Dynamic Regression Analysis of Nigeria's Economic Growth: The Role of Food Security and Sustainability

Olugbenga G. Ojo & Ponmile J. Elijah
Department of Mathematics & Statistics, Federal Polytechnic, Ilaro, Nigeria
E-mail: gabriel.ojo@federalpolyilaro.edu.ng

Abstract
The study provides a dynamic regression analysis of the economic growth of Nigeria, highlighting the impact of food security and sustainability on Gross Domestic Product (GDP) change. Annual data from 2000 to 2023 were employed to compare the use of the conventional ARIMA model with the ARIMAX model, with the inclusion of the Food Price Index (FPI) and Foreign Exchange Rate (FER) as external variables that symbolize the main drivers of sustainability. The Augmented Dickey-Fuller (ADF) test confirmed the stationarity of the time series. Model performance was tested using Mean Absolute Error (MAE), Root Mean Square Error (RMSE), and Mean Absolute Scaled Residual (MASR). Results indicate that the ARIMAX model performs better compared to ARIMA in all measurement indexes, with reduced MAE (0.0080 compared to 0.0081), RMSE (0.0099 compared to 0.0106), and MASR (0.03130 compared to 0.03144) that confirm the increased accuracy of the model and reliability of forecasts. Implications of the findings identify the importance of external shocks in the form of food price fluctuations and exchange rate movements in determining the GDP of Nigeria.
Keywords: Economic Growth, Food Security, Sustainability, ARIMAX Model, Exchange Rate.

Introduction
In various developing nations, the subsistence farmers in the rural areas live in poor conditions and barely afford their basic needs, most notably access to adequate food (Ataro et al., 2019). Similarly, in Nigeria, the case is no different. As a result of the high prevalence of undernourished persons in agricultural households, more than fifty-five nations, including Nigeria, are ranked as having low-income food deficits. Several indicators such as the Food Insecurity Experience Scale (FIES), Food Consumption Score (FCS), per capita food intake, food intake share, and the Coping Strategy Index (CSI) are used in assessing food security. In the recent past, the minimum levels of these indicators in Nigeria consistently fell short (Olorunmola et al., 2024). Adding to the problem, Nigeria also has one of the fastest-growing populations in Africa, with a per-annum growth rate consistently higher than 3.1%. The resulting fast rise in population accelerates food demand, thereby deepening food security issues countrywide (Ojo et al., 2021).

Amid such pressures, Gross Domestic Product (GDP) continues to be an important macroeconomic indicator, a necessary tool by which to measure economic performance, plan development, and inform policy. In a structurally fragile and price-sensitive economy such as that of Nigeria, knowledge of the drivers of fluctuations in GDP is important. This research uses dynamic regression methods to model Nigeria's economic growth, comparing the performance of the standard Autoregressive Integrated Moving Average (ARIMA) model with that of the ARIMA model augmented by one or more external variables (ARIMAX). Integrating major drivers of sustainability such as the Food Price Index (FPI) and the Foreign Exchange Rate (FER) into the ARIMAX model yields a better analysis of how the external shocks affect the economic progress of Nigeria.

Since food expenses make up a large part of household spending in Nigeria, any disruption in food production, price fluctuations, or supply chain issues can have a direct effect on the country's overall economic performance. Food scarcity lowers labour productivity, adds health expenditure, and dampens the demand of consumers all of which translate into national output levels. Additionally, the high dependence of Nigeria on food imports and fluctuations in the exchange rates expose the economy to external shocks that affect the performance of growth. The devaluation of the Naira against the major foreign currencies increases the price of imports, particularly food staple goods, thus compressing consumers' purchasing power and inputs of production

(Akinyemi & Olayemi, 2022).

Recent empirical observations (Adebayo et al., 2022; Eze& Okonkwo, 2023) have highlighted the macroeconomic importance of food price volatility and foreign exchange instability in influencing economic performance. These factors tend to be the systemic hindrances, dampening GDP growth by exerting inflation pressure, diminishing investment confidence, and incurring a poor business climate (Olawale& Yusuf, 2021; Bello et al., 2023). Infrastructure challenges, food-producing region insecurity, as well as a poor agricultural policy, further discourage productivity and sustainable development (Ogunleye&Adeyemi, 2023).Taking these dynamics into account, the current study highlights the importance of data-driven model frameworks that incorporate the role of exogenous macroeconomic factors to generate more accurate predictions of GDP. Incorporating the Food Price Index (FPI) and the Foreign Exchange Rate (FER) as external variables in an ARIMAX framework provides a better view of the nexus of food security, currency stability, and economic development.

