THE IMPACT OF CRUDE OIL PRICE SHOCKS ON THE NIGERIAN EXCHANGE RATE: A TIME SERIES ANALYSIS USING ARIMAX MODELS

David, R. O.[1], Zangdap, K. L.[1], Nnamani, C. N.[1], Ishaq, A. I.[1] and Obalowu, J.[2]
[1]Department of Statistics, Ahmadu Bello University, Zaria
[2]Department of Statistics, University of Ilorin, Ilorin

Corresponding author: rodavid@abu.edu.ng ; +2348037557300

RSS-NLG 2025 Conference Proceedings

ABSTRACT

Fluctuations in crude oil prices significantly impact the value of Nigeria's Naira relative to the US Dollar. Understanding the link between crude oil price shocks and exchange rate movements is vital for effective monetary policy and economic stability. This study examines the effect of crude oil price shocks on the USD/NGN exchange rate using time series analysis. Historical data on crude oil prices and the exchange rate were analyzed with ARIMAX models, incorporating crude oil prices as an exogenous variable. The ARIMAX (1,1,1) model provided the best fit based on AIC and BIC criteria, with diagnostic checks revealing no autocorrelation in residuals, ensuring model adequacy. The findings suggest that crude oil price changes exert a small negative effect on the exchange rate, but historical values and past errors play significant roles. The study concludes that while crude oil price changes influence the exchange rate, additional factors like inflation, foreign reserves, and government policies could have a greater effect. Recommendations include diversifying the economy and implementing policy reforms to improve exchange rate stability in Nigeria.

1. INTRODUCTION

The exchange rate between a country's currency and foreign currencies plays a critical role in shaping economic policy, trade, and financial stability. For oil-dependent economies like Nigeria, fluctuations in crude oil prices significantly influence exchange rate behavior (Nasir, Sa'ad, Sanusi & Usman, 2023). A country's reliance on oil as its primary export commodity makes the currency susceptible to changes in global oil prices. Sharp declines in oil prices can lead to economic instability, foreign exchange shortages, and inflation, while price increases often trigger currency appreciation. In Nigeria, oil exports generate substantial revenue and serve as a major source of foreign exchange for the economy. Although, available statistics show that oil's contribution to Nigeria GDP is relatively small (5.34% in Q2 2023 and 5.48% in Q3 2023), oil exports account for around 92% of Nigeria's total exports in 2023, an increase from 87.5% in 2022 (Sasu, 2024). This dependence on oil revenues exposes the country to the volatility of global oil prices. As highlighted in the literature (Farzanegan & Markwardt, 2007; Mordi & Adebiyi, 2010; and Alimi & Fatukasi, 2014), fluctuations in oil prices significantly affect the economic performance of oil-exporting nations like Nigeria, which rely heavily on oil proceeds as a primary source of foreign exchange.

The relationship between crude oil price shocks and exchange rates has been a focal point of financial and economic research. Traditional exchange rate models, such as the Purchasing Power Parity (PPP) and Balance of Payments models, often fail to adequately capture the complexities of oil price fluctuations in resource-dependent economies like Nigeria. These limitations have prompted researchers to explore sophisticated econometric tools to analyze the effects of oil prices on exchange rates.

Several studies have examined the transmission mechanisms through which oil price volatility influences exchange rates, including trade balances, foreign reserves, and macroeconomic policy responses. For instance, Narayan and Narayan (2007) and Gosh (2011) emphasized the role of these mechanisms in shaping exchange rate movements in oil-exporting economies. Similarly, Akpan (2008) focused on Nigeria, concluding that the country's reliance on oil revenue amplifies exchange rate volatility in response to crude oil price shocks.

RSS-NIG 2025 Conference Proceedings

Empirical studies like Turhan, Hacıhasanoğlu, and Soytas (2012), Shafi and Hua (2014), and Pershin, Molero, and Gracia (2015) have demonstrated that oil price fluctuations are a significant driver of exchange rate movements, particularly in developed economies. In contrast, Sahbaz, Adıguzel, Bayat, and Kayhan (2014) found a causal relationship from real exchange rates to oil prices in Romania over the medium and long term. This underscores the bidirectional nature of oil price and exchange rate dynamics, which can vary across oil-exporting and oil-importing economies.

