Dynamic Interactions between Exchange rate Volatility and Inflation Volatility in Nigeria: A VARX Analysis.

Abstract:

Exchange rate instability is frequently identified as an important source of inflationary pressure in Nigeria; however, whether exchange rate uncertainty translates into inflation uncertainty remains less clear. This study examines the dynamic relationship between exchange rate volatility and inflation volatility in Nigeria using monthly data from 2004 to 2024. Volatility is measured using the three-month rolling standard deviation of monthly changes in the underlying macroeconomic variables. A Vector Autoregression with Exogenous Variables (VARX) framework is employed, incorporating money supply, foreign reserves, and interest rate volatility as endogenous variables, while oil-price volatility is treated as exogenous. Granger causality tests, impulse response functions, and forecast error variance decomposition are used to evaluate volatility transmission. The results provide little evidence of significant dynamic interaction between exchange rate volatility and inflation volatility. Granger causality is insignificant in both directions, while impulse responses are small, transitory, and statistically insignificant. Forecast error variance decomposition further shows that exchange rate volatility accounts for only a small proportion of fluctuations in inflation volatility, which is predominantly explained by its own innovations. These findings suggest that although exchange rate movements may influence the level of inflation in Nigeria, exchange rate volatility itself is not a major source of inflation volatility over the period examined.

Keywords: *Exchange Rate Volatility, Inflation Volatility, VARX, Nigeria.*

1.0 Introduction:

In recent years, achieving macroeconomic stability has become increasingly difficult for many emerging economies, especially in the face of persistent internal and external shocks (Ndume & Akanegbu, 2025). Among the key sources of this instability are exchange rate volatility and inflation volatility, both of which play an important role in shaping economic outcomes. In Nigeria, these are not just abstract economic concepts; they are realities that affect everyday life, from the cost of food to the price of transportation and housing (Ogundipe et al., 2013).

A common experience in Nigeria clearly illustrates this relationship. When the Naira depreciates, prices of goods and services, especially imported goods, often increase almost immediately. However, when the Naira appreciates, prices rarely fall at the same speed, and in many cases, they do not fall at all. This asymmetry reflects what is commonly referred to as price stickiness, and it raises important questions about how exchange rate movements are transmitted into domestic prices. It also suggests that the relationship between exchange rate changes and inflation is not only strong but may behave differently depending on the direction and stability of those changes.

Nigeria's economic structure further amplifies this challenge. As a mono-product economy heavily dependent on crude oil exports, which account for over 95% of foreign exchange earnings and a large share of government revenue, the country remains highly exposed to external shocks. Changes in global oil prices, capital flows, and external demand are quickly transmitted into the foreign exchange market, resulting in frequent and sometimes severe fluctuations in the value of the Naira. These fluctuations, in turn, affect domestic prices through the exchange rate pass-through mechanism, although the extent and consistency of this transmission remain uncertain in a highly volatile environment.

Over time, Nigeria has experimented with different exchange rate regimes, ranging from fixed systems to more flexible arrangements following the Structural Adjustment Programme (SAP) (Olaiye et al., 2024). As of today, Nigeria operates under a floating exchange rate system, where the value of the Naira is largely determined by market forces. While this system is expected to improve efficiency and reflect economic fundamentals, it has also been associated with increased exchange rate volatility, which continues to pose significant challenges for price stability and economic planning.

Recent global shocks, including the COVID-19 pandemic and the Russia-Ukraine conflict, have further intensified these pressures by disrupting global supply chains and increasing commodity prices (IMF, 2022). In response, the Central Bank of Nigeria has adopted a tight monetary policy stance, raising interest rates in an effort to control inflation and stabilize the currency. However, these policy actions often involve difficult trade-offs, as measures aimed at stabilizing the exchange rate may have unintended consequences for inflation and overall economic activity (Ndume & Akanegbu, 2025).

While a substantial body of literature has examined the relationship between exchange rates and inflation, much of the focus has been on price levels rather than volatility. However, in a highly uncertain environment like Nigeria, volatility itself becomes important. Exchange rate instability may lead to unstable inflation through frequent price adjustments, or it may reduce responsiveness if firms choose to delay price changes due to uncertainty. This creates an important empirical question: does exchange rate volatility translate into inflation volatility?

Despite extensive research on Nigeria's macroeconomic dynamics, there is still no clear consensus on how these variables interact, particularly in a dynamic setting (Bawa et al., 2016). Many existing studies rely on single-equation models such as Ordinary Least Squares (OLS) or Autoregressive Distributed Lag (ARDL) approaches, which may not fully capture the feedback effects and dynamic interactions between variables (Ndume & Akanegbu, 2025).

This study addresses these gaps by employing a Vector Autoregression with Exogenous Variables (VARX) framework to examine the dynamic interactions between exchange rate volatility and inflation volatility in Nigeria. The VARX approach is particularly suitable as the framework allows the domestic variables to interact endogenously while accounting for the influence of exogenous oil-price volatility. By utilizing impulse response functions and forecast error variance decomposition, the study provides a comprehensive understanding of both the short-run dynamics and the relative importance of these volatilities. In addition, the study contributes to the literature by incorporating recent data extending up to 2024, thereby capturing current macroeconomic realities and recent policy developments.

By integrating real-world observations, such as the asymmetric response of prices to exchange rate movements, into a formal empirical framework, this study offers a more grounded understanding of macroeconomic transmission mechanisms in Nigeria. The findings are expected to provide useful insights for policymakers seeking to manage exchange rate instability and achieve more stable inflation outcomes.

2.0 Literature Review:

The relationship between exchange rate movements and price stability represents a central theme in Nigerian macroeconomic discourse, especially as the nation grapples with the fallout of oil price shocks and domestic policy shifts. While extensive research has addressed the correlation between the levels of these variables, a more complex narrative emerges when examining the dynamic interactions between their volatilities. This literature review synthesizes the theoretical underpinnings and empirical findings regarding exchange rate and inflation volatility, specifically within the Nigerian context.

2.1. Theoretical Foundations: Pass-Through and Price Stickiness

The theoretical nexus between exchange rates and inflation is often viewed through the lens of Exchange Rate Pass-Through (ERPT), which describes the extent to which fluctuations in the value of a currency are reflected in domestic prices (Ndume & Akanegbu, 2025). In an import-dependent economy like Nigeria, this transmission is typically immediate and significant, as the cost of imported raw materials and finished goods rises following a naira depreciation (Bello & Sanusi, 2019)

Central to this interaction is the concept of price stickiness, particularly within the New Keynesian Phillips Curve (NKPC) framework. This theory posits that prices do not adjust instantaneously to shocks due to nominal rigidities and staggered contracts (Bekiros et al. 2017). In Nigeria, this stickiness is often asymmetric; empirical evidence suggests that domestic prices respond more aggressively to naira depreciations (negative shocks) than to appreciations (positive shocks) (Nwosa, 2023). This asymmetry is frequently driven by market expectations and speculative behavior, where economic agents anticipate further currency weakness and adjust prices upward to hedge against future losses (Bello & Sanusi, 2019). Furthermore, the "fear of floating" hypothesis suggests that Nigerian monetary authorities often intervene to limit exchange rate volatility to avoid these persistent inflationary consequences (Calvo & Reinhart, 2002). Though, Nigeria has overcome the “fear” by adopting a floating exchange rate regime.

