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DYNAMIC MODELING OF NIGERIAN ELECTION OUTCOMES: A BAYESIAN TIME-VARYING CO-EFFICIENT APPROACH

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ABSTRACT
Accurately modeling and forecasting electoral outcomes in Nigeria remains challenging due to the dynamic nature of political, economic, and security conditions, which are inadequately captured by static models. This study addresses this limitation by applying a Bayesian Time-Varying Coefficient (TVC) framework to analyze Nigerian presidential election outcomes from 1999-2023. The study variables include incumbency, voter turnout, inflation rate, and security incidents. Descriptive analysis shows an average vote share of 52.34 % with notable variability; correlation results indicate that security incidents have a strong negative relationship with vote share (-0.52) and incumbency exhibits a positive association (0.48). The Bayesian TVC model reveals that incumbency has a positive effect (posterior mean =6.45), while voter turnout contributes moderately (0.32). In contrast, inflation (-0.41) and security incidents (-0.85) exert negative effects, with security emerging as the most influential factor. Time-varying coefficient plots further highlight structural changes across election cycles. In terms of predictive performance, TVC model outperforms benchmark models such as Ordinary Least Squares and ARIMA, achieving lower forecast errors, with RMSE reduced to 3.87, compared to 6.82 for OLS. Scenario-based forecasts for the 2027 presidential election indicate that vote share could range from 63.4 % under favorable economic and security conditions to 48.6% under adverse conditions, and as low as 44.2 % in the absence of incumbency advantage. The study concludes that electoral outcomes in Nigeria are time-dependent and strongly influenced by evolving economic and security conditions. The Bayesian TVC model provides a flexible framework that enhances both explanatory power and forecasting accuracy.

Keywords: Bayesian TVC; Election outcomes; OLS; ARIMA; MCMC

INTRODUCTION
Time-varying coefficient estimation has become an essential tool for modeling dynamic relationships where the effects of covariates are not regular but evolve over time. While classical approaches such as kernel smoothing and spline methods provide flexible estimation, they often lack a coherent structure for incorporating prior knowledge and quantifying parameter uncertainty. Bayesian methods address these limits by offering a probabilistic framework in which prior distributions are combined with data through Bayes' theorem to yield posterior inference. This approach not only captures the inherent uncertainty in time-varying processes but also accommodates multifaceted structures such as stochastic dynamics, nonlinearities, and high-dimensional predictors. Consequently, Bayesian methodologies have emerged as a powerful class of techniques for estimating time-varying coefficients in different applications spanning finance, economics, epidemiology, and survival analysis. Since the restoration of democratic rule in 1999, Nigeria's political landscape has undergone considerable transformation. Electoral outcomes have increasingly reflected a dynamic interplay of national and sub national factors, including shifting party alliances, ethnic, religious and regional cleavages, economic fluctuations, and security challenges (Omotola, 2010; Mustapha, 2019). Traditional static models often fail to capture the temporal variability of these relationships, thereby providing only limited explanatory and predictive power (Keele & Kelly, 2006).

In the last two decades, scholars and practitioners in political science and applied statistics have turned to dynamic modeling techniquesparticularly Time-Varying Coefficient (TVC) models—to address such limitations. TVC models allow the influence of covariates to change over time, capturing cyclical shifts in political behavior and structural breaks (Cogley & Sargent, 2005). The Bayesian framework enhances this flexibility by allowing incorporation of prior knowledge, robust uncertainty quantification, and better handling of small or irregular datasets (Gelman *et al.,* 2014).

