

Macroeconomic Interactions in Nigeria: VECM-Based Analysis (2001-2023)

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Article Info:

Submitted:	Revised:	Accepted:	Published:
Jan 27, 2026	Mar 15, 2026	Apr 8, 2026	Apr 13, 2026

Abstract

Understanding the dynamic relationships among major macroeconomic variables is essential for evaluating economic stability and informing policy design in developing economies such as Nigeria. This study aimed to investigate the interrelationships among Gross Domestic Product (GDP), inflation, broad money supply (M2), interest rate, exchange rate, and unemployment in Nigeria over the period 2001–2023. Annual data were obtained from the Central Bank of Nigeria, World Bank, International Monetary Fund, and CEIC databases and analyzed using a Vector Error Correction Model (VECM) implemented in Python's *statsmodels* framework to capture both short-run adjustments and long-run equilibrium dynamics. The findings reveal the presence of three stable long-run cointegrating relationships among the variables. Inflation was found to respond strongly to changes in GDP, interest rates, and exchange-rate movements, whereas the effects of money supply and unemployment were relatively weaker. The results further indicate that economic growth contributes to modest reductions in unemployment, while persistent inflationary pressures and volatile interest rates tend to worsen labor-market outcomes. Exchange-rate

depreciation also emerged as a major source of macroeconomic instability. Diagnostic tests suggest that the estimated model is broadly robust, although mild indications of serial correlation and multicollinearity remain. The study concludes that Nigeria's macroeconomic environment is shaped by deep structural weaknesses that require stronger policy coordination, improved exchange-rate management, and sustained structural reforms to enhance price stability and employment outcomes. These findings contribute empirical evidence on long-run and short-run macroeconomic interactions in Nigeria and provide policy-relevant insights for strengthening economic management.

Keywords: Vector Error Correction Model; Cointegration; Inflation Dynamics; Exchange Rate; Nigerian Economy

INTRODUCTION

Inflation remains one of the most persistent macroeconomic challenges in Nigeria, with wide-ranging consequences for household welfare, investment decisions, employment conditions, and overall economic stability. Over the period from 2001 to 2023, inflation rates in Nigeria consistently remained high, often exceeding an annual average of 12 percent, despite sustained monetary policy efforts by the Central Bank of Nigeria aimed at stabilizing prices (World Bank, 2023; CBN, 2023). This prolonged inflationary pressure reflects deep structural weaknesses, recurring policy shocks, and limitations in the effectiveness of conventional stabilization tools.

Nigeria's inflation dynamics are shaped by a combination of domestic structural constraints and external shocks. Events such as the global financial crisis, repeated fluctuations in international oil prices, the COVID-19 pandemic, and recent exchange rate and fuel subsidy reforms have exerted renewed pressure on prices and heightened macroeconomic instability (IMF, 2022; NBS, 2022; World Bank, 2023). These shocks often interact with existing supply bottlenecks, heavy import dependence, and labor market rigidities, thereby reinforcing inflation persistence and constraining economic growth.

Economic theory suggests that inflation does not occur in isolation but is closely connected to developments in output, monetary conditions, interest rates, exchange rate movements, and labor market outcomes. Monetarist perspectives emphasize the role of excessive monetary expansion in driving sustained inflation (Jahan & Papageorgiou, 2014), while New Keynesian approaches highlight the importance of aggregate demand pressures,

supply constraints, expectations, and nominal rigidities (Clarida et al., 1999; Blanchard & Johnson, 2017, Galí, 2018). The Phillips Curve hypothesis posits a relationship between inflation and unemployment (Phillips, 1958; Samuelson & Solow, 1960), though empirical evidence suggests this relationship is often unstable in developing economies such as Nigeria.

Recent empirical studies on Nigeria provide mixed evidence on the determinants and consequences of inflation. Exchange-rate depreciation, monetary policy shocks, and inflation persistence have been identified as major drivers of price instability (Alege et al., 2020; Chuku et al., 2021; Akinlo & Lawal, 2021). Other studies emphasize the role of macroeconomic shocks and policy credibility in shaping inflation outcomes (Akinlo & Akinwale, 2022). Evidence on inflation and unemployment further suggests that inflationary episodes in Nigeria are frequently accompanied by weak employment performance, questioning the relevance of a stable Phillips Curve trade-off (Akinwale & Grobler, 2019).

