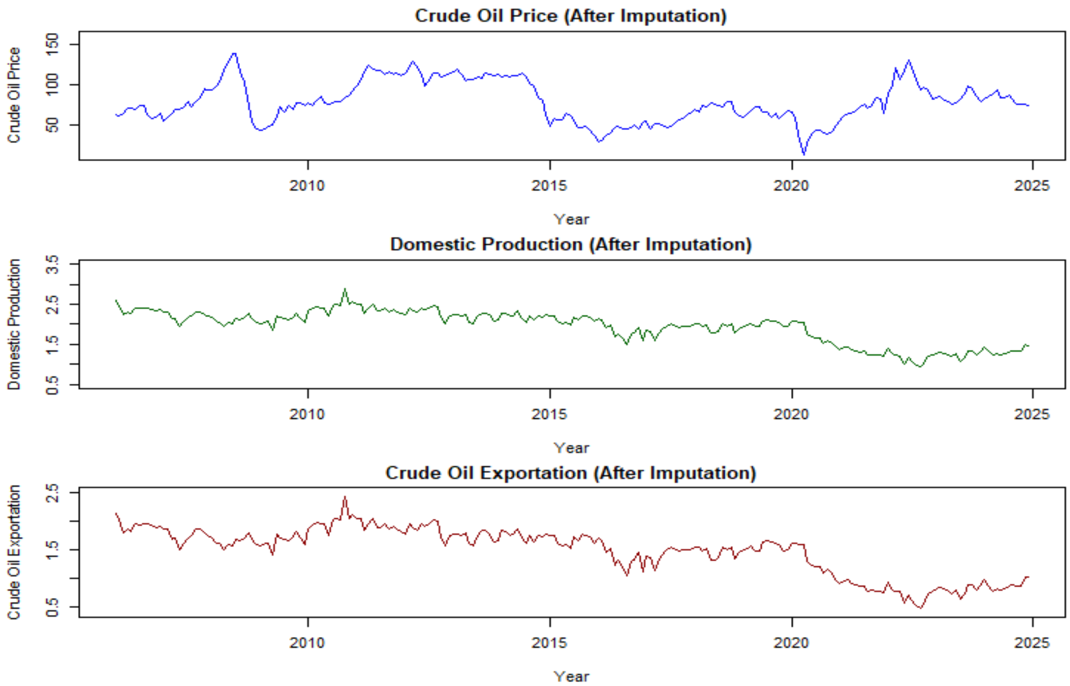

Figure 2: Time Series Plots of Crude Oil Price, Domestic Production, and Exportation After Linear Interpolation (Jan 2006 – Dec 2024)

4.1.3 Seasonal-Trend Decomposition using Loess (STL)

To further analyze long-term trends and seasonal variations, STL decomposition was performed on crude oil price, production, and exportation data. This decomposition separates each time series into trend, seasonal, and remainder (residual) components, providing a visual and analytical understanding underlying periodicities.

Figures 3, 4 and 5 display the STL decomposition plots for crude oil prices, production, and exportation. Each time series demonstrates distinguishable seasonal patterns across months, with trends revealing periods of stability, volatility, and structural shifts, notably around the 2014 oil price collapse and the 2020 COVID-19 pandemic.