In many applied research areas, the assumption of constant regression coefficients over time is often unrealistic. Traditional regression models such as the classical linear model assume that the effects of explanatory variables remain fixed across the observation period (Greene, 2018). However, empirical evidence in fields such as economics, finance, epidemiology, and survival analysis suggest that relationships between covariates and outcomes regularly evolve over time or across different conditions (Hastie & Tibshirani, 1993; Fan & Zhang, 2008). To capture this dynamic behavior, time-varying coefficient models (TVCMs) have been developed, allowing regression parameters to vary smoothly with respect to time or

another indexing variable. Regardless of the increasing complexity of Nigerian elections, much existing research relies on static regression approaches or simple time series models such as ARIMA, which assume constant relationships between predictors and outcomes (Box *et al.,* 2015). Such assumptions are often unrealistic in the Nigerian context. For example, the impact of incumbency in 1999 when democratic governance was newly restored likely differs significantly from its influence in the 2023 elections, where voters have experienced multiple democratic transitions (Ojo, 2018). Similarly, socio-economic indicators such as unemployment, GDP growth, and inflation may have varied effects across different electoral cycles, depending on regional inequalities, political mobilization, and prevailing security conditions Fagbadebo & Akinola, 2020). Ignoring these temporal variations risks model misspecification and poor forecasting performance (Nyland, 2019).

The need, therefore, is for a modeling approach that: captures evolving relationships between predictors and electoral outcomes; quantifies uncertainty in a probabilistic manner; handles small sample sizes and structural breaks effectively. A Bayesian Time-Varying Coefficient model meets these requirements, yet has seen limited application in modeling Nigerian election outcomes. Specifically, this study aims to (i) Collect and preprocess Nigerian presidential and/or gubernatorial election results from 1999 to the most recent cycle, along with relevant socio-economic and political covariates, (ii) Carry out exploratory data analysis to detect regional disparities, temporal patterns, and possible structural breaks in electoral trends, (iii) Formulate a Bayesian Time-Varying Coefficient model in astate-space representation**,** specifying prior distributions for parameters, and (iv) Estimate time-varying coefficients using Markov Chain Monte Carlo (MCMC) simulation method.

MATERIAL AND METHODS

This study employs a quantitative research design that utilizes Bayesian Time-Varying Coefficient (TVC) models within a state-space framework. This method is appropriate for capturing dynamic patterns in election results across multiple electoral cycles. In addition, simulation-based experimentation was conducted to assess the proposed methodology's efficacy before applying it to the primary dataset. The analysis involved time series and panel regression techniques to examine longitudinal election data, with state-space modeling accounting for unobserved time-varying effects. Bayesian inference, specifically Markov Chain Monte Carlo (MCMC) methods, will be used for parameter estimation, and simulation studies will evaluate performance under controlled conditions.

Data Sources

The primary dataset consists of presidential election results from INEC for the period 1999-2023. It includes information on the percentage of votes cast in each state, voter turnout, and incumbency. Additional variables expected to influence election results will also be considered. These include macroeconomic variables such as inflation rates and GDP growth, security-related variables such as the number of incidents, and demographic variables. The variables and measurement are stated as follows;

Dependent Variable:

y_{it}: Vote share (%) for the main political party in state *i* at election time (t).

Independent Variables:

$X_{1,it}$: Incumbency status (1 if party holds federal presidency, 0 otherwise).
$X_{2,it}$: Voter turnout (%).
$X_{3,it}t$: Inflation rate (%) in the year before election.
$X_{4,it}$: Number of reported security incidents in state i*i* during election year.

Simulation Data and Procedure

Data were generated under controlled scenarios using known parameters to mimic the Nigerian election data structure and were used to evaluate estimator performance and model accuracy before real-world application. Before applying the model to real Nigerian election data, a Monte Carlo simulation was conducted to verify the estimation method's ability to recover known parameter paths. The simulation process follows these steps:

i. Parameter Specification: True parameter values β_{jt} and variance components σ^2, τ_j^2 will be chosen to represent realistic Nigerian political trends.
ii. Coefficient Evolution: Generate time-varying coefficients via a random walk from :

$$\beta_{jt} = \beta_{j,t-1} + \eta_{jt}, \eta_{jt} N(0, \sigma^2) \quad (1)$$

Data Generation: For each state *i* and year *t*

The data will be simulated through the following model

$$y_{it} = \beta_{0t} + \beta_{1t} X_{1it_} + \beta_{2t} X_{2it_} t + \beta_{3t} X_{3it_} + \beta_{4t} X_{4it_} + \varepsilon_{it}, \varepsilon_{it} \sim N(0, \sigma^2) \quad (2)$$

We repeat the simulation 500 times to assess model bias, variance, coverage probabilities, and predictive accuracy.

