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A Parametric Evaluation of Nigeria Inflation Rates using SARIMAX Multiple Time Series Model

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Abstract: *The influence of a few economic factors on predicting the inflation rate in Nigeria are looked at in this study. Between 2005 and 2020, monthly data on Nigeria's inflation rate were taken from the CBN website. Models such as ARIMA, SARIMA, and SARIMAX were fitted to the data. The model with the lowest Akaike's Information Criterion (AIC) and Root Mean Square Error (RMSE) was deemed to be the best model, with SARIMAX models outperforming ARIMA and SARIMA models in terms of accuracy with reduced error metrics. The SARIMAX model also concluded that the exogenous factors included in this study—the All-Share index, the money supply, the interest rate, and the exchange rate—have an adverse influence on the inflation rate. As a consequence, the findings show that the model is effective, and only the interest rate was statistically significant at the 5% among the four exogenous variables.*

Keywords: ARIMA, Exchange rate, Exogenous variables, Inflation rate, Root Mean Square Error, SARIMAX

Introduction

A key description of the economy of every nation is given by the phenomena of inflation dynamics, which denotes a general and widespread rise in the cost of goods and services over a long period of time (Martin, 2022). Furthermore, a constant inflation rate is often a requirement for a country's sustainability in terms of its economic condition, which at long last takes care of its welfare state. Inflation in Nigeria has continued to be extremely erratic throughout time. Since the dynamics of inflation have changed over time, a univariate factor or its movement in conjunction with some explanatory variables is crucial in determining the stability of the nation's econometrics (Tamuke et al., 2018). In order to decrease error and increase prediction accuracy, various explanatory variables must be taken into account while forecasting the dynamics of inflation.

SARIMA Models were used by Otu et al. (2014) to forecast Nigeria's inflation rates and their findings showed a decline in the pattern of inflation rates during the course of the investigation. Yang et al. (2018) compared seasonal Autoregressive Integrated Moving Average (ARIMAX) model to the conventional Autoregressive Integrated Moving Average (ARIMA) model for forecasting instantaneous traffic, then shown that ARIMAX model performed better than ARIMA model. Ulyah et al. (2019) examined the effectiveness of a nonparametric regression model and Seasonal Autoregressive Integrated Moving Average with Exogenous Inputs (SARIMAX) model in forecasting the claim reserve of education insurance. The use of the ARIMA technique to the modeling and forecasting of Nigerian inflation rate was studied by Namadina (2021). Using exogenous variables, Christogonus (2021) used ARIMA to anticipate economic growth. According to their study's findings, import outperformed its counterparts for GDP dynamics. To determine the optimal model efficiency and predict Covid-19 lockdowns, Hardik (2022) used the ARIMA and SARIMA modeling approaches.

The goal of this study is to decrease forecasting error by employing a number of exogenous variables, including interest rate, money supply, inflation, and All-Share Index, which are some of the main contributors to Nigeria's high inflation rates using SARIMAX model.

Materials and Methods

In this study, the Central Bank of Nigeria (CBN)'s monthly data for all items—including the inflation rate (INF), All-Share index (ASI), money supply (MS), interest rate (INT), and exchange rate (EXCH)—was utilized. The data were analyzed using RStudio and covered the time period from January 2005 to December 2020.

Model Estimations

ARIMA (p, d, q) which generalizes the stationary ARMA (p, q) process for the situation when the differencing order is uncertain can be specify as;

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$$(1-B)dY_t - \omega_1(1-B)dY_{t-1} - \omega_2(1-B)dY_{t-2} - \cdots - \omega_k(1-B)dY_{t-k} = \varepsilon_t - \rho_1\varepsilon_{t-1} - \rho_2\varepsilon_{t-2} - \cdots - \rho_a\varepsilon_{t-a} \quad (1)$$

As an extension of the ARIMA model, the ARIMAX (p, d, q) model may account for the effects of covariates by adding the covariate to the right hand of the equation. In the equation with the exogenous variables, we have;

$$\Phi(B)(1-B)\Delta^d Y_t = \omega(B)X_t + \ddot{\theta}(B)e_t \quad (2)$$

where $\omega(B) = (1-\omega_1 B^1 - \omega_2 B^2 - \cdots - \omega_k B^r)$ and X_t is the exogenous variables at time t.