In Nigeria, studies have provided insights into the unique relationship between oil prices and exchange rates. Adeniyi et al. (2012), using GARCH and EGARCH models, discovered that an increase in oil prices leads to the Naira's appreciation against the US dollar. Similarly, Obioma and Charles (2015) employed a Vector Autoregressive (VAR) model to investigate the interaction of crude oil prices, consumer price levels, and exchange rates. They found that crude oil price shocks negatively impact exchange rates, with a significant portion of exchange rate variation attributable to oil price fluctuations.

Recent studies have introduced advanced modelling techniques to better capture the complexities of oil price-exchange rate interactions. Bhagat, Sharma, and Saxena (2022) applied machine learning algorithms, including ARIMAX, to model the relationship between macroeconomic variables and WTI crude oil prices. Their findings highlighted that the US dollar and consumer price index exerted a significant influence on oil prices, with ARIMAX emerging as the most efficient model.

Nasir *et al*. (2023) expanded on this by employing linear and non-linear autoregressive distributed lag (ARDL) models to study oil prices' impact on Nigeria's exchange rate. Their results showed that oil prices positively and significantly influence exchange rates in both the long and short run. Notably, the non-linear ARDL model revealed that the depreciating effect of

RSS-NIG 2025 Conference Proceedings

a fall in oil prices was more pronounced than the appreciating effect of a rise in oil prices of equal magnitude.

These advancements underscore the utility of econometric frameworks like ARIMAX in isolating the impact of exogenous variables such as oil prices. By incorporating lagged relationships and historical shocks, the ARIMAX model captures both the immediate and delayed effects of oil price fluctuations on exchange rates. Its flexibility makes it particularly well-suited for analyzing the complex dynamics of oil-dependent economies like Nigeria, where crude oil remains a dominant export and source of foreign exchange. Understanding the effect of crude oil price shocks on the exchange rate is essential for developing effective monetary policies to cushion adverse impacts on the economy. This paper investigates the relationship between crude oil prices and the USD/NGN exchange rate using time series analysis, with the ARIMAX model employed to capture the effects of crude oil price shocks on the exchange rate.

2. METHODOLOGY

2.1 Data

This study utilizes daily data on crude oil prices (measured in USD per barrel) and the USD/NGN exchange rate spanning 14 years (January 2010 to May 2024). Both sets of data are sourced from www.cenbank.org.

2.2 ARIMAX Model Specification

The Autoregressive Integrated Moving Average with exogenous variable (ARIMAX) model is an extension of the Autoregressive Integrated Moving Average (ARIMA) model. An ARIMA (*p*,*d*,*q*) is given by:

$$\phi(L)\Delta^d Y_t = \phi_0 + \theta(L)\varepsilon_t , \quad (1)$$

RSS-NLG 2025 Conference Proceedings

where ϕ (L) and $\theta(L)$ are the autoregressive and moving average polynomials expressed respectively as:

$$\phi(L) = 1 - \phi_1 L^1 - \phi_2 L^2 - \phi_3 L^3 - \ldots - \phi_p L^p \tag{2}$$

and

$$\theta(L) = 1 - \theta_1 L^1 - \theta_2 L^2 - \theta_3 L^3 - \ldots - \theta_q L^q \,. \tag{3}$$

Also, Y_t is a dependent variable (USD/NGN exchange rate) in period, t; L^d denotes the difference, ϕ_0 is the intercept and ε_t is the white noise process. The ARIMAX model (an expansion of the ARIMA) is specified as follows:

$$\phi(L)\Delta^d Y_t = \phi_0 + \varphi(L) X_t + \theta(L)\varepsilon_t \,, \tag{4}$$

where X_t is the exogenous variable (crude oil price) at time t

$$\varphi(L) = 1 - \varphi_1 L^1 - \varphi_2 L^2 - \varphi_3 L^3 - \ldots - \varphi_r L^r \tag{5}$$

X_t is the exogenous variable at time t. ARIMAX (1,1,1) is the simplest ARIMAX model and its full form is given as:

$$Y_t = \phi_0 + \phi_1 Y_{t-1} + \theta_1 \varepsilon_{t-1} + \varphi X_t + \varepsilon_t \,, \tag{6}$$

where Y_t is exchange rate at time t, X_t is crude oil price at time t, ϕ_1 is autoregressive coefficient, θ_1 is moving average coefficient, φ is coefficient of the exogenous variable (crude oil prices), and ε_t is error term.