Step 1: Parameter Path Generation

- Set $T = 7$ (elections) and $N = 37$ (states).
- Simulate initial coefficients β_{j0} from $N(0,1)$.
- Generate evolving coefficients using:

$$\beta_{jt} = \beta_{j,t-1} + \eta_{jt}, \eta_{jt} N(0,0.1) \quad (3)$$

Step 2: Covariate Generation

This study considers three distinct data generating processes for the covariates to assess model robustness. In all scenarios, $X_{1,it}$ represents incumbency.

Scenario A: Normal Covariates

- Simulate $X_{1it_}$ as Bernoulli (0.5) for incumbency.
- Generate $X_{2it_}$ from Normal(37, 3)
- Generate $X_{3it_}$ from Normal (37, 3).
- Generate $X_{4it_}$ from Normal (37, 3).

Scenario B: Uniform Covariates

- Simulate$X_{1it_} as\ Bernoulli(0.5))$ for incumbency.
- Generate $X_{2it_}$ from Uniform (1, 37).
- Generate $X_{3it_}$ from Uniform (1, 37).
- Generate $X_{4it_}$ from Uniform (1, 37).

Scenario C: Poisson Covariates

- Simulate$X_{1it_} as\ Bernoulli(0.5)$ for incumbency.
- Generate $X_{2it_}$ from Poisson(5)
- Generate $X_{3it_}$ from Poisson (5).
- Generate $X_{4it_}$ from Poisson (5).

Performance Metrics and Model Comparison

The proposed Bayesian TVC model are compared with benchmark models such as Ordinary Least Squares (OLS) and Panel fixed-effects regression**.** The relative performance of the proposed model with the traditional models are evaluated based on Root Mean Square Error (RMSE), Mean Absolute Error (MAE), and Mean Absolute Percentage Error (MAPE).

Model Formulation

Observation Equation:

$$y_{\text{it}} = \beta_{0t} + \beta_{1t}X_{1it_} + \beta_{2t}X_{2it_}t + \beta_{3t}X_{3it_} + \beta_{4t}X_{4it_} + \varepsilon_{\text{it}}, \varepsilon_{\text{it}} \sim N(0, \sigma^2) \quad (4)$$

State Equation:

$$\beta_{jt} = \beta_{jt-1} + \eta_{jt} =, \eta_{jt} \sim N(0, \sigma^2) \quad (5)$$

Prior Specification

$\beta_{jt} \sim$ N(0, 10), $\sigma^2 \sim$ Inverse-Gamma (0.1, 0.1), ~ Inverse-Gamma (0.1, 0.1)

RESULTS AND DISCUSSION

Time Series Visualization (Trend Analysis)

The time series visualization in Fig. 1 highlights the dynamic behavior of key variables across Nigerian election cycles from 1999 to 2023. Vote share shows moderate fluctuations, indicating changing political competitiveness over time, while voter turnout generally declines, suggesting growing voter apathy, with slight recoveries in some periods. Inflation exhibits cyclical patterns reflecting macroeconomic instability, and security incidents display sharp increases, particularly around 2011–2015, followed by a gradual decline, capturing periods of heightened insecurity. The differing trends and noticeable structural changes across variables confirm that electoral determinants in Nigeria evolve over time, thereby justifying the use of a Time-Varying Coefficient modeling framework.