ISSN NUMBER: 1116-249X

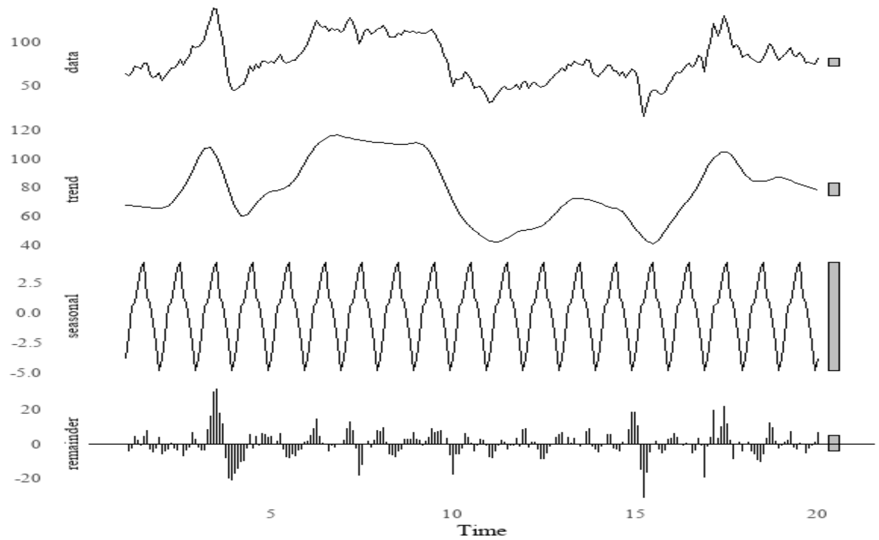

Figure 3: Crude Oil Price Decomposition

- **Trend Component:** The trend lines in the decomposition plots highlight the overall direction of crude oil price, production, and exportation. The results confirm periods of sustained growth and decline, reinforcing the findings from the time-series plots.
- **Seasonal Component:** The seasonal patterns reveal recurring fluctuations at regular intervals. For crude oil price, we observe consistent peaks and troughs that may be linked to seasonal demand changes, such as increased heating oil consumption in winter.
- **Residual Component:** The residuals represent short-term irregularities that are not explained by trend or seasonality. These fluctuations may be due to unexpected geopolitical events, economic crises, or sudden supply chain disruptions.

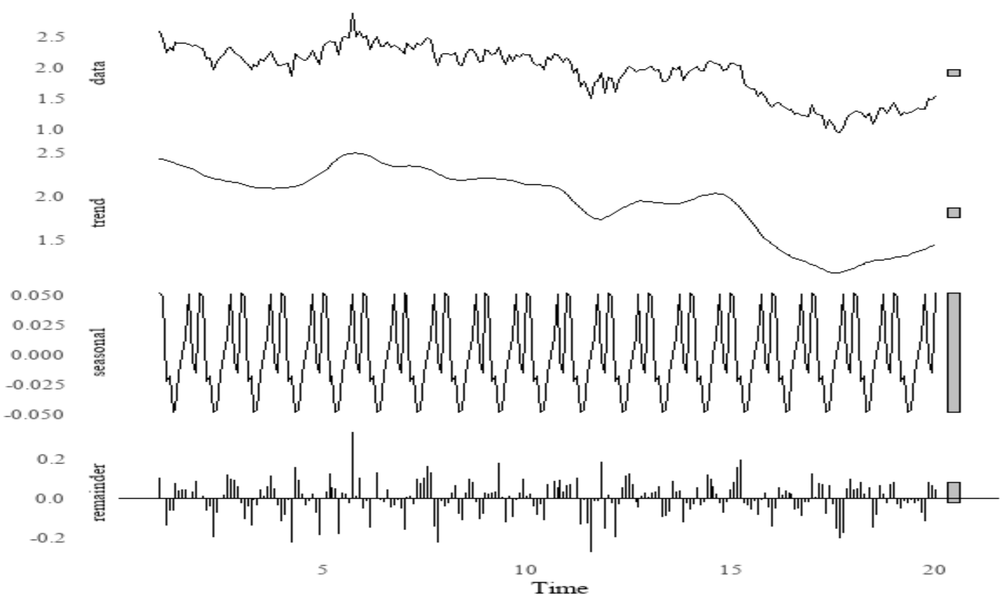

Figure 4: Crude Oil Production Decomposition

ISSN NUMBER: 1116-249X

Similar patterns of seasonality and trend are observed in crude oil production, influenced by global demand cycles, maintenance schedules, or policy-driven production adjustments.