2.2. Empirical Evidence on the Exchange Rate-Inflation Relationship

The empirical literature on Nigeria reveals a long-standing debate between monetarist and structuralist perspectives on inflation. One school of thought emphasizes that inflation is primarily a monetary phenomenon driven by excessive growth in the money supply (Mohammed et al, 2025). Conversely, structuralists argue that supply-side constraints, such as infrastructure deficits and agricultural bottlenecks, are the dominant drivers (Ibrahim & Aminu, 2020).

Despite these differing views, there is a broad consensus that the exchange rate plays a pivotal role. Studies utilizing Autoregressive Distributed Lag (ARDL) and Error Correction Models (ECM) have consistently found a significant long-run relationship where currency depreciation fuels inflation (Olaiye et al, 2024). For instance, recent research highlights that the 2023 exchange rate unification and fuel subsidy removal have introduced unprecedented inflationary pressures, as the naira's value plummeted (Ayenigba et al, 2025).

2.3. Macroeconomic Volatility and Dynamic Interactions

A shift in the literature has moved the focus from price levels to volatility dynamics. Volatility represents uncertainty, which researchers argue is often more damaging than predictable changes in levels (Obode & Gini, 2025). In Nigeria, exchange rate volatility has been identified as a major source of macroeconomic instability, accounting for a considerable share of inflation variance in the medium term (Ndume & Akanegbu, 2025).

Recent studies employing GARCH-family models (such as TGARCH and EGARCH) have demonstrated that both exchange rate and inflation volatility are highly persistent (Obode & Gini, 2025). This means that once instability begins, it tends to endure, creating a cycle of uncertainty that complicates monetary policy (Obode & Gini, 2025). Furthermore, there is evidence of bidirectional causality; while exchange rate shocks exert an immediate impact on prices, high inflation can also undermine exchange rate stability by eroding the purchasing power of the naira and discouraging foreign investment (Mohammed et al, 2025).

2.4. Methodological Evolution and the VARX Approach

The methodological literature has evolved from static estimation techniques such as Ordinary Least Squares (OLS) toward dynamic time-series frameworks capable of capturing interactions among macroeconomic variables (Shaibu & Osamwonyi, 2020). Although models such as the Autoregressive Distributed Lag (ARDL) approach are useful for examining short-run and long-run relationships, they are less suited to a research objective centered on dynamic interactions and feedback among multiple volatility measures (Ndume & Akanegbu, 2025).

The Vector Autoregression (VAR) framework provides a useful approach for examining such dynamic interrelationships because it allows variables within the system to respond to their own past values as well as the past values of other variables. In the present study, this framework is extended to a Vector Autoregression with Exogenous Variables (VARX) model, allowing the domestic volatility measures to be treated as endogenous while oil price volatility is incorporated as an exogenous influence. This specification recognizes that international oil price movements are largely determined outside the Nigerian economy while still allowing their potential effects on domestic macroeconomic volatility to be accounted for.

The VARX framework also facilitates the use of Granger causality tests, Impulse Response Functions (IRFs), and Forecast Error Variance Decomposition (FEVD). These tools make it possible to examine predictive relationships, trace the responses of variables to unexpected shocks, and determine the relative importance of different shocks in explaining fluctuations over time. The approach is therefore particularly suitable for assessing the direction, magnitude, and persistence of volatility interactions within Nigeria's macroeconomic environment.

2.5. Research Gap and Motivation

Despite the richness of the existing literature, a significant research gap remains. First, the vast majority of studies focus on the levels of exchange rates and inflation rather than the dynamic interactions between their volatilities (Oyadeyi O. O. 2026). Second, there is a lack of consensus on the direction and persistence of these volatility interactions, with some studies suggesting that domestic structural bottlenecks are more important than currency shocks (Ibrahim & Aminu, 2020). Third, many existing analyses rely on data that precedes the massive structural shifts of 2023 and 2024, such as the full liberalization of the foreign exchange market (Mohammed et al, 2025)

This study addresses these gaps by focusing specifically on the dynamic interactions between exchange rate volatility and inflation volatility rather than movements in their levels. It employs a Vector Autoregression with Exogenous Variables (VARX) framework, in which inflation, exchange rate, money supply, foreign reserves, and interest rate volatility are modeled as endogenous variables, while oil price volatility is treated as exogenous to the Nigerian economy. Using monthly data through 2024, the study captures recent episodes of heightened macroeconomic instability and provides contemporary evidence on the nature and extent of volatility transmission within the Nigerian economy.

3.0 Research Methodology

3.1 Research Design and Empirical Framework

This study adopts a multivariate time-series econometric approach to examine the dynamic relationship between exchange rate volatility and inflation volatility in Nigeria. Specifically, it investigates whether exchange rate instability translates into instability in domestic prices.

To achieve this objective, the study employs a Vector Autoregression with Exogenous Variables (VARX) model, which allows the endogenous variables to be jointly determined while accounting for the influence of an external variable. The VARX framework is appropriate because it captures the dynamic interdependencies among inflation volatility, exchange rate volatility, money supply volatility, foreign reserve volatility, and interest rate volatility, while treating oil price volatility as exogenous. This specification allows the domestic variables to interact dynamically without imposing restrictive a priori assumptions about the direction of their relationships, while recognizing that global oil price movements are largely determined outside the Nigerian economy.

3.2 Data Sources and Variable Description

The study utilizes monthly time-series data spanning January 2004 to December 2024, sourced from the Central Bank of Nigeria Statistical Bulletin and the National Bureau of Statistics Nigeria.

The variables employed in the analysis include: Consumer Price Index (CPI) which proxied for the general price level, Exchange Rate (Naira per US dollar), Money Market Rate which proxied for interest rate, Money Supply (M2)**,** External Reserves and Oil Prices (Brent Crude).