SARIMAX is an upgraded version of the ARIMA model which integrates seasonal effects and exogenous variables in addition to the model's autoregressive and moving average components. The SARIMAX models can be quantitatively described using equation (3).

$$\Phi(B)\Phi(B^s)(1-B)\Delta^d\Delta_s^D Y_t = A(t) + \ddot{\theta}(B)\ddot{\theta}(B^s)\varepsilon_t \quad (3)$$

where

$\Phi(B) = non-seasonal\ autoregressive\ lag\ polynomial$

,

$\Phi(B^s) = seasonal\ autoregressive\ lag\ polynomial,$

$(1-B)\Delta^d\Delta_s^D Y_t = time\ series\ differenced\ d\ times, seasonal\ dif$

$A(t) = trend\ polynomial.$

$\ddot{\theta}(B) = non-seasonal\ moving\ average\ lag\ polynomial$

and

Ӫ(B^s)= seasonal moving average lag polynomial.

Model Evaluation Metrices

The AIC and RMSE for performance predictions are used in this study to choose the best models.

$$\text{RMSE} = \sqrt{\frac{\sum_{i=1}^{L}(\tau_{n+l}-\hat{\tau}_n(l))^2}{L}} \quad (4)$$

where τ_{n+l} is out-of-sample data, $\hat{\tau}_{n(l)}$is forecast value and L is the total out-of-sample data.

The order of an ARIMA model is determined using AIC. It can be written as

$$AIC = -2log(L) + 2(p+q+k+1), \quad (5)$$

where L is the maximum likelihood of the data, and $p+q+k+1$ is $number\ of\ independently\ adjusted\ parameters\ within\ the\ model.$

Results

Inflation Rate Time Series Plot

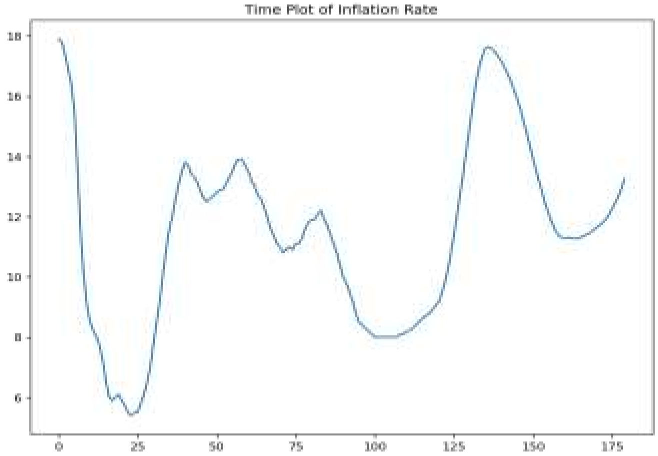

Fig. 1: Plot of Inflation Rate

Stationarity Test and Series Differencing

Testing the Augmented Dickey-Fuller (ADF) unit root, th e Dickey-Fuller = -3.9771 at maximum Lag of order 5 wi th p-value = 0.0118. P-value is less than 0.05 means that t he null hypothesis (H_o) cannot be rejected. Therefore, de duced that the data has no unit root and is stationary. Hen ce, there is no need differencing the data.