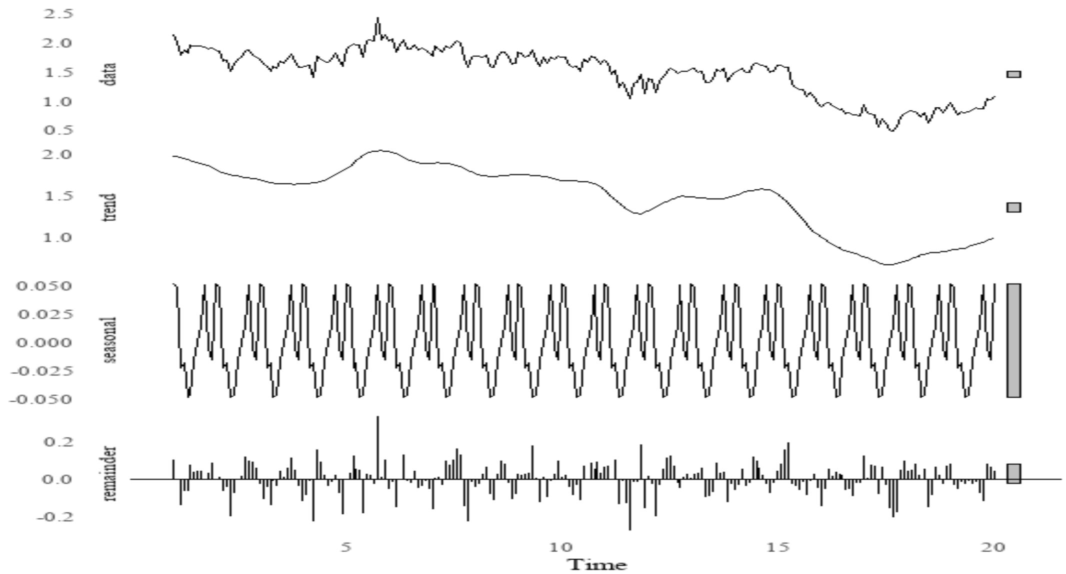

Figure 5: Crude Oil Exportation Decomposition

Crude oil exportation also follows seasonal variations, possibly driven by market agreements, international trade restrictions, or economic shifts in importing countries.

To assess seasonal variation in Nigeria's crude oil indicators, the Kruskal-Wallis test was applied to monthly groupings of price, production, and exportation data. Contrary to visual indications, statistical results revealed that no statistically significant seasonal pattern was detected ($p > 0.98$ in all cases). These findings suggest that oil sector behavior in Nigeria is not seasonally patterned, possibly due to external market dependencies, global pricing mechanisms, or production stability driven by fixed quotas and long-term contracts. Accordingly, the null hypothesis (H_0) could not be rejected.

Notably, crude oil production and exportation exhibit nearly perfect linear correlation ($r = 1.00$), indicating a strong dependency structure. This relationship results in identical non-significant Kruskal-Wallis statistics for the two variables, a consequence of rank-based testing applied to highly collinear series.

4.1.4 Lag Analysis and Causality

Temporal Relationships and Lag Effects:

This section investigates whether fluctuations in crude oil prices have any lagged influence on Nigeria's crude oil production. Specifically, the aim was to test the hypothesis:

H_0: There is no lagged relationship between crude oil price fluctuations and production dynamics in Nigeria.

To achieve this, the study employed Vector Autoregressive (VAR) modeling combined with Granger causality tests, which are suitable techniques for analyzing dynamic interactions between time series variables.

ISSN NUMBER: 1116-249X

Monthly data on crude oil price and production were used. Prior to modeling, the time series were subjected to the Augmented Dickey-Fuller (ADF) test to ensure stationarity—a key assumption for VAR modeling and Granger causality testing.

- The original series were found to be non-stationary; hence they were differenced.
- The null hypothesis of a unit root (non-stationarity) was rejected after differencing.

Table 2: Stationarity Tests Results before and After Diffferencing

Series	Before Differencing		After Differencing	
	ADF statistic	p-value	ADF statistic	p-value
Crude Oil Price (USD)	-2.480	0.3743	-5.8843	< 0.01
Dom Crude Oil Production(mb/d)	-1.9204	0.6094	-6.2185	< 0.01
Crude Oil Exportation(mb/d)	-1.9204	0.6094	-6.2185	< 0.01

During preliminary analysis, the crude oil exportation variable was found to be perfectly correlated with domestic crude oil production (r =1.0), suggesting redundancy. To avoid multicollinearity issues in the VAR model, the exportation variable was excluded from further modeling, retaining only crude oil price and production for VAR estimation.

VAR Model Specification

The optimal lag length for the Vector Autoregressive (VAR) model was selected using four commonly applied information criteria: the Akaike Information Criterion (AIC), Hannan–Quinn Criterion (HQ), Schwarz Criterion (SC), and Final Prediction Error (FPE). The AIC and FPE both suggested an optimal lag length of 2, while the HQ and SC favored a more parsimonious lag of 1. Given the study's focus on forecasting and dynamic interactions, a VAR (2) model was chosen as it offered a better balance between model complexity and predictive power.

The VAR(2) model was estimated using the first-differenced crude oil price and production return series to ensure stationarity. The coefficients of the lagged crude oil price terms in the crude oil production equation were found to be statistically insignificant. This suggests that changes in crude oil prices do not have a strong lagged predictive effect on production levels, underscoring a weak dynamic linkage between the two variables in the short run.

