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FORECASTING NIGERIA FOREIGN EXCHANGE RATE DYNAMICS

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Abstract

This study introduces an examination of the forecasting of Nigeria's foreign exchange rate dynamics using time series data considering the Monthly official foreign exchange rate between the Nigerian Naira and the US Dollar. Utilizing the Box-Jenkins ARIMA approach, the monthly data spanning from January 2011 to December 2023 was forecasted. Analysis of the results indicated that the series achieved stationarity upon differentiation. Through diagnostic evaluation, it was determined that the ARIMA (0, 1, 2) model was the most suitable based on the Akaike's information criterion (AIC). Projections for future exchange rates indicated a consistent revaluation of the Naira. These predictions could offer valuable insights for policymakers in Nigeria to anticipate the Exchange rate variations and potential fluctuation ranges of the Nigerian Naira against the US Dollar in the future.

Keywords: Exchange rate, Akaike's information criteria, Box-Jekins ARIMA, Forecast

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Introduction

Nigeria is on a floating exchange rate arrangement, which means that the value of the Nigerian Naira is determined by market forces against other foreign currencies. Historically, Nigeria’s currency regime has changed from fixed currencies to more flexible exchange arrangements as it has attempted to be in tune with global economic trends and strengthen its economic base (Ismaila 2016).

The oscillations in Nigeria's exchange rate have attracted scholarly attention and policy considerations due to their substantial repercussions on various economic sectors. The instability of the Naira in relation to major currencies has consequences for inflation levels, balance of payments, foreign direct investments, and the general competitiveness of Nigeria's economy on the global stage (Owuru, 2016).

Numerous elements contribute to the intricacies inherent in Nigeria's exchange rate fluctuations. These include a multitude of internal determinants such as fiscal policies, monetary policies, trade balances, inflation rates, as well as external factors like global oil prices, foreign exchange reserves, geopolitical tensions, and capital inflows (Udah & Ite, 2017).

The Nigerian economy, predominantly dependent on oil exports, is highly vulnerable to fluctuations in global oil prices, thus exposing the exchange rate to external shocks (Najaf & Najaf, 2016).

Moreover, the correlation between monetary policy decisions, particularly in the context of inflation and interest rate management, and their effects on the exchange rate highlights the intricate link between domestic policy measures and currency valuation (Abada, 2016).

Effiong (2014) stresses the importance of modeling Nigeria's exchange rate behavior concerning the Naira-US dollar rates utilizing conventional monetary fundamentals, underscoring the significance of integrating monetary variables in exchange rate modeling.

Najaf & Najaf (2016) analyze the dynamic interplay among crude oil prices, the Nigerian stock market, and exchange rates, offering insights into the direct influence of crude oil prices on Nigeria's stock exchange, with an emphasis on external factors shaping exchange rate dynamics.

Okumoko and Karimo Ogbonna (2015) illustrate the relevance of the parallel market exchange rate in modeling money demand in Nigeria, emphasizing the necessity of incorporating informal exchange rate mechanisms in economic modeling.

Omojimite & Oriavwote (2012) explore the real exchange rate and its implications for macroeconomic performance in Nigeria, seeking to validate the Balassa-Samuelson hypothesis, which links real exchange rates to productivity variances, thereby shedding light on the determinants of the real exchange rate in Nigeria.

Methodology

The methodology employed in this study was time series analysis, with a specific focus on autoregressive integrated moving averages (ARIMA). The dataset used in this research comprises annual time series data sourced from the Central Bank of Nigeria (CBN). As a result, the primary objectives of the study included pattern evaluation, model validation, assessment of model adequacy, and generation of forecasts for the upcoming three years.

The expression AR(p) represents the autoregressive model of order p. It is formulated as the AR(p) model.

$$X_t = C + \sum_{i=1}^{p} \theta_i X_{t-i} + \varepsilon_t \quad (1)$$

θ_i ,… θ_p are parameters, C is a constant and the random variable ε_t is white noise (error term)

Model of the Moving - Average
33µµ
The notation MA (q) represents the moving average characterized by a specific order denoted as q.

$$X_t = \mu + \varepsilon_t + \sum_{i=1}^{q} \beta_i \varepsilon_{t-i} \quad t=1,2\ldots \quad (2)$$

β_1 ,…, β_q are parameters, µ is the expectation of Y_t and the random variable ε_t is white noise (error term)

Model of ARMA (p, q)

The ARMA (p, q) notation denotes a mathematical model that encompasses p autoregressive terms and q moving-average terms. Ultimately, the ARMA (p, q) model can be obtained by merging equation 1 and 2

$$X_t = C + \varepsilon_t + \sum_{i=1}^{p} \theta_i + \sum_{i=1}^{q} \beta_i \varepsilon_{t-i} \quad (3)$$

Model of ARIMA(p,d,q)

If it is deemed essential to perform "d" differences on a time series to attain stationarity, followed by the application of the ARMA (p, q) model, the initial time series is categorized as ARIMA (p, d, q). This signifies an autoregressive integrated moving average time series, where "p" denotes the autoregressive terms count, "d" indicates the necessary differentiations for achieving stationarity, and "q" represents the moving average terms count. Consequently, an ARIMA (2, 1, 2) time series necessitates one differentiation (d = 1) for stationarity attainment, and the resulting stationary time series (post first differentiation) can be represented as an ARMA (2, 2) process. The value of "d," which corresponds to the number of differencing instances in the series, defines the "d" order. Therefore, when the data is stationary (d = 0), the ARIMA (p, d, q) model can be equivalently presented as ARMA (p, q).

Estimation of Model

Once an optimal model is identified, the methods for model estimation enable the simultaneous estimation of all process parameters, the order of integration coefficient, and ARMA structure parameters. The estimators for the exact maximum likelihood, as proposed, are the vector $\beta = (d, \varphi, \theta)$ that maximizes the log likelihood function L (β).

$$L(\beta) = -\left(\frac{n}{2}\right) \text{In}(2\pi) - \left[\frac{1}{2}\right] \text{In}(R) - \left[\frac{1}{2}\right] X' R^{-1} X \qquad (4).$$

Here, R represents the variance-covariance matrix of the process.

Verification of Model

It involves assessing the residuals of the model to determine its acceptance or rejection. If any deficiencies in the model or new data emerge, the model building process may need to be restarted from step 2 or step 1. This iterative and interactive approach to model building might require several repetitions before arriving at a final decision. Thus, model building encompasses an iterative and interactive methodology.

When faced with multiple competing models, the selection of a final model is done using a common method known as the model selection criterion. This criterion includes