3.3 Data Transformation and Construction of Volatility Measures

To capture the degree of uncertainty and fluctuations in the macroeconomic variables, this study measures volatility using the three-month rolling standard deviation of monthly changes in each variable. For the consumer price index (CPI), exchange rate, money supply, foreign reserves, and international crude oil prices, monthly changes are calculated as the first difference of their natural logarithms. This transformation expresses changes in proportional terms, reduces differences in scale across the variables, and facilitates comparison of their fluctuations over time. Inflation is specifically derived as the monthly log change in the CPI. The interest rate, however, is not logarithmically transformed because it is already expressed as a percentage rate; its monthly change is therefore calculated using the first difference in percentage points.

Volatility is subsequently calculated as the rolling standard deviation of these monthly changes over a three-month moving window. For each month, the volatility measure is based on the monthly change in the current month together with the changes observed in the preceding two months. The resulting measure therefore varies over time, with higher values indicating greater instability in the underlying macroeconomic variable and lower values indicating relatively more stable conditions.

The three-month rolling window is adopted because the study is primarily concerned with short-run volatility dynamics. Compared with a longer rolling window, it allows the volatility measure to respond more quickly to changes in macroeconomic conditions while still using multiple observations to distinguish sustained variability from a single monthly movement. In particular, a twelve-month rolling window produces substantial overlap between consecutive observations, as adjacent windows share eleven of the same twelve monthly changes. Such overlap can generate excessive smoothing and persistence in the resulting volatility series and may obscure short-run fluctuations. The three-month window therefore provides a balance between capturing short-run changes and reducing the influence of isolated monthly movements.

Standard deviation is used rather than variance because it expresses volatility in the same units as the underlying monthly changes, making the magnitude of fluctuations more readily interpretable. It also avoids the squared units associated with variance and the additional amplification of extreme observations that results from squaring deviations. The resulting volatility measures for inflation, exchange rate, money supply, foreign reserves, and interest rates are incorporated as endogenous variables in the VARX model, while oil-price volatility is treated as an exogenous variable to account for external volatility originating outside the Nigerian economy. The volatility measure employed in this study is formally expressed as follows:

$$\sigma_t = \sqrt{\frac{1}{2} \sum_{i=0}^{2} (r_{t-i} - \bar{r}_t)^2}$$

Where σ_t is volatility at time t, r_{t-i} is monthly change of the variable, $\bar{r}_t$ is mean of the monthly changes over the 3-month rolling window, and 2 is the degrees-of-freedom adjustment $(n-1)$ for a 3-month window.

For the variables that were log-transformed (exchange rate, CPI, money supply, foreign reserves, and oil prices), the monthly change is computed as:

$$r_t = \ln(X_t) - \ln(X_{t-1})$$

where X_t denotes the value of the macroeconomic variable in month t.

For the interest rate, which was not log-transformed, the monthly change is computed as:

$$r_t = IR_t - IR_{t-1}$$

where IR_t is the interest rate in month t.

3.4 Model Specification

The study specifies Vector Autoregression with Exogenous Variables (VARX) model of order p as follows:

$$Y_t = A_0 + \sum_{i=1}^{p} A_i Y_{t-i} + BX_t + \varepsilon_t$$

where: Y_t is a vector of endogenous variables comprising inflation volatility, exchange rate volatility, money supply volatility, foreign reserve volatility, and interest rate volatility. X_t represents the exogenous variable, oil price volatility. A_0 is a vector of intercept terms, A_i represents the matrices of coefficients associated with the lagged endogenous variables, B is the vector of coefficients associated with the exogenous variable, p denotes the optimal lag length, and ε_t is a vector of error terms.

Oil price volatility is treated as exogenous because international crude oil prices are largely determined by global market conditions and are unlikely to be significantly influenced by movements in Nigeria's domestic macroeconomic variables. The VARX specification therefore allows the domestic volatility measures to interact dynamically while controlling for the potential influence of external oil price volatility.

3.5 Model Justification and Comparison with Alternative Approaches

The choice of the Vector Autoregression with Exogenous Variables (VARX) framework is motivated by the study’s objective of examining the dynamic interrelationships among domestic macroeconomic volatility measures, with particular emphasis on the interaction between exchange rate volatility and inflation volatility, while accounting for the influence of exogenous oil price volatility

VARX versus ARDL:

The Autoregressive Distributed Lag (ARDL) model is commonly used to examine short-run and long-run relationships, particularly when variables exhibit different orders of integration. However, the ARDL framework typically requires the specification of a particular dependent variable and is therefore less suited to the present study, which is concerned with dynamic interactions and feedback among multiple volatility measures.

In contrast, the VARX framework allows the endogenous variables to interact dynamically while also accounting for the influence of an external variable. This makes it more appropriate for examining volatility transmission and feedback effects, which are central to the objective of this study.

VARX versus GARCH-type Models:

Models in the Generalized Autoregressive Conditional Heteroskedasticity (GARCH) family are specifically designed to estimate time-varying conditional volatility and capture volatility clustering within a time series. Although these models are well suited for modeling the evolution and persistence of volatility, the primary objective of this study is not to model the conditional variance of individual variables. Rather, it seeks to examine the dynamic transmission and interaction of volatility across a broader macroeconomic system.

The VARX framework is therefore more appropriate for the present study because it allows the endogenous volatility measures to interact dynamically through their lagged relationships while simultaneously accounting for exogenous influences. This structure facilitates the analysis of volatility transmission, feedback effects, impulse responses, and forecast error variance decomposition, which are central to the objectives of the study.

Justification for the Chosen Approach:

Given the study's focus on dynamic interdependence, volatility transmission, and feedback effects, the VARX framework provides a more suitable empirical approach than ARDL or GARCH-type models. It allows the study to examine how shocks originating from one volatility measure are transmitted through the system and affect other variables over time, while also accounting for external influences through the inclusion of exogenous factors. Furthermore, the framework supports Granger causality analysis, impulse response functions, and forecast error variance decomposition, providing a comprehensive assessment of the direction, magnitude, and persistence of volatility interactions.

3.6 Stationarity Testing

To avoid spurious regression and ensure the suitability of the variables for VARX estimation, the time-series properties of all volatility series are examined using the Augmented Dickey-Fuller (ADF) test. Given the monthly frequency of the data, a maximum lag length of 12 is initially considered. Rather than imposing the same lag length on every variable, the appropriate lag for each series is determined using a general-to-specific procedure. The ADF test begins with 12 lags, after which the significance of the final lagged difference term is examined. Where the final lag is statistically insignificant, the lag length is progressively reduced until an appropriate specification is obtained. This procedure allows the lag structure of the ADF regression to reflect the individual dynamics of each volatility series.