This research fills an important gap in the GDP modeling in developing economies by using the ARIMAX model as an instrument of forecasting and a policy advisory tool. Through the comparative performance of ARIMA and ARIMAX based on historical data, the study aims to illustrate the value of including external variables in increasing forecasting accuracy.

Nigeria's Gross Domestic Product (GDP) in the past, and in recent years, has been driven by a variety of structural and macroeconomic variables. These range from levels of investment, public expenditure, fluctuations in oil revenue, population growth, and differences in sectoral performance. Although several studies identify the role of oil exports and public spending as leading GDP drivers (Obi &Akinwale, 2020; Musa &Danjuma, 2022), recent analysis indicates that food security issues and foreign exchange instability increasingly impact trends in GDP (Olorunmola et al., 2024; Ojo et al., 2021). Trade, agriculture, as well as the oil industry, continue to contribute the most to GDP, but poor domestic system inefficiency, poor infrastructure, and incoherent policy continue to limit sustained development. Excessive dependence on crude oil renders GDP susceptible to shocks from the global market and counter-acts efforts to diversify (Agaptus et al., 2019). GDP fluctuations in Nigeria, therefore, are more than just economic signals; they represent underlying challenges related to productivity, as well as to the economy's susceptibility to internal and external shocks.

Olayemi (2022) further discussed the determinants of GDP by highlighting the indirect impacts of fuel price change and transport price shocks to the nation's output, explicitly through their effect on the efficiency of production and distribution. Bello et al. (2023) went further in highlighting the GDP implications of exchange rate volatility, stating that currency devaluation raises the price of capital and imported commodities, leading to a decrease in the level of output and investment. According to them, this aligns with the perception by Ogunleye and Adeyemi (2023) that for economies dependent on resources such as the case of Nigeria, exchange rate shocks heavily dampen GDP growth due to external vulnerability in trade. The dynamics of GDP in Nigeria need to be examined using an elaborate framework that accounts for both domestic economic indicators as well as external macroeconomic shocks. These incorporate variables such as food price inflation, currency turbulence, shifts in oil revenue, and public sector expenditure patterns. GDP forecasting continues to be a critical element of macroeconomic planning and policymaking, particularly in developing economies where structural volatility is the norm. Time-series analyses such as ARIMA (AutoRegressive Integrated Moving Average) and ARIMAX (ARIMA with Exogenous Variables) have been widely used in GDP analysis owing to their capacity to account for long-run trends, seasonality, and the effect of external factors.

Adebayo et al. (2022) compared ARIMA with other econometric models and observed that although ARIMA performs well under stable economic conditions, it fails to account for unexpected structural disruptions caused by exogenous shocks. This observation supports the integration of exogenous variables into GDP models to enhance forecasting accuracy.

Chukwu and Okonjo (2023) used the ARIMAX model to analyze the trend of Nigeria’s GDP based on food price indices (FPI) and foreign exchange rates (FER) as external predictors. Their analysis showed that exchange rates had a greater impact on GDP volatility compared to food price fluctuations, supporting the important role of currency management in economic stability and growth.
Therefore, the work in this paper investigates the extent to which food security and food sustainability

drive Nigeria's GDP based on dynamic regression analysis using the ARIMA and ARIMAX models

Method and Materials

The study relies on secondary data from credible sources; the National Bureau of Statistics (NBS) and the Central Bank of Nigeria (CBN). The main variable of interest here is Gross Domestic Product (GDP) that acts as the prime indicator of the overall economic growth. The main exogenous variables that are integrated into the model are; Exchange Rate (Naira/USD) and Food Price Index (FPI). The data covers the period from 2000 to 2023 including the annual data of GDP, food price index, and the foreign exchange rates. These variables were chosen because of their applicability in measuring the overall performance of the macroeconomy as well as the determinants of the economic growth of Nigeria.