Models Selection

Table 2: Suggested ARIMA Models for Inflation Rate

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MODEL	*AIC*
ARIMA (2, 0, 1)	**-145**
ARIMA (1, 0, 1)	33.08
ARIMA (1, 0, 2)	-49.12
ARIMA (2, 0, 2)	-143.25

ARIMA Model

Table 3: Estimates, Standard Error and P-value of ARIMA (2, 0, 1) Model

Parameters	*Estimates*	*Std.Error*	*z value*	*Pr(>|z|)*
AR1 ($\boldsymbol{\theta_1}$)	1.881744	0.034063	55.242	<2.2e-16 ***
AR2 ($\boldsymbol{\theta_2}$)	-0.898457	0.034409	-26.111	< 2.2e-16 ***
MA1($\boldsymbol{\emptyset_1}$)	0.202017	0.075691	2.669	0.007608 **
Intercept	11.753285	0.812291	14.469	< 2.2e-16 ***

Source: Extracted from R-Studio Output

SARIMA Models

Table 4: Estimates, Standard Error and P-value of SARIMA (2,0,1)(1,1,1)[12] Model

Parameters	*Estimates*	*Std.Error*	*z value*	*Pr(>|z|)*
AR1 ($\boldsymbol{\theta_1}$)	1.893983	0.032754	57.8246	<2.2e-16 ***
AR2 ($\boldsymbol{\theta_2}$)	-0.906559	0.032791	-27.6467	<2.2e-16 ***
MA1($\boldsymbol{\emptyset_1}$)	0.173245	0.079995	2.1657	0.03034 *
SAR1($\boldsymbol{\theta_1}$)	-0.302541	0.098412	-3.0742	0.00211 **
SMA1($\boldsymbol{\emptyset_1}$)	-0.999910	0.096083	-10.4067	< 2e-16 ***

Source: Extracted from R-Studio Output

SARIMAX Models

Table 5: Estimates, Standard Error and P-value of SARI MAX (2,0,1)(1,1,1)[12] Model

Parameters	*Estimates*	*Std.Error*	*z value*	*Pr(>|z|)*
AR1 ($\boldsymbol{\theta_1}$)	1.8940	0.032747	57.8358	< 2.2e-16 ***
AR2 ($\boldsymbol{\theta_2}$)	-0.90617	0.032796	-27.6305	< 2.2e-16 ***
MA1($\boldsymbol{\emptyset_1}$)	0.17336	0.079615	2.1774	0.029448 *
SAR1($\boldsymbol{\theta_1}$))	-0.29911	0.098268	-3.0439	0.002336 **
SMA1($\boldsymbol{\emptyset_1}$)	-0.99990	0.099937	-10.0052	< 2e-16 ***
ASI	-1.6376e-06	NA	NA	NA
MS	-9.0861e-09	NA	NA	NA
INT	-2.6444e-03	1.0538e-03	-2.5093	0.012096 *
EXCH	-1.5627e-04	1.7960e-04	-0.8701	0.384249

Significant codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
Source: Extracted from R-Studio Output