ISSN NUMBER: 1116-249X

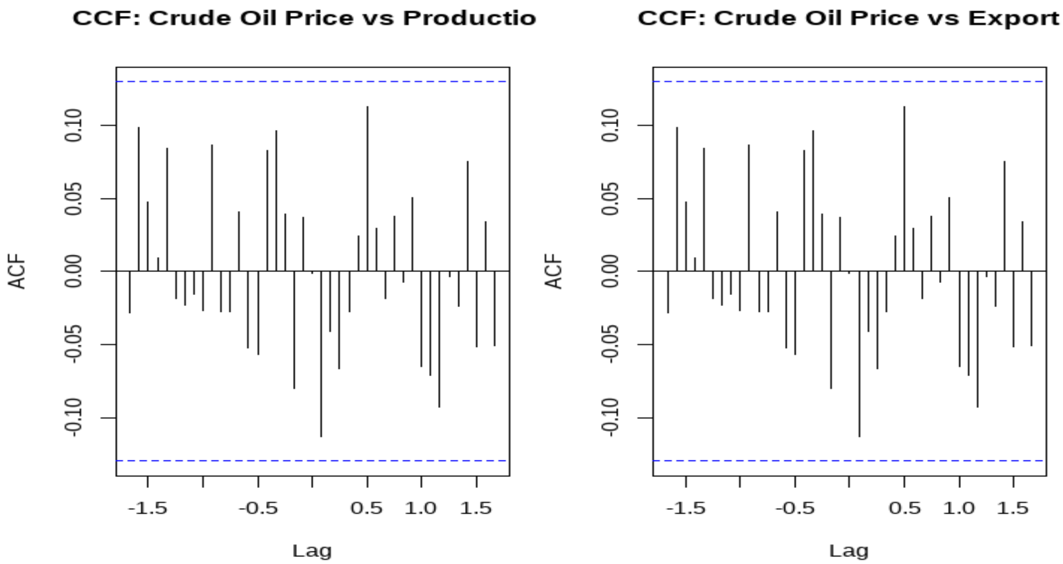

Figure 6: Cross-Correlation Function (CCF) Plots of Crude Oil Price with Domestic Production and Exportation

Cross-correlation functions (CCFs) were computed to explore potential lead-lag relationships between crude oil price and both domestic crude oil production and crude oil exportation. The resulting CCF plots showed that all correlation coefficients at various lags fell within the 95% confidence bands, indicating a lack of statistically significant correlations at any lag. This suggests no clear evidence of a temporal dependency based on visual inspection alone.

However, further formal testing using Granger causality analysis will be conducted to statistically validate or refute the existence of lagged relationships.

Granger Causality Test

A formal Granger causality test was conducted using the estimated VAR (2) model to determine whether crude oil price fluctuations significantly predict future values of production.

Results:

F-statistic = 0.80943   p-value = 0.4458

Since the p-value exceeds the conventional significance threshold of 0.05, the null hypothesis could not be rejected. Thus, there is no statistically significant lagged causal relationship from crude oil price to production in Nigeria. That is, past movements in oil prices do not Granger-cause changes in production levels.

4.1.5 Volatility Modeling and Transmission Analysis

Volatility Transmission Analysis using DCC-GARCH Model:

ISSN NUMBER: 1116-249X

To quantify the volatility transmission between crude oil prices and production levels, the Dynamic Conditional Correlation Generalized Autoregressive Conditional Heteroskedasticity (DCC-GARCH) model was employed. The exportation series was excluded due to its perfect correlation with production returns, which could induce multicollinearity in the model. This multivariate time series approach captures time-varying co-movements in volatilities, allowing us to assess whether shocks in crude oil price volatility significantly spill over to production volatility.

The model was specified as a DCC (1,1) with univariate GARCH (1,1) for each return series (crude oil price (Crude_ return) and crude oil domestic Production (Prod_return)).

The estimation results:

Model Fit and Information Criteria:

Number of observations: 228, Log-likelihood: 567.2683, AIC: 5.0725, BIC: 5.2380

Table 3: Univariate GARCH Parameters

Series	ω	α_1	β_1
Crude_Return	11.2764	0.4526 (***)	0.3635 (***)
Prod_Return	0.0031	0.1181 (*)	0.6315 (***)

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

These results confirm the presence of conditional heteroskedasticity in both series, justifying the use of GARCH-type modeling.

Table 4: DCC Parameters (Volatility Transmission)

Parameter	Estimate	Std error	z-value	p-value
α_1	0.0008	0.0220	0.0340	0.9730
β_1	0.9523	0.0525	18.1510	< 0.001

While β_1 is highly significant, indicating strong persistence in the dynamic correlation process, the α_1 is statistically insignificant (0.9730). This suggests that volatility shocks from crude oil prices do not cause immediate volatility changes in production returns. Thus, the results provide no sufficient evidence of short-term volatility transmission from crude oil prices to production. However, the significant β_1 value shows strong persistence in conditional correlations over time, indicating that while immediate shock transmission is weak, long-run co-movement may still exist.