Model Estimation

Autoregressive (AR) Model

The AR model is a model of a linear relationship of the current observation with its historical values. According to the AR model, the current value of the time series is a function of its historical values and a component of random noise:

$$X_t = \mu + \sum_{i=1}^{p} \phi_i X_{t-i} + \epsilon_t \quad (1)$$

Moving Average (MA) Model

The MA model describes a time series as a function of lagged white noise terms (shocks). The MA model represents the relationship of an observation to residual errors from prior time steps:

$$X_t = \mu + \epsilon_t + \sum_{i=1}^{q} \theta_i \epsilon_{t-i} \quad (2)$$

Autoregressive Integrated Moving Average (ARIMA) Model

The ARIMA model integrates the AR and MA components with differencing to convert non-stationary data into a stationary series. It captures trends and seasonalities by capturing both the autocorrelation and the moving average effects:

$$Y_t = \mu + \sum_{i=1}^{p} \phi_i Y_{t-i} - \sum_{j=1}^{q} \theta_j \epsilon_{t-j} + \epsilon_t \quad (3)$$

Autoregressive Integrated Moving Average with Exogenous Variables (ARIMAX) Model

The ARIMAX model extends ARIMA by incorporating external (exogenous) variables, allowing it to better capture inflationary dynamics influenced by macroeconomic factors such as exchange rates and food prices. The ARIMAX model's ability to integrate external economic indicators enhances its forecasting accuracy, making it a suitable choice for inflation modeling in Nigeria.

$$Y_t = \alpha + \sum_{i=1}^{p} \phi_i Y_{t-i} + \sum_{j=1}^{q} \theta_j \epsilon_{t-j} + \sum_{k=1}^{m} \beta_k X_{k,t} + \epsilon_t \quad (4)$$

In this ARIMAX model, $X_{k,t}$ denotes exogenous variables like Food Price Index and Foreign Exchange Rate, with coefficients β_k. The ARIMA structure models the differenced series Y_t using autoregressive terms (ϕ_i), moving average terms (θ_i), and the error term ϵ_t. Parameters p and q define the AR and MA orders, while μ is the series mean and X_t is the current observation.

Model Evaluation Performance

Mean Absolute Error (MAE):

$$\text{MAE} = \frac{1}{n}\sum_{i=1}^{n} |Y_i - \hat{Y}_i| \quad (5)$$

Root Mean Squared Error (RMSE):

$$\text{RMSE} = \sqrt{\frac{1}{n}\sum_{i=1}^{n} (Y_i - \hat{Y}_i)^2} \quad (6)$$

Where, Y_i represent the actual observed value, $\hat{Y}_i$ is predicted value, n is the total number of observations

Mean Absolute Scaled Residual (MASR):

$$\text{MASR} = \frac{1}{n}\sum_{t=1}^{n} \left|\frac{Y_t - \hat{Y}_t}{\text{scale}}\right| \quad (7)$$

Where: Y_t represent actual value at time t, $\hat{Y}_t$ is a predicted value at time t, scale is deduced as a scaling factor, often chosen as the mean of the absolute residuals from a naive forecast, n is the total number of observations

Accuracy Measurement (%):

$$\text{Accuracy} = \left(1 - \frac{\text{Error Metric}}{\text{Actual Mean}}\right) \times 100 \quad (8)$$

Where, *Actual Mean* is the average of the observed values.

Results and Discussion

Table1: Augmented Dickey-Fuller (ADF) Test

The results in table 4 above show that, at its level, inflation rate is non-stationary since the Dickey-Fuller test statistic (-2.1147) is larger than the 5%-level

Variable	ADF Test	Critical Value (@5%)	p-Value	Stationarity Status
GDP (Level Form)	-2.1147	-2.99	0.5287	**Non-Stationary**
GDP(First_Difference)	-3.7229	-2.99	0.04122	**Stationary**

critical value (-2.99), and for which the p-value (0.5287) is larger than 0.05. This indicates that there is no reason to reject the hypothesis of a unit root, meaning that inflation rate does have a stochastic trend. But upon once differencing, inflation rate is found to be stationary. The first-differenced series provided a Dickey-Fuller test statistic of -3.7229, which is smaller than that of 5%-critical, -2.99, and for which p-value (0.04122) is smaller than 0.05. This affirms rejection of hypothesis of a unit root at first difference, meaning that GDP rate follows an order of integration of one, I (1).