Diagnostic Check of the fitted models

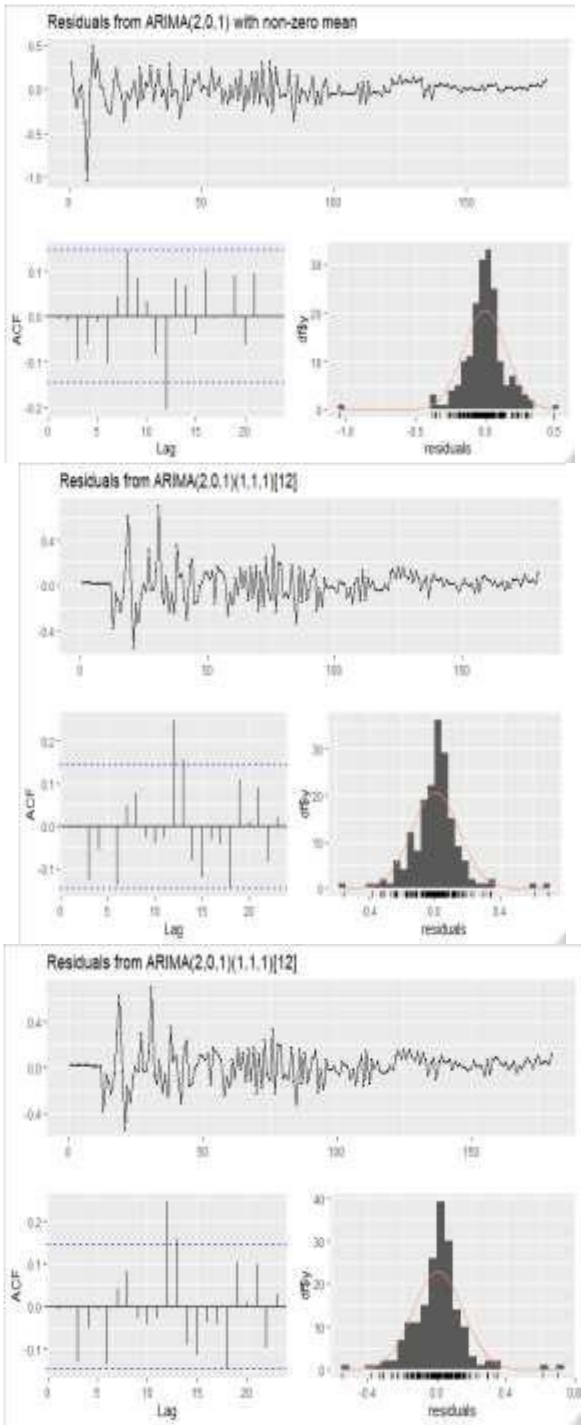

Fig. 2: Residual Diagnostic Check plots of the fitted Models

Table 6: Jarque-Bera Test of Residual Normality
H_0 : the residuals is normal

Models	*Chi-square*	*p- value*
ARIMA	1048.3	< 2.2e-16
SARIMA	175.09	< 2.2e-16
SARIMAX	178.27	< 2.2e-16

Table 7: Ljung-Box Portmanteau Test

	χ^2 - *value*	*df*	*P-value*
ARIMA	10.586	6	0.10200
SARIMA	9.4251	5	0.09326
SARIMAX	20.884	3	0.00011

Comparison check and forecast performances on the adopted Models using Different Loss Functions

Table 8: Forecast Evaluation

Models	*RMSE*	*Estimated Variance*	*ACF*
ARIMA	0.1538275	0.02366	-.00652
SARIMA	0.1451432	0.02256	-.00554
SARIMAX	**0.1448785**	**0.02247**	**-.00752**

Discussion

Fig. 1 shows the time series plot of Nigeria inflation rate. The movement of the series was a cyclical in nature with some element of seasonality. Table 2 presents different ARIMA models suggested for Nigeria Inflation Rate. AIC was used to ascertain the parameters p and q of the ARIMA model. The model with the smallest AIC were considered the best model. Therefore, ARIMA (2, 0, 1) with the least AIC was selected as the best to build ARIMA, SARIMA and SARIMAX models. Table 3 lists the calculated ARIMA (2, 0,1) parameters, standard errors, z-values, and p-values. At the 1% level of significance, every parameter is statistically significant. This suggests that the ARIMA (2, 0, 1) model may accurately forecast inflation rate. The estimated parameters for SARIMA (2,0,1)(1,1,1)[12] are shown in Table 4. At the 5% level of significance, every parameter is statistically significant. This suggests that the model can accurately estimate the inflation rate. The estimated parameters for SARIMAX (2,0,1)(1,1,1)[12] are shown in Table 5. At the 5% level of significance, each model parameter is statistically significant. This suggests that the model can accurately estimate the inflation rate. Exogenous factors have detrimental influence on the inflation rate. Only the interest rate is statistically significant at the 5% level of significance among the four exogenous variables.