Despite these contributions, much of the existing literature remains fragmented. Many studies rely on econometric approaches that fail to fully capture dynamic interactions and long-run equilibrium relationships among macroeconomic variables. Although threshold and exchange-rate-focused studies exist (Olubusoye et al., 2017; Olayungbo & Akinbobola, 2019), relatively few studies incorporate recent structural developments such as post-2020 exchange-rate reforms and pandemic-related shocks. These changes have altered transmission mechanisms linking inflation, output, monetary variables, and labour-market outcomes, creating the need for updated multivariate evidence.

In response to these gaps, the present study employs a Vector Error Correction Model to examine the interactions among inflation, gross domestic product, money supply, interest rate, exchange rate, and unemployment in Nigeria from 2001 to 2023. This framework allows for the analysis of both short-run dynamics and long-run equilibrium relationships among the selected variables. By adopting a multivariate approach and extending the sample period to include recent structural changes, this study provides a more comprehensive and policy-relevant understanding of Nigeria's macroeconomic dynamics.

METHODS

This study adopts a quantitative research approach, appropriate for analyzing numerical data using econometric techniques to test theoretical relationships and draw objective inferences. Quantitative approaches emphasize measurement, hypothesis testing,

and formal modeling, which are essential in macroeconomic analysis (Gujarati & Porter, 2009; Blanchard, 2022).

Research Design

The study employs a time-series research design to examine dynamic interactions among macroeconomic variables in Nigeria over the period 2001–2023. Time-series methods are widely applied in macroeconomic research due to their ability to capture temporal dependence and dynamic adjustments (Enders, 2015). Given the likelihood of long-run equilibrium relationships, the study applies a Vector Error Correction Model (VECM), which integrates short-run dynamics with long-run equilibrium relationships in a multivariate framework (Engle & Granger, 1987; Johansen, 1991).

The VECM framework is particularly suitable for analyzing inflation, output, monetary variables, and exchange-rate dynamics in developing and emerging economies (Lütkepohl, 2005; Enders, 2015).

Population and Sample

The population of the study comprises Nigeria's macroeconomic environment over the period 2001–2023. Given the time-series nature of the research, the sample consists of annual observations covering this entire period. The study focuses on key macroeconomic indicators that reflect Nigeria's growth, monetary conditions, price stability, and labour market performance.

Data Collection Instruments and Techniques

This study relies exclusively on secondary data obtained from reputable and internationally recognized sources. Annual data were collected from the Central Bank of Nigeria (CBN), the World Bank, the International Monetary Fund (IMF), and the CEIC database. The variables employed include real Gross Domestic Product (GDP), inflation rate (measured using the Consumer Price Index), broad money supply (M2), monetary policy rate, unemployment rate, and the nominal Naira–US dollar exchange rate. These sources ensure data reliability, consistency, and comparability over time.

Data Analysis

Data analysis was performed using Python's "statsmodels" package (Seabold & Perktold, 2010). To enhance comparability across variables and reduce the risk of heteroscedasticity, selected series were transformed into their natural logarithmic forms

where appropriate. The choice of variables is grounded in established macroeconomic theory, Nigeria's monetary and fiscal policy framework, and evidence from prior empirical studies. The transformed and untransformed series were subsequently subjected to econometric analysis to examine both short-run dynamics and long-run equilibrium relationships among the variables.

Model Specification and Estimation

The VECM framework separates system dynamics into short-run fluctuations and long-run equilibrium adjustments through an error-correction term. Short-run behavior is captured by lagged differenced variables, while the error-correction component reflects the speed at which deviations from long-run equilibrium are corrected. Estimation was performed using Python's statsmodels package (Seabold & Perktold, 2010).