The model assumes stationarity, achieved by differencing the exchange rate series. Estimating the unknown parameters of the model involves maximizing the likelihood function of the model or minimizing the squared errors between the observed and predicted values. The best model is selected based on Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC).

RSS-NLG 2025 Conference Proceedings

2.3 Diagnostic Checking

Once the candidate ARIMAX models have identified and estimated, to assess the adequacy of the selected models to the data, the residuals should be approximately white noise (the residual have zero mean and variance (σ_{ε}^{2})) and they should be uncorrelated. This is achieved using the residual plot, the ACF and PACF of the residuals. This can also be achieved using a formal test like the Ljung-Box test statistic. The test statistic is calculated as:

$$Q = n\left(n+2\right)\sum_{k=1}^{h}\frac{\rho_k^2}{\left(n-k\right)} , \tag{7}$$

where n is the sample size, h is number of lags, and ρ_k is sample autocorrelation at lag k. Equation (7) follows a chi-squared distribution with h degrees of freedom. The null hypothesis that the residuals are randomly distributed is not rejected in favour of the alternative if $Q < \chi^2\left(h,\alpha\right)$ where α is the significance level. Alternatively, the Ljung-Box Q-test revealed no significant autocorrelation in the residuals if p-value > α -level.

3. RESULTS AND DISCUSSION

3.1 Preliminary Result

Figure 1 indicates the time series plot of the USD/NGN exchange rate and crude oil price. The plots indicate the two series are characterized by trends representing non-stationarity.

RSS-NLG 2025 Conference Proceedings

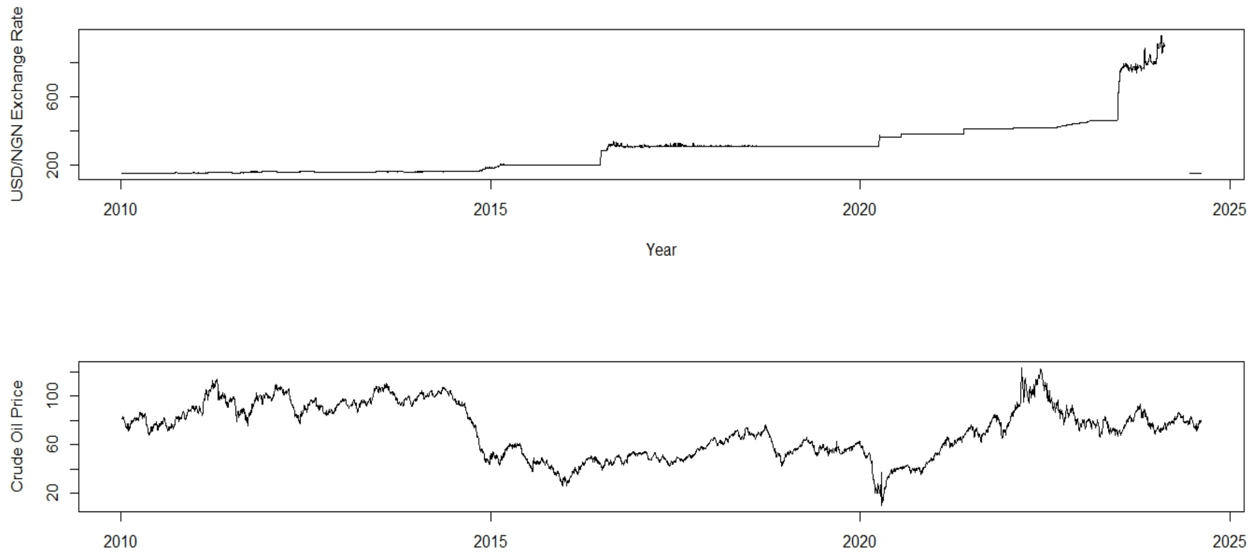

Figure 1: Time plot of USD/NGN exchange rate and crude oil price

After differencing both series once, the ADF test results showed stationarity, thereby necessitating further modelling. Figure 2 is the plot of the exchange rate and crude oil price differenced series.