The null hypothesis of the ADF test is that the series contains a unit root and is therefore non-stationary. Stationarity is established when the null hypothesis is rejected at conventional significance levels. Any volatility series found to be non-stationary in its initial form is first-differenced and subsequently retested for stationarity. Following differencing, the lag-selection procedure is repeated rather than automatically retaining the lag length selected for the series in levels, since differencing may alter the underlying serial correlation structure. Only stationary series are subsequently included in the VARX estimation.

3.7 Lag Length Selection

The optimal lag length for the VARX model is determined using the Akaike Information Criterion (AIC). Given the monthly frequency of the data, a maximum lag length of 12 is considered to allow for potentially important dynamics over a one-year period. The AIC evaluates alternative lag specifications by balancing model fit against model complexity, thereby reducing the risk of selecting an unnecessarily overparameterized model. The lag order associated with the lowest AIC value is selected for the final VARX specification. Based on this criterion, a lag length of five months is selected for the model.

3.8 Model Estimation and Stability Condition

The VARX model is estimated using the stationary volatility series and the optimal lag length identified by the AIC. The stability of the estimated model is subsequently assessed by examining the eigenvalues of the companion matrix. The VARX model satisfies the stability condition when the modulus of every eigenvalue lies strictly within the unit circle. This condition ensures that shocks to the system are temporary and that their effects diminish over time rather than producing explosive dynamics.

3.9 Post-Estimation Procedures

Following the estimation and stability assessment of the VARX model, a series of diagnostic and post-estimation procedures are conducted to evaluate the adequacy of the model and examine the dynamic relationships among the variables. First, the Lagrange Multiplier (LM) test for residual autocorrelation is conducted to determine whether serial correlation remains in the model residuals. The Jarque-Bera residual normality test is also performed to assess the distributional properties of the disturbances.

Following these diagnostic tests, Granger causality tests are employed to determine whether past values of one endogenous variable contain useful information for predicting another. Impulse Response Functions (IRFs) are then used to trace the direction, magnitude, and persistence of the response of the endogenous variables to unexpected shocks over time. Finally, Forecast Error Variance Decomposition (FEVD) is used to determine the proportion of the forecast-error variance of each endogenous variable attributable to its own innovations and to shocks originating from other variables in the system.

Because the orthogonalized IRFs and FEVD rely on Cholesky identification, an ordering-sensitivity check is also conducted by reversing the ordering of the two principal variables to assess whether the main findings are sensitive to the assumed contemporaneous ordering. Together, these procedures provide a comprehensive assessment of the predictive relationships, shock transmission, and dynamic interactions within the VARX system.

4.0 Result and Analysis

This section presents and discusses the empirical findings of the study. The analysis begins with the descriptive statistics, which provide an overview of the characteristics and variability of the volatility measures over the sample period. This is followed by the stationarity tests, lag length selection, VARX estimation, model stability, and residual diagnostic tests. The section then examines the dynamic relationships among the variables using Granger causality tests, impulse response functions, and forecast error variance decomposition. Finally, an ordering sensitivity analysis is conducted to assess the robustness of the results to alternative Cholesky ordering.

4.1 Descriptive Statistics:

Table 4.1 presents the descriptive statistics of the volatility measures used in the study over the sample period. Each volatility series contains 250 observations.

Table 4.1 Data Summary

Variable	Observations	Mean	Std. Dev.	Minimum	Maximum
Inflation Volatility	250	0.4840	0.627	0.0028	4.4826
Exchange Rate Volatility	250	1.8028	4.2438	0.0000	34.1632
Money Supply Volatility	250	5.9145	13.1769	0.0283	100.5717
Foreign Reserve Volatility	250	2.8138	2.2858	0.1735	16.0342
Interest Rate Volatility	250	0.2747	0.4801	0.0000	2.3094
Oil Price Volatility	250	8.5763	9.3897	0.3942	98.0751

Source: Computed using study data

The descriptive statistics reveal considerable differences in the magnitude and variability of the volatility measures. Inflation volatility recorded a mean of 0.4840 and a standard deviation of 0.6270, with values ranging from 0.0028 to 4.4826. Exchange rate volatility averaged 1.8028, but its relatively large standard deviation of 4.2438 and maximum value of 34.1632 indicate the occurrence of periods of substantial exchange rate instability during the sample period.

Money supply volatility recorded the highest variability among the domestic variables, with a mean of 5.9145, a standard deviation of 13.1769, and a maximum value of 100.5717. Foreign reserve volatility had a mean of 2.8138 and a standard deviation of 2.2858, while interest rate volatility exhibited comparatively lower fluctuations, with a mean of 0.2747 and a standard deviation of 0.4801. Oil price volatility, which enters the VARX model as an exogenous variable, recorded a mean of 8.5763 and a standard deviation of 9.3897, with a maximum value of 98.0751, indicating substantial episodes of volatility in the international oil market.

Overall, the statistics indicate that the volatility measures exhibit considerable variation over the study period, although the magnitude differs substantially across variables.

4.2 Stationarity Test Results:

Before estimating the VARX model, the stationarity properties of the volatility series were examined using the Augmented Dickey-Fuller (ADF) unit root test. Following the general-to-specific procedure described in the methodology, a maximum of 12 lags was initially considered for each series, with insignificant higher-order lagged difference terms progressively removed. Consequently, the final ADF lag length differs across variables according to their individual time-series properties.

The null hypothesis of the ADF test is that a series contains a unit root and is therefore non-stationary. The null hypothesis is rejected when the ADF test statistic is sufficiently negative relative to the relevant critical value or when the associated p-value is below the chosen significance level.

The ADF test results are presented in Table 4.2:

Table 4.2. Stationarity Test Results

Variable	ADF Lag	ADF Statistic	p-value	Decision	Order
Inflation Volatility	11	-1.963	0.3032	Non-Stationary	-
Δ Inflation Volatility	11	-8.824	0.0000	Stationary	I(0)
Exchange Rate Volatility	12	-2.996	0.0353	Stationary	I(0)
Money Supply Volatility	9	-3.820	0.0027	Stationary	I(0)
Foreign Reserve Volatility	3	-5.767	0.0000	Stationary	I(0)
Interest Rate Volatility	3	-4.922	0.0000	Stationary	I(0)
Oil Price Volatility	3	-5.541	0.0000	Stationary	I(0)

Source: stata using study data

Note: Δ denotes the first difference.

The results indicate that exchange rate volatility, money supply volatility, foreign reserve volatility, interest rate volatility, and oil price volatility are stationary in their original volatility forms, as the null hypothesis of a unit root is rejected at the 5 percent significance level. Inflation volatility is the only series for which the unit-root null cannot be rejected in level form, with an ADF statistic of -1.963 and a p-value of 0.3032.

