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Analyzing Nigeria Monthly Consumer Price Index Using the ARIMA Model

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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Abstract

Consumer Price Index (CPI) serves as economic vital indicator that helps decision makers to apply the right approach to investment areas in the midst of limited resources. CPI measures the changes in the broad

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spectrum level of prices pof consumer goods and services that households employ for utilization. This paper seeks to investigate the fluctuations of Nigeria Consumer Price Index from 2009-2024 using an Autoregressive Integrated Moving Average (ARIMA) model to predict future values of Nigeria CPI based on past values. The data was analyzed to make well informed economic decisions as it indicates the change in consumers' purchasing power. The forecast based on the ARIMA (3,2,2) model shows a continuous upward trend in CPI, with the point forecasts suggesting rising inflation rates throughout 2024 and 2025. The Seasoned Autoregressive Integrated Moving Average, SARIMA (3,2,2) (2,0,0)12 model was identified as the best fitted model for the CPI. The study therefore concluded that the model has been shown to adequately explain the variation in the monthly CPI.

Keywords: ARIMA; consumer price index; stationarity; forecasting; inflation.

1 Introduction

Consumer Price Index (CPI) measures changes in consumers' prices over time by considering the cost of purchasing a fixed basket of consumer goods and services of constant quality and characteristics, with the products in the basket being selected to be representative of households' expenditure during a year or other specified period (Rossouw, 2015).

Different Researchers have worked on Consumer Price Index (CPI) through predictive and forecasting models. The major culture has been to compare and contrast the accuracy of the predictive or forecasting models relative to univariate time series models. British Broadcasting Corporation (2024) verified that the inflation in Nigeria remains an economic battle that frustrates its citizens, as the country's inflation rate hits 32.2%. The inflation rate of food prices in Nigeria hit 37.5% in 2024 and the removal of fuel subsidy is the germane factor behind this.

National Bureau of Statsitics (2024) validated that the CPI in Nigeria measures the change over time in prices of 740 goods and services by people for basic daily living. The index weights are based on expenditures of both urban and rural households in the 36 states and the FCT. The most vital in the categories are food and beverages (non-alcoholic), housing, water, electricity, gas and other fuel, clothing and footwear, transportation, household equipment maintenance, and furnishings.

Zhang (2024) discovered that CPI increases more quickly than earnings, which has an impact on our cost of living. The consumer price index demonstrates the general level of inflation in the economy and it is regarded as an indicator of the standard of living of the population and socio-economic development. To regulate price increases, it is important to adopt statistical models to estimate inflation rate based on a scientific analysis of the changes in the costs or prices of goods and services.

Corpin et al., (2024) investigated that businesses used inflation estimates to plan their production schedules and establish prices for their goods and services. When precise forecasting results aid in the development of future government policies, forecasting becomes an important tool in the corporate world.

Prapcoyo and As'ad (2022) adopted single exponential smoothing to make predictions based on the weighted average of past observations. Single exponential smoothing is a simple and widely used technique for forecasting future values in time series, especially when the data does not exhibit complex patterns, trends or seasonality. The researchers also discussed the Mean Squared Error (MSE); which is another commonly used performance metric to evaluate the accuracy of a forecasting model. It measures the average of the squared differences between the predicted values and the actual values.

Boniface and Martin (2019) Investigated time series modeling and forecasting of Consumer Price Index in Ghana using the Box-Jenkins model methodology to formulate the appropriate model for the CPI. The trend analysis used by the researchers for the CPI considered linear, quadratic, exponential growth model and S-curve model**,** and it was concluded that the trend of the CPI in Ghana had an S-model.

For a number of economic factors, including efficiency, financial markets, and monetary policy, it is critical to accurately estimate the change in the CPI (Wanto et al, 2018). Furthermore, the general public, decision-makers, and researchers will place a great deal of importance on developing a reliable and precise CPI forecasting model (Rohmah et al, 2021; Syintya et al, 2021; Laban and Enid, 2023; Anas and Olagunju, 2020; Hyndman and

Athanasopoulos, 2012; Ord and Fildes, 2013). This study therefore aims at forecasting the Consumer Price Index in Nigeria between 2009 and 2024 using the ARIMA (3,2,2) model.