4.1.6 Regime-Based Comparative Analysis

Pre- and Post-2014 Oil Price Regime

ISSN NUMBER: 1116-249X

A comparative analysis of Nigeria's crude oil market across the pre- and post-2014 periods reveals notable structural changes. The average crude oil price declined from $92 (pre-2014) to $68.8 (post-2014), with a mild reduction in volatility (SD: 23.6 vs. 21.3). In contrast, average production and exportation declined substantially, from 2.26 and 1.81 million barrels/day to 1.68 and 1.23 million barrels/day, respectively. Importantly, their standard deviations increased—indicating higher relative volatility in the post-2014 era.

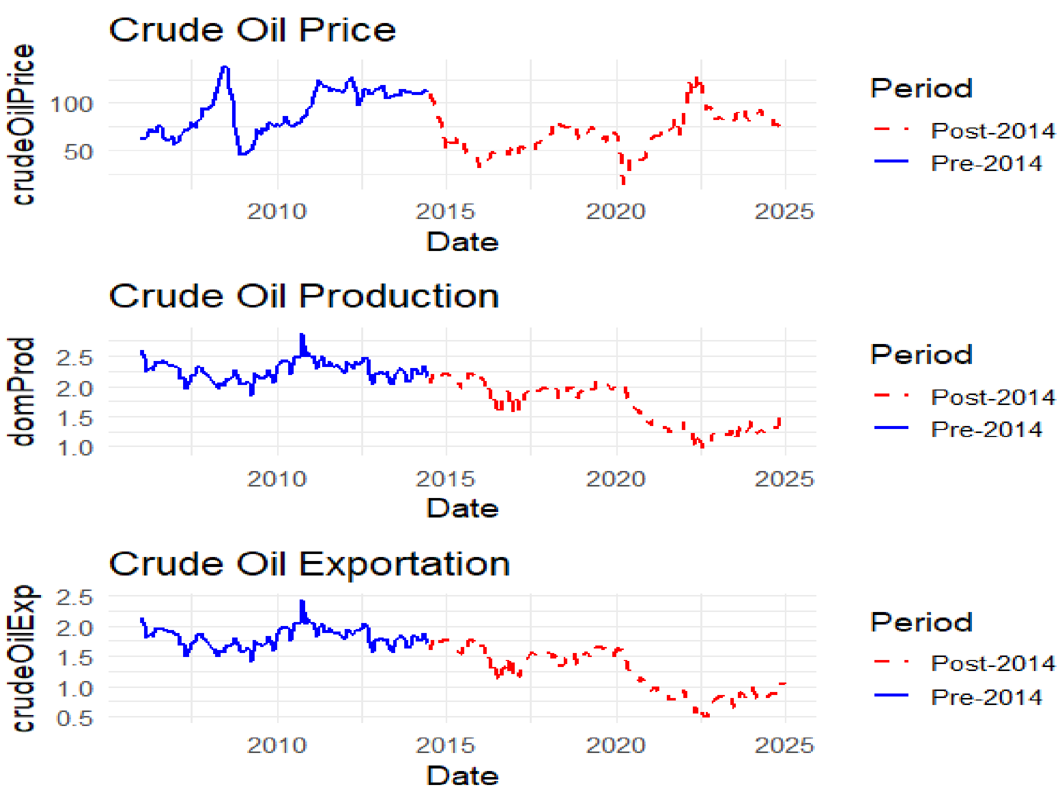

Figure 7: Crude Oil Price, Production, and Exportation in Nigeria — Pre- vs Post-2014 Periods

Crude Oil Price

The chart shows a noticeable shift in price dynamics between the pre-2014 and post-2014 periods.

- **Pre-2014**: Prices were relatively high and more stable, hovering consistently above $90/barrel, with only moderate fluctuations.
- **Post-2014**: A significant collapse is evident after mid-2014, with increased volatility. Prices became more erratic, with deep troughs (e.g., around 2020 due to COVID-19) and sharp recoveries. This indicates a more unstable price environment post-collapse.

Crude Oil Production

- **Pre-2014**: Production remained relatively high, fluctuating slightly around 2.2–2.5 million barrels/day.

- **Post-2014**: There's a consistent downward trend in production, particularly sharp from 2016 onwards. This may reflect the challenges of sustaining production in a more volatile and less profitable market.