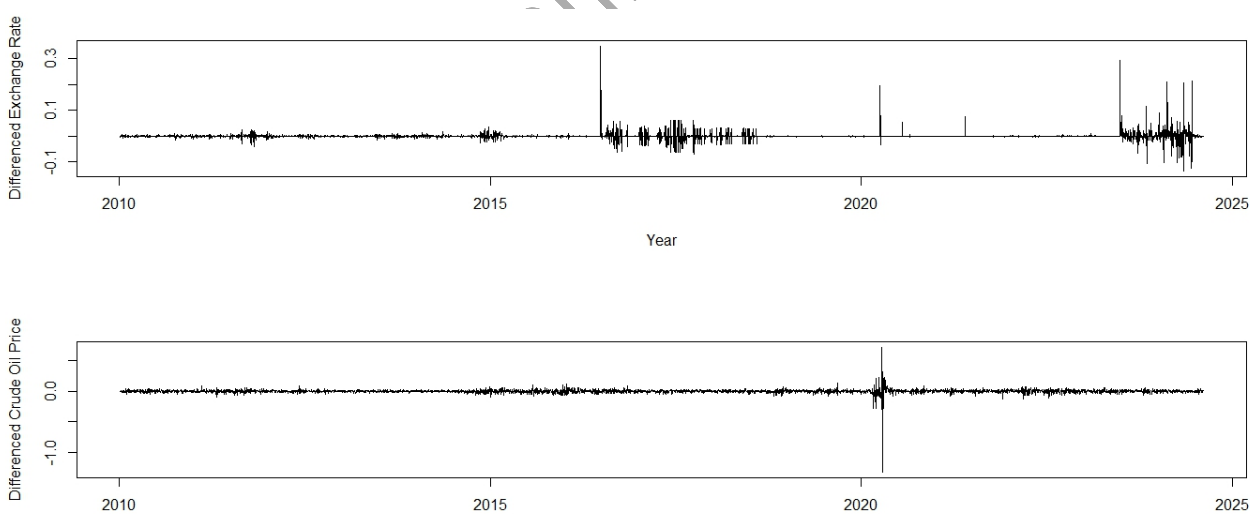

Figure 2: Differenced Time plot of USD/NGN exchange rate and crude oil price

3.2 Model Fitting

The ARIMAX models were fitted to the differenced USD/NGN exchange rate data using crude oil price changes as an exogenous variable. The output for each model resulting from the determination of the order of AR and MA from the autocorrelation and partial autocorrelation functions are presented in Table 1.

Table 1: Estimates of fitted models

Model	**Parameter**	**Estimates**	**Standard Error**	**AIC**	**AICc**	**BIC**
ARIMAX (1,1,0)	*Constant*	6.00E-04	2.00E-04	-20908.84	-20908.83	-20883.91
	AR(1)	-0.1735	0.0165			
	Xreg	-0.0051	0.0072			
ARIMAX (0,1,1)	*Constant*	6.00E-04	2.00E-04	-20897.62	-20897.61	-20872.69
	MA(1)	-0.1554	0.0154			
	Xreg	-0.0056	0.0072			
ARIMAX (1,1,1)	*Constant*	6.00E-04	2.00E-04	-20912.09	-20912.07	-20880.93
	AR(1)	-0.3559	0.0737			
	MA(1)	0.1864	0.0765			
	Xreg	-0.0056	0.0071			

The ARIMAX(1,1,0) model shows a negative *AR*(1) coefficient of -0.1735, suggesting a slight negative relationship between past exchange rate values and the current exchange rate. The exogenous variable's coefficient is also negative, indicating that crude oil price shocks have a small, negative impact on the exchange rate.

