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Predictive Analysis of GDP-Debt Dynamics: An Econometric Approach

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Abstract: This study investigates the impact of external debt on economic growth in Nigeria over the period 2000 to 2023. Utilising a combination of econometric modelling, diagnostic testing, and predictive analytics, the research explores the debt-growth nexus, diagnoses econometric concerns, and forecasts future debt dynamics based on key macroeconomic indicators. The Ordinary Least Squares (OLS) regression results reveal that external debt exhibits a negative but statistically insignificant effect on economic growth, while variables such as foreign direct investment, government revenue, and inflation displayed limited explanatory power. Unit root tests indicate that most variables achieve stationarity after first or second differencing, except for inflation, which remains non-stationary despite several transformations and structural break adjustments. Diagnostic checks confirmed the absence of autocorrelation and heteroskedasticity; however, multicollinearity is detected among key predictors. This is addressed using ridge regression, which stabilises coefficient estimates and retains all explanatory variables for policy interpretation. Forecasting through the ARIMA (0,2,1) model projects a continued rise in external debt through 2028, while the Random Forest model identifies exchange rate, total debt, and government revenue as the most influential predictors. Marginal effects analysis further highlighted the significant roles of exchange rate and total debt in driving external borrowing. Scenario-based forecasting under alternative GDP growth rates shows minimal change in projected debt levels, suggesting that economic growth alone may be insufficient to reduce external debt burdens without comprehensive fiscal and structural reforms. The study concludes with actionable policy recommendations aimed at promoting sustainable debt management in Nigeria.

Keywords: *External Debt, Economic Growth, Random Forest, Ridge Regression, Stationarity.*

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I. INTRODUCTION

The choice of Nigeria for this study was induced by diverse debates among successive administrations regarding the impact of debt on the nation's economic growth. Nigeria's external debt has experienced significant fluctuations over the past decades, reflecting the nation's economic policies and global economic conditions. In 2006, Nigeria made a landmark achievement by fully paying off its debt, reducing the external debt stock to approximately US$3.3 billion by March 2007 (Nigeria External Debt (CEIC), 2023). However, in subsequent years, the external debt began to rise again. By December 2015, during President Goodluck Ebele Jonathan's administration, the external debt had increased to US$10.7 billion (Debt Management Office Nigeria DMO, 2023). This upward trend continued under President Muhammadu Buhari's administration, reaching US$27.6 billion by December 2019 (International Debt Statistics IDS, 2023). As of June 2023, under the current administration, Nigeria's external debt stood at approximately US$43.2 billion, marking an all-time high (Nigeria External Debt (CEIC), 2023).

The rapid accumulation of external debt by developing countries has become a central concern for policymakers and researchers, particularly in Sub-Saharan Africa. Nigeria, as the largest economy in the region, has experienced recurrent challenges in managing its external debt stock, which has raised questions about the implications for economic growth. The growing reliance on external borrowing to finance development projects, especially in the face of declining oil revenues, has reignited debates on the debt-growth relationship.

This study explores the relationship between external debt and economic growth in Nigeria using annual data from 2000 to 2023. It integrates traditional econometric modelling with predictive analytics to understand not only the short-run statistical influence of external debt on GDP growth but also the long-run implications through forecasting models. Given Nigeria's fiscal vulnerabilities, exchange rate pressures, and growing budget deficits, it is crucial to reassess how external borrowing impacts growth and whether current borrowing patterns are sustainable.

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The study is guided by the following objectives: (i) to estimate the relationship between external debt and economic growth using an econometric model, (ii) to evaluate econometric assumptions using diagnostic tests, (iii) to develop predictive models for forecasting debt trends, and (iv) to simulate debt outcomes under various economic growth scenarios.

The structure of the paper is as follow: Section 1 introduces the paper. Section 2 presents the literature review of relevant studies on the relationship between external debt and economic growth. Section 3 explain the methodological strategy used to accomplish the study's goals. Section 4 presents the data and empirical results, while section 5 renders the summary, conclusion and policy recommendation.

II. LITERATURE REVIEW

The relationship between external debt and economic growth has been a longstanding issue in development economics, generating extensive theoretical and empirical debate. Theoretically, several frameworks attempt to explain how external borrowing affects macroeconomic performance in developing countries. The Dual-Gap Theory (Chenery & Strout, 1966) argues that countries face both savings and foreign exchange gaps, which constrain investment and growth. External borrowing is necessary to fill these gaps, but only when funds are used productively. Similarly, the Debt Overhang Theory (Krugman, 1988; Sachs, 1989) contends that when a country's debt level is perceived to be unsustainable, the expectation of future tax burdens discourages private investment, leading to slow growth or stagnation.

The Solow Growth Model provides another important framework. While it does not explicitly focus on debt, it emphasises capital accumulation, technological progress, and labour as drivers of economic growth. External debt can facilitate capital accumulation, particularly in low-income countries with limited domestic savings. However, if borrowed resources are not effectively allocated, the resultant debt burden may lead to reduced public investment and fiscal constraints, contradicting the growth objectives. The Ricardian Equivalence Hypothesis (Barro, 1974) offers a contrasting view by positing that government borrowing has no real effect on economic output because rational agents anticipate future taxation and adjust their savings accordingly.

Empirical studies provide mixed findings regarding the debt-growth relationship. For instance, Adegbite et al. (2008) and Ogunmuyiwa (2011) found a negative and statistically significant impact of external debt on economic growth in Nigeria. Similarly, Iyoha (1999) and Sulaiman & Azeez (2012) concluded that debt accumulation in Sub-Saharan Africa reduces growth potential, especially when debt service obligations crowd out essential investment. Conversely, some studies like Ajayi and Oke (2012) reported a positive relationship under certain macroeconomic conditions, suggesting that external debt may stimulate growth when channelled into productive ventures such as infrastructure and education.

Other researchers have emphasised the role of debt sustainability and institutional quality in shaping the debt-growth outcome. For instance, Jarju et al. (2016) and Adedoyin et al. (2015) used panel and time-series models, respectively, to show that the impact of debt on growth depends heavily on whether countries maintain sustainable fiscal positions. Where governance is weak and transparency is limited, external debt tends to be misallocated, leading to lower economic returns and higher risk of default. These findings align with the debt intolerance hypothesis, which suggests that developing countries are more vulnerable to debt crises even at lower debt levels.

In the Nigerian context, studies such as Sede & Osifo (2016) and Michael & Sulaiman (2012) have utilised Autoregressive Distributed Lag (ARDL) and cointegration techniques to analyse long-run and short-run effects. Their results consistently show that while short-term borrowing may provide fiscal space, long-term accumulation without structural reform exacerbates macroeconomic instability. More recent research has focused on debt accumulation trends post-2015 under the Buhari administration, revealing significant increases in Nigeria's external debt stock due to reliance on foreign loans to finance budget deficits and infrastructure projects (Odeniyi *etal*, 2022).

In terms of methodology, previous studies have applied various econometric approaches ranging from OLS regression (Ayansola *etal*, 2023), Vector Autoregressive Models (VAR), and Error Correction Models (ECM) to Bayesian averaging and machine learning algorithms like Random Forest. However, many of these studies neglect structural breaks in the time series, particularly around major policy shifts such as the 2005 Paris Club debt relief or post-2015 borrowing surges. Moreover, few have incorporated predictive models like ARIMA or scenario-based simulations to forecast future debt patterns or assess policy impact.

Despite the breadth of literature, significant gaps remain. Most notably, few studies combine diagnostic testing, predictive analytics, and structural break assessments within a unified framework. Additionally, the use of recent data (up to 2023) is rare, which limits the relevance of findings for current policymaking. This study addresses these gaps by incorporating ARIMA forecasting, Ridge regression for handling multicollinearity, and scenario analysis for policy simulation, thereby providing a more comprehensive understanding of how external debt influences economic growth in Nigeria under evolving fiscal conditions.

III. METHODOLOGY

The theoretical foundation of this study draws from the Solow Growth Model, the Dual Gap Theory, and the Debt Overhang Theory. The Solow model emphasises the roles of capital accumulation, labour, and technological progress in driving long-run growth. In empirical adaptations, macroeconomic indicators such as external debt, inflation, and government

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spending are incorporated to reflect country-specific determinants of output growth.

The Dual Gap Theory posits that developing economies face both savings and foreign exchange gaps, which hinder investment and growth. External borrowing fills these gaps when domestic resources are insufficient. This relationship can be summarised as:

$$S + B = I \tag{1}$$

Where S is domestic savings, B is external debt, and I is total investment.

The Debt Overhang Theory (Krugman, 1988) suggests that beyond a certain threshold, external debt deters investment because expected future returns are used to service debt rather than reinvested. The theoretical production function under this condition is:

$$Y_t = f(K_t, L_t, D_t) \tag{2}$$

Where Y is output, K is capital, L is labor, and D is external debt. Excessive D results in declining productivity and lower output growth.

➢ *Model Specification*

An augmented Solow-type growth model is used to empirically test the relationship between external debt and economic growth. The model includes key macroeconomic control variables:

$$GDPGR_t = \beta_0 + \beta_1 EXTD_t + \beta_2 FDI_t + \beta_3 INF_t + \beta_4 REV_t + \beta_5 TGE_t + \beta_6 TDS_t + \beta_7 INTR_t + \beta_8 EXR_t + \varepsilon_t \tag{3}$$

where GDPGR is the GDP growth rate, EXTD is external debt, FDI is foreign direct investment, INF is inflation, REV is government revenue, PE is public expenditure, TDS is total debt stock, INTR is interest rate, EXR is exchange rate, and ε is the error term.