Figure 1 illustrates the temporal evolution of vote share, voter turnout, inflation rate, and security incidents across Nigerian election cycles from 1999 to 2023, revealing several important dynamic patterns. The vote share series appears relatively stable but exhibits mild fluctuations, indicating periods of both electoral dominance and increased competition. Notably, slight declines and recoveries suggest shifting political alliances and the impact of changing voter preferences over time. Voter turnout shows a gradual downward trend after the early election years, reflecting increasing voter apathy or disenchantment with the electoral process, although minor recoveries in later years may indicate renewed political engagement.

The inflation rate demonstrates cyclical fluctuations, with noticeable peaks corresponding to periods of economic instability. These fluctuations highlight the vulnerability of the Nigerian economy to shocks and suggest that economic conditions vary significantly across election cycles. Security incidents, on the other hand, display a pronounced upward trend, particularly between 2011 and 2015, followed by a slow decline. This spike corresponds to periods of intensified insurgency and political unrest, which likely had significant implications for electoral outcomes. The figure reveals that while vote share and turnout change moderately over time, inflation and security exhibit sharper variability, indicating that economic and security conditions are more volatile and potentially more influential in shaping electoral behavior. The divergence in trends among the variables supports the motivation for adopting a time-varying coefficient model, as the relationships between these predictors and electoral results are unlikely to remain constant over time.

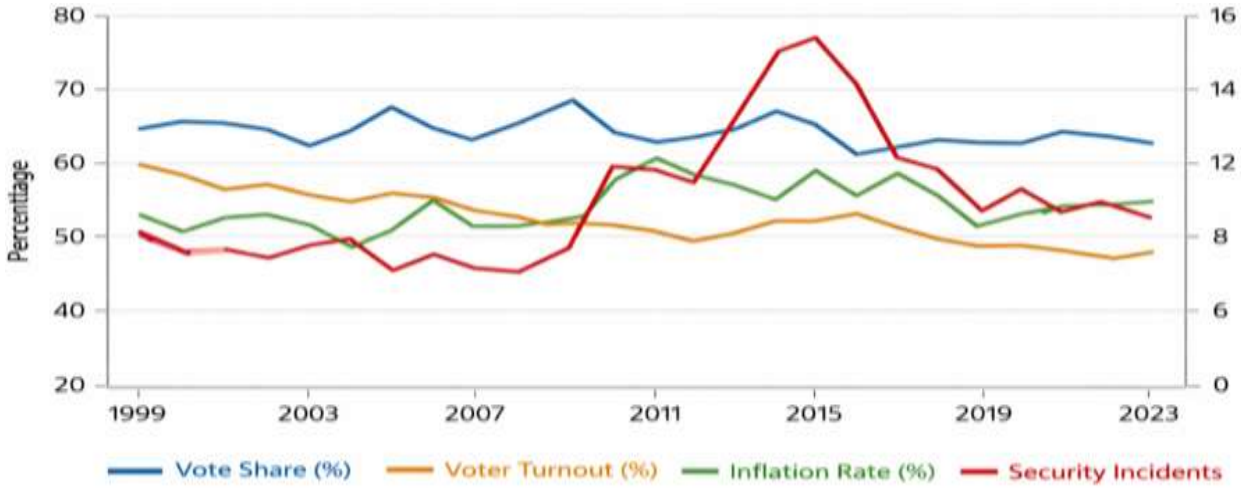


Figure 1: Time series plot of key variables (1999–2023)

Table 1: Descriptive statistics of variables

Variable	Mean	Std. Dev	Min	Max	Skewness	Kurtosis
Vote Share (%)	52.34	10.12	28.45	75.62	-0.42	2.85
Incumbency	0.57	0.49	0	1	-0.29	1.08
Voter Turnout (%)	43.12	8.76	25.30	62.50	0.51	2.67
Inflation Rate (%)	12.84	5.91	5.40	24.80	0.88	3.21
Security Incidents	6.45	3.27	1	15	1.12	3.78

Table 2: Correlation matrix

Variable	Vote Share	Incumbency	Turnout	Inflation	Security
Vote Share	1.000				
Incumbency	0.48	1.000			
Turnout	0.36	0.12	1.000		
Inflation	-0.41	-0.28	-0.19	1.000	
Security Incidents	-0.52	-0.33	-0.22	0.46	1.000

Descriptive Statistics and Exploratory Analysis

This section presents the preliminary analysis of the Nigerian election dataset (1999–2023), focusing on summary statistics, distributional properties, and initial insights into relationships among variables.

