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Analysis of Crude Oil Market Volatility and Macroeconomic Conditions: Empirical Evidence from Nigeria

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ABSTRACT

This study **aims** to investigate the relationship between the volatility of the crude oil market and the macroeconomic conditions in Nigeria. The author used the **methods** of the auto-regressive distributed lag (ARDL) model in conjunction with the generalized autoregressive conditional heteroscedasticity (GARCH) to determine the extent of volatility using a monthly dataset from January 2012 to December 2022. The author regressed the crude oil price volatility index on Organization of the Petroleum Exporting Countries (OPEC) production quotas, conflicts, GDP growth rate, exchange rate and inflation. The r**esults** indicate that oil price volatility relates negatively to GDP, implying that the volatility of crude oil prices dampens growth in Nigeria. The paper **concludes** that rising oil prices heighten inflation, depreciate the exchange rate and depress growth in Nigeria. To hedge against oil price volatility, the paper recommends that the Nigerian government adopt policy measures that would increase energy efficiency and reduce the country's dependency on oil exports through diversification in other related productive sectors such as agriculture and manufacturing.

Keywords: oil price; volatility; geopolitical risk index; conflict; GDP; inflation; exchange rate; macroeconomics; Nigeria

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ОРИГИНАЛЬНАЯ СТАТЬЯ

Анализ волатильности рынка сырой нефти и макроэкономических показателей: эмпирические данные из Нигерии

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АННОТАЦИЯ

Целью данного исследования является изучение взаимосвязи между волатильностью рынка сырой нефти и макроэкономическими показателями в Нигерии. Автор использовал **методы** авторегрессионного распределенного лага (ARDL) в сочетании с обобщенной авторегрессионной условной гетероскедастичностью (GARCH) для определения степени волатильности рынка на основе ежемесячных данных с января 2012 по декабрь 2022 г. Автор проводит регрессионный анализ индекса волатильности цен на сырую нефть и квот добычи Организации стран — экспортеров нефти (ОПЕК), конфликтов, темпов роста ВВП, обменного курса и инфляции. Результаты показывают, что волатильность цен на нефть отрицательно связана с ВВП. Это означает, что волатильность цен на сырую нефть снижает темпы роста в Нигерии. В статье делается **вывод**, что рост цен на нефть усиливает инфляцию, обесценивает обменный курс и снижает темпы роста в Нигерии. Чтобы избежать зависимости от волатильности цен на нефть, автор статьи **рекомендует** правительству Нигерии принять политические меры, которые позволят повысить энергоэффективность и снизить зависимость страны от экспорта нефти путем диверсификации в смежные производственные сектора, такие как сельское хозяйство и обрабатывающая промышленность.

Ключевые слова: цена на нефть; волатильность; индекс геополитического риска; конфликт; ВВП; инфляция; обменный курс; макроэкономика; Нигерия

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Introduction

Crude oil is one of the dominant mineral resources that Nigeria is endowed with. This makes the country one of the largest oil exporters in Africa [1]. In Nigeria, oil accounts for over 95% of export earnings, 25% of gross domestic product (GDP), and approximately 90% of government revenues.

Over the past few years, the global economy, including Nigeria, has experienced significant fluctuations in crude oil prices. The dynamics of world oil prices, in addition to demand and supply imbalances, is determined by several factors, including the actions of the Organization of Petroleum Exporting Countries (OPEC) to limit crude oil production (supply reduction), and heightened geopolitical events such as wars, terrorism and other political tensions such as the Iraq war, Gulf war, the Arab oil embargo, the global financial crisis of 2008–2009 and the ongoing Russian-Ukrainian conflict [2].

Nigeria has also experienced different geopolitical tensions, such as the Niger-Delta militancy and the Boko Haram insurgency. The activities of this group of terrorists led to massive destruction of property, pipe vandalism, crude oil theft, kidnapping and supply chain disruptions in Nigeria. It is pertinent to recall that in January 2023, after the removal of petroleum subsidies by the Nigerian Federal Government, Bonny Light oil prices swiftly rose to $110 per barrel, and diesel and gas prices also increased to N800 per litre (N stands for Nigerian currency, Naira; N800 approximately equals $1). Similarly, the price of Prime Motor Spirit (PMS) has also gone up from N195 to N617 per litre, with ripple effects on inflation pressures in the economy. Higher energy costs have the potential to push up commodity prices, production and transportation costs [3].