To capture structural changes, dummy variables were introduced:

$$\mathrm{GDPGR_t} = \beta_0 + \sum_{i=1}^{8} \beta_i X_{it} + \gamma_1 D_{PC} + \gamma_2 D_{2015} + \varepsilon_t \tag{4}$$

Where D_{PC} represents a Paris Club debt relief period (2005-2006) and D_{2015} captures 2015 debt accumulation dynamics.

The OLS method is used to estimate the base linear regression model. It minimises the sum of squared residuals and provides unbiased and efficient estimates under classical assumptions.

The Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests are applied to evaluate the stationarity of variables. The ADF test accounts for autoregressive dynamics, while the PP test adjusts for serial correlation and heteroskedasticity using non-parametric techniques.

The ADF and PP regressions are, respectively:

$$\Delta Y_t = \alpha + \delta Y_{t-1} + \sum_{i=1}^{p} \lambda_i \Delta Y_{t-i} + \varepsilon_t \tag{5}$$

And

$$Y_t = \alpha + \beta t + \gamma Y_{\{t-1\}} + \varepsilon_t \tag{6}$$

Stationarity is confirmed if δ (ADF) or γ (PP) is negative and statistically significant.

To account for unknown structural breaks, the Zivot-Andrews test is employed. Unlike ADF and PP, this test endogenously detects one break in the intercept or trend, ensuring that structural shifts (e.g., debt relief or policy reforms) do not bias the unit root results.

Diagnostic checks were conducted to verify the validity of the regression results:

- **Autocorrelation:** Breusch-Godfrey LM Test
- **Multicollinearity:** Variance Inflation Factor (VIF)
- **Heteroskedasticity**: Breusch-Pagan and White Tests

To address the presence of multicollinearity identified among key predictors such as external debt, total debt, exchange rate, and government revenue, ridge regression was employed. Ridge regression introduces a penalty term to the regression model that shrinks the coefficients of collinear variables, thereby improving the stability of estimates without dropping any theoretically important variables. This approach preserves the explanatory power of the model while mitigating the distortions caused by multicollinearity. The optimal regularisation parameter (lambda) was selected using cross-validation to minimise mean squared error.

➢ *Forecasting and Predictive Modelling*

The Autoregressive Integrated Moving Average (ARIMA) model is used to forecast Nigeria's external debt. The model captures historical trends and projects future values based on autoregressive (AR), differencing (I), and moving average (MA) components. The best-fit ARIMA(0,2,1) model was selected using the Akaike Information Criterion (AIC) and validated through residual diagnostics(Ogundunmade, 2024). The model provides a 5-year forecast under current economic trends.

Random Forest, a machine learning method, is applied to identify the most important macroeconomic predictors of external debt. The technique constructs multiple decision trees and averages their outcomes to enhance predictive accuracy and minimise overfitting. It is especially useful in cases of multicollinearity or nonlinear interactions. The model also generates variable importance scores that help prioritise policy focus areas.

Scenario analysis is conducted to simulate external debt outcomes under alternative economic growth rates (e.g., 2%, 3%, 4%) while holding other macroeconomic variables constant. This allows policymakers to anticipate debt

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sustainability risks under different economic conditions and assess the fiscal space needed to accommodate growth-inducing expenditures.

IV. DATA, RESULTS AND DISCUSSION

The study relies on annual time-series data from 2000 to 2023. GDP growth and foreign direct investment data were obtained from the World Bank. External debt, debt servicing, exchange rate, inflation, and interest rate data were sourced from the Central Bank of Nigeria (CBN). Government revenue and public expenditure data were obtained from the National Bureau of Statistics (NBS).

This section provides a statistical analysis to examine the effect of external debts on economic growth in Nigeria. It aims to analyse if there exists a relationship between external debt and economic growth in Nigeria. A time series approach was adopted, such as the unit root test (Augmented Dickey Fuller (ADF)), and PP (Philip Perron), multiple linear regression, correlation analysis, and exploratory data analysis (EDA) were performed to achieve our objectives. Table 1 presents the summary statistics of key macroeconomic variables used in the study over the period 2000–2023. The table includes minimum, maximum, mean, and standard deviation values, offering a descriptive overview of the data distribution and variability.

Table 1 Summary Statistics

Variable	**Min**	**Max**	**Mean**	**Std. Dev.**
External Debt (USD Billion)	18.58	105	48.38	25.27
Economic Growth Rate (%)	-1.79	15.33	4.97	3.65
Exchange Rate (NGN/USD)	101.7	450	209.46	110.68
Inflation Rate (%)	5.39	250	22.52	48.6
Foreign Direct Investment (USD)	-0.19	8.84	3.91	2.56
Government Revenue (USD Billion)	5.12	28.81	14.48	7.25
Total Expenditure (USD Billion)	9.76	30.86	15.96	4.83
Total Debt (USD Billion)	20.95	200	81.29	54.38
Real Interest Rate (%)	-5.63	18.18	5.39	5.67

Source: Research Findings

The summary statistics reveal that external debt ranged from $18.58 billion to $105 billion, with a mean of $48.38 billion and a standard deviation of $25.27 billion, indicating a significant increase and considerable variation in debt levels over the study period. The economic growth rate fluctuated between -1.79% and 15.33%, with an average of approximately 4.97% and a standard deviation of 3.65%, reflecting moderate but volatile growth. The exchange rate exhibited persistent depreciation, rising from ₦101.7 to ₦450, with a mean of ₦209.46 and a standard deviation of ₦110.68. Inflation showed extreme volatility, ranging from 5.39% to 250%, with a high average of 22.52% and a standard deviation of 48.60%, suggesting structural price instability. Foreign direct investment (FDI) varied from -0.19 to 8.84 USD, with an average of 3.91 USD and a standard deviation of 2.56, indicating moderate inflow variability. Government revenue ranged from $5.12 billion to $28.81 billion, averaging $14.48 billion with a standard deviation of $7.25 billion, reflecting some inconsistency in revenue generation. Total expenditure ranged from $9.76 billion to $30.86 billion, with an average of $15.96 billion and a standard deviation of $4.83 billion, suggesting moderate fluctuations in public spending. Total debt showed significant variation, from $20.95 billion to $200 billion, with a mean of $81.29 billion and a standard deviation of $54.38 billion, highlighting Nigeria's increasing debt burden. Finally, the real interest rate ranged from -5.63% to 18.18%, with a mean of 5.39% and a standard deviation of 5.67%, indicating varied monetary conditions across the years.

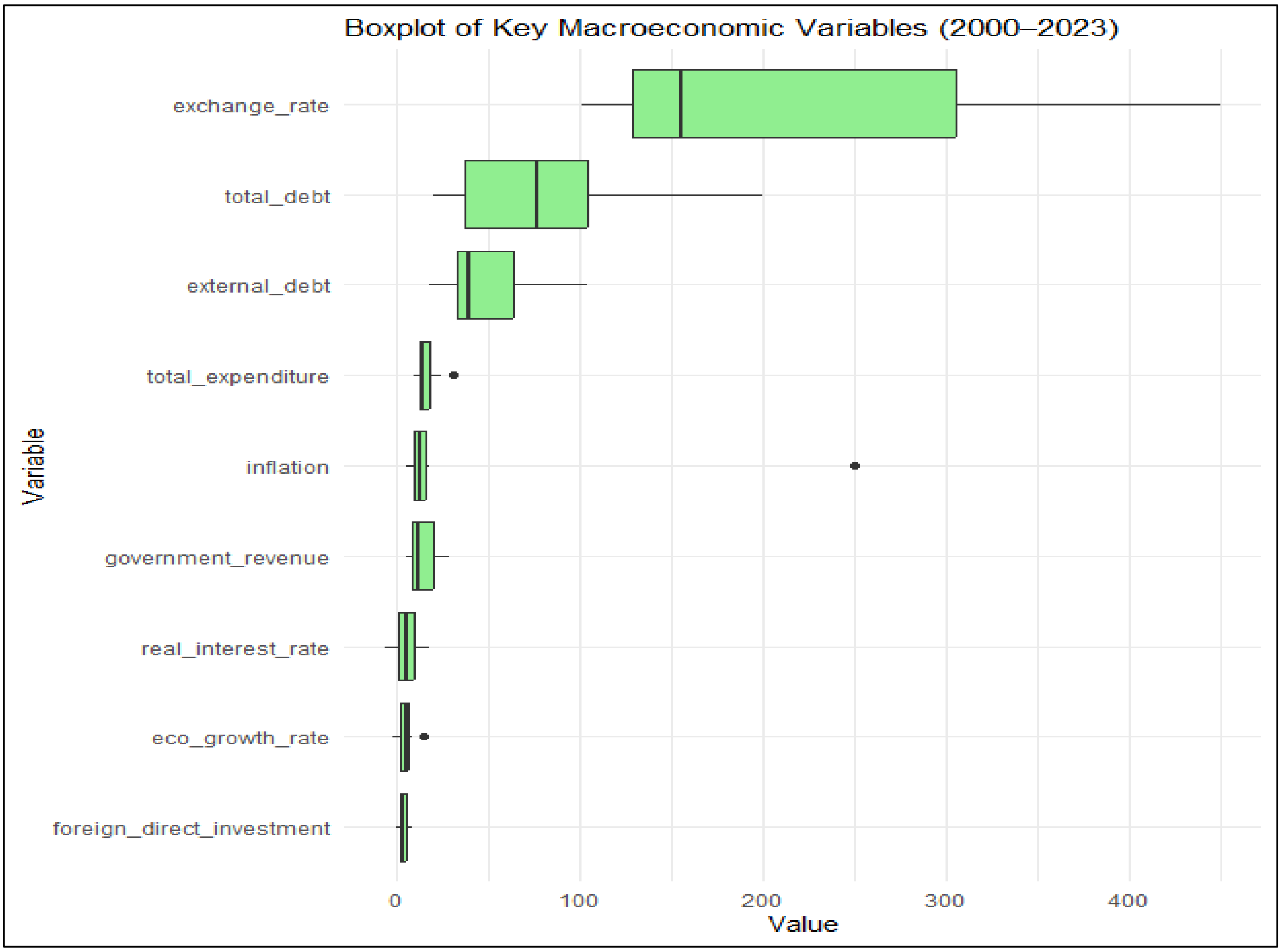

Fig 1 Boxplot of Key Macroeconomic Variables

➢ *Regression Estimate from the Multiple Linear Model Predicting External Debt*

Table 2 presents the coefficient estimates from the multiple linear regression model examining the influence of key macroeconomic variables on external debt. The table includes standard errors, t-values, and p-values used to assess the statistical significance of each predictor.