Inflation volatility was therefore first-differenced and subjected to the ADF test again. The differenced series was found to be stationary, with an ADF statistic of approximately -8.824 and a p-value of 0.0000. Consequently, the stationary transformation of inflation volatility is used in the VARX model, while the remaining volatility measures enter the model in their stationary level forms.

4.3 Lag Length Selection

Following the stationarity tests, the appropriate lag length for the VARX model was determined using the Akaike Information Criterion (AIC). Given the monthly frequency of the data, a maximum lag length of 12 months was considered to allow sufficient flexibility in capturing the dynamic relationships among the variables. Oil price volatility was included as an exogenous variable during the lag-selection procedure to ensure consistency with the final VARX specification.

The lag-order selection results are presented in Table 4.3.

Table 4.3. Akaike-Information Criterion

Lag	AIC
0	20.58
1	18.0067
2	18.0731
3	17.8376
4	17.5342
5	17.4715*
6	17.4973
7	17.5631
8	17.6743
9	17.6803
10	17.7564
11	17.7023
12	17.7075

Source: stata using study data

Note: * indicates the optimal lag according to the Akaike Information Criterion.

The AIC reaches its minimum value of 17.4715 at lag 5, indicating that a five-month lag structure provides the preferred balance between model fit and complexity. Although other information criteria suggested shorter lag structures, the AIC was adopted as the primary lag-selection criterion because it was specified for model selection in this study. Consequently, the subsequent analysis is based on a VARX (5) model, implying that the current value of each endogenous variable is modeled as a function of five months of lagged information from the endogenous system, while controlling for oil price volatility as an exogenous variable

4.4 VARX Estimation and Stability Test:

Following the stationarity and lag-selection procedures, a VARX(5) model was estimated using the stationary volatility series. Inflation volatility entered the model in first-differenced form because the original volatility series was found to be non-stationary, while exchange rate, money supply, foreign reserve, and interest rate volatility entered in their stationary forms. Oil price volatility was included as an exogenous variable.

Before proceeding to the dynamic analysis, the stability of the estimated VARX model was examined using the eigenvalue stability condition. A VARX model is considered stable when the modulus of every eigenvalue associated with the endogenous system lies strictly inside the unit circle. The stability test showed that all eigenvalues had moduli below one, indicating that the estimated VARX(5) satisfies the stability condition.

The largest eigenvalue modulus was approximately 0.856, with the remaining eigenvalues also lying within the unit circle. The stability condition is therefore satisfied, indicating that the endogenous dynamics of the estimated system are non-explosive and that the effects of shocks dissipate over time. This result supports the use of the estimated model for subsequent Granger causality, impulse response, and forecast error variance decomposition analyses.

Table 4.4 VARX Stability Test

Stability Criterion	Result	Decision
Maximum eigenvalue modulus	0.856	Less than 1
All eigenvalues inside unit circle	Yes	Stability condition satisfied
Overall assessment	Stable	Proceed with dynamic analysis

Source: stata using study data

4.5 Residual Diagnostic Tests

Residual diagnostic tests were conducted to assess the adequacy of the estimated VARX(5) model. Specifically, the Lagrange Multiplier (LM) test was used to examine residual serial correlation, while the Jarque-Bera test was employed to assess residual normality.

4.5.1 Residual Autocorrelation Test

The LM test examines the null hypothesis that there is no residual autocorrelation at a given lag order. The test was conducted for up to 12 lags to determine whether the VARX model adequately captures the temporal dependence in the data.

Table 4.5 Lagrange Multiplier Test for Residual Autocorrelation

Lag	Chi-Square	p-value	Decision at 5%
1	28.7549	0.2743	No autocorrelation
2	29.5808	0.2404	No autocorrelation
3	28.2503	0.2965	No autocorrelation
4	26.1066	0.4019	No autocorrelation
5	25.2474	0.4486	No autocorrelation
6	41.2374	0.0217	Autocorrelation detected
7	27.3263	0.3398	No autocorrelation
8	36.8785	0.0593	No autocorrelation
9	25.6496	0.4265	No autocorrelation
10	29.1381	0.2582	No autocorrelation
11	25.3799	0.4413	No autocorrelation
12	15.0747	0.9396	No autocorrelation

Source: stata using study data

The LM results indicate that the null hypothesis of no residual autocorrelation cannot be rejected at the 5 percent significance level for 11 of the 12 lag orders examined. The exception occurs at lag 6, where the p-value of 0.0217 indicates evidence of residual autocorrelation. Thus, while the model appears to capture most of the serial dependence in the data, the isolated rejection at lag 6 indicates that some residual dependence remains at that particular lag. This limitation is acknowledged when interpreting the subsequent dynamic results.

4.5.2 Residual Normality Test

The normality of the VARX residuals was assessed using the Jarque-Bera test, supplemented by separate tests for skewness and kurtosis. The null hypothesis is that the residuals are normally distributed**.**

Table 4.6: Jarque-Bera Residual Normality Test

Equation	Chi-Square	df	p-value	Decision
Inflation Volatility	1922.438	2	0.0000	Reject normality
Exchange Rate Volatility	7780.891	2	0.0000	Reject normality
Money Supply Volatility	26000	2	0.0000	Reject normality
Foreign Reserve Volatility	113.174	2	0.0000	Reject normality
Interest Rate Volatility	855.593	2	0.0000	Reject normality
Joint Test	36000	10	0.0000	Reject normality

Source: stata using study data

The Jarque-Bera results strongly reject the null hypothesis of normally distributed residuals for each equation and for the system as a whole. The accompanying skewness and kurtosis tests similarly indicate substantial departures from normality, with the residual distributions exhibiting pronounced skewness and excess kurtosis.

The non-normality of the residuals is not entirely unexpected given that the model is constructed from macroeconomic volatility series, which may contain large and infrequent shocks associated with episodes of economic and financial instability. Nevertheless, the violation of residual normality should be recognized as a limitation, particularly when interpreting statistical inference based on normality assumptions.

Overall diagnostic assessment

Taken together, the diagnostic results indicate that the VARX(5) model is stable and largely free from residual autocorrelation, although an isolated autocorrelation problem is detected at lag 6. Residual normality, however, is strongly rejected. These findings warrant some caution in statistical inference but do not, by themselves, invalidate the estimated dynamic relationships. The subsequent Granger causality, impulse response, and variance decomposition results are therefore interpreted alongside these diagnostic limitations.

4.6 Granger Causality Results:

Following the diagnostic assessment of the VARX(5) model, Granger causality tests were conducted to examine the predictive relationships among the endogenous volatility measures. The test evaluates whether the lagged values of one variable provide statistically significant information for predicting another variable, conditional on the other variables included in the system. The null hypothesis is that the excluded variable does not Granger-cause the dependent variable.