Fig. 1 shows the historical trend of oil prices. As shown above, crude oil prices were $19.64, $21.54, $20.54 and $18.43 in 1989, 1991, 1993 and 1995, respectively. In 1999, crude oil prices averaged $19.35 per barrel. In 2005, the price increased to US$56.6 per barrel, and in 2007, it declined to US$55.8 per barrel. As reflected in the figure, the highest crude oil price was recorded in 2008, when it rose to US$145.29 per barrel, as against US$55.8 per barrel in the previous years. In 2009, the world entered a recession popularly known as the global financial crisis, which led to a sharp drop in oil price to US$53.4 per barrel. In 2010, the price rose to US$79.48, $94.88 in 2011, US$112 in 2014 and slumped to US$38.5 in 2015. In 2016, it increased to US$43.29 and in 2017, the price rose to US$50.8 and then to US$65.23 in 2018. However, between 2019 and 2020, crude oil prices dropped to US$56.99 and US$39.65, respectively, due to the COVID-19 pandemic. In 2021, the Brent crude oil price increased to US$70.86 per barrel, up from US$39.65 in previous years.

This was probably due to the post-pandemic recovery of the economies of China and other Asian Pacific region countries, leading to an increase in the demand for oil. On February 24, 2022, with the beginning of the Russian special military operation in Ukraine, Brent oil swiftly jumped to US$103.08 in February 2022 and rose to US$125.53 per barrel in May 2022. By December of the same year, the Brent price traded at US$103.93 per barrel. The short-term, sudden increase in oil prices in the spring of 2022, immediately after the start of the conflict, was purely speculative. In January 2023, due to the presence of a discount on Russian oil, the price dropped to US$83.42 and dwindled further to US$74.51 as of June 2023.

Although several studies on oil price volatility exist, such as [4–6]. None of these studies make concerted efforts to explore the correlation between the volatility of the crude oil market and macroeconomic conditions in Ni-

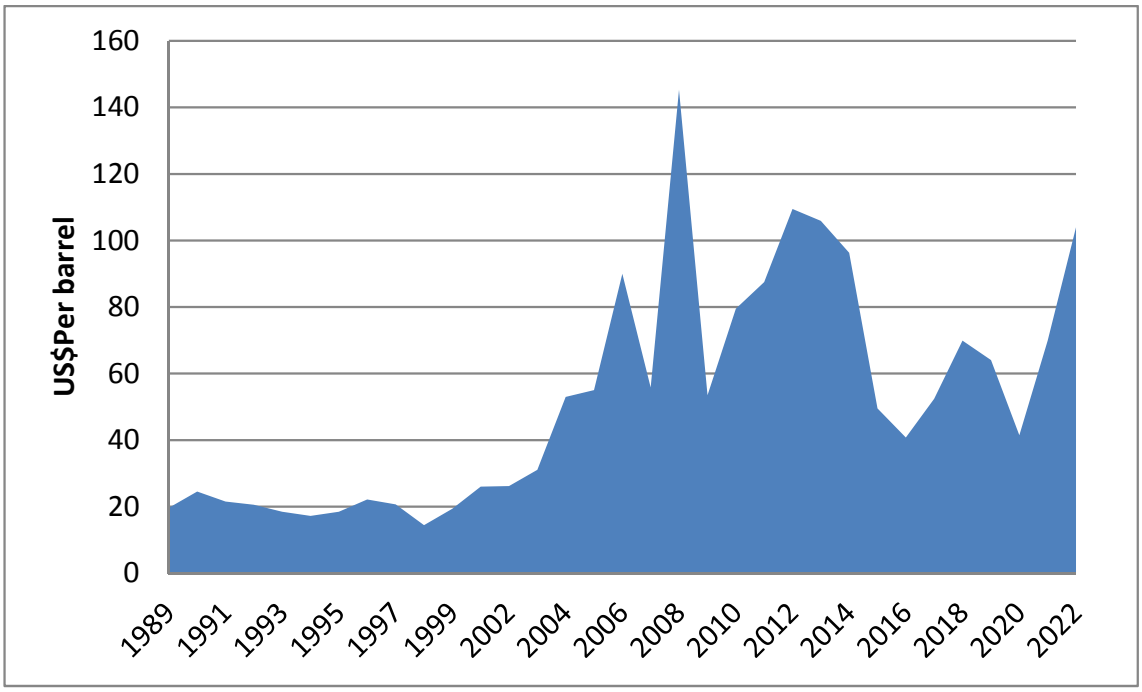

Fig. 1. **Trends of Brent crude oil prices, 1989–2022 (US$)**

Source: U.S. Energy Information Administration (EIA). URL: https://fred.stlouisfed.org/series/DCOILBRENTEU (accessed on 17.08.2023).

geria. The majority of previous studies focused more on the nexus between oil price volatility and growth; more importantly, volatility models were not appropriately applied. Therefore, there is a need for an empirical examination of the nexus between the volatility of oil prices and the Nigerian macro-economy using appropriate models. This is the research gap addressed in the current paper.