Table 2 Results of Multiple Linear Model Prediction

Variable	Estimate	Std. Error	t-value	p-value	Significance
(Intercept)	-9.9845	4.8222	-2.071	0.0561	**Yes**
External Debt	-0.0197	0.1031	-0.191	0.8507	
Foreign Direct Investment	0.3349	0.2633	1.272	0.2228	
Inflation	-0.0039	0.0123	-0.313	0.7583	
Government Revenue	0.3454	0.249	1.387	0.1857	
Total Expenditure	0.3253	0.255	1.276	0.2214	
Total Debt	-0.0346	0.0305	-1.132	0.2752	
Real Interest Rate	0.1902	0.1475	1.289	0.2168	
Exchange Rate	0.02995	0.0223	1.343	0.1991	

Source: Research Findings

Significance codes: `***` p < 0.001, `**` p < 0.01, `*` p < 0.05, `.` p < 0.1

The model explains 77.78% of the variation in economic growth (R^2 = 0.07778), with an adjusted R^2 of 0.6593, indicating a reasonably good fit. The F-statistic ($6.565,\ p = 0.0009271$) confirms the overall significance of the model. However, none of the independent variables are statistically significant at the 5% level, though the intercept ($-9.9845,\ p = 0.0561$) is marginally significant at the 10% level. Among the predictors, government revenue (p = 0.1857), Exchange Rate (p = 0.1991), and Real Interest Rate (p = 0.2168) show relatively stronger associations with economic growth but remain statistically insignificant.

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Foreign Direct Investment, Government Revenue, Total Expenditure, Real Interest Rate, and Exchange Rate exhibit positive effects, suggesting that an increase in these variables is associated with high economic growth. Conversely, External Debt, Inflation, and Total Debt have negative coefficients, indicating a weak negative relationship with economic growth.

Figure 2 below assesses the assumptions of the linear regression model. The Residuals vs. Fitted Plot (Top Left) checks linearity and homoscedasticity (constant variance), but the residuals are not randomly scattered around zero, and the curvature in the red trend line suggests possible non-linearity, indicating that the relationship between predictors and economic growth may not be perfectly linear. Additionally, some potential outliers are present. The Q-Q Plot (Top Right) evaluates whether residuals follow a normal distribution. While the residuals mostly align with the diagonal reference line, slight deviations at the tails suggest some departure from normality, likely due to a few influential points. The Scale-Location Plot (bottom left) tests for homoscedasticity, but the non-flat red line indicates that residual variance changes with fitted values, suggesting some heteroscedasticity, meaning the model might not have fully captured the variability in economic growth. Finally, the Cook's Distance Plot (bottom right) identifies influential observations, revealing that Observation 24 is extremely influential, potentially acting as an outlier or leverage point, while Observations 2 and 12 also exhibit some influence but to a lesser extent.

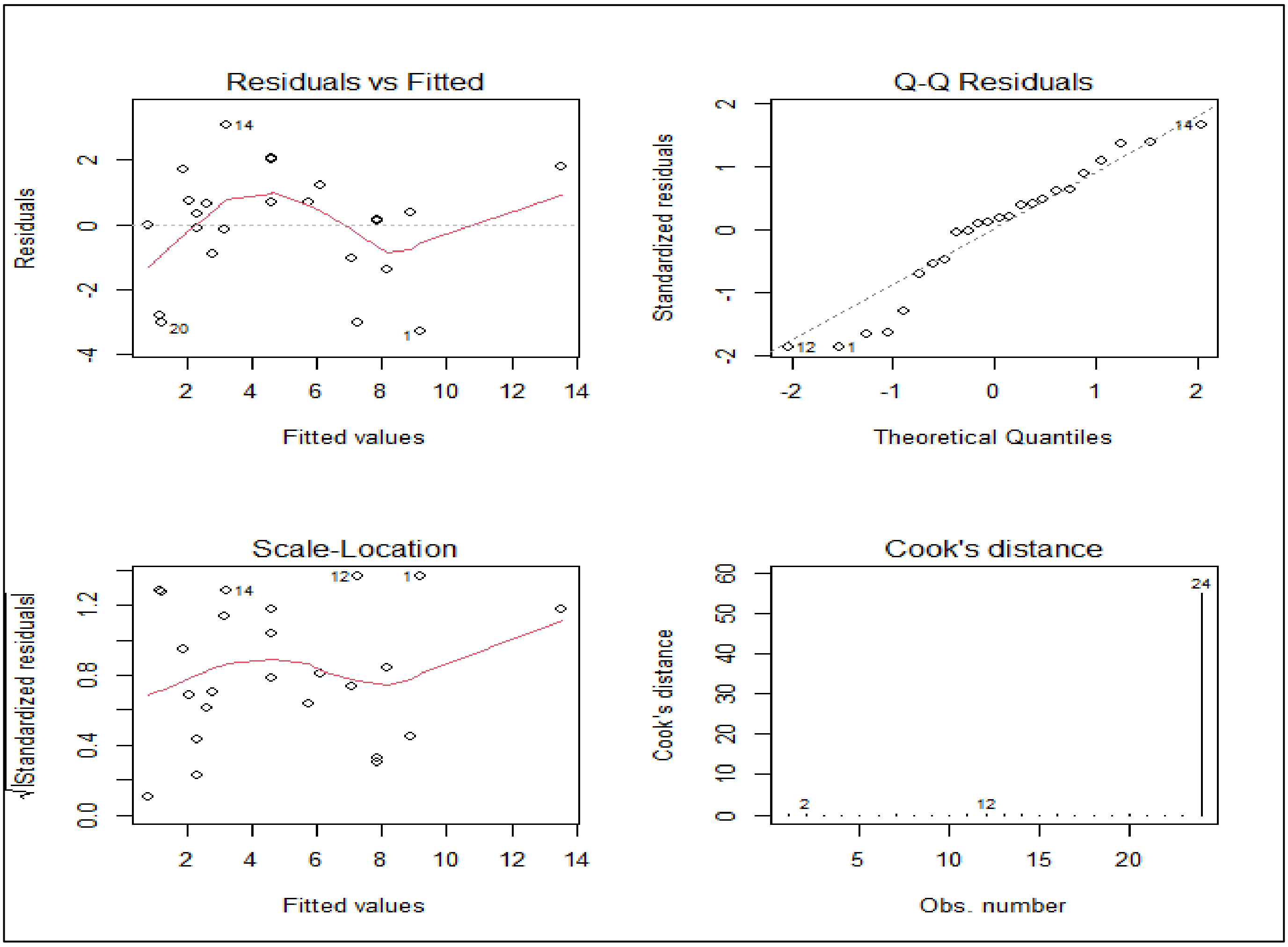

Fig 2 Regression Diagnostic Plots for the Ordinary Least Square Model

➢ *Trend and Correlation Analysis Between External Debt and GDP Growth Rate*

Table 3 displays the results of trend and correlation analysis between external debt and economic growth rate in Nigeria. The analysis reveals both the direction and strength of the association, providing insights into how changes in external debt levels relate to fluctuations in economic growth over the study period.

Table 3 Results of Correlation Analysis

Variable	External Debt	GDP Growth Rate
External Debt	1	-0.4889
GDP Growth Rate	-0.4889	1

Source: Research Findings

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The left plot below illustrates trends in external debt and GDP growth, where the blue line represents external debt (USD billion), showing a general increase, particularly after 2010, while the red line represents GDP growth rate (%), which exhibits significant fluctuations and periods of high volatility. An inverse relationship appears evident, as sharp increases in external debt often coincide with declines in GDP growth. The right plot, a scatter plot, depicts the relationship between external debt and GDP growth rate, with the negative slope of the fitted regression line suggesting a negative correlation higher external debt is generally associated with lower GDP growth. Although the data points show some variability, the overall trend indicates that rising external debt corresponds with declining economic growth.