Given the objective of this study, particular attention is given to the relationship between exchange rate volatility and inflation volatility. The relevant results are presented in Table 4.7.

Table 4.7 Granger Causality Results for the main variables

Null Hypothesis	Chi-square	df	p-value	Decision
Exchange Rate Volatility Does not Granger-cause Inflation rate volatility	1.9692	5	0.853	Fail to reject the Null
Inflation Rate Volatility Does not Granger-cause Exchange rate volatility	1.7818	5	0.878	Fail to reject the Null

Source: stata using study data

The results provide no evidence of Granger causality between exchange rate volatility and inflation volatility in either direction. For the effect of exchange rate volatility on inflation volatility, the test produces a chi-square statistic of 1.9692 and a p-value of 0.853. Since the p-value exceeds the 5 percent significance level, the null hypothesis that exchange rate volatility does not Granger-cause inflation volatility cannot be rejected. This indicates that past movements in exchange rate volatility do not provide statistically significant additional information for predicting changes in inflation volatility within the estimated VARX system.

Similarly, the reverse relationship is statistically insignificant. The test of whether inflation volatility Granger-causes exchange rate volatility produces a chi-square statistic of 1.7818 and a p-value of 0.878. The null hypothesis is therefore not rejected, indicating that past changes in inflation volatility do not significantly improve the prediction of exchange rate volatility.

Overall, the findings indicate an absence of statistically significant predictive causality in either direction between the two principal volatility measures. This suggests that, after accounting for their own lagged dynamics, the other endogenous variables, and exogenous oil price volatility, fluctuations in one of the two volatility measures do not provide significant predictive information about the other.

It is important, however, to distinguish this finding from the conventional relationship between exchange rate movements and inflation. The absence of Granger causality found here relates specifically to volatility transmission and should not be interpreted as evidence that changes in the exchange rate have no effect on the level or rate of inflation in Nigeria. The study examines whether exchange rate uncertainty translates into inflation uncertainty, which is distinct from the traditional exchange rate pass-through relationship.

Oil price volatility does not appear separately in the Granger causality table because it is specified as an exogenous variable in the VARX model rather than as part of the jointly endogenous system. Its influence is therefore controlled for in the estimation but is not included in the endogenous Granger causality tests.

This outcome may reflect underlying structural characteristics of the Nigerian economy, including price rigidities and policy interventions, which can dampen the immediate pass-through of exchange rate fluctuations into domestic price volatility. In addition, the degree of public trust in monetary policy may play a role in stabilizing inflation expectations, thereby weakening the responsiveness of inflation volatility to exchange rate shocks. Overall, these factors suggest a weak short-run linkage between the two volatility measures.

4.7 Impulse Response Analysis:

Impulse Response Functions (IRFs) were estimated to examine how inflation volatility and exchange rate volatility respond over time to unexpected shocks originating from each other. The responses were traced over a 12-month horizon, corresponding to one year given the monthly frequency of the data. The analysis uses orthogonalized impulse response functions based on the Cholesky decomposition, with 95 percent confidence intervals used to assess the statistical significance of the responses.

4.7.1 Response of Inflation Volatility to an Exchange Rate Volatility Shock

Figure 4.1: Response of Inflation Volatility to an Exchange Rate Volatility Shock

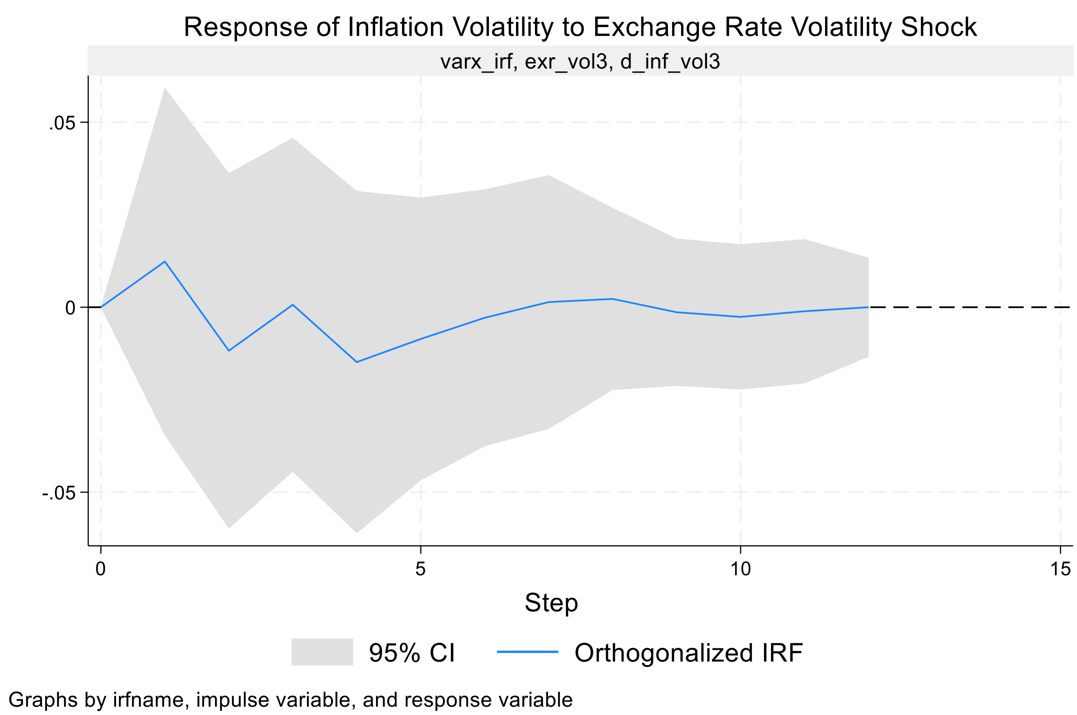

Figure 4.1 shows the response of inflation volatility to a positive shock in exchange rate volatility. The response is initially positive but relatively small. It subsequently becomes negative and fluctuates around zero over the following months before gradually dissipating toward the end of the forecast horizon. The pattern suggests that exchange rate volatility shocks generate only a small and temporary response in inflation volatility rather than a persistent effect.

More importantly, the 95 percent confidence interval contains zero throughout the entire 12-month horizon. The response is therefore not statistically significant at the 5 percent level at any point during the forecast period. This indicates that an unexpected increase in exchange rate volatility does not produce a statistically significant dynamic response in inflation volatility within the estimated VARX model.