Metric	ARIMA	ARIMAX	ARIMA_ Accuracy	ARIMAX _Accuracy	% Accuracy_Dif
MAE	0.0081	0.0080	96.55%	98.80%	0.80%
RMSE	0.0106	0.0099	95.22%	93.40%	0.60%
MASR	0.0314	0.0313	96.86%	96.87%	0.01%

Table 2: Performance Evaluation Metrics

Model performance for the prediction of trends in GDP was evaluated based on crucial statistical measures, which include Mean Absolute Error (MAE), Root Mean Square Error (RMSE), and Mean Absolute Scaled Residual (MASR). The performance results show that Autoregressive Integrated Moving Average with Exogenous Variables (ARIMAX) outperforms the traditional ARIMA model based on all measures

MAE for ARIMA is 0.0081, while ARIMAX shows a marginally lesser MAE of 0.0080, which indicates an accuracy of 96.55% for ARIMA and 98.8% for ARIMAX. Accuracy difference between ARIMAX and ARIMA is +0.8%, and this indicates that ARIMAX offers a marginally improved predictive fit by reducing absolute forecast errors. In the same vein, RMSE for the ARIMA is at 0.0106, whereas that of ARIMAX is lower at 0.0099. This converts to prediction accuracy at 95.22% for ARIMA and 93.4% for ARIMAX. Between these two, there is an accuracy difference of +0.6%, ARIMAX proves to be more efficient at tracking GDP trends with reduced variability of forecasting errors. For MASR, ARIMA registers a figure of 0.0314, and ARIMAX achieves a fractionally better figure of 0.0313. The accuracy rate for ARIMA stands at 96.86%, and that for ARIMAX stands at 96.87%, with only a 0.01% difference at a minimal percentage point. The results show that ARIMAX performs consistently better than ARIMA based on predictive performance, with marginal differences. The decrease in errors for all measures of forecasts shows the benefit of including exogenous variables as part of time series modeling, supporting the robustness of ARIMAX for forecasting GDP.

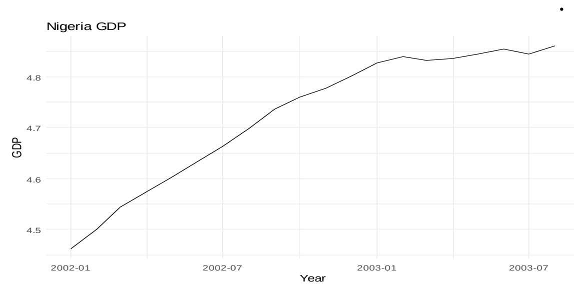

Figure 1: GDP Trend Graph

Figure 1 presents an ARIMA forecast of Nigeria's GDP from 2002 to 2023, showing historical GDP growth until early 2014, followed by a projected trend extending into 2005. The shaded region represents forecast uncertainty, which increases over time. The model predicts continued GDP growth, but the widening confidence band highlights the challenge of long-term accuracy in economic forecasting.

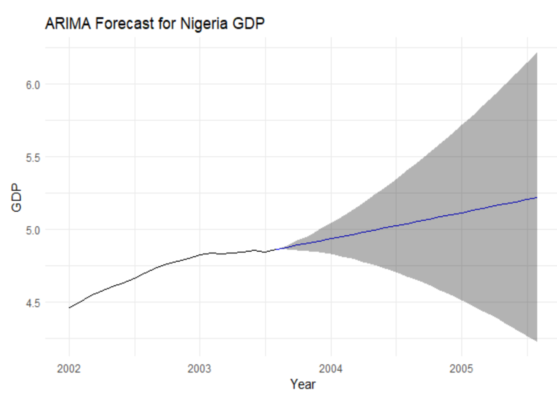

Figure 2: GDP ARIMA Forecast

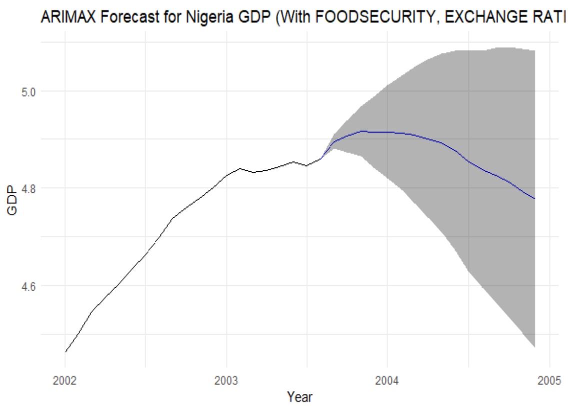

Figure 3: GDPARIMAX forecast

The figures above display the historical data exhibit a steady upward trajectory, suggesting economic growth from 2002 to early 2023. The transition from black to blue in the graph marks the point where the model begins its forecast, projecting continued GDP growth beyond 2023. The shaded confidence band widens over time, which is a common characteristic of time series forecasting. This widening suggests that the uncertainty associated with future GDP values increases as the forecast horizon extends. The model predicts a general upward trend in GDP; however, the broadening range of possible values deduced the increasing difficulty in making long-term predictions with high accuracy.