1.1 Significance of the study

Forecasting the CPI is very vital for managing inflation and guiding monetary policy, assisting Central Banks of different countries to set interest rates and stabilize their individual economy. This study will therefore assist Nigeria and other countries in budgeting, adjusting wages, and ensuring social programs align with inflation trends. Businesses and investors will be able to use CPI forecasts for pricing strategies, cost management, and financial planning, while consumers adjust spending to preserve purchasing power. With this work, accurate CPI predictions will support Nigeria economic stability, safeguard vulnerable populations, and build confidence in public institutions.

2 Methodology

The model used in this study was Autoregressive Integrated Moving Average (ARIMA) to predict future values based on past values Model identification was adopted in the analysis, as we tested for stationarity of the original data, by checking, Autocorrelation Function (ACF), Partial Autocorrelation Function (PACF), and Augmented Dickey-Fuller test. Akaike Information Criterion (AIC) was used to select the best fitted model of the stationary series.

Estimation of the ARIMA model:

$$\begin{aligned} &AR(1): X_t = \phi_1 x_t + e_t \\ &X_t - \phi X_{t-1} = e_t \\ &(1-\phi B)X_t = e_t \\ &\phi(B)X_t = e_0 \\ &\phi_1(B) = 1 - \phi B \end{aligned} \tag{1}$$

$$\begin{aligned} &AR(2): \phi(D)X_t = e_t \\ &\phi_2(B) = (1 - \phi_1 B - \phi_2 B^2) \\ &\phi_2(B) = 0, \\ &1 - \phi_1 B - \phi_2 B^2 = 0 \end{aligned} \tag{2}$$

$$MA(1): Y_t = e_t - \theta e_{t-1} \tag{3}$$

$$\begin{aligned} &MA(2): \rho_1 = \frac{-\theta_1 + \theta_1\theta_2}{1+\theta_1^2+\theta_2^2} \\ &\rho_2 = \frac{-\theta_2}{1+\theta_1^2+\theta_2^2} \end{aligned} \tag{4}$$

$$SMA(1): Y_t = \theta_2(B)H_a[B^s]e_t \tag{5}$$

where AR(1), AR(2), MA(1), MA(2) and SMA(1) are Autoregressive model of order 1, Autoregressive model of order 2, Moving Average of order 1, Moving Average of order 2 and Seasonal Moving Average of order 1 respective.

This paper focuses on an ARIMA model, a particular linear variety of autoregressive models. The ARIMA model utilizes lagged averages to level time series data and is used in technical analysis to forecast future CPIs. The algorithm of the model makes the presumption that what the current economic situation is, will affect the future economic situation. Augmented Dickey-Fuller models were used to test for stationarity. The series was differenced two times to achieve stationarity.

Estimation of the model was done by ACF and PACF. In the model diagnostic test, the model residual analysis was performed. Thereafter, forecast was made using the best fitted model.

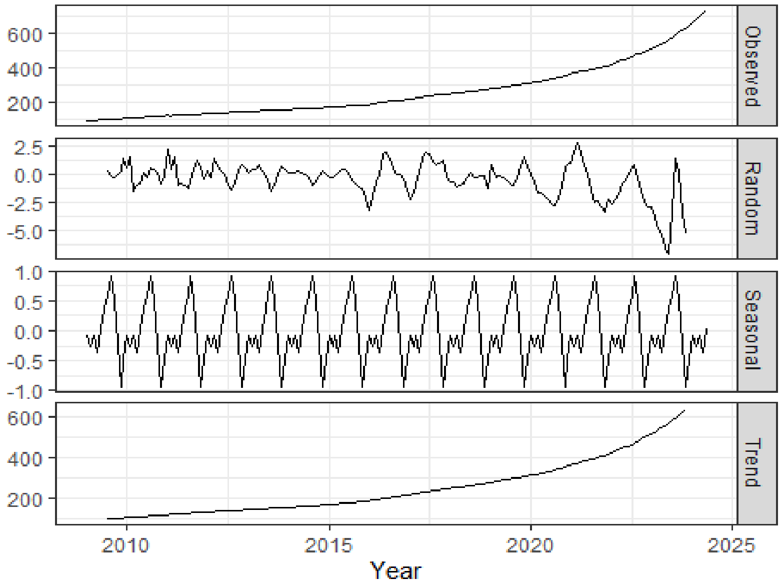
$$Y_t = \phi_1 X_{t-1} + \phi_2 X_{t-2} + \phi_3 X_{t-3} + \phi_4 X_{t-4} + \phi_{12} X_{t-12} + \phi_{24} X_{t-24} + \theta_1 e_{t-1} + \theta_2 e_{t-2} + e_t \tag{6}$$