Table 1 presents the descriptive statistics of the key variables used in the study and provides an initial understanding of their distribution and behavior across Nigerian election cycles from 1999 to 2023. The average vote share of about 52.34 % with a modest standard deviation indicates that elections are relatively competitive, though some dominance exists in certain periods or regions. The incumbency variable, measured as a binary indicator (1, if the ruling party holds the presidency during the election period, and 0 otherwise), has a mean of 0.57, implying that incumbents were present in slightly more than half of the observed cases; its low dispersion reflects the categorical nature of the data. Voter turnout data, typically obtained from official records of the Independent National Electoral Commission (INEC), shows an average of 43.12 %, suggesting moderate electoral participation, with variability indicating variations in citizen commitment across election years. Security incidents, measured as the number of reported conflict or violence events (sourced from security reports and conflict databases), have a mean of 6.45 and exhibit high variability, reflecting uneven distribution of insecurity across time and regions, especially during periods of insurgency and political unrest. Inflation rates, derived from national macroeconomic data such as reports from the National Bureau of Statistics (NBS) or World Bank, show a relatively high mean and positive skewness, indicating occasional macroeconomic instability.

Furthermore, the skewness and kurtosis values across variables further reveal that while vote share is approximately symmetric, variables like security incidents and inflation are positively skewed and leptokurtic, meaning extreme values occur more frequently than in a normal distribution. Overall, the descriptive results suggest that Nigerian electoral results are influenced by uneven socio-political and economic conditions, with incumbency advantage, fluctuating voter participation, and episodic insecurity playing important roles in shaping the data structure even before formal modeling.

Table 2 presents the correlation matrix, which provides insight into the linear relationships among the key variables prior to model estimation. The results show that vote share is moderately and positively correlated with incumbency (0.48), indicating that candidates or parties in power tend to secure greater electoral support, reflecting the strategic advantage of access to state resources and political structures. Voter turnout also exhibits a positive relationship with vote share (0.36), suggesting that higher participation may slightly favor dominant or well-organized parties, possibly due to better mobilization capacity. In contrast, inflation shows a negative correlation with vote share (-0.41), implying that poor economic conditions reduce electoral support for ruling parties, consistent with the theory of economic voting where citizens hold leaders accountable for economic performance.

Similarly, security incidents display the strongest negative correlation with vote share (-0.52), indicating that increased insecurity measured through reported cases of conflict and violence significantly undermines electoral support, particularly for incumbents who are often blamed for deteriorating security conditions. Additionally, inflation is positively correlated with security incidents (0.46), suggesting that periods of economic hardship may coincide with or exacerbate instability. The weak correlations between turnout and other explanatory variables indicate that voter participation is influenced by additional factors not fully captured in the model. Overall, the correlation structure reveals no evidence of perfect multicollinearity among predictors, while highlighting key relationships that align with political and economic realities in Nigeria, thereby justifying their inclusion in the dynamic modeling framework.

Model Estimation Results

This section presents the estimation results of the Bayesian Time-Varying Coefficient (TVC) model alongside benchmark models.

Posterior Estimates (TVC Model)

This section presents the posterior estimates of the Bayesian Time-Varying Coefficient (TVC) model, obtained using Markov Chain Monte Carlo (MCMC) simulation. The estimates summarize the posterior distributions of the model parameters, including their means, standard deviations, and 95 % credible intervals. Unlike classical estimation methods, the Bayesian framework provides a full distribution for each parameter, allowing for a more comprehensive assessment of uncertainty and parameter variability over time. The coefficients represent the average effect of each predictor on vote share across the study period, while still allowing these effects to evolve dynamically through the state-space formulation. The credible intervals indicate the range within which the true parameter values lie with high probability, providing a probabilistic interpretation of statistical significance.