Crude Oil Exportation

- **Pre-2014**: Exportation mirrored production levels, with relatively stable patterns above 1.5 million barrels/day.
- **Post-2014**: A downward shift is also observed in export volumes, with a notable decline beginning around 2016 and bottoming out during the COVID-19 period.

Levene's test was used to formally assess the equality of variances. The results indicated significant differences in return volatility for crude oil prices ($p = 0.0077$) and exportation ($p = 0.0061$), and marginal significance for production ($p = 0.0672$). These outcomes support the hypothesis of heightened volatility transmission and instability in crude oil exportation dynamics following the 2014 oil price collapse.

These findings highlight the critical need for more adaptive production and export policies in Nigeria's oil sector to buffer against price shocks and market instability.

GARCH (1,1) Model Analysis of Crude Oil Returns Pre- and Post-2014

To examine the volatility dynamics of crude oil prices across different time periods, GARCH (1,1) models were estimated separately for the pre-2014 and post-2014 samples. The results indicate a notable shift in the nature of crude oil return volatility between the two periods.

In the pre-2014 period, the model yielded a statistically insignificant mean return ($\mu = 0.0037$, $p = 0.497$), while the volatility parameters were highly persistent. The GARCH term ($\beta_1 = 0.6821$, $p = 0.0205$) and ARCH term ($\alpha_1 = 0.3169$, $p = 0.0101$) were both significant, with the sum $\alpha_1 + \beta_1 \approx 0.999$ suggesting near-unit root behavior in volatility. This indicates that shocks to crude oil returns during this period had long-lasting effects, reflecting a high degree of volatility clustering and persistence.

In contrast, the post-2014 period exhibited different volatility characteristics. While the mean return remained statistically insignificant ($\mu = 0.0057$, $p = 0.524$), the volatility dynamics showed a higher sensitivity to recent shocks. The ARCH term increased substantially ($\alpha_1 = 0.6409$, $p = 0.002$), whereas the GARCH term ($\beta_1 = 0.1293$, $p = 0.344$) was no longer statistically significant. The combined persistence measure ($\alpha_1 + \beta_1 = 0.7702$) was also much lower than in the pre-2014 period, indicating a regime shift toward more transitory volatility.

Diagnostic tests confirmed the adequacy of the fitted models in both periods. The Ljung-Box tests on squared standardized residuals and Autoregressive Conditional Heteroskedasticity Lagrange Multiplier (ARCH LM) tests did not indicate remaining autocorrelation or heteroskedasticity, validating the appropriateness of the GARCH (1,1) specification. Furthermore, the Nyblom stability test indicated parameter stability in the post-2014 model but marginal instability in the pre-2014 estimates, possibly reflecting structural shifts prior to 2014.

ISSN NUMBER: 1116-249X

Thus, the results suggest a significant change in the volatility structure of crude oil prices post-2014, characterized by reduced persistence but increased sensitivity to recent price shocks. This could reflect broader changes in the global oil market, such as increased market speculation, evolving geopolitical dynamics, and the rise of unconventional oil production methods.

4.1.7 Pre- and Post-COVID-19 Volatility

To evaluate the impact of the COVID-19 pandemic on Nigeria's crude oil sector, the dataset was segmented into Pre-COVID (before March 2020) and Post-COVID periods. Descriptive statistics reveal notable shifts across all key indicators:

- Crude Oil Prices averaged \$79.5 (SD = 25.7) before the pandemic, compared to \$77.3 (SD = 23.2) after, indicating a slight decline in average prices accompanied by persistent volatility.
- Domestic Production experienced a significant reduction, dropping from a mean of 2.15 million barrels per day (SD = 0.217) pre-COVID to 1.34 million barrels per day (SD = 0.214) post-COVID.
- Similarly, Crude Oil Exportation levels fell sharply, from an average of 1.70 million barrels per day (SD = 0.217) to 0.89 million barrels per day (SD = 0.214).

These figures suggest a substantial contraction in Nigeria's crude oil output and export activities in the aftermath of the pandemic, with the standard deviations remaining comparable across periods—hinting at stable but lower activity levels post-COVID.