Formally, the VECM can be expressed as:

$$\Delta y_t = \alpha \beta' y_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \Delta y_{t-i} + \varepsilon_t$$

Where:

- Y_t is an $n \times 1$ vector of endogenous variables (Inflation, GDP, Money Supply, Interest Rate, Exchange Rate, Unemployment).
- β represents the cointegration matrix defining long-run relationships.
- α is the adjustment matrix indicating the speed at which variables return to equilibrium.
- Γ_i captures short-run dynamics.
- ε_t is the error term.

The selection of these variables reflects their key roles in macroeconomic transmission mechanisms and aligns with prior empirical studies and official CBN policy frameworks. To further examine interrelationships, Granger causality tests, impulse-response functions, and forecast error variance decomposition were employed, providing insights into directional influences, variable responses to shocks, and the relative contribution of each variable within the system.

Pre-Estimation Procedures

Prior to model estimation, each time series was tested for stationarity using the Augmented Dickey–Fuller (ADF) and Phillips–Perron (PP) unit root tests (Dickey & Fuller,

1979). These tests were conducted at both levels and first differences to determine the order of integration of each variable. The optimal lag length for the multivariate system was selected based on multiple information criteria, including the Akaike's Information Criterion (AIC), Schwarz Bayesian Criterion (SBC), and Hannan–Quinn Criterion (HQC).

Cointegration was assessed using the Johansen methodology (Johansen & Juselius, 1990) to determine the presence and number of long-run equilibrium relationships among the variables. Evidence of cointegration provides justification for estimating a VECM rather than an unrestricted VAR.

RESULTS

Table 1. Descriptive Statistics of Macroeconomic Variables (2001 to 2023)

Variable	Mean	Std Dev	Min	Median	Max
GDP (Billion USD)	346.07	146.33	73.56	375.75	574.18
Inflation (%)	13.42	4.35	5.39	12.88	24.56
Interest Rate (%)	13.60	3.13	6.00	13.00	20.50
Money Supply (₦ Trillion)	17.91	15.98	1.32	14.40	62.00
Unemployment Rate (%)	4.08	0.68	3.07	3.77	5.71
Exchange Rate (₦/USD)	215.52	112.80	111.23	157.00	460.70

Table 1 presents descriptive statistics for the study period. GDP exhibited significant growth accompanied by notable volatility. Inflation remained above 13%, indicating persistent price pressures. Interest rates were relatively high, reflecting ongoing monetary-policy interventions. The rapid growth of money supply coincided with relatively low reported unemployment, possibly masking underemployment. Meanwhile, the exchange rate showed substantial

Pre-Estimation Tests

Table 2. Augmented Dickey-Fuller (ADF) Test for Stationarity

Variable	ADF Statistic	p-value	Stationary
GDP	-2.02	0.278	No
Inflation (CPI)	2.53	0.999	No
Exchange Rate	-4.66	0.0001	Yes
Interest Rate	-2.45	0.128	No
Unemployment	-0.27	0.930	No
Money Supply (M2)	1.32	0.997	No

Note: Null hypothesis = Presence of Unit Root. Critical value at 5%

Table 3. ADF Test at First Differences

Variable	ADF Statistic	p-value	Stationary	Order of Integration
GDP	-3.31	0.015	Yes	I(1)
Inflation	4.47	1.000	No	Non Stationary
Exchange Rate	-3.18	0.021	Yes	I(1)
Interest Rate	-1.84	0.363	No: Stationary at 2nd Difference	I(2)
Unemployment	-3.05	0.030	Yes	I(1)
Money Supply	2.65	0.999	No	Non Stationary

Results from the Augmented Dickey-Fuller and Phillips-Perron tests (Tables 2 and 3) suggest that most series are non-stationary at levels but attain stationarity after first differencing. Johansen's trace test (Table 4) identified three long-run cointegrating vectors, confirming the appropriateness of the VECM for analyzing both short-term and long-term dynamics.