The contributions of this paper to the existing body of knowledge are twofold. First, this research provides an empirical study on a topical issue that has gained little attention in the literature. Second, the findings would help us understand the dynamics of the world oil market and assist policymakers in adopting appropriate policy measures to counteract price shocks and alleviate long-term impacts on the economy.

This paper demonstrates novelty by adopting the GARCH model to test the extent of volatility in the oil market and by computing the geopolitical risk index for Nigeria, which was not covered by the existing geopolitical risk (GPR) index [7]. The practical significance of this study is that the findings would help us to understand the dynamics of world oil prices and the need to reduce the country's dependency on oil exports through diversification of its export base to hedge against volatility.

The objective of this study is to investigate the relationship between the volatility of the crude oil market and the macroeconomic conditions in Nigeria. To achieve this goal, the study uses the GARCH model and the ARDL approach using a monthly dataset from January 2012 to December 2022.

Literature review

A study [8] found that wars and geopolitical tensions affect crude oil and stock market prices using time-varying parameter vector autoregressions (TVP/VAR) analysis. A study [9] also explored the effect of oil price volatility using structural VAR from 1991 to 2020. They found that oil price shocks lead to inflation in India. A study [10] investigated the effect of oil price shocks on oil-importing countries. They discovered that geopolitical risk increases oil prices, and oil-dependent countries are more sensitive to geopolitical risk. This finding is consistent with conclusions in other studies [11]. Similarly, a study [12] examined how geopolitical risk affects foreign direct investment outflows in China. Their findings show that geopolitical risk

is detrimental to foreign direct investment performance in China. An empirical study [13] on the impact of oil price shocks on Azerbaijan's economy using VAR showed a strong significant influence of crude oil price shocks on GDP. A study [14] on the impact of oil price changes in Malaysia from 1975 to 2015 used non-linear autoregressive distributed lags (NLARDL). Findings indicated that changes in crude oil prices contributed to GDP growth. The outcome in Malaysia is consistent with the findings by other scholars [9, 13].

Similar research on oil price shocks was also carried out in Nigeria. Ogungbenla [1] used data from 1980 to 2019 and employed the VAR regression technique. He found that volatile oil prices had a negative impact on real GDP using variables GDP, oil price (OILP), inflation (INF), and exchange rate (EXR). Using data from 2000 to 2018, study [4] found a similar investigation by applying the VAR regression technique. It was discovered that oil price shocks inversely affected GDP.

Maud and Evangelos [15] conducted research on oil price volatility from 1990 to 2021. The data were analyzed using the ARDL model. The results confirmed the existence of a negative association between oil prices and GDP growth. Their findings find support in previous studies [9]. In the same analysis, a study [4] used data from 1990 to 2012 to investigate oil price volatility. The data were analyzed using the ARDL model. The outcome of this research is consistent with [13]. A similar study was conducted [12] using structural vector auto-regression (SVAR) on a dataset from 1970 to 2010. The results confirmed that the volatility of oil prices negatively affected growth. Their findings also support those of [16–19].

Materials and Methods

The dataset used in this study contains monthly data and spans from January 2012 to December 2022. The period was selected based on the fact that Nigeria started experiencing major conflicts and terrorist attacks in oil-producing areas, which affected oil production levels. Data on GDP growth rate, inflation and exchange rate are obtained from the Central Bank of Nigeria Statistical Bulletin online database.[1] Data on Brent oil prices are from the U.S. Energy Information Administration (EIA), while data on OPEC oil production quotas are obtained from OPEC Annual Statistical Bulletin.[2]