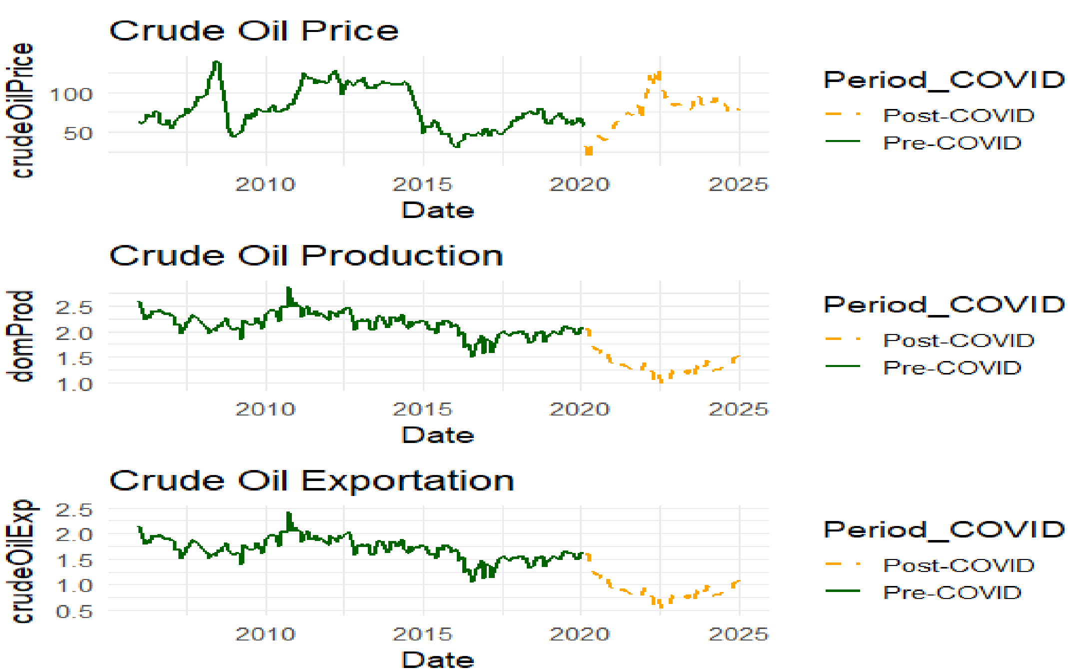

Figure 8: Crude Oil Price, Production, and Exportation in Nigeria — Pre- vs Post-COVID-19 Periods

Levene's Test was also conducted to assess whether the variance (volatility) of crude oil market variables differed significantly between the Pre- and Post-COVID-19 periods.

- For Crude Oil Price, results were marginally significant (p = 0.0525), suggesting that price volatility may have increased after the onset of the COVID-19 pandemic. This aligns with the dramatic fluctuations observed visually during 2020–2021.
- For both Production and Exportation, p-values were above 0.05, indicating no statistically significant change in variance across the two periods.

4.2 Discussion

This study examined the interrelationships among crude oil prices, production, and exportation in Nigeria over the period 2006–2024 using advanced time-series techniques. The results both affirm and diverge from several previous studies.

The lack of statistically significant seasonal patterns, confirmed through Kruskal-Wallis tests, suggests that Nigeria's oil market dynamics are less influenced by cyclical trends and more by structural and external shocks. This finding contrasts with studies like Chinanuife et al. (2021), who emphasized seasonal inflation patterns linked to oil price shocks, but aligns with Yunusa (2020) who emphasized that Nigeria's crude oil exports are more driven by exchange rate volatility and trade conditions, rather than intrinsic seasonal variation.

The absence of a significant Granger causal relationship between crude oil prices and production contradicts the conclusion by Usoro and Ekong (2022), who found bilateral causality between price and production using MGARCH models. The discrepancy may be due to differences in methodology; while Usoro and Ekong used raw monthly data without differencing, this study applied differencing and vector autoregression, which better handles non-stationarity.

Furthermore, Faruk (2020) identified a long-run relationship between oil price and production in the Niger Delta using ARDL, whereas our national-level VAR (2) model found no significant lagged effects, indicating that local dynamics may not translate to national production outcomes. This supports the idea that external market signals may not influence Nigeria's output in the short run, possibly due to OPEC quotas, outdated infrastructure, or political constraints.

The DCC-GARCH analysis provided novel insight. While previous works such as Kuhe et al. (2024) and Adi et al. (2022) confirmed the presence of volatility clustering and significant spillovers in oil markets, our results showed strong persistence in volatility, but no significant short-term volatility transmission from prices to production. This distinction is crucial: it indicates that although oil price shocks are persistent, they do not immediately disrupt production — likely due to delayed operational response or rigid production contracts.

The post-2014 and post-COVID-19 regime analyses revealed significant structural changes. Price volatility became more sensitive to recent shocks, while production and export levels declined sharply. This finding is consistent with Ige and Obi (2018) who noted that oil price volatility disrupts macroeconomic stability, although our study goes further by quantifying volatility behavior using GARCH decomposition pre- and post-events.