Table 4: Johansen Cointegration Test Results (Trace Statistics)

Rank (r)	Trace Statistic	5% Critical Value	Cointegration
$r = 0$	249.46	95.75	Yes
$r \leq 1$	133.44	69.82	Yes
$r \leq 2$	69.41	47.85	Yes
$r \leq 3$	28.52	29.80	No
$r \leq 4$	8.45	15.49	No
$r \leq 5$	0.003	3.84	No

On Table 4 which reports Johansen's trace statistics confirm that three cointegrating vectors were identified at the 5 percent level, showing that GDP, inflation, exchange rate, interest rate, money supply, and unemployment share long-run equilibrium relationships.

Table 5. Selected VECM Short-Run Dynamics

Dependent Variable	Significant Drivers (lagged)	Effect	Interpretation
GDP	GDP(-1), Inflation (-1)	Negative	Past low growth and Inflation reduce current GDP.
Inflation	GDP(-1), Inflation(-1), Interest Rate (-1), Exchange Rate (-1)	Positive	Inflation persistence reinforced by Exchange Rate depreciation.
Interest Rate	Inflation(-1), Money Supply (-1)	Mixed	Tightens with Inflation, loosens with liquidity expansion.
Unemployment	GDP(-1), Inflation(-1), Interest Rate (-1),	Mixed	Growth lowers joblessness, Inflation and high rates worsen it.

Table 6. Long-Run Cointegration Relationships

Equation (Dependent)	Key Long-Run Influences	Direction
GDP	- Money Supply, -Exchange Rate, + Interest Rate	Mixed
Inflation	- Money Supply (dominant driver)	Negative
Interest Rate	+Inflation, + Money Supply, - Exchange Rate	Mixed

Source: VECM Estimates (2001-2023).

The short- and long-run VECM estimates (Tables 5 and 6) indicate that lagged values of GDP, interest rate, and exchange rate significantly impact inflation, demonstrating both persistence in price dynamics and sensitivity to currency movements. In contrast, GDP growth generally mitigates unemployment, whereas shocks from inflation and interest rates tend to exacerbate joblessness, reflecting stagflationary patterns.

Table 7. Summary of Diagnostic and Stability Tests

Test	Statistic/Value	p-value	Decision (5%)	Interpretation
Breusch-Godfrey LM (Serial Correlation)	LM=6.05	0.049	Reject H_0	Mild serial correlation present
White's Test (Heteroscedasticity)	$\chi^2=22.02$	0.339	Fail to reject H_0	No heteroscedasticity
VIF (Multicollinearity)	Max VIF = 103.14	-	-	Severe Collinearity (Money supply, Exchange Rate)
Ramsey RESET (Specification Test)	F=0.0039	0.9512	Fail to reject H_0	Model correctly specified
Jarque-Bera (Normality)	JB=0.90-5.69	>0.05(most)	Fail to reject H_0	Residual broadly normal

Diagnostic assessments (Table 7) show minor serial correlation and notable multicollinearity between money supply and exchange rate, but no significant heteroscedasticity or functional misspecification. Residuals approximate normality, and the model demonstrates overall stability.

DISCUSSION

The empirical results reveal complex and interdependent relationships among Nigeria's key macroeconomic indicators over the period 2001-2023. Although real GDP exhibited an overall upward trend, growth remained vulnerable to domestic policy distortions

and external shocks, particularly exchange-rate instability. This outcome is consistent with recent evidence highlighting Nigeria's exposure to global shocks and structural dependence on external conditions (IMF, 2023; World Bank, 2023).

Inflation emerged as one of the most persistent macroeconomic challenges during the study period. The VECM results indicate that inflation responds strongly to movements in GDP, interest rates, and exchange-rate fluctuations, suggesting that price dynamics in Nigeria are driven largely by real-sector constraints and external pressures. This finding aligns with recent studies emphasizing exchange-rate pass-through and inflation persistence in Nigeria and other emerging economies (Akinlo & Lawal, 2021; Bonga-Bonga & Kabundi, 2020; Akinlo & Akinwale, 2022). The relatively weaker long-run influence of money supply suggests that structural rigidities, import dependence, and policy credibility issues play a more prominent role than pure monetary expansion (Chuku et al., 2021).