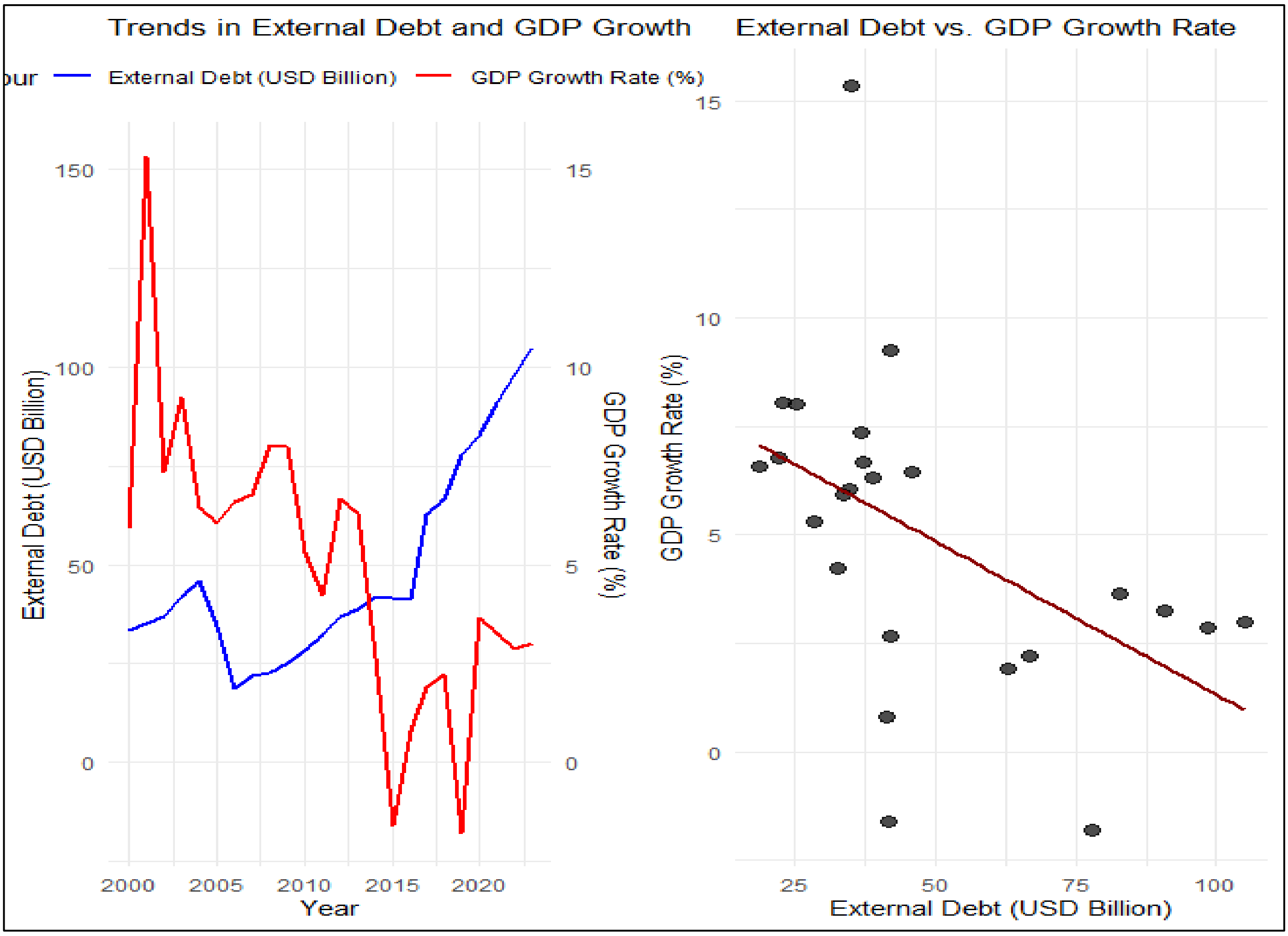

Fig 3 Trend and Correlation Plots of External Debts and GDP Growth Rate

- ➢ *Augmented Dickey-Fuller (ADF) Test for Stationarity under the Null Hypothesis of Non-Stationary*

Table 4 presents the results of the Augmented Dickey-Fuller (ADF) test conducted to examine the stationarity of the time series variables. The test assumes a null hypothesis of non-stationarity (presence of a unit root), and rejection of the null indicates that the variable is stationary at its level or after differencing.

Table 4 Results of ADF Unit Root Test

Variable	I (0)	I (1)	I (2)	I (3)	I (4)	I (5)
GDP Growth Rate	0.4657	0.0100				
External Debt	0.9364	0.0632	0.0453			
Foreign Direct Investment	0.6837	0.5544	0.01			
Inflation	0.9900	0.9900	0.9794	0.8338	0.648	0.9089
Government Revenue	0.9015	0.0657	0.0100			
Total Expenditure	0.7549	0.0955	0.0100			
Total Debt	0.7006	0.3622	0.0804	0.0100		
Real Interest Rate	0.0778	0.0100				
Exchange Rate	0.9899	0.0900	0.0113			

Source: Research Findings

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From table 4 above, the ADF test results indicate varying integration orders among Nigeria's macroeconomic variables: the Real Interest Rate is nearly stationary at level [I(0)]; GDP Growth Rate and Real Interest Rate (R.I.R) attains stationarity after first differencing [I(1)], with Exchange Rate, Government Revenue, and Total Expenditure showing signs of approaching stationarity at the same level. External Debt becomes stationary only after second differencing [I(2)], which also fully stabilizes the Foreign Direct Investment (FDI), Government Revenue, Total Expenditure and Exchange Rate, while Total Debt requires third differencing [I(3)] to achieve stationarity. Inflation, however, remains non-stationary even after fifth differencing [I(5)], reflecting a strong and persistent trend that resists all standard transformation methods.

Table 5 presents the results of stationarity tests applied to the inflation series under various transformations, including level, first difference, and second difference. These tests help determine the appropriate form in which inflation can be reliably included in the regression model without violating the assumption of stationarity.

Table 5 Results of Stationarity Test for Inflation under Various Transformation

Transformation Method	ADF Statistic	P-value	Stationarity at 5%	Interpretation
Log Transformation	0.0133	0.9900	**No**	Inflation remains highly non-stationary after log transformation
Log-First Differences	-1.5593	0.7403	**No**	Log return do not induce stationarity
Percentage Change	-0.2092	0.9875	**No**	Arithmetic rate of change also fails to make the series stationarity.

Source: Research Findings

Table 5 above show case that inflation remains highly non-stationary after log transformation with probability value ($p = 0.9900$) which tends to above the significance level ($\alpha = 0.05$), as neither log returns nor the arithmetic rate of change are sufficient to induce stationarity in the series as the p-value hold ($0.7403, 0.9875$), respectively.

Table 6 presents the results of the Zivot-Andrews unit root test applied to the inflation series, allowing for a single structural break in the trend or intercept. The test assesses whether inflation is non-stationary while accounting for possible policy or economic shocks that could affect the stability of the series.

Table 6 Results for Zivot-Andrew Test for Structural Breaks Test for Inflation

Component	Estimate	Std. Error	t-value	p-value	Significance
Interpret	11.64949	5.31108	2.193	0.0457	Yes
y.11(lagged)	0.03075	0.38119	0.081	0.9368	No
Trend	0.02559	0.14461	0.177	0.8621	No
y.d11	0.40935	0.29595	1.383	0.1883	No
y.d12	0.10595	0.21952	0.483	0.6368	No
du (break in intercept)	-227.2267	7.6859	-29564	5.11e-14	Yes
dt (break in trend)	231.6068	4.8294	47.958	$< 2e^{16}$	Yes

Source: Research Findings

Table 7 provides a summary of the Zivot-Andrews test outcomes, including the test statistic, breakpoint year, and critical values. This helps identify whether a significant structural break exists in the inflation series, which could influence its stationarity and impact on the regression model.

Table 7 Zivot-Andrews Test Summary for Structural Breaks in Inflation Series

Test Statistic	Critical Value (5%)	Stationary at 5%	Breakpoint
-2.5427	-508	**No**	Position 22

Source Research Findings.

All transformation methods log, log-difference, and percentage change fail to make inflation stationary, as reflected by high p-values in the ADF tests; although the Zivot-Andrews structural break test identifies a significant break in both the intercept and trend of the inflation series at observation 22, likely corresponding to a major economic policy or event, the test statistic of -2.5427 does not exceed the critical value of -5.08, and thus the null hypothesis of a unit root cannot be rejected, indicating that inflation remains non-stationary even after accounting for a structural break.

Table 8 presents the results of the Phillips-Perron (PP) unit root test conducted to assess the stationarity of the time series variables. The test assumes a null hypothesis of non-stationarity, and rejection of this hypothesis indicates that the variable is stationary at the specified level or after differencing.

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Table 8 Results of Philip-Perron Unit Root Test

Variable	I (0)	I (1)	I (2)
GDP Growth Rate	0.01		
External Debt	0.978	0.0299	
Foreign Direct Investment	0.7876	0.01	
Inflation	0.9900	0.9900	0.01
Government Revenue	0.3217	0.0100	
Total Expenditure	0.2182	0.01	
Total Debt	0.9237	0.0644	0.0100
Real Interest Rate	0.01		
Exchange Rate	0.9833	0.1658	0.0504

Source: Research Findings

GDP Growth Rate and Real Interest Rate are stationary at level [I(0)], as shown by their p-values of 0.01, which are below the 5% significance level, indicating the absence of a unit root and confirming their suitability for models that require stationary variables. In contrast, External Debt, Foreign Direct Investment, Government Revenue, and Total Expenditure are non-stationary at level but become stationary after first differencing [I(1)], with first-difference p-values all below 0.05, making them appropriate for inclusion in ARDL models that accommodate a mix of I(0) and I(1) variables. However, Inflation, Total Debt, and Exchange Rate remain non-stationary at both level and first difference but become stationary only after second differencing [I(2)], with respective p-values of 0.01, 0.01, and 0.0504, indicating that they are integrated of order two a condition that violates the assumptions of ARDL and VAR models, which require variables to be at most I(1).

This section presents the results of key econometric diagnostic tests used to evaluate the robustness of the regression model. These include tests for autocorrelation, multicollinearity, and heteroscedasticity, all of which assess whether the classical assumptions of Ordinary Least Squares (OLS) are upheld in the study.

Table 9 displays the results of the autocorrelation tests used to determine whether the residuals from the regression model are serially correlated. The presence of autocorrelation violates one of the key assumptions of OLS and may bias standard error estimates.