The ARIMAX(0,1,1) model presents a negative MA(1) coefficient of -0.1554, indicating that past errors negatively influence the current exchange rate. Similar to the previous model, the coefficient for the exogenous variable is slightly negative, reinforcing the idea that crude oil price fluctuations have a minor adverse effect.

The ARIMAX(1,1,1) model provides a more complex representation, with an AR(1) coefficient of -0.3559 indicating a stronger negative relationship with past values. The positive MA(1) coefficient of 0.1864 suggests that past errors can lead to an increase in the current exchange rate, indicating potential overreactions to past shocks. The *Xreg* coefficient is slightly negative, consistent with the previous models.

RSS-NLG 2025 Conference Proceedings

Based on the Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) values presented in Table 1, the ARIMAX (1,1,1) model is identified as the best-fitting model for the data. It not only has the lowest AIC and BIC values but also captures the dynamics of the exchange rate more effectively with both AR and MA components. This model suggests that both past exchange rate values and past errors significantly influence the current exchange rate, with crude oil price shocks continuing to have a minor negative impact.

3.3 Diagnostic Checks

Diagnostic checks were conducted on the residuals of the best-fitting model (ARIMAX (1,1,1)) to verify the model's adequacy. The Ljung-Box test statistic yielded a *p*-value of 0.0001174, indicating that there is no autocorrelation left in the residuals, which suggests an improved model and a good fit.

3.4 Forecasting

Using the selected ARIMAX (1,1,1), USD/NGN exchange rate forecasts were generated for market days in the month of June 2024 using crude oil price as the exogenous regressor. The point forecasts and confidence intervals are provided in Table 2.

Table 2: Point and interval forecasts for USD/NGN exchange rate

			95% C.I.	
Date	**Actual Rate**	**Point Forecast**	**Lower**	**Upper**
3/6/2024	1482.00	1425.29	1384.13	1467.68
4/6/2024	1500.00	1522.43	1477.84	1568.37
5/6/2024	1500.00	1493.25	1449.44	1538.39
6/6/2024	1500.00	1503.42	1459.30	1548.88
7/6/2024	1450.00	1449.94	1407.39	1493.78
10/6/2024	1510.00	1511.00	1466.66	1556.68
11/6/2024	1525.00	1525.77	1480.99	1571.90
12/6/2024	1525.00	1525.89	1481.11	1572.02
13/06/2024	1525.00	1525.88	1481.10	1572.02

RSS-NLG 2025 Conference Proceedings

14/06/2024	1505.00	1505.92	1461.73	1551.45
17/06/2024	1481.64	1482.32	1438.82	1527.14
18/06/2024	1495.00	1495.76	1451.87	1540.99
19/06/2024	1495.00	1495.99	1452.09	1541.22
20/06/2024	1495.00	1495.73	1451.83	1540.95
21/06/2024	1515.00	1516.05	1471.56	1561.89
24/06/2024	1515.00	1515.81	1471.32	1561.64
25/06/2024	1525.00	1525.99	1481.21	1572.13
26/06/2024	1525.00	1525.90	1481.12	1572.04
27/06/2024	1525.00	1525.82	1481.04	1571.95
28/06/2024	1525.00	1525.93	1481.15	1572.07

The forecasts indicate a true reflection of USD/NGN exchange rate for the period which the forecasts have been obtained.

3.5 Discussion

The results confirm that crude oil price shocks have a measurable, albeit small, negative effect on the USD/NGN exchange rate. This aligns with existing literature emphasizing the vulnerability of oil-dependent economies to external price shocks. The ARIMAX (1,1,1) model's AR(1) coefficient of -0.3559 highlights the stronger negative influence of past exchange rate values, while the positive MA(1) coefficient of 0.1864 suggests that past errors can drive short-term overreactions in exchange rate movements. The slightly negative coefficient of the exogenous variable reinforces the idea that crude oil price fluctuations modestly affect the exchange rate. Diagnostic checks, including the Ljung-Box test, confirmed the adequacy of the model, with no residual autocorrelation, further supporting its reliability.