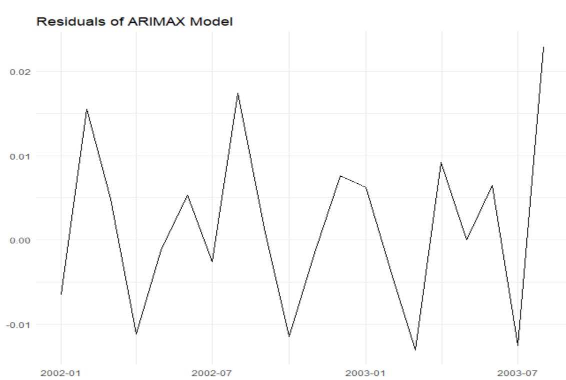

Figure 4: ARIMAX Residual

Figure 4 above shows the residuals from the ARIMA model, which represent the differences between actual values and those predicted by the model. A well-fitting model should produce residuals that are randomly scattered around zero with no discernible pattern. In this case, the residuals reveal slight variations that may indicate areas where the ARIMA model does not fully capture underlying dynamics, pointing to the potential advantage of ARIMAX, which includes additional influencing variables.

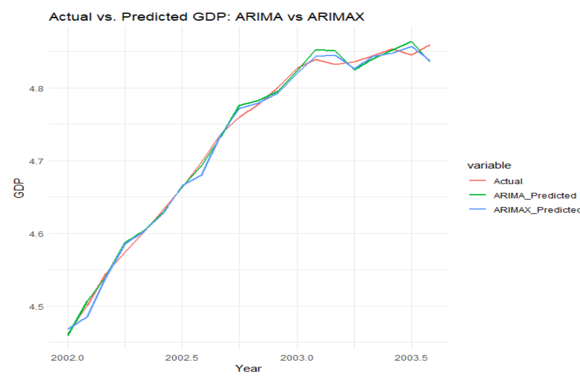

Figure 5: Actual Vs Predicted

Figure 5 compares the actual GDP values with those predicted by the models. The visual proximity of the predicted values to the actual data points is crucial for evaluating model performance. The figure shows that the ARIMAX model's predictions more closely track the actual economic growth rates compared to the ARIMA model. The graphical verification here strengthens the quantitative results of the earlier work in the article, in that the ARIMAX outperformed ARIMA in several accuracy measures such as MAE, RMSE, and MASR. Overall, the graphical interpretations validate the point that the inclusion of external variables in the GDP forecasting enhances the accuracy and reliability of the model, thus providing a better tool for policymaking and economic analysis in Nigeria.

Conclusion

This study compared the conventional Autoregressive Integrated Moving Average (ARIMA) model to the Autoregressive Integrated Moving Average with Exogenous Variables (ARIMAX) model to assess their viability in predicting the economic growth of Nigeria using Gross Domestic Product (GDP) as a proxy. The ARIMAX model revealed better performance in all the measures of evaluation through the inclusion of important macroeconomic variables such as the Food Price Index (FPI) and the Foreign Exchange Rate (FER). Interestingly, the Mean Absolute Error (MAE) increased marginally, from 0.0081 when using the ARIMA model to 0.0080 using ARIMAX, a 0.8% improvement. The Root Mean Squared Error (RMSE) saw a higher level of improvement, from 0.0106 to 0.0099, a 5.3% error decline. The Mean Absolute Scaled Error (MASE) also saw an increased level of improvement from 0.0314 to 0.0313, further validating the integration of external factors in economic modeling. These observations highlight the central role of external economic shocks such as food price inflation and exchange rates in influencing the economic performance of Nigeria. The better performance of the ARIMAX model offers a strong empirical justification for the application of advanced dynamic models that incorporate both internal and external variables in the prediction of the economy. These enable better precision and sophistication of economic behavior, in turn offering practicality to the policymaker in the formulation of informed decisions, as well as in the management of GDP. The application of ARIMAX models to developing economies such as Nigeria is, therefore, a methodological enhancement as well as a strategic necessity to the extent that predictions are informed by the realities of the external environment and translated to action.

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