Fig. 2 presents the residual diagnostic check plots of heteroscedasticity, autocorrelation and normality for the fitted ARIMA, SARIMA and SARIMAX models respectively. The Jarque-Bera test in table 6, has a test statistic of 1048.3, 175.09 and 178.27 for ARIMA, SARIMA and SARIMAX models respectively with p-values of 2.2×10^{-16} each at 5% significance level. The p-values of the three models are less than the level of significance. This indicates that their residuals are normally distributed. It is evident in the diagnostic plots of residuals. Table 7 presents the Ljung-Box test of no serial correlations. The p-values of the fitted ARIMA and SARIMA residuals proposed that their residuals are serially correlated at 5%level of significance while that of the fitted SARIMAX model is less than the 1% level of significance, hence, the null hypothesis that the autocorrelation functions are zero cannot be rejected. This indicates that SARIMAX model captured the dependency in the series. Since the residuals of SARIMAX model is a white noise. Then, an evident were recalled in the diagnostic plots in figure 2 to affirm the notations. Table 8 shows RMSE, estimated variance and ACF values of the fitted ARIMA, SARIMA and SARIMAX models which were used for the model's performance evaluation. The model with the best forecasting performance has the least RMSE, Estimated variance and ACF values. The results show that SARIMAX model has the lowest RMSE, estimated variance and with the largest of ACF values as compared to its counterparts (ARIMA and SARIMA) models. However, showed that SARIMAX model outperform ARIMA and SARIMA models and outrightly deduced as the best model in forecasting Nigeria Inflation rate.

Conclusion and Future Works

A SARIMAX model was used in this study to forecast Nigeria's inflation rate, with the interest rate, money supply, inflation, and the All-Share Index as exogenous variables. The main goal of the study was to reduce the forecasting error of Nigeria's inflation rate using monthly inflation data; by comparing the results with the traditional ARIMA and SARIMA models, it was possible to assess how well the model fit the data and satisfied the models' assumptions. Using the loss functions (RMSE, AIC), the best models were determined to be SARIMAX compared to its counterparts (ARIMA and SARIMA). Additionally, the SARIMAX model's residuals indicated through denotations that they were white noise with a zero mean and finite variance. The All-Share Index, Money Supply, Interest Rate, and Exchange Rate are examples of

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exogenous factors that have a negative impact on the inflation rate, according to the forecasting findings of the SARIMAX model. Only the interest rate, out of the four exogenous variables, was statistically significant at the 5% level of significance. This study demonstrates that interest rates and inflation typically move in the opposite direction for a variety of reasons. That is, higher interest rates are likely to change how supply and demand are balanced, motivate the nation's population to spend more sparingly and intelligently and save more, and therefore slow the rate of inflation.

References

Christogonus, I. U., Chinwendu, A. U. and Dominic, O. U. (2021). Application of ARIMAX Model on Forecasting Nigeria's GDP. *American Journal of Theoretical and Applied Statistics*; **10**(5): 216-225.

Hardik, C. (2022) A Comparative Study of ARIMA and SARIMA Models to Forecast Lockdowns Due to Covid-19. *Research Square, https://doi.org/10.21203/rs.3.rs-2069129/v1.*

Martin, H. (2022) Inflation explained: What lies behind and what is ahead?.*European Parliamentary Research Service, PE 729.352.*

Namadina, H. (2021). Modeling and Forecasting Inflation in Nigeria using Autoregressive Integrated Moving Average Technique. *Gusau International Journal of Management and Social Sciences*, **4**(1); 93-114.

Otu, A. O., Osuji, G. A., Opara, j., Mbachu, H. I., and Iheagwara, A. I. (2014). Application of SARIMA Models in Modelling and Forecasting Nigeria's Inflation Rates. *American Journal of Applied Mathematics and Statistics, **2**(1), 16-28.*

Tamuke, E., Jackson, E. A., Sillah, A. (2018). Forecasting Inflation in Sierra Leone Using ARIMA and ARIMAX: A Comparative Evaluation. Model Building and Analysis Team, *Theoretical and Practical Research in Economic Field*, (Volume IX, Summer), **1**(17):63-74.

Ulyah, S. M., Mardianto, M. F. and Sediono, F. (2019). Comparing the Performance of Seasonal ARIMAX Model and Nonparametric Regression Model in Predicting Claim Reserve of Education Insurance. *Journal of Physics: Conference Series, 1397 (2019) 012074.*

Yang, M., Jiaohong, X., Peipei, M., Chao, W., and Zhirui, Y. (2018). Application of the ARIMAX Model on Forecasting Freeway Traffic Flow. *Conference Paper*; https://www.researchgate.net/publication/324744195.