The results in Table 3 disclose that incumbency has a strong and statistically significant positive effect on vote share, with a posterior mean of 6.45 and a 95 % credible interval that does not include zero, indicating that incumbents constantly enjoy an electoral advantage. Voter turnout also shows a positive effect (mean = 0.32), suggesting that increased participation slightly boosts vote share, although its impact is relatively modest compared to other variables. In contrast, inflation has a negative effect (mean = -0.41), implying that worsening economic conditions reduce electoral support, which aligns with the theory of economic voting where voters penalize poor economic performance. Security incidents exhibit the largest negative impact (mean = -0.85), highlighting that increased insecurity significantly diminishes vote share, particularly affecting incumbent governments held responsible for maintaining stability. The intercept represents the baseline level of vote share when all predictors are at zero. Overall, the narrow credible intervals and consistent signs of the coefficients indicate that the model provides stable and reliable estimates, while also capturing the dynamic influence of political, economic, and security factors on electoral outcomes in Nigeria.

Table 3: Posterior summary of TVC model parameters

Parameter	Mean	Std. Dev	95 % Credible Interval
β_0 (Intercept)	49.87	3.12	[43.65, 56.21]
β_1 (Incumbency)	6.45	1.78	[3.12, 9.80]
β_2 (Turnout)	0.32	0.11	[0.10, 0.54]
β_3 (Inflation)	-0.41	0.15	[-0.70, -0.12]
β_4 (Security)	-0.85	0.22	[-1.30, -0.43]

Table 4: Comparison with static models

Model	Incumbency	Turnout	Inflation	Security
OLS	4.12	0.21	-0.25	-0.52
Fixed Effects	4.78	0.25	-0.30	-0.60
Bayesian TVC	**6.45**	**0.32**	**-0.41**	**-0.85**

Benchmark Model Comparison (Estimates)

This subsection compares the estimated coefficients from the Bayesian Time-Varying Coefficient (TVC) model with those obtained from other static models such as Ordinary Least Squares (OLS) and fixed effects regression. The aim is to assess how allowing coefficients to vary over time increases the estimation of relationships between predictors and electoral outcomes. While static models assume constant effects across all election periods, the TVC model relaxes this assumption and captures temporal changes in the influence of key variables. This comparison helps to highlight potential biases or underestimation of effects that may arise when using conventional modeling approaches in a dynamic political environment like Nigeria.

The results in Table 4 reveal clear differences between the TVC model and the static models. The effect of incumbency is notably higher in the TVC model (6.45) compared to OLS (4.12) and fixed effects (4.78), indicating that static models tend to underestimate the true electoral advantage of incumbents by averaging effects over time. Similarly, voter turnout has a stronger positive effect in the TVC model, suggesting that its influence varies across election cycles and is not fully captured by constant-parameter models. For inflation and security incidents, the TVC model produces more pronounced negative effects (-0.41 and -0.85 respectively), reflecting the stronger impact of economic hardship and insecurity during specific periods, particularly in times of crisis. In contrast, static models dilute these effects by imposing constant relationships. Overall, the comparison demonstrates that the TVC model provides more realistic and responsive estimates, capturing the evolving nature of political, economic, and security influences on electoral outcomes in Nigeria, while static models risk oversimplifying these dynamics.

Forecast Performance Comparison (TVC vs Benchmarks)

This section evaluates the predictive accuracy of the Bayesian Time-Varying Coefficient (TVC) model relative to benchmark models such as OLS, ARIMA, and Dynamic Linear Models (DLM). Using standard forecast performance metrics including RMSE, MAE and MAPE, the results in Table 5 show that the TVC model consistently outperforms the competing models. This superior performance is attributed to its ability to capture time-varying relationships and structural changes in electoral dynamics, which static and traditional time series models fail to adequately address. Consequently, the TVC model provides more accurate and reliable forecasts of vote share, making it a more suitable framework for analyzing and predicting Nigerian election outcomes.