Table 9 Results of Autocorrelation Test

Test	**Test Statistic**	**Degrees of Freedom**	**p-value**	**Autocorrelation Present?**
Durbin-Watson Test	2.2456	–	0.2698	**No**
Breusch-Godfrey (BG) Test (Order 2)	2.8233	2	0.2437	**No**

Source: Research Findings

The Durbin-Watson statistic of 2.2456, being close to 2, indicates little to no first-order autocorrelation in the residuals, and with a p-value of 0.2698 (greater than 0.05), we fail to reject the null hypothesis of no autocorrelation; similarly, the Breusch-Godfrey test for higher-order autocorrelation up to lag 2 yields a test statistic of 2.8233 and a p-value of 0.2437, which is not statistically significant, leading to the conclusion that there is no evidence of serial correlation up to the second lag.

Table 10 shows the Variance Inflation Factor (VIF) values used to assess multicollinearity among the independent variables. VIF values greater than 10 typically indicate a high degree of multicollinearity, which can distort the reliability of coefficient estimates in the regression model.

Table 10 Results of Variance Inflation Factor for Multicollinearity

Predictor Variable	**VIF Value**	**Multicollinearity Severity**
External Debt	34.30	Severe
Foreign Direct Investment	2.30	Low
Inflation	1.82	Low
Government Revenue	16.46	Severe
Total Expenditure	7.67	Moderate
Total Debt	13.93	Severe
Real Interest Rate	3.54	Low to Moderate
Exchange Rate	30.79	Severe

Source Research Findings

A VIF value above 10 typically indicates serious multicollinearity, which can inflate standard errors and obscure the individual effects of predictors; in this case, External Debt (34.30), Government Revenue (16.46), Total Debt (13.93), and Exchange Rate (30.79) exhibit severe multicollinearity, while Total Expenditure (7.67) shows moderate multicollinearity, and the remaining variables have acceptable VIF values below 5, suggesting low multicollinearity concerns.

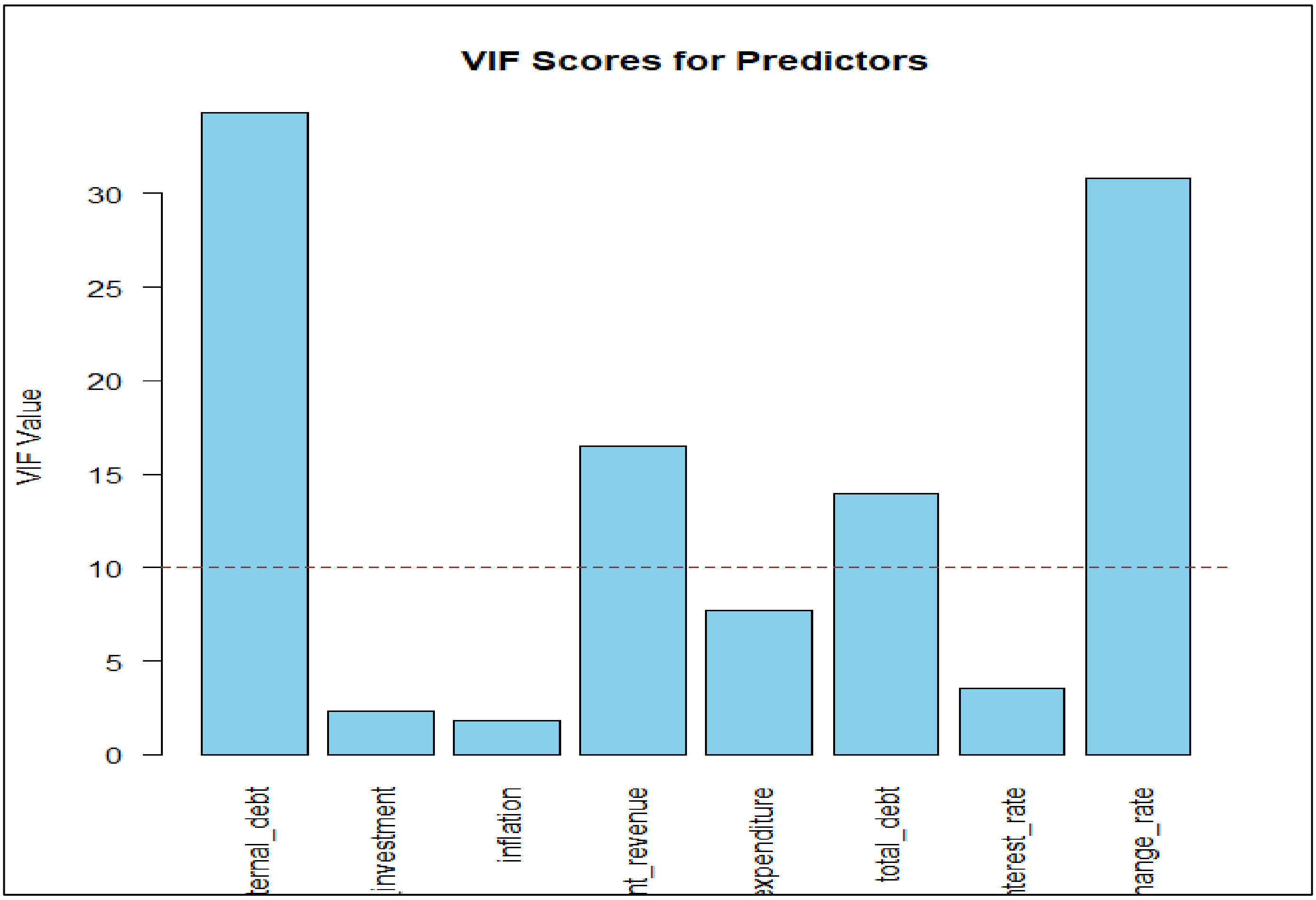

Fig 4 Variance Inflation Factor Plot for the Variables

Ridge regression was employed to address multicollinearity among explanatory variables in the growth model. The method applies a penalty to the magnitude of coefficients, allowing all variables to remain in the model while reducing instability due to high intercorrelation. The output presents the regularized coefficients after cross-validation tuning.

Table 11 Ridge Regression Coefficients for Predicting Economic Growth

Variable	**Coefficient**
(Intercept)	4.33
External Debt	-0.0052
Total Debt	-0.0033
Exchange Rate	-0.0015
Foreign Direct Investment	0.0173
Inflation	-0.0002
Government Revenue	0.0328
Total Expenditure	0.0555
Real Interest Rate	0.007

The Ridge regression results reveal the shrinkage effect on variable coefficients due to regularization, with external debt and total debt both showing negative coefficients (−0.0052 and −0.0033 respectively), indicating a potential inverse relationship with GDP growth, though with reduced magnitudes owing to penalty adjustment. The exchange rate also exhibits a slight negative impact, aligning with economic theory that persistent currency depreciation may hinder growth. In contrast, government revenue, total expenditure, and foreign direct investment maintain positive coefficients, supporting the notion that fiscal expansion and investment promote economic performance. Notably, total expenditure (0.0555) holds the largest coefficient, suggesting it exerts the strongest influence on economic growth in the regularized model. Although the coefficients are not directly interpretable as marginal effects, their signs and relative magnitudes provide meaningful insights into the contribution of each predictor to the growth process.

Figure 5 shows the cross-validation curve for Ridge Regression. The vertical line indicates the value of $\lambda = 29.3841$, which minimizes the cross-validated MSE and was selected for the final model.