4.7.2 Response of Exchange Rate Volatility to an Inflation Volatility Shock

Figure 4.2: Response of Exchange Rate Volatility to an Inflation Volatility Shock

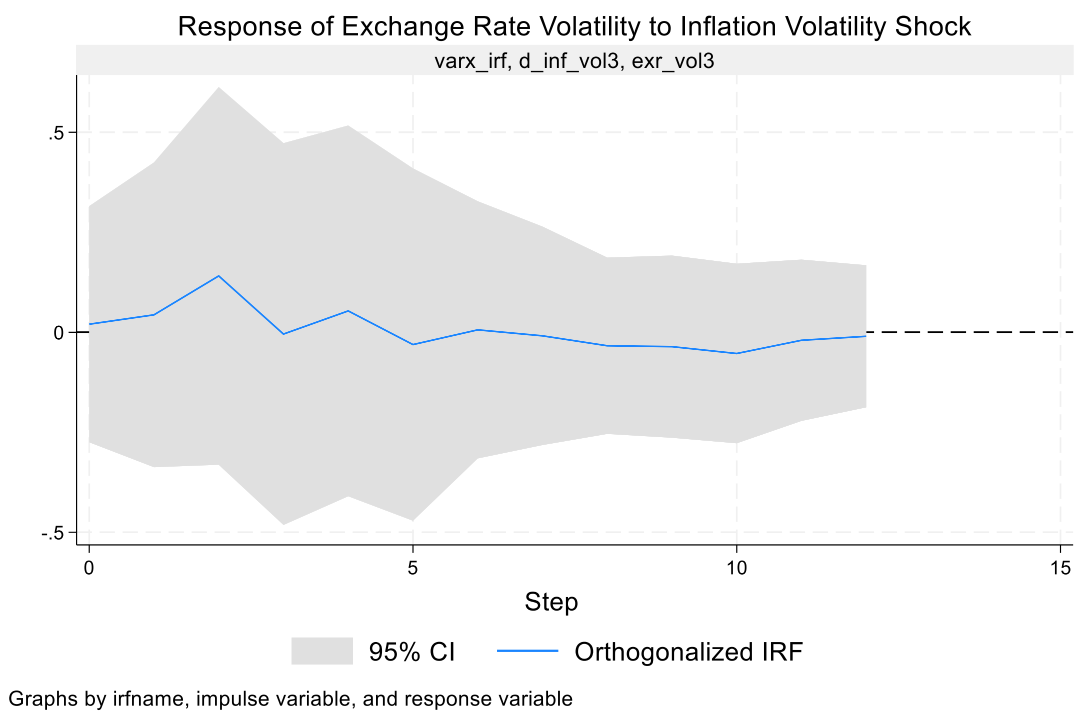

Figure 4.2 presents the response of exchange rate volatility to a positive shock in inflation volatility. Exchange rate volatility initially responds positively, with the response increasing slightly during the early months. Thereafter, the response declines and fluctuates around zero before gradually dissipating over the remainder of the forecast horizon.

As with the response in the opposite direction, the 95 percent confidence interval includes zero throughout the forecast horizon, indicating that the response is not statistically significant at the 5 percent level. Thus, an unexpected shock to inflation volatility does not generate a statistically significant or persistent response in exchange rate volatility.

Taken together, the impulse response results provide little evidence of a strong volatility transmission mechanism between exchange rate volatility and inflation volatility. Shocks originating from either variable generate relatively small and short-lived responses in the other, with neither response statistically distinguishable from zero over the 12-month horizon. These findings are consistent with the Granger causality results, which similarly indicate an absence of statistically significant predictive relationships between the two volatility measures.

It is important to emphasize that these findings relate specifically to volatility transmission. They do not imply that exchange rate movements have no effect on inflation in Nigeria. Rather, the results suggest that shocks to the uncertainty or instability of the exchange rate do not translate into statistically significant shocks to inflation uncertainty within the period and specification examined.

4.8 Forecast Error Variance Decomposition

Forecast Error Variance Decomposition (FEVD) was conducted to determine the relative importance of shocks from the endogenous variables in explaining fluctuations in inflation volatility over the forecast horizon. While the impulse response analysis shows the direction and persistence of responses to shocks, FEVD provides information on the proportion of forecast uncertainty attributable to each shock in the VARX system. Given the primary objective of the study, particular attention is paid to the contribution of exchange rate volatility to inflation volatility.

Table 4.8: Forecast Error Variance Decomposition of Inflation Volatility

Forecast Error Variance Decomposition

Step	Inflation Rate Volatility	Exchange Rate Volatility	Money Supply Volatility	Foreign Reserve Supply	Interest Rate Position
1	100%	0%	0%	0%	0%
2	97.61%	0.098%	0.17%	1.75%	0.37%
3	96.83%	0.18%	0.18%	2.31%	0.49%
4	96.10%	0.30%	0.40%	2.61%	0.73%
5	95.95%	0.30%	0.39%	2.62%	0.74%
6	95.53%	0.34%	0.42%	2.60%	1.11%
7	95.32%	0.34%	0.42%	2.78%	1.13%
8	95.23%	0.34%	0.47%	2.80%	1.17%

Analysis was performed using stata

The FEVD results show that fluctuations in inflation volatility are overwhelmingly explained by its own innovations. At the first-month horizon, inflation volatility's own shocks account for essentially 100 percent of its forecast-error variance. Although this contribution declines gradually as the forecast horizon increases, it remains approximately 95 percent after 8 months. This indicates that innovations within inflation volatility itself remain the dominant source of its forecast uncertainty throughout the period examined.

In contrast, the contribution of exchange rate volatility is very small. Exchange rate volatility accounts for approximately 0.10 percent of the forecast-error variance of inflation volatility after two months and increases only gradually to approximately 0.34 percent after 8 months. Thus, even over an eight-month horizon, exchange rate volatility explains less than one percent of the forecast uncertainty in inflation volatility.

Among the remaining endogenous variables, foreign reserve volatility makes the largest contribution to inflation volatility, accounting for approximately 2.8 percent of its forecast-error variance toward the end of the horizon. Interest rate volatility contributes approximately 1.2 percent, while money supply volatility accounts for approximately 0.5 percent. These contributions nevertheless remain substantially smaller than the contribution of inflation volatility's own innovations.

Overall, the FEVD results reinforce the findings from the Granger causality and impulse response analyses. Exchange rate volatility plays only a marginal role in explaining fluctuations in inflation volatility, while inflation volatility is predominantly driven by its own shocks. The consistency of these results across the different analytical procedures provides further evidence of a weak short-run volatility transmission from exchange rate instability to inflation instability in Nigeria.

4.9 Ordering Sensitivity and Robustness Check

Because the impulse response functions and forecast error variance decomposition rely on Cholesky identification, an ordering sensitivity check was conducted to determine whether the main findings were influenced by the ordering of the two principal variables. The baseline ordering placed inflation volatility before exchange rate volatility, while the alternative specification reversed this ordering.