These findings align with existing literature, underscoring the vulnerability of oil-dependent economies like Nigeria to external price shocks. However, the small magnitude of the crude oil price coefficient suggests that while oil price movements contribute to exchange rate

RSS-NLG 2025 Conference Proceedings

fluctuations, additional factors such as inflation, foreign reserves, and fiscal policy play a more significant role.

4. CONCLUSION

This study demonstrates the utility of ARIMAX models in understanding the relationship between crude oil prices and exchange rate movements. While crude oil price shocks significantly influence the USD/NGN exchange rate, the small coefficient highlights the role of other macroeconomic factors. The findings underscore the need for economic diversification to reduce Nigeria's dependence on oil revenue. Policies promoting industrialization, agriculture, and technology sectors can help mitigate the effects of oil price volatility on the exchange rate.

Additionally, the Central Bank of Nigeria (CBN) should implement flexible exchange rate mechanisms to absorb external shocks while maintaining adequate foreign reserves. Fiscal discipline and targeted interventions, such as subsidized foreign exchange for essential imports, can further stabilize the currency.

RSS-NG 2025 Conference Proceedings

REFERENCES

Akpan, E. O. (2008). Oil price shocks and Nigeria's macroeconomy. *Journal of Economic Analysis*, 45(3), 45-68.

Alimi, R. S. & Fatukasi, B. (2014). The role of oil prices and real exchange rate on the output growth in Nigeria. *International Journal of Financial Economics*, 3(2), 70-79.

Bashar, O. K. M. R. & Kabir, S. H. (2013). Relationship between Commodity Prices and Exchange Rate in Light of Global Financial Crisis: Evidence from Australia. *International Journal of Trade, Economics and Finance*, 4(5), 265-269.

Farzanegan, M. & Markwardt, G. (2007). The effects of oil price shocks on the Iranian economy, faculty of business. Germany: Dreden University of Technology, D-01062, Dresden

Ghosh, S. (2011). Examining crude oil price–Exchange rate nexus for India during the period of extreme oil price volatility. *Applied Energy*, 88(5), 1886-1889

Mordi, C. N. & Adebiyi, M. A. (2010). The asymmetric effects of oil price shocks on output and prices in Nigeria using a structural VAR model. *Economic and Financial Review*, 48(1), 1-32.

Narayan, P. K. & Narayan, S. (2007). Modelling oil price volatility. *Energy Economics*, 29(1), 18-27.

Nasir N. I., Sa'ad S., Sanusi A. R. & Usman A. B. (2023). Accounting for the Effects of Oil Prices on Exchange Rate in Nigeria: Empirical Evidence from Linear and Non-Linear ARDL Models. *European Scientific Journal*, 19 (16), 284-307. https://doi.org/10.19044/esj.2023.v19n16p284

Obioma, B. K. & Eke, C. N. (2015). An Empirical Analysis of Crude Oil Price, Consumer Price Level and Exchange Rate Interaction in Nigeria: A Vector Autoregressive (VAR) Approach. *American Journal of Economics*, 5(3), 385-393.

Sahbaz, A., Adıguzel, U., Bayat, T. & Kayhan, S. (2014). Relationship between oil prices and exchange rates: the case of Romania. *Economic Computation and Economic Cybernetics Studies and Research/Academy of Economic Studies*, 48(2), 245-256.

Sasu, D. D. (2024, November 5). Oil industry in Nigeria - statistics & facts. https://www.statista.com/topics/6914/oil-industry-in-nigeria/#topicOverview

Turhan, I., Hacihasanoglu, E., & Soytas, U. (2012). Oil prices and emerging market exchange rates. *Central Bank of the Republic of Turkey WP*, 12(01).

Zivot, E., & Wang, J. (2006). *Modeling financial time series with S-Plus*. Springer.

RSS-NLG 2025 Conference Proceedings