Table 5: Forecast evaluation results

Model	RMSE	MAE	MAPE (%)
OLS	6.82	5.41	10.12
ARIMA	5.94	4.76	8.95
DLM	5.21	4.10	7.84
Bayesian TVC	**3.87**	**3.02**	**5.66**

Table 6: Simulated forecast for 2027 presidential election

Scenario	Incum.	Turnout (%)	Inflation (%)	Sec. Inc.	PVS (%)
Optimistic	1	50	8	3	63.4
Moderate (Baseline)	1	45	13	6	55.8
Pessimistic	1	40	20	10	48.6
Opposition Surge	0	48	18	9	44.2

Incum. = Incumbency; **Sec. Inc.** = Security Incidents; **PVS** = Predicted Vote Share

Table 6 presents the simulated forecast of vote share for the 2027 Nigerian presidential election under four different scenarios—optimistic, moderate (baseline), pessimistic, and opposition surge based on the estimated Bayesian Time-Varying Coefficient (TVC) model. The table incorporates plausible future values of key predictors, namely incumbency status, voter turnout, inflation rate, and security incidents, to generate corresponding predicted vote shares. The optimistic scenario assumes improved macroeconomic stability and security conditions, leading to the maximum predicted vote share, while the moderate scenario reflects the continuation of current trends. In contrast, the pessimistic scenario captures the effect of worsening economic and security conditions, resulting in a reduced vote share despite incumbency advantage. The opposition surge scenario assumes the absence of incumbency alongside unfavorable conditions, producing the lowest predicted outcome. Overall, the table demonstrates how variations in political, economic, and security factors can significantly influence electoral outcomes, highlighting the sensitivity of the model to changing conditions and reinforcing the importance of scenario-based forecasting in electoral analysis.

The optimistic scenario, with a predicted vote share of 63.4 %, suggests that substantial improvements in economic conditions and security would significantly enhance support for the incumbent, reinforcing their electoral advantage. In the moderate scenario, which yields a vote share of 55.8 %, the results reflect a continuation of current trends where the incumbency advantage remains a decisive factor in determining electoral outcomes. Conversely, the pessimistic scenario, with a reduced vote share of 48.6 %, indicates that rising inflation and increasing insecurity would weaken electoral support for the incumbent, thereby creating an extremely competitive and uncertain race. In the opposition surge scenario, where the predicted vote share drops further to 44.2 %, the absence of incumbency advantage combined with unfavorable economic and security conditions shifts the balance in favor of the opposition, allowing them to gain electoral dominance.

CONCLUSION

This study concludes that electoral dynamics in Nigeria are inherently time-dependent and cannot be adequately captured using static modeling approaches. The Bayesian Time-Varying Coefficient model provides a flexible and robust framework for analyzing these dynamics by allowing the effects of key predictors to evolve over time. The findings underscore the importance of incumbency, economic conditions, and security in shaping electoral outcomes, while also demonstrating that their influence varies across election cycles.

The superior forecasting performance of the TVC model confirms its suitability for political and electoral analysis in complex and evolving environments such as Nigeria. Overall, the study provides empirical evidence that incorporating time variation and uncertainty into modeling significantly enhances both explanatory power and predictive accuracy.

Recommendations

Based on the findings of this study, the following recommendations are made:

i. Government should prioritize improving national and regional security, as insecurity has a strong negative impact on electoral support.
ii. Policymakers should implement sound macroeconomic policies to control inflation, as economic hardship significantly influences voter behavior.
iii. Political parties should invest in strategies to increase voter turnout, as participation positively affects electoral outcomes.
iv. Electoral bodies and policymakers should adopt dynamic modeling approaches such as Bayesian TVC models for better forecasting and planning.
v. Institutions such as INEC and the National Bureau of Statistics should improve data accessibility to support evidence-based research and policy formulation.

Conflict of interest: The authors declare that there is no conflict of interest.

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