3 Results and Discussion

Table 1. Descriptive statistics

Min.	Q1	Median	Mean	Q3	Max.
88.88	141.10	206.68	257.30	330.10	733.40

The descriptive statistics of the Nigerian CPI data reveal significant variability in the prices over time. The minimum CPI value is 88.88, while the maximum is 733.40, indicating a steep rise in prices over the period under review. The mean CPI is 257.30, with a standard deviation of 153.28, further confirming the presence of substantial fluctuations in the data. The high variance suggests considerable volatility in the inflation rate during this period.



$$X_t = 0.7719X_{t-1} - 0.4617X_{t-2} + 0.347X_{t-12} - 0.1275X_{t-24} - 1.2202e_{t-1} + 0.8098e_{t-2} + e_t$$

Fig. 1. Grid-plot of time series decomposition

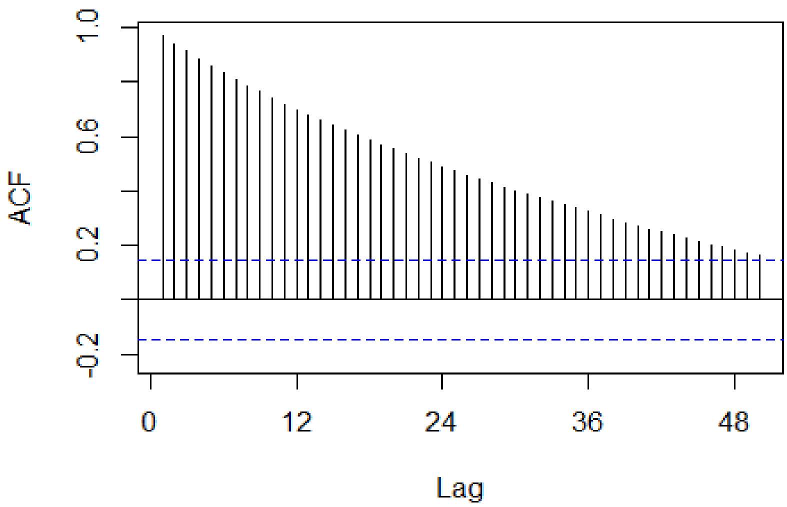


Fig. 2. ACF plot of consumer price index

Fig. 2 illustrates the ACF values across 50 lags. It was observed that there is a gradual decline in the ACF coefficients as the lag increases. This observation leads us to suspect that the time series data may be non-stationary. To further investigate this, we conducted a unit root test using the Augmented Dickey-Fuller test to assess the stationarity of the data. The results yielded a p-value of 0.99. since the p-value exceeds the significance level of 0.05, we do not reject the null hypothesis, indicating that the data lacks stationarity.

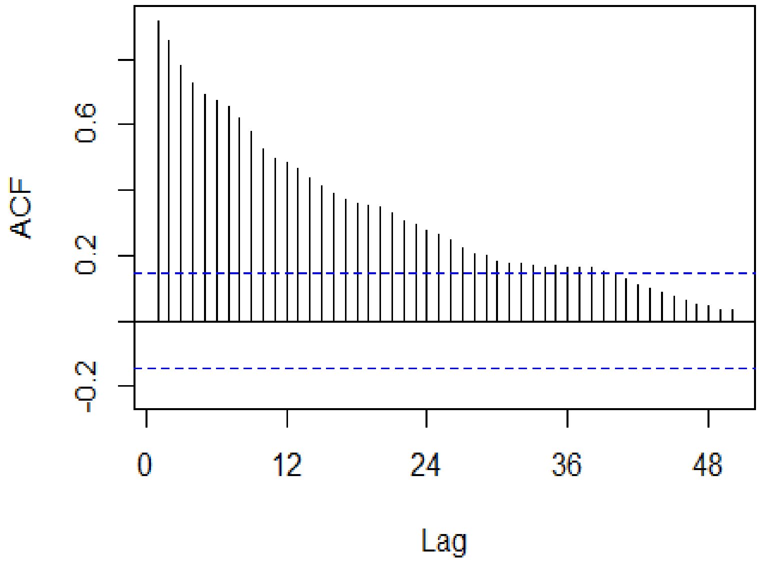


Fig. 3. ACF test after first difference

The stationarity of the CPI series was tested using the Augmented Dickey-Fuller (ADF) test. Initially, the ADF test on the original data returned a p-value of 0.99, indicating non-stationarity. The non-stationarity was also confirmed by the presence of significant autocorrelations in the Autocorrelation Function (ACF) plot. To address this issue, the data was differenced. The first difference, however, still showed non-stationarity with a p-value of 0.99. Finally, upon applying a second difference, the ADF test indicated stationarity, with a p-value of 0.01, making the data suitable for further time series modeling.