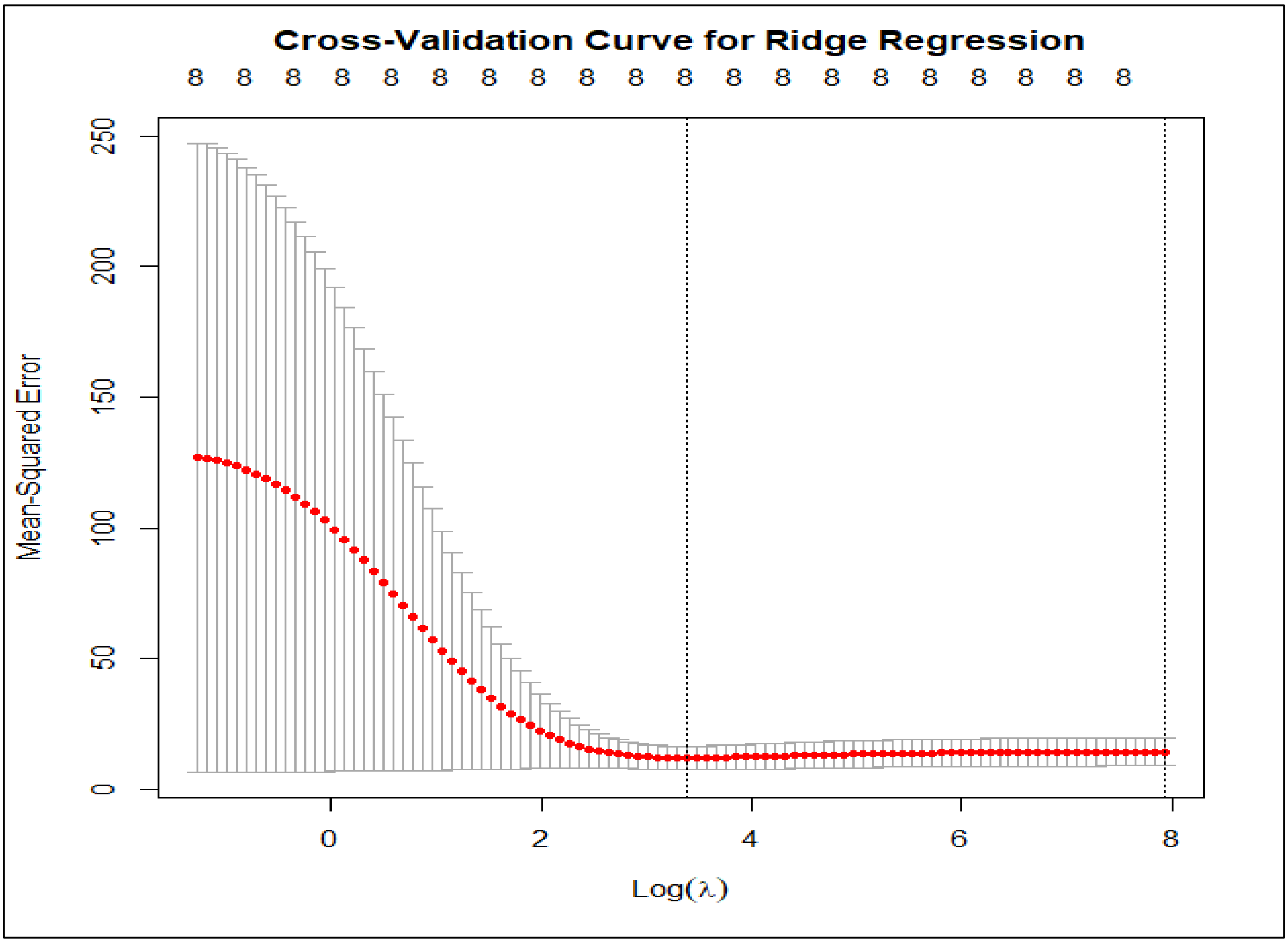

Fig 5 Cross Validation Curve for Ridge Regression

Table 12 presents the results of the Breusch-Pagan test conducted to detect heteroscedasticity in the regression model. The test evaluates whether the variance of the residuals is constant. A significant p-value indicates the presence of heteroscedasticity, violating the assumption of homoscedasticity in OLS regression.

Table 12 Results of Breusch-Pegan Test Results for Heteroscedasticity

Statistic	**Value**
Test Type	Studentized Breusch-Pagan
BP	9.138
Df	8
p-value	0.3308

Source: Research findings

The Breusch-Pagan test, which assesses the presence of heteroskedasticity in a linear regression model, yielded a (p-value = 0.3308 > 0.05). Since is greater than significance levels we fail to reject the null hypothesis of homoskedasticity, indicating no significant evidence of heteroskedasticity in the model's residuals.

➢ *Predictive Modelling*

This section presents the predictive modeling techniques employed to forecast Nigeria's external debt and identify key macroeconomic drivers. Two approaches were used: the Autoregressive Integrated Moving Average (ARIMA) model and the Random Forest machine learning algorithm.

Figure 6 illustrates the historical trend and five-year forecast of Nigeria's external debt using the ARIMA(0,2,1) model, where the black line represents actual debt levels from 2000 to 2023, and the shaded blue region reflects projected values from 2024 to 2028 with 95% and 80% confidence intervals; the model reveals a sharp rise in external debt, particularly from 2015 onward, and forecasts a continued upward trajectory, potentially surpassing ₦160 billion by 2028, with the widening forecast bands indicating increasing uncertainty over time due to strong non-stationarity in the original series, as evidenced by the second-order differencing (d = 2), which implies an accelerating debt growth rate.

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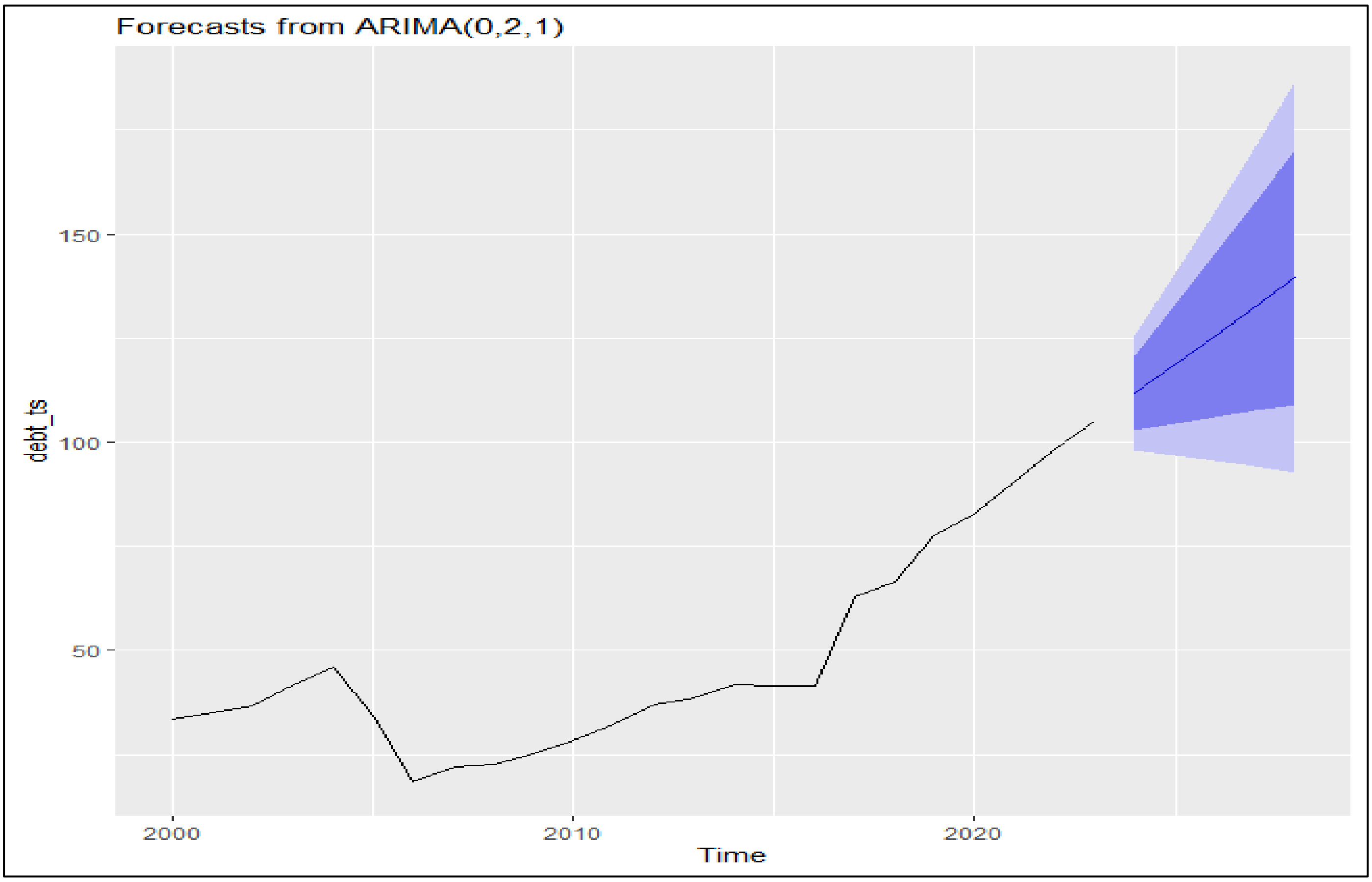

Fig 6 Arima (0, 2,1) Forecast Plot

➢ *Variable Importance Ranking from Random Forest Model for Predicting External Debt*

Table 13 presents the variable importance rankings generated from the Random Forest model used to predict Nigeria's external debt. The values reflect each variable's contribution to improving the model's predictive accuracy, with higher values indicating greater influence. This analysis helps identify the most significant macroeconomic factors associated with external debt dynamics. Beyond importance ranking, the model's predictive performance was assessed using R^2 and $RMSE$ confirming its robustness.

Table 13 Results of Variable Importance Ranking from Random Forest Model

Rank	**Variable**	Importance (IncNodePurity)
1	Exchange Rate	27.0167
2	Total Debt	25.0690
3	Government Revenue	15.6011
4	Economic Growth Rate	11.5710
5	Inflation	7.6071
6	Foreign Direct Investment	5.8304
7	Real Interest Rate	3.7949
8	Total Expenditure	3.5108

Source: Research findings.

Table 13 above presents the variable importance scores derived from the Random Forest model used to predict Nigeria's external debt. The values represent the increase in node purity, which indicates how much each variable contributes to reducing model error. A higher value suggests greater importance in predicting the response variable (external debt). The exchange rate, total debt, and government revenue emerged as the most influential predictors, while total expenditure and real interest rate had relatively lower predictive importance. This suggests that fluctuations in exchange rate and the burden of existing debt are crucial drivers in explaining Nigeria's future external debt levels.

Figure 7 illustrates the ranked importance of predictor variables in the Random Forest model used to forecast external debt. Variables with higher scores contributed more significantly to reducing prediction error, with exchange rate, total debt, and government revenue emerging as the top predictors.