We use the GPR index as an indicator of conflict. It is pertinent to note that the existing global GPR index by Caldara and Lacoviello [7] did not cover Africa and Nigeria in particular.[3] It only focused on developed and emerging economies without considering Africa. Our objective is to construct the GPR index for Nigeria, following the approach of Caldara and Lacoviello [7]. We calculate the monthly GPR index from January 2012 to December 2022 by counting the number of articles related to geopolitical events. Similar to [7, 20], we extracted relevant news articles from ten notable newspapers mentioning geopolitical events. These newspapers include Vanguard, This Day, The Punch, the Guardian, Independent Nigeria, Business Day, Daily Trust, Daily Champion, Nigerian Tribune, and P.M. News. We use relevant keywords (e.g., terrorism, terror, insecurity, bandits, Boko Haram, insurgent) relating to geopolitical events similar to the method of Caldara and Lacoviello [7], but with particular reference to Nigerian settings.

The generalized autoregressive conditional heteroscedasticity (GARCH (1, 1)) method was used to forecast crude oil price volatility. This approach is justified because of its adequacy in measuring volatility as used in most empirical literature [21, 22–26]. The main reason is that oil prices are subject to random movements, and failure to measure volatility may result in spurious regression; hence the use of the GARCH model. Following [26], the GARCH (1, 1) model takes the following form:

$$Y_t = \varphi_0 + \mu_t,$$

where Y_t denotes crude oil market volatility series; $\mu_t \sim N(0, \sigma^2_t)$

$$\sigma^2_t = \omega + \alpha_1 e_{t-1} + \beta h_{t-1},$$

$$\varepsilon_t = \alpha_t + \sigma^2_{t-1},$$

[1] URL: www.cbn.gov.ng
[2] URL: www.opec.org
[3] URL: http://www.matteoicoviello.com/gpr.htm

Table 1
Descriptive statistic results

	OILPV	CONF	OPEC	GDP	EXR	INFL
Mean	39.42000	50.82636	78.21818	86.27848	63.43879	68.49970
Median	9.700000	49.49000	15.10000	102.1000	37.74000	19.80000
Maximum	279.8000	145.2900	450.0000	161.9300	200.0700	157.5000
Minimum	–2.340000	16.60000	–12.40000	7.980000	6.130000	10.80000
Std. Dev.	80.61406	32.86887	124.9454	56.92622	57.05584	59.51063
Skewness	2.364066	0.836726	1.782341	–0.198368	0.661863	0.307081
Kurtosis	6.937446	3.158982	5.050664	1.418925	2.276235	1.273690
Jarque-Bera	52.05572	3.885356	23.25425	3.653649	3.129618	4.616344

Source: The author's computations.

Table 2
Results of GARCH (1, 1)

Variable	Coeff.	Std. Error	z-Statistic	Prob.
Mean Equation C***	0.085890	0.338521	0.253721	0.7997
oilpv(–1)***	2.219443	0.810438	2.738571	0.0062
	Variance Equation			
C*	1.131363	0.305707	3.700814	0.0009
ARCH*	–0.174157	0.090197	–1.930855	0.0535
GARCH(–1)***	0.043771	0.071363	0.613363	0.5396
	Diagnostic Test			
	ARCH-LM			
Obs.R^2	–0.107611			0.5557

Notes: *, ** and *** explain 10%, 5% and 1% significance level.

Source: The author's computations.

where σ^2_{t-1} represents the GARCH term; ω and h_{t-1} are the conditional mean and variance of the crude oil market.

Similar to [14], we the use crude oil price volatility index as the dependent variable, which is regressed on conflict, proxy by the geopolitical risk index, OPEC production, GDP growth, exchange rate, and inflation rate. We employ the autoregressive distributed lag (ARDL) model to estimate the equation. Thus, we specify our model in the following form:

$$OILPV = f(CONF, OPEC, GDP, EXR, INFL).$$

The econometric specification of the model can be written as follows:

$$OILPV = \delta_0 + \Sigma\delta_1 CONF + \delta_2 OPEC + \delta_3 GDP + \delta_4 EXR + \delta_5 INFL + \varepsilon.$$

The Auto-regressive Distributed Lag (ARDL) model takes the following form:

$$OILPV = \lambda_0 + \Sigma\delta_1 CONF_{t-i} + \Sigma\delta_2 OPEC_{t-i} + \delta_3 GDP_{t-i} + \Sigma\delta_4 EXR_{t-i} + \delta_5 INFL_{t-i} + \delta_6 ecm + \varepsilon_t,$$

where OILPV stands for oil price volatility index measured by Brent oil price, CONF is conflict measured by geopolitical risk index, OPEC is the OPEC production quotas, GDP is growth rate of GDP, EXR is nominal exchange rate (naira/US dollar), INFL is inflation rate, while λ_0 is the intercept, $\delta_1 - \delta_5$ are coefficients of