Notably, the perfect correlation between production and exportation (r = 1.00) suggests a lack of diversification in Nigeria's crude oil utilization — reinforcing the conclusions drawn by Obaka

ISSN NUMBER: 1116-249X

et al. (2022), who emphasized the detrimental impact of export-dependent oil economies on sustainable development.

This study, by integrating VAR and DCC-GARCH approaches, contributes uniquely by demonstrating persistent but decoupled volatility transmission, a nuanced finding absent in many prior works that did not differentiate between short-term shock spillover and long-term volatility co-movement.

5.0 Summary and Recommendations

This study investigated the dynamic relationships between crude oil prices, production, and exportation in Nigeria from 2006 to 2024 using robust time-series techniques. Key findings reveal that while crude oil prices exhibit high volatility, there is no significant seasonal pattern in any of the variables. Additionally, the results indicate no meaningful lagged relationship between crude oil prices and production or exportation, suggesting that production levels are not immediately responsive to price fluctuations.

Volatility analysis showed strong persistence in both price and production variances, but no evidence of short-term volatility spillovers. Structural analysis across pre- and post-2014, as well as pre- and post-COVID-19 periods, revealed marked declines in production and exportation, accompanied by changes in the behavior of volatility—shifting from highly persistent to more shock-sensitive patterns.

Overall, the findings highlight Nigeria's vulnerability to global oil shocks and underscore the need for adaptive strategies that can cushion the economy from external price disruptions. Enhancing domestic refining capacity, diversifying revenue sources, and improving production resilience remain critical steps for stabilizing the country’s oil sector and broader economy.

References

Abdulkareem, A., & Abdulhakeem, K. A. (2016). Analyzing oil price–macroeconomic volatility in Nigeria. *CBN Journal of Applied Statistics, 7*(1a), 1–22.

Adi, A. A., Adda, S. P., & Wobilor, A. K. (2022). Shocks and volatility transmission between oil price and Nigeria’s exchange rate. *Springer Nature Business & Economics, 2*, Article 47. https://doi.org/10.1007/s43546-022-00228-z

Ayodele, O. I., Salufu, S. O., Onolemhemhen, O. R. U., & Isehunwa, S. O. (2024). Crude oil price volatility and its impact on the development of marginal fields: A case study from the Niger Delta Basin, Nigeria. *Springer Nature Business & Economics, 4*, Article 72. https://doi.org/10.1007/s43546-024-00672-z

Chinanuife, E., Magboo, K., & Zekeri, M. (2021). Oil price volatility and inflation level in Nigeria: An exponential GARCH approach. *International Journal of Advanced Research, 9*(8), 1–8. https://doi.org/10.21474/IJAR01/13219

ISSN NUMBER: 1116-249X

Faruk, B. U. (2020). Relationship between volatility in domestic oil production, oil price and exchange rate in Nigeria: Co-integration and Granger causality tests. *Bullion, 44*(4), 1–16.

Ige, O. G., & Obi, B. (2018). The impact of crude oil price volatility on the Nigerian economy. *Bingham Journal of Economics and Allied Studies, 1*(1), 1–18.

Kuhe, D. A., Udoumoh, E. F., & Oche, D. (2024). Volatility analysis of crude oil prices in Nigeria. *FUDMA Journal of Sciences, 8*(1), 125–134. https://doi.org/10.33003/fjs-2024-0801-2212

Obaka, A. I., Ogboru, I., & Goshit, G. G. (2022). Oil price volatility and the Nigerian economy: ARDL and Granger causality approaches. *Kampala International University Journal of Social Sciences, 7*(1), 7–28.

Sami, S., & Taiwo, M. (2023). Effect of crude oil prices and production on the performance of Nigerian gross domestic product: A conceptual framework. *Journal of Human Resource and Sustainability Studies, 11*, 698–711. https://doi.org/10.4236/jhrss.2023.113038

Usoro, A. E., & Ekong, A. (2022). Modeling Nigeria crude oil production and price volatility using multivariate generalized autoregressive conditional heteroscedasticity models. *African Journal of Mathematics and Statistics Studies, 5*(1), 33–54. https://doi.org/10.52589/AJMSS-L4FI9DW6

Yunusa, L. A. (2020). Exchange rate volatility and Nigeria crude oil export market. *Scientific African, 9*(1), 1–13. 10.1016/j.sciaf.2020.e00538

ISSN NUMBER: 1116-249X