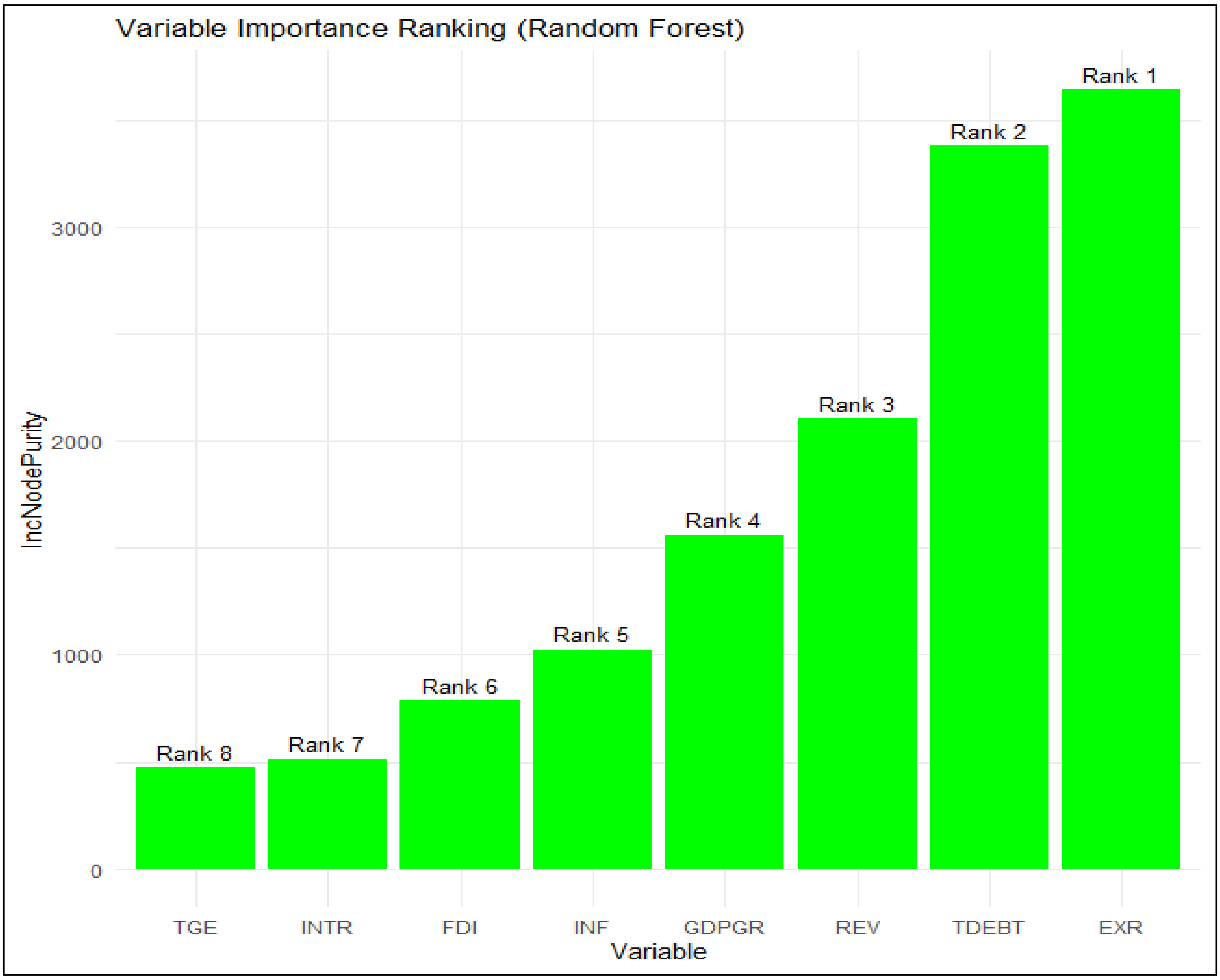

Fig 7 Variable Importance Rankings for Random Forest Model

Table 14 presents the evaluation results of the Random Forest model applied to predict Nigeria's external debt. Key performance indicators such as the coefficient of determination (R^2) and Root Mean Squared Error (RMSE) are used to assess the model's predictive accuracy.

Table 14 Results of Performance Metrics of the Random Forest Model for Predicting External Debt

Metric	Value	Interpretation
RMSE	10.2351	Indicates the model's average prediction error is approximately ₦10.24 billion
R^2	0.8287	Suggest that 82.87% of the variation in external debt is explained by the model.

Table 13 above shows that the random forest model used to predict Nigeria's external debt yields an R^2 of 0.8287, indicating that the model explains approximately 83% of the variation in the external debt series. This reflects a strong predictive performance and suggests that the selected macroeconomic variables (GDP growth rate, total debt, inflation, exchange rate, etc.) provide substantial explanatory power. The Root Mean Squared Error (RMSE) is ₦10.24 billion, which measures the average magnitude of the model's prediction errors. While RMSE does not distinguish between under- and over-prediction, a lower RMSE value (relative to the scale of the response variable) indicates better model accuracy. In this context, an RMSE of ₦10.24 billion is reasonable, given the size of Nigeria's external debt stock. Thus, the model not only identifies key variable importance but also delivers reliable quantitative forecasts, reinforcing its value for forward-looking debt policy and planning.

The chart below shows the trend alignment between actual and predicted external debt values from 2000 to 2023. The random forest model closely tracks the actual trend, though some deviations exist, reflecting model sensitivity to nonlinear shocks or macroeconomic volatility. The visual confirms the model's effectiveness in capturing debt dynamics, complementing the strong R^2 (0.83) and acceptable RMSE (₦10.24 billion) previously reported.

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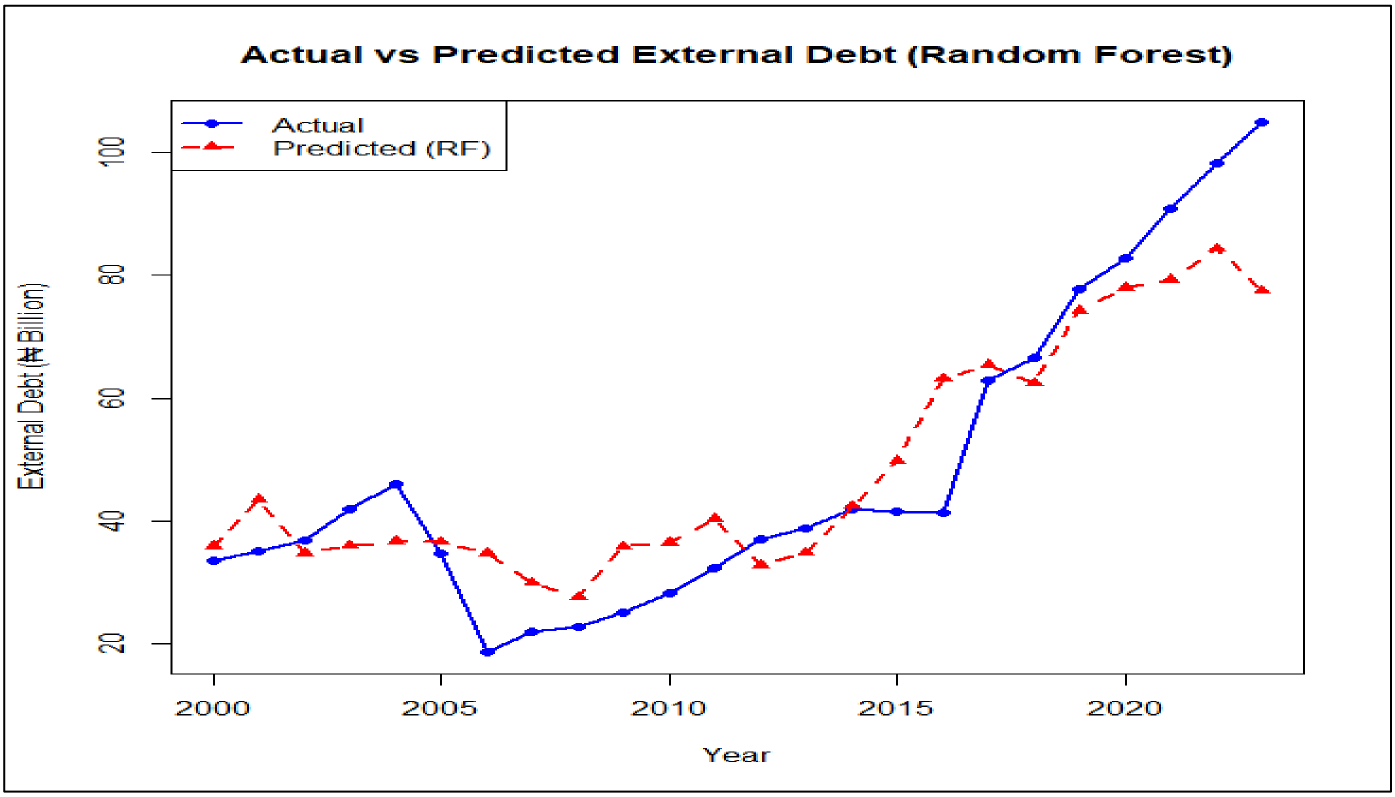

Fig 8 Actual vs. Predicted External Debt Using Random Forest Model

Table 15 displays the marginal effects estimated from the linear regression model, indicating how a unit change in each economic indicator affects the level of external debt, holding other variables constant. Statistically significant values highlight variables with meaningful influence on external debt.

Table 15 Results of Marginal Effects of Economic Indicators on External Debt (Linear Model)

Variable	AME	Std. Error	z-value	p-value	95% CI Lower	95% CI Upper
Economic Growth Rate	-0.1235	0.6451	-0.1914	0.8482	-1.3878	1.1408
Exchange Rate	0.1617	0.0417	3.8759	0.0001***	0.0799	0.2435
Foreign Direct Investment	-0.8169	0.6603	-1.2372	0.2160	-2.1111	0.4773
Government Revenue	0.5319	0.6472	0.8218	0.4112	-0.7367	1.8004
Inflation	-0.0042	0.0309	-0.1367	0.8912	-0.0649	0.0564
Real Interest Rate	-0.0024	0.3889	-0.0063	0.9950	-0.7648	0.7599
Total Debt	0.1805	0.0645	2.7985	0.0051**	0.0541	0.3069
Total Government Expenditure	0.5084	0.6586	0.7719	0.4402	-0.7825	1.7992

Source: Research Findings

Significance codes: *p < 0.001, p < 0.01, *p < 0.05*

The results from table 15 above indicate that the exchange rate exerts a positive and statistically significant marginal effect on external debt at the 1% level, with a unit increase (reflecting naira depreciation) leading to an average rise of approximately ₦0.16 billion in external debt, highlighting Nigeria's susceptibility to currency fluctuations. Similarly, total debt also demonstrates a positive and significant effect at the 1% level, suggesting a reinforcing dynamic where rising public debt is associated with increased external borrowing. In contrast, other variables such as economic growth, inflation, and government revenue do not exhibit statistically significant marginal effects on external debt, although some maintain expected directional influences, such as a negative association between growth and debt.