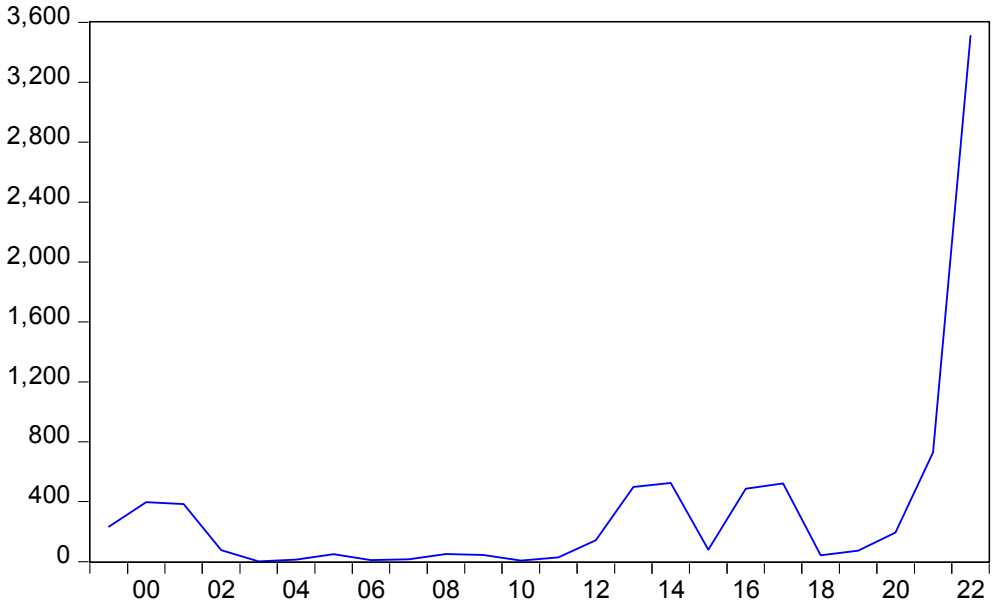

Fig. 2. **Conditional variance of oil price volatility series**

Source: Compiled by the author.

the independent variables and ε_t is a vector white noise.

Results and discussion

The results of the descriptive statistics are presented in *Table 1*. In *Table 2,* we present the result of the GARCH (1, 1) model and its diagnostic test. We proceed to calculate the volatility series (*oilpv*), by taking the first difference of the logarithm of the oil price [27–29]. The oil price volatility series is then tested for stationarity in line with [30]. We observed that the crude oil price is stationary in its level form using ADF and PP tests. As indicated in *Table 2*, the fact that the sum of the ARCH and GARCH coefficients are close to unity suggests that wars, conflicts, and other geopolitical events make the oil market more volatile. The diagnostic procedures of the GARCH (1, 1) in *Table 2* indicate that the mean and variance equations are correctly specified, and there is no problem of serial correlation, as reflected by the low probability values. Furthermore, the LM test demonstrates the absence of ARCH effect. *Fig. 2* plots the volatility series. The oil price volatility series over this time period show that changes in oil prices are persistent [31].

Our descriptive statistics in *Table 1* indicate the existence of negative asymmetry. The fact that Jarque-Bera values are greater than their Kurtosis values further demonstrates that the series are normally distributed. In addition, stationarity test results in *Table 3* show that the series CONF, OPEC, *GDP,* and *EXR* are stationary at order I(1), whereas *OILPV* and *INFL* are stationary at I(0). This means that the variables' levels of integration vary, as demonstrated by the ADF and PP unit root tests. Given the mixed order of integration in this instance, ARDL is preferable. Furthermore, to determine whether the variables used in this study have any long-term relationships, we used the bounds co-integration test. The computed F-statistic exceeds the critical value, as shown in *Table 4*. This indicates that stable long-term relationships exist among the variables.

The estimated results of the ARDL model are presented in *Table 5*. The short-run estimates show that wars, conflicts and other geopolitical events contribute to the volatility of crude oil prices. Our finding reveals a significant positive correlation between the geopolitical tensions in Nigeria and the volatility of the crude oil market, which is in line with the findings of [17, 19, 21–23].