The results remained essentially unchanged. Under the baseline ordering, exchange rate volatility accounted for approximately 0.349 percent of the forecast error variance of inflation volatility after 12 months, compared with 0.354 percent under the alternative ordering. Similarly, the impulse response of inflation volatility to an exchange rate volatility shock remained small, transitory, and statistically insignificant throughout the forecast horizon.

These results indicate that the main finding of a weak and statistically insignificant volatility relationship between exchange rate volatility and inflation volatility is robust to the alternative Cholesky ordering.

5.0 Conclusion and Policy Implications

This study set out to examine an important but less explored dimension of Nigeria's inflation problem: whether instability in the exchange rate translates into instability in inflation. This distinction is important because the fact that exchange rate depreciation can increase domestic prices does not necessarily imply that fluctuations in the exchange rate are the principal source of fluctuations in inflation. By focusing on volatility rather than the conventional relationship between exchange rate and inflation levels, the study provides a different perspective on Nigeria's inflation dynamics.

The central conclusion of the study is that exchange rate volatility is not a major driver of inflation volatility in Nigeria. Rather, fluctuations in inflation volatility appear to be predominantly explained by innovations originating within inflation volatility itself, suggesting that once inflation becomes unstable, the sources of that instability extend beyond contemporaneous fluctuations in the foreign exchange market. This finding is particularly relevant in the Nigerian context, where discussions of inflation frequently place considerable emphasis on the naira and movements in the foreign exchange market.

This does not diminish the importance of the exchange rate to the Nigerian economy. Exchange rate depreciation can increase the domestic cost of imported food, fuel, machinery, raw materials, and other intermediate inputs and may consequently affect the level of consumer prices. The important distinction emerging from this study is that exchange rate pass-through and volatility transmission are not the same phenomenon. Exchange rate movements may affect inflation without exchange rate volatility necessarily generating persistent inflation volatility.

The policy implication is therefore that attempts to achieve price stability should not rely excessively on exchange rate management. Interventions aimed at reducing disorderly movements in the foreign exchange market may contribute to broader macroeconomic stability, but they are unlikely, on their own, to resolve the underlying sources of inflation instability. Nigeria's inflation problem requires attention to the domestic conditions that cause price shocks to emerge and persist.

In particular, greater emphasis should be placed on improving the credibility and consistency of monetary policy, strengthening the anchoring of inflation expectations, and reducing uncertainty surrounding policy decisions. Frequent policy reversals or inconsistent communication can make it more difficult for households and businesses to form expectations about future prices. A credible and predictable monetary policy environment can therefore play an important role in limiting the persistence of inflationary shocks.

At the same time, monetary policy alone cannot address many of Nigeria's structural sources of inflation. Persistent constraints in electricity supply, agricultural production, transportation and logistics, insecurity, storage facilities, domestic manufacturing, and supply chains increase production and distribution costs and make prices more vulnerable to shocks. Policies that improve domestic productive capacity and remove these bottlenecks can therefore complement monetary policy in achieving more durable price stability.

Ultimately, the study suggests a broader way of thinking about inflation management in Nigeria. Stabilizing the naira should not be treated as synonymous with stabilizing inflation. Exchange rate stability remains important, but sustainable price stability requires policies that address the mechanisms through which inflationary shocks originate, spread, and persist within the domestic economy. The policy challenge is therefore not simply to prevent exchange rate fluctuations, but to build an economy that is sufficiently resilient that external and domestic shocks do not repeatedly translate into prolonged periods of inflation instability.

6.0 Limitations of the Study

Although this study provides useful evidence on the dynamic relationship between exchange rate volatility and inflation volatility in Nigeria, several limitations should be acknowledged.

First, volatility is measured using a three-month rolling standard deviation of monthly changes rather than a model-based conditional volatility measure such as GARCH. The three-month window was selected to capture relatively short-run fluctuations while avoiding the excessive smoothing and persistence associated with longer rolling windows. Nevertheless, rolling standard deviation is sensitive to the choice of window length, and alternative volatility measures or window specifications may produce somewhat different dynamics.

Second, the construction of rolling volatility measures creates overlapping observations, since consecutive three-month windows share two monthly observations. Although a shorter window substantially reduces the degree of overlap compared with a twelve-month rolling window, some persistence may still be introduced mechanically into the volatility series. This should be considered when interpreting the dynamic relationships estimated by the model.

Third, the study relies on monthly macroeconomic data from 2004 to 2024. While monthly data provide considerably more information on short-run dynamics than annual or quarterly observations, some important economic and policy developments occur at higher frequencies. Exchange rate conditions, financial market responses, and policy announcements can change within days or weeks and may not be fully captured by monthly observations. Conversely, monthly data may also conceal structural relationships that operate over much longer horizons.

Fourth, the estimated VARX model exhibits non-normal residuals, reflecting substantial skewness and excess kurtosis in the volatility series. Such behavior is not unusual for volatility data, particularly in an economy that has experienced large macroeconomic shocks. Nevertheless, the departure from normality represents a limitation for statistical inference. In addition, the residual autocorrelation test indicated an isolated rejection of the no-autocorrelation hypothesis at one lag, suggesting that some residual serial dependence may remain despite the overall adequacy of the model.

Fifth, the VARX framework captures dynamic statistical relationships but does not provide full structural identification of the underlying economic shocks. Consequently, the results should primarily be interpreted as evidence of dynamic and predictive relationships rather than definitive causal effects. Although the ordering sensitivity analysis indicates that the principal findings are robust to reversing the ordering of inflation and exchange rate volatility, alternative identification strategies could provide additional evidence.

Sixth, the model necessarily represents a simplified version of Nigeria's inflationary environment. Inflation volatility may also be influenced by factors that are difficult to capture consistently at monthly frequency, including fiscal operations, food supply disruptions, insecurity, energy and transportation costs, exchange rate market segmentation, administered prices, and changes in government policy. The exclusion of some of these factors is partly attributable to limitations in the availability and consistency of monthly data over the full sample period.

Finally, the period from 2004 to 2024 contains substantial structural and policy changes in the Nigerian economy, including changes in exchange rate management, monetary policy arrangements, global commodity market conditions, and major domestic and international shocks. The VARX model estimates average dynamic relationships across the full sample and therefore may not fully capture changes in the relationship between exchange rate volatility and inflation volatility across different policy regimes.

These limitations do not invalidate the findings of the study but define the context within which they should be interpreted. Future research could examine alternative volatility measures, different rolling-window lengths, structural VAR specifications, regime-dependent models, or subsample analyses to determine whether volatility transmission changes across different episodes of Nigeria's macroeconomic and exchange rate history.

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