This section presents the policy simulation exercises conducted to assess how changes in key macroeconomic indicators particularly economic growth might influence Nigeria's external debt trajectory. The simulations are based on the linear regression model estimates and aim to provide evidence-based insights for debt management strategies.

This table 16 below presents the predicted levels of Nigeria's external debt under three hypothetical economic growth scenarios (2%, 3%, and 4%), based on the fitted multiple linear regression model. Each row shows the predicted external debt level (*fit*) along with its 95% confidence interval (*lwr* for lower bound, *upr* for upper bound):

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Table 16 Results of Scenario Forecast of External Debt under Varying Economic Growth Rate

Scenario	Predicted External Debt (₦ Billion)	Lower Bound (₦ Billion)	Upper Bound (₦ Billion)
2% Growth	48.75	44.05	53.44
3% Growth	48.62	45.06	52.19
4% Growth	48.50	45.82	51.17

Source: Research Findings

The table 16 results above suggest that as economic growth increases from 2% to 4%, the predicted level of external debt decreases slightly, although the effect is marginal. This aligns with economic theory that improved growth may reduce dependence on external borrowing. However, the small changes and overlapping confidence intervals indicate that the effect of economic growth alone may not be statistically strong enough to significantly alter debt levels without additional supporting fiscal and monetary policies.

The scatter plot in figure 9 below illustrates the relationship between Nigeria's external debt and its economic growth rate over the study period. Each point represents a yearly observation, while the blue line is a fitted regression line showing the trend, and the shaded region represents the 95% confidence interval. The plot shows a negative linear relationship between external debt and GDP growth rate. As external debt increases, the economic growth rate tends to decline. This suggests that higher levels of external debt may be associated with slower economic growth, possibly due to debt servicing burdens, reduced fiscal flexibility, or inefficiencies in debt utilization. However, while the trend is downward, the spread of the data points indicates that the relationship may not be strongly deterministic and could be influenced by other macroeconomic factors.

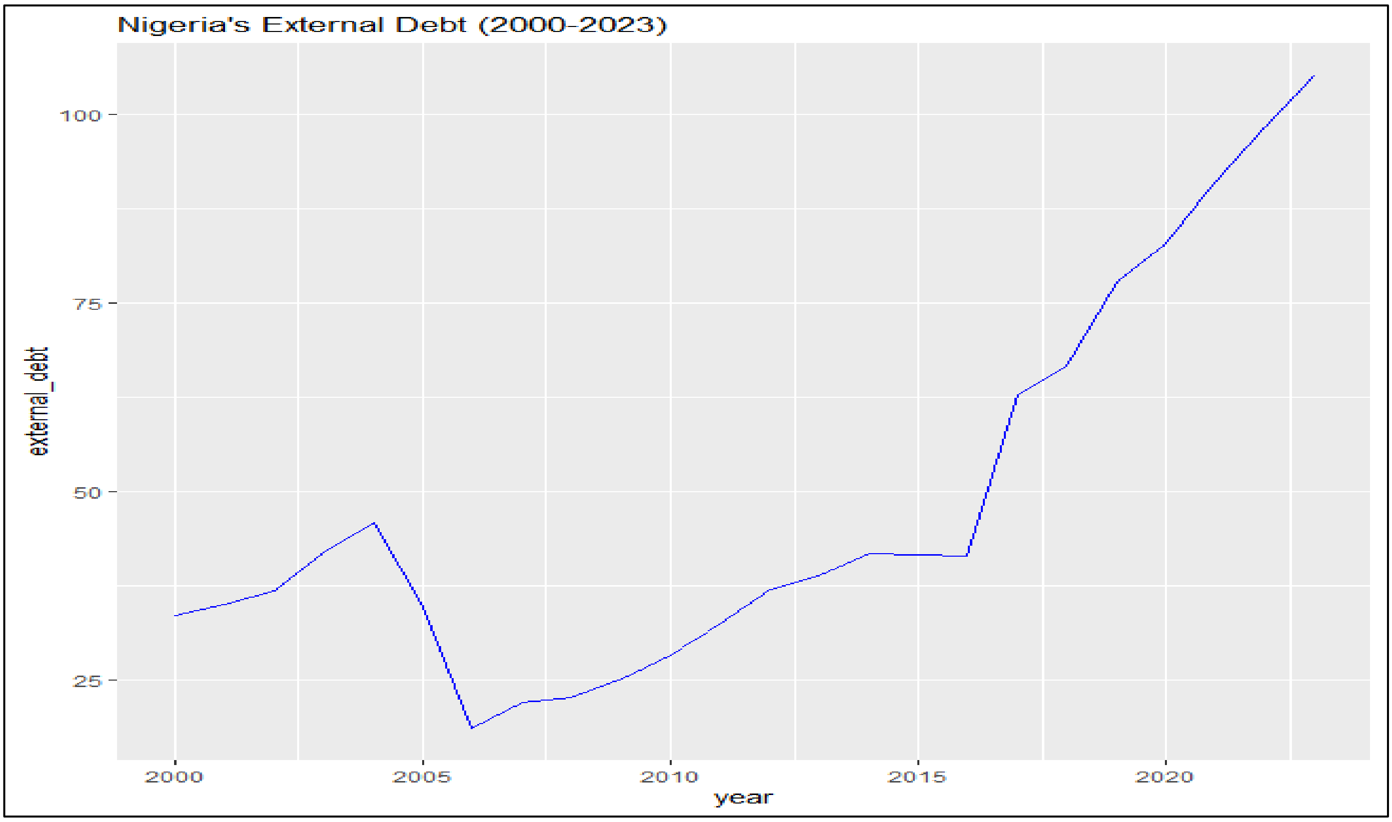

Fig 9 Scatterplot for External Debt vs, GDP Growth Rate

V. CONCLUSION AND POLICY RECOMMENDATION

This study examined the relationship between external debt and economic growth in Nigeria using both econometric and predictive modeling approaches. While external debt was found to have a negative but insignificant effect on GDP growth, other macroeconomic variables such as exchange rate and government expenditure play a more substantial role in shaping debt dynamics. Forecasting results suggest that Nigeria's external debt is on an upward trajectory, and economic growth alone may not be sufficient to reverse this trend.

The following policy recommendations are proposed: (1) adopt a sustainable borrowing strategy focused on concessional loans; (2) strengthen domestic revenue generation to reduce reliance on external financing; (3) implement fiscal discipline to control expenditure; and (4) stabilize the exchange rate through coordinated monetary and fiscal policies.

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APPENDIX

Table 17 Macroeconomic Variables

year	eco_growth_rate	foreign_direct_investment	external_debt	total_debt	exchange_rate	real_interest_rate	inflation	government_revenue	total_expenditure
2000	5.92	1.14	33.51	39.07	101.7	-1.14	6.93	28.81	24.74
2001	15.33	1.19	34.98	38.83	111.23	12.14	18.87	27.64	30.86
2002	7.35	1.87	36.78	40.66	120.58	3.02	12.88	20.72	19.38
2003	9.25	2.01	41.86	43.32	129.22	9.94	14.03	21.01	23.21
2004	6.44	1.87	45.91	46.26	132.89	-2.6	14.99	23.83	18.34
2005	6.06	4.98	34.61	32.13	131.27	-1.59	17.86	22.72	17.81
2006	6.59	4.85	18.58	20.95	128.65	-5.63	8.23	21.08	12.32
2007	6.76	6.04	21.95	21.28	125.81	9.19	5.39	17.02	18.13
2008	8.04	8.19	22.66	24.03	118.57	6.68	11.58	20.08	14.38
2009	8.01	8.56	25.06	25.63	148.88	18.18	12.54	10.1	15.43
2010	5.31	6.03	28.26	34.67	150.3	1.07	13.74	12.42	16.59
2011	4.23	8.84	32.38	72.18	153.86	5.69	10.83	17.73	17.3
2012	6.67	7.07	36.98	81.02	157.5	6.22	12.22	14.71	14.84
2013	6.31	5.56	38.77	94.18	157.31	11.2	8.5	11.48	14.14
2014	2.65	4.69	41.8	99.72	158.55	11.36	8.05	10.94	13.37
2015	-1.62	3.06	41.54	100.1	192.44	13.6	9.01	7.25	11.05
2016	0.81	3.45	41.36	94.73	253.49	6.69	15.7	5.12	9.76
2017	1.92	2.41	62.79	91.15	305.79	5.79	16.5	6.58	11.99
2018	2.21	0.78	66.57	116.78	306.08	6.06	12.1	8.5	12.82
2019	-1.79	2.31	77.71	138.41	306.92	4.52	11.4	7.83	12.49
2020	3.65	2.39	82.83	149.23	358.81	5.37	13.25	6.52	12.09
2021	3.25	3.31	90.89	157.53	401.15	1.23	16.95	7.08	12.56
2022	2.86	-0.19	98.34	189.16	425.98	0.92	18.85	8.96	14.38
2023	3	3.5	105	200	450	1.5	250	9.5	15

Source: World Bank (WB), Central Bank of Nigeria (CBN), National Bureau of Statistics (NBS)