OPEC oil production is found to be significant in explaining the dynamics of prices during the period of study, supporting findings by [14, 16]. The finding indicates that the influence of OPEC production quotas on

Table 3
Unit root test

Variable	ADF	Remark	PP	Remark
GDP	−4.64*	I(1)	−3.62*	I(1)
OILPV	−3.25***	I(0)	−4.39***	I(0)
GPR	−5.36***	I(1)	−5.36***	I(1)
TOP	−4.53***	I(1)	−4.53***	I(1)
INFL	−3.51**	I(1)	−4.65**	I(1)
EXR	−3.64**	I(0)	−3.75**	I(0)

Notes: *, ** and *** denote 10%, 5% and 1% significance levels, respectively.

Source: The author's computations.

Table 4
Bounds test results

Model	K	Computed F-statistics	Remarks
(F(OILPV, CONF, OPEC, GDP, EXR, INFL))***	5	4.271478	reject H0

K	10%		5%		1%	
5	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)
	2.08	3.00	2.39	3.38	3.06	4.14

Note: *** shows 1% significance level.

Source: The author's computations.

oil price volatility is positive and significant. This means that an increase in OPEC oil production would lead to a decline in crude oil price in international market, while a cut in OPEC production quotas leads to an increase in price.

Our analysis also reveals that oil price volatility slows down growth, as demonstrated by the negative value of GDP. The estimated coefficient of error correction term of –0.26 was significant at the five percent level, indicating that about 26 percent of any disequilibrium would be easily corrected in a short period of time.

The long-term association between OPEC production quotas and crude oil price is positive and significant, meaning that excess supply and production of crude oil by OPEC lead to surpluses and reductions in price, while a reduction in OPEC production has the potential to drive prices up. The import of this analysis is that shocks in oil production by OPEC can trigger higher oil price volatility. Our result also indicates that oil price shocks trigger inflation in Nigeria. A change in oil prices causes inflation to increase by 1.85 percent. The economic growth proxy by GDP growth rate was significantly and negatively impacted by oil price volatility. This result implies that OILPV slows growth over the long term. Additionally, OILPV relates negatively to the exchange rate. This means that over time, OILV would lead to a depreciation of the exchange rate.

The post-estimation test findings in *Table 6* show that the model does not have an autocorrelation problem because the probability value of the serial correlation LM test is 0.79, which is higher than 0.05. The model also does not have a heteroskedasticity issue. We also

Table 5
Estimated ARDL model

Dependent Variable: OILPV

Variables	Coefficient	t-Statistic	Prob.
Short-run			
CONF(−1)*	0.465875	2.300903	0.0352
D(OPEC)**	2.802577	7.019782	0.0000
D(OPEC(−1))**	1.032950	2.958014	0.0093
D(GDP)**	0.062744	2.359158	0.0400
D(GDP(−1))**	−3.380960	−5.030246	0.0005
D(EXR)**	−0.773321	−1.990892	0.0639
D(EXR(−1))**	1.843255	2.402754	0.0371
D(INFL)**	0.831096	2.231574	0.0403
ECT***	−0.269204	−10.84409	0.0000
Long-run			
CONF*	1.061804	2.043539	0.0578
OPEC***	1.520060	2.275624	0.0370
GDP**	0.062744	2.359158	0.0400
EXR***	−0.538709	−4.894435	0.0006
INFL**	1.858986	7.219760	0.0000
C***	−57.07929	−1.927503	0.0719
Diagnostic test			
Serial correlation	0.79^{p}		
Heteroscedasticity	0.55^{p}		
Specification bias	075^{p}		

Notes: *, ** and *** explain 10%, 5% and 1% significance levels respectively; ^{p} *indicates F-Statistic Probability.*

Source: Author's computations.

discover that the model does not suffer misspecification bias.

We ran the CUSUM and CUSUMSQ in order to confirm the model's stability. *Figs. 3* and *4* illustrate the results. The stability of the model is shown by the graphs of CUSUM and CUSUMSQ. None of the recursive residuals were outside the two critical lines; all are inside the 5% critical lines.