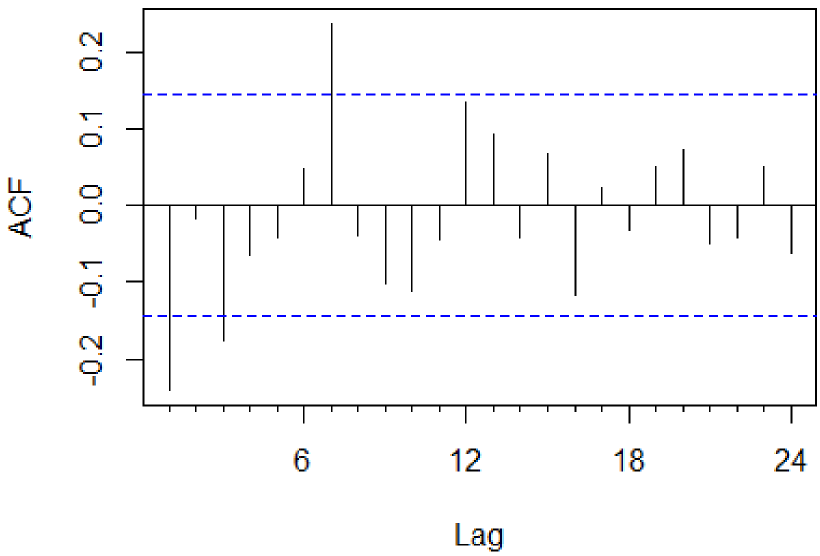


Fig. 4. ACF test after second difference

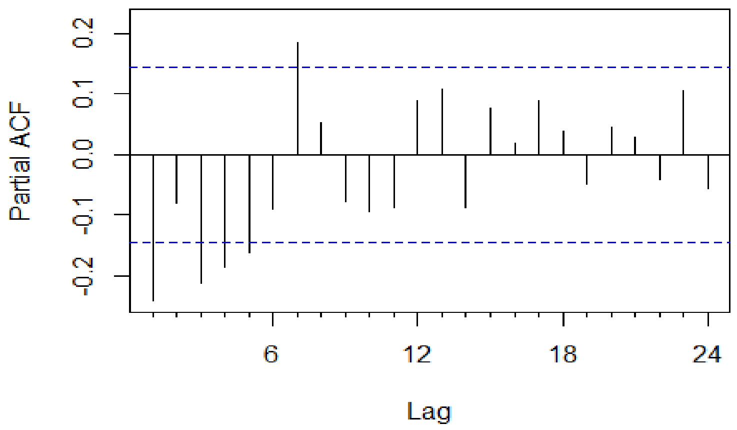


Fig. 5. PACF test after second difference

The Seasonal ARIMA (SARIMA) model was identified as the best fit for the CPI data. The final selected model, SARIMA(3,2,2)(2,0,0)$_{12}$, accounts for both non-seasonal and seasonal components of the time series. The coefficients of this model, including the Autoregressive (AR) and Moving Average (MA) terms show a good fit based on their standard errors. The log-likelihood, AIC, and BIC values also suggest that the selected model is the most appropriate among the candidate models.

"Model 3 is the best fit model," such that:

$$X_t = 0.7719X_{t-1} - 0.4617X_{t-2} + 0.4029X_{t-3} + 0.347X_{t-12} - 0.1275X_{t-24} - 1.2202e_{t-1} + 0.8098e_{t-2} + e_t \quad (7)$$

Table 2. Diagnostic test

ARIMA	AIC	BIC	RMSE	MAE
ARIMA(2,2,3)(2,0,0)[12]	603.86	629.53	1.19271	0.7448711
ARIMA(2,2,2)(0,0,1)[12]	614.03	633.28	1.160711	0.7559140
ARIMA(3,2,2)(2,0,0)[12]	583.44	609.12	1.120701	0.735912
ARIMA(4,2,1)(2,0,0)[12]	599.66	625.34	1.178977	0.7438939