The relationship between economic growth and unemployment reflects a pattern of jobless or weakly inclusive growth. Although GDP growth was associated with modest reductions in unemployment, the effect was limited, particularly during periods of elevated inflation and tight monetary conditions. This finding supports recent evidence of stagflationary tendencies and weak labour-market transmission in Nigeria (Akinwale & Grobler, 2019). The instability of the inflation–unemployment relationship reinforces doubts about the applicability of a stable Phillips Curve in the Nigerian context.

Exchange-rate depreciation emerged as a key destabilizing force within the macroeconomic system. Its strong influence on inflation and interest-rate dynamics underscores Nigeria's vulnerability to external shocks and foreign-exchange constraints, consistent with recent policy-focused analyses (Alege et al., 2020; IMF, 2023). Diagnostic tests suggest that overlapping transmission channels between money supply and exchange rate may weaken policy effectiveness.

Overall, the findings highlight persistent structural weaknesses within Nigeria's macroeconomic framework. Inflation inertia, exchange-rate instability, and limited employment gains suggest that short-term policy responses have been insufficient to address underlying constraints.

CONCLUSION

This study investigated the dynamic relationships among key macroeconomic variables in Nigeria; namely inflation, Gross Domestic Product (GDP), money supply, interest rate, exchange rate, and unemployment, over the period 2001 to 2023 using a Vector Error Correction Model (VECM). The empirical findings confirm the existence of stable long-run equilibrium relationships among the variables, alongside meaningful short-run adjustment processes. These results demonstrate that Nigeria's macroeconomic system is characterized by strong interdependence, where shocks to one variable transmit across multiple channels over time.

The analysis reveals that inflation remains a persistent macroeconomic challenge, driven primarily by movements in output, interest rates, and exchange-rate fluctuations rather than monetary expansion alone. This suggests that inflationary pressures in Nigeria are increasingly shaped by structural constraints, supply-side inefficiencies, and external vulnerabilities, particularly currency depreciation. Although economic growth recorded a generally upward trend during the study period, its capacity to generate substantial employment gains was limited. The weak response of unemployment to GDP growth highlights the prevalence of jobless growth, reflecting labor-market rigidities and the dominance of capital-intensive sectors. Additionally, exchange-rate instability emerged as a central source of macroeconomic imbalance, amplifying inflationary pressures and complicating the effectiveness of monetary-policy interventions. While the estimated model exhibits overall robustness, the presence of overlapping transmission mechanisms underscores the need for coordinated and comprehensive policy responses. Taken together, the findings indicate that Nigeria's macroeconomic challenges cannot be effectively addressed through short-term or isolated policy measures. Instead, sustainable stability requires a balanced policy framework that integrates monetary discipline, exchange-rate management, and structural reforms aimed at enhancing productive capacity and employment creation. These insights contribute to the empirical literature on Nigeria's macroeconomic dynamics and offer valuable guidance for policymakers seeking to promote long-term economic stability.

Policy Implications

The results carry important implications for macroeconomic management in Nigeria. First, reliance on reactive monetary tightening has proven insufficient in curbing inflation

when exchange-rate instability and supply-side rigidities persist. Second, the weak growth–employment linkage highlights the limitations of output expansion as a sole development strategy. Third, overlapping policy channels, particularly between money supply and exchange-rate management reduce the effectiveness of isolated interventions and call for improved policy coordination.

Recommendations

1. Strengthen Monetary Coordination: The CBN should adopt a forward-looking monetary framework that anticipates inflationary pressures rather than reacting to them. Clear communication of policy targets would reinforce market confidence.
2. Stabilize the Exchange Rate: Address the underlying causes of naira depreciation through foreign-exchange-market reforms, export diversification, and improved foreign-reserve management.
3. Undertake Structural Reforms: Long-term stability demands structural changes such as expanding the formal labour market, boosting agricultural productivity, and improving infrastructure to reduce production costs and stimulate economic growth.
4. Enhance Data Quality and Transparency: National data agencies should refine unemployment and inflation measurements to include underemployment and informal-sector participation, ensuring accurate inputs for policy design and facilitates evidence-based decision-making.

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