Conclusion

This study examined the volatility risk of the crude oil market and macroeconomic conditions in Nigeria using monthly data from January 2012 to December 2022. We used the GARCH (1, 1) model to estimate the volatility of the oil market and the ARDL method to analyze the data. We discovered that conflicts in Nigeria and OPEC oil production are significant in explaining the dynamics of the price of oil during the study period. Oil price volatility has also led to a high inflation rate, exchange rate depreciation and slowed down GDP. The paper concludes that oil price volatility significantly influences inflation and exchange rate depreciation. The alarming

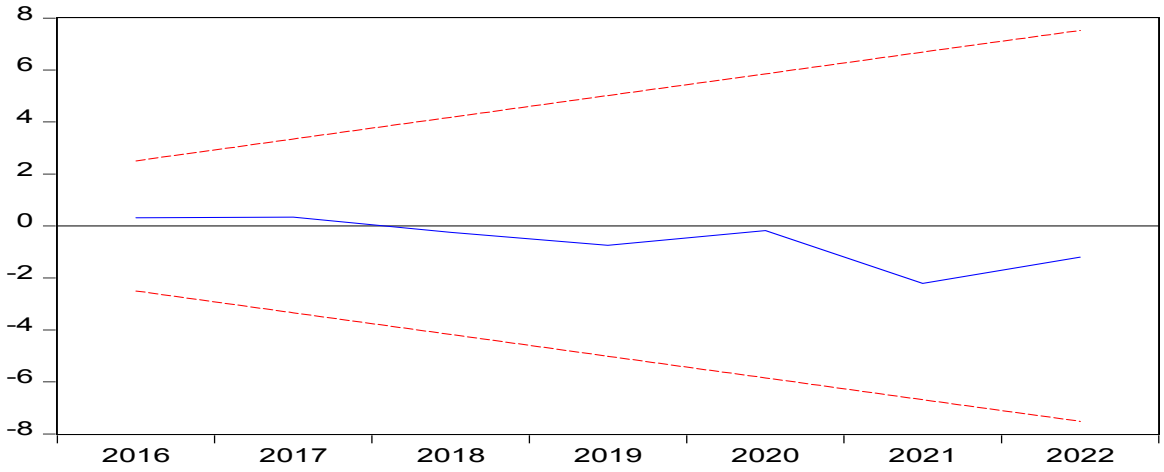

Fig. 3. **CUSUM**

Source: Author's computations.

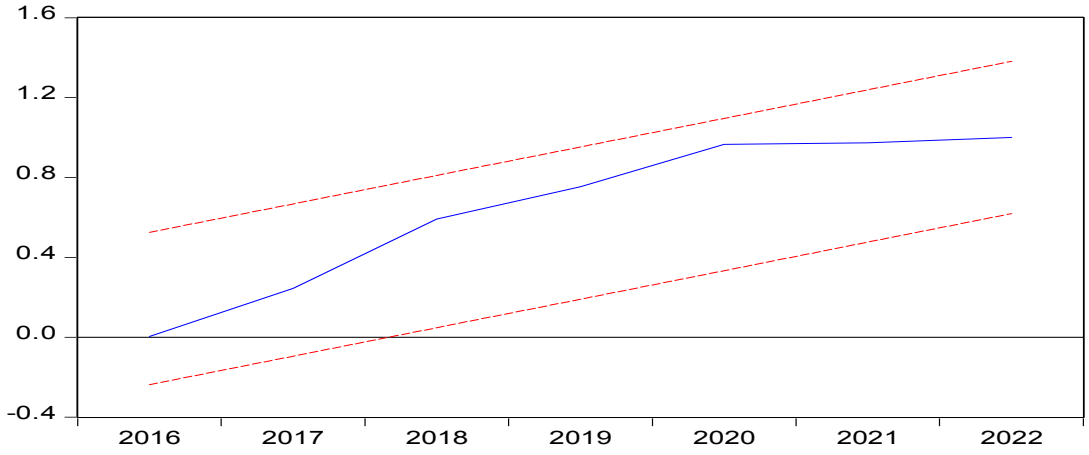

Fig. 4. **CUSUMSQ**

Source: The author's computations.

inflation rate in Nigeria is attributed to the sharp increase in oil prices.

Our findings have long-term policy implications for the Nigerian economy. Oil price volatility has heightened inflation pressures, causing spikes in energy and commodity prices, depreciation of currency, and a depressing long-term growth prospect.

This paper suggests that the Nigerian government and policymakers need to strongly adopt policy measures that would increase energy efficiency and lessen the country's dependency on oil exports through diversification of its export base to hedge against oil volatility; otherwise, the economy would deteriorate and crumble eventually as the volatility persists.

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