Table 3. Model residuals and forecast

Date	Point Forecast	Lo 80	Hi 80	Lo 95	Hi 95
Jun 2024	749.3847	747.9122	750.8572	747.1327	751.6367
Jul 2024	769.2592	766.5408	771.9775	765.1018	773.4165
Aug 2024	791.8379	787.7145	795.9613	785.5317	798.1441
Sep 2024	812.9621	807.4687	818.4556	804.5606	821.3636
Oct 2024	831.9255	825.0088	838.8422	821.3474	842.5037
Nov 2024	849.4550	840.9553	857.9547	836.4558	862.4542
Dec 2024	866.1849	855.8382	876.5315	850.3610	882.0087
Jan 2025	884.4934	872.0361	896.9507	865.4417	903.5451
Feb 2025	906.1086	891.3754	920.8417	883.5761	928.6410
Mar 2025	929.2113	912.1588	946.2638	903.1318	955.2908
Apr 2025	950.7115	931.3533	970.0698	921.1057	980.3174
May 2025	970.3920	948.7084	992.0757	937.2297	1003.5544
Jun 2025	988.2980	963.9561	1012.6399	951.0703	1025.5257
Jul 2025	1006.2484	978.9749	1033.5220	964.5371	1047.9598
Aug 2025	1025.7791	995.3084	1056.2499	979.1782	1072.3801
Sep 2025	1047.3314	1013.5189	1081.1438	995.6196	1099.0431
Oct 2025	1069.6144	1032.3942	1106.8345	1012.6910	1126.5377
Nov 2025	1090.8699	1050.1921	1131.5477	1028.6585	1153.0812
Dec 2025	1110.1897	1065.944	1154.4300	1042.5300	1177.8494
Jan 2026	1128.2018	1080.2249	1176.1787	1054.8275	1201.5762

Diagnostic tests on the model's residuals indicated that the model captures most of the data's structure, as there was no significant autocorrelation left in the residuals. The residuals appear to be normally distributed, confirming the adequacy of the model.

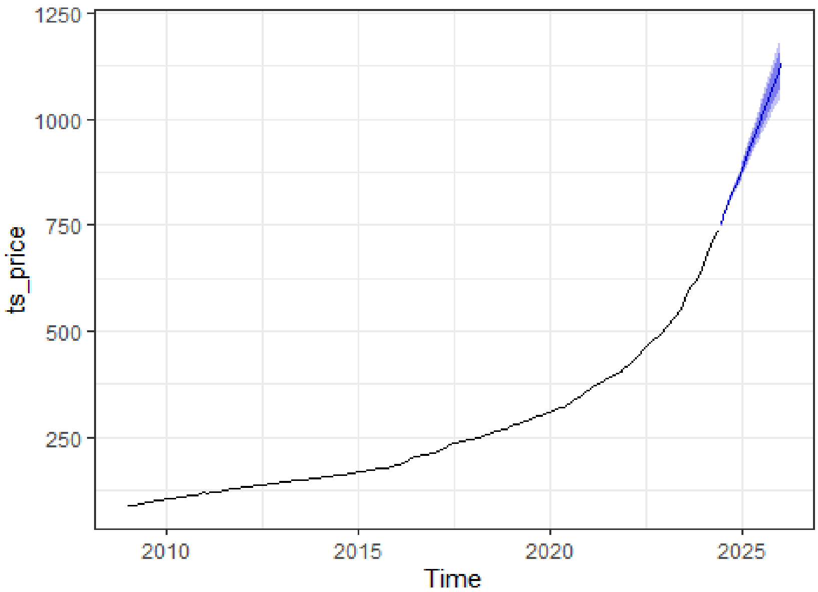


Fig. 6. Time series forecast of consumer price index from May 2024 - Jan 2026

The forecast based on this model shows a continuing upward trend in CPI, with the point forecasts suggesting that there is rise in inflation rates throughout 2024 and 2025. The prediction intervals indicate a reasonable level of confidence in these forecasts, although the broad intervals reflect the uncertainty in predicting economic variables such as inflation over a longer horizon (BBC, 2024; Corpin et al., 2023).

4 Conclusion

The study is an attempt to select the best and accurate model among various ARIMA models which possess a high potential to fit the CPI and high predictability for forecasting the future value from January 2009 to May 2024. The main focus was to figure out the best model for the CPI and forecast the monthly fluctuation in the future value. For this purpose, different ARIMA models were fitted and the best model was selected based on various diagnostic, selection and evaluation. ARIMA (3, 2, 2) was found to be the most suitable model to describe and forecast the CPI values.

Disclaimer (Artificial Intelligence)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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Competing Interests

Authors have declared that no competing interests exist.

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