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Stochastic Modelling and Long-Horizon Forecasting of Food Inflation in Nigeria

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Abstract

Food inflation constitutes one of the most volatile and economically significant components of the consumer price index in developing economies, with profound implications for household welfare, food security, poverty levels, and macroeconomic stability. In Nigeria, persistent fluctuations in food prices have intensified concerns regarding the effectiveness of monetary and fiscal policy interventions aimed at maintaining price stability. This study applies stochastic time-series modeling techniques to analyze and forecast food inflation dynamics in Nigeria using monthly food inflation data spanning January 2004 to December 2023. The methodological framework is based on the Autoregressive Integrated Moving Average (ARIMA) model, following rigorous statistical procedures including stationarity testing, differencing, model identification, parameter estimation, and diagnostic evaluation. The results indicate that the food inflation series exhibits non-stationary behavior at level but achieves stationarity after first differencing. Among the competing specifications examined, the ARIMA(1,1,1) model emerged as the most parsimonious and statistically robust forecasting model based on established information criteria and residual diagnostic tests. Empirical findings reveal strong inflation persistence, suggesting that past food price shocks continue to influence future inflationary movements. Furthermore, the observed volatility clustering indicates periods of heightened inflation uncertainty followed by relatively tranquil phases, reflecting the inherent instability of food price dynamics in Nigeria. Long-term forecasts generated from the fitted ARIMA (1,1,1) model over 5-, 10-, and 20-year horizons project sustained upward pressure on food prices, accompanied by widening forecast intervals that signify increasing uncertainty over time. The study provides a mathematical and empirical justification for ARIMA-based forecasting of food inflation and contributes to the growing literature on inflation modeling, forecasting, and policy analysis in developing African economies.

Keywords

Food inflation;
ARIMA model;
Time series analysis;
Forecasting; Nigeria

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Introduction

Food inflation has emerged as a persistent macroeconomic challenge in many developing economies [1]. In Nigeria, food prices account for a substantial share of household expenditure, making food inflation particularly welfare-sensitive. Persistent increases in food prices erode purchasing power, exacerbate poverty, and pose challenges for macroeconomic stabilization [2] [3].

Empirical evidence suggests that food inflation in Nigeria exhibits strong persistence, structural shifts, and volatility, reflecting supply-side constraints, transportation costs, and policy-induced shocks. From a mathematical standpoint, these characteristics motivate the application of stochastic time-series models capable of capturing non-stationarity and dynamic dependence [4].

Among available approaches, the Box–Jenkins ARIMA methodology remains a foundational framework for univariate time-series forecasting due to its theoretical rigor and empirical robustness.[5] Despite extensive research on inflation dynamics, relatively few studies focus explicitly on long-horizon stochastic forecasting of food inflation using extended monthly datasets. This study addresses this gap by modeling and forecasting Nigerian food inflation over multiple horizons within a formal ARIMA framework.

Literature Review

Early studies on inflation dynamics in Nigeria emphasized monetary and fiscal drivers, including money supply growth and exchange rate movements. Subsequent research highlighted the increasing importance of supply-side and structural factors, particularly in food price formation [2] [3].

Food inflation has attracted growing attention due to its volatility and distributional effects. Empirical studies demonstrate that food price shocks disproportionately affect low-income households, amplifying poverty and food insecurity. Methodologically, timeseries models dominate the inflation forecasting literature, with ARIMA models serving as a benchmark due to their flexibility and statistical efficiency [6] [7].

However, much of the existing literature focuses on headline inflation or short-term forecasting horizons. Limited attention has been paid to food inflation-specific modeling with long samples and extended forecasting horizons. This study contributes by providing a mathematically rigorous ARIMA-based analysis of food inflation persistence and predictability.

Data Description

Monthly food inflation data for Nigeria covering January 2004 to December 2023 are used in this study [8]. The data represent year-on-year percentage changes in the food component of the Consumer Price Index and were obtained from the National Bureau of Statistics. Figure 1 displays the food inflation series. The plot reveals a pronounced upward trend and several sharp spikes, suggesting non-stationarity and potential volatility clustering.

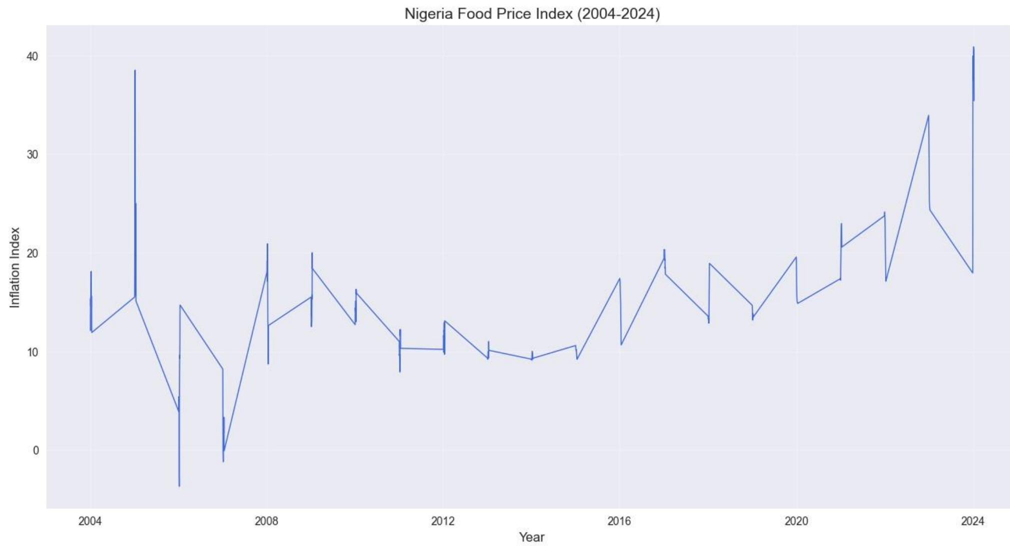

Figure 1: Monthly food inflation in Nigeria (2004–2023)

Methodology

Stationarity Testing

Stationarity is a fundamental requirement for ARIMA modeling.

Definition 1. *A stochastic process* $\{Y_t\}$ *is weakly stationary if its mean, variance, and autocovariance are time-invariant.*

The Augmented Dickey–Fuller (ADF) test is employed to test for unit roots. Results indicate that the series is non-stationary in levels but stationary after first differencing, implying integration of order one [6].

ARIMA Model

Definition 2. *An ARIMA(p,d,q) process is defined as*

$$\phi(L)(1-L)^d Y_t = \theta(L)\varepsilon_t,$$

where ε_t *is white noise.*

Theorem 1. *If* $\{Y_t\}$ *is an integrated process of order d and the roots of* $\phi(L)$ *and* $\theta(L)$ *lie outside the unit circle, then the ARIMA(p,d,q) process is stable and invertible [7].*

Proof. Differencing d times removes the stochastic trend, yielding a stationary ARMA(p,q) process. Stability and invertibility follow from standard ARMA conditions on characteristic roots. □

This result justifies the use of ARIMA models for non-stationary food inflation series.

Model Identification and Estimation

The autocorrelation and partial autocorrelation functions of the differenced series suggest low-order AR and MA components. Competing models are evaluated using Akaike and Bayesian information criteria.

Table 1 shows that ARIMA(1,1,1) minimizes both criteria.

Table 1: Model selection criteria

Model	AIC	BIC
ARIMA(1,1,0)	6.21	6.30
ARIMA(0,1,1)	6.18	6.27
ARIMA(1,1,1)	**6.05**	**6.16**

Estimated parameters are statistically significant, indicating strong inflation persistence.

Diagnostic Analysis

Residual diagnostics confirm the absence of serial correlation, validating the adequacy of the mean equation. However, ARCH effects are detected, indicating volatility clustering.

Figure 2 presents residual diagnostics, showing periods of high variance consistent with inflation shocks.

These findings illustrated that while ARIMA captures conditional mean dynamics, extensions such as ARIMA-GARCH may be suitable for modeling the food inflation variance dynamics.

4.4 Forecasting Results and Model Diagnostics

The predictive performance of the selected ARIMA (1,1,1) model was evaluated through residual diagnostic analysis and long-term out-of-sample forecasting. Forecasts were generated over three projection horizons of 5, 10, and 20 years beyond the sample period (January 2004–December 2023) to assess the future trajectory of food inflation in Nigeria.

The resulting forecast paths and their associated confidence intervals are presented in Figures 3–5, while the residual diagnostic results are shown in Figure 2.

Residual Diagnostic Analysis

Figure 2 presents the residual diagnostic plots for the fitted ARIMA (1,1,1) model. The standardized residual series fluctuates randomly around zero without any discernible trend or systematic pattern, indicating that the model has adequately captured the underlying temporal structure of the food inflation data. The residual density distribution closely approximates normality, with only minor deviations in the tails, suggesting acceptable distributional assumptions for forecasting purposes. The Normal Q-Q plot further confirms that the residuals largely follow a normal distribution, as most observations lie close to the reference line. Additionally, the correlogram of residuals reveals that autocorrelation coefficients remain within the 95% confidence bounds across all lags, indicating the absence of significant serial correlation. These diagnostic outcomes demonstrate that the residuals behave as white noise, confirming the statistical adequacy and forecasting reliability of the ARIMA (1,1,1) specification.

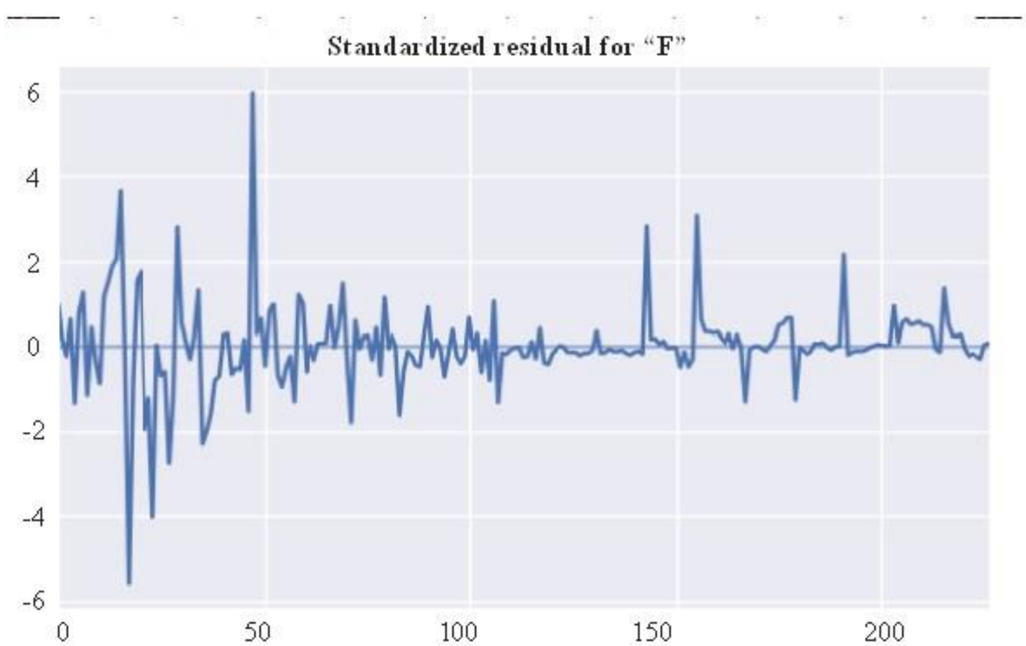

Figure 2: Residual diagnostics of ARIMA (1,1,1)

Five-Year Forecast Horizon

Figure 3 illustrates the projected food inflation trajectory for the next five years. The forecast indicates a continuation of the upward trend observed during the historical period, reflecting the persistence of inflationary pressures in the Nigerian food sector. The central forecast line exhibits a gradual increase over time, while the confidence intervals widen moderately as the forecast horizon extends. This widening reflects the accumulation of forecast uncertainty associated with future economic conditions, policy interventions, climatic variability, exchange rate fluctuations, and supply-chain disruptions. Nevertheless, the relatively narrow confidence bands during the early forecast years suggest a reasonable degree of predictive confidence in the short to medium term.

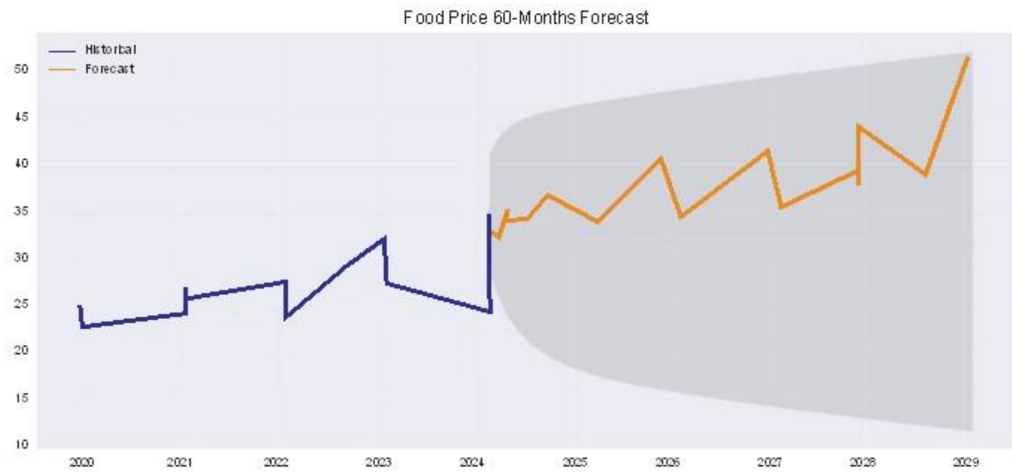

Figure 3: 5 years food inflation forecasts

Ten-Year Forecast Horizon

Figure 4 presents the ten-year forecast of food inflation. The results indicate sustained inflationary momentum, with the forecasted series maintaining its upward trajectory throughout the projection period. Compared with the five-year forecast, the confidence intervals become noticeably wider, reflecting increased uncertainty associated with longer-term predictions. This pattern is expected in stochastic forecasting models because forecast errors accumulate over time. The results suggest that unless significant structural reforms, productivity improvements, or effective monetary interventions are implemented, food prices may continue to experience persistent upward pressure over the medium to long term.

Figure 4: 10 years food inflation forecasts

Twenty-Year Forecast Horizon

Figure 5 shows the twenty-year forecast horizon and represents the longest projection considered in this study. The forecast continues to indicate an overall upward movement in food inflation, highlighting the long-run persistence embedded in the historical inflation process. The prediction intervals expand substantially over this horizon, demonstrating the growing uncertainty inherent in long-term economic forecasting. Such uncertainty may arise from future structural changes in agricultural production, demographic growth, climate-related shocks, technological advancements, fiscal and monetary policy adjustments, and global commodity market fluctuations.

Although the point forecast suggests continued inflation growth, the broad confidence intervals imply that actual future outcomes may deviate considerably from the central projection. Consequently, these long-term forecasts should be interpreted as indicative scenarios rather than precise predictions. The results nevertheless provide valuable insights for policymakers and economic planners regarding the likely direction and potential volatility of food inflation over extended periods.

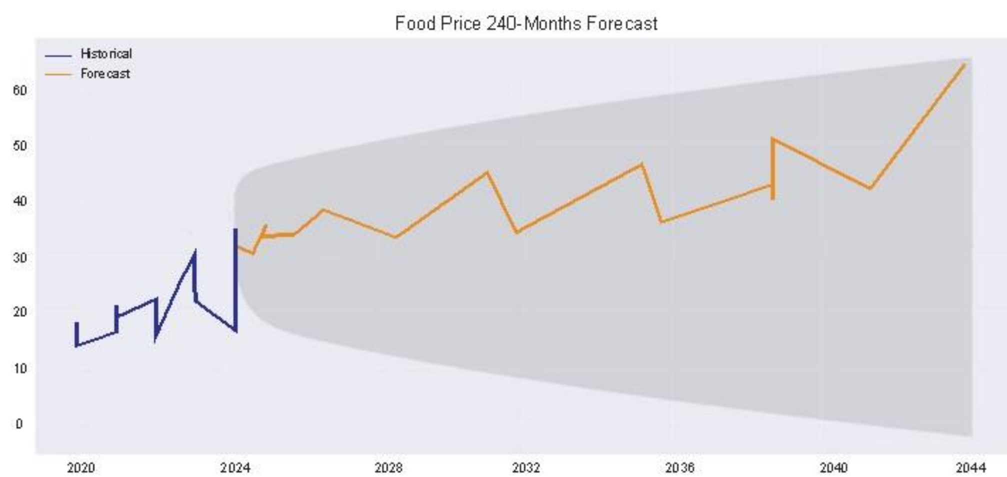

Figure 5: 20 years food inflation forecasts

5. Conclusion

This study employed a stochastic time-series modeling framework based on the Autoregressive Integrated Moving Average (ARIMA) methodology to investigate the dynamics and forecast future trends of food inflation in Nigeria using monthly observations spanning January 2004 to December 2023. The empirical analysis demonstrated that the food inflation series is non-stationary at its level form but attains stationarity after first differencing, thereby justifying the application of an ARIMA modeling approach. Following model identification, estimation, and diagnostic evaluation, the ARIMA (1,1,1) specification was selected as the optimal forecasting model based on its statistical adequacy, information criteria, and residual diagnostic performance.

The findings reveal that food inflation in Nigeria exhibits strong persistence, implying that inflationary shocks tend to have prolonged effects on future price movements. Furthermore, the observed volatility clustering suggests that periods of high inflation uncertainty are often followed by similar periods of elevated volatility, reflecting the influence of structural and macroeconomic factors on food price dynamics. Diagnostic tests confirmed that the model residuals behave as white noise, indicating that the selected model adequately captures the underlying stochastic process governing food inflation.

Long-term forecasts generated over 5-, 10-, and 20-year horizons consistently indicate sustained upward pressure on food prices, accompanied by progressively widening confidence intervals. This pattern highlights not only the persistence of inflationary tendencies but also the increasing uncertainty associated with long-term economic forecasting. The results underscore the need for effective monetary policies, improved agricultural productivity, enhanced food supply chains, and broader structural reforms aimed at mitigating food price instability.

Overall, this study provides a mathematical and empirical basis for ARIMA-based food inflation forecasting in Nigeria and contributes to the growing literature on inflation modeling in developing economies. Future studies may improve forecasting accuracy by incorporating exogenous macroeconomic variables such as exchange rates, money supply, interest rates, crude oil prices, and agricultural output through multivariate frameworks including Vector Autoregressive (VAR), ARIMAX, and Vector Error Correction Models (VECM). In addition, volatility-based models such as Generalized Autoregressive Conditional Heteroskedasticity (GARCH) and its variants may be employed to explicitly capture the time-varying volatility characteristics inherent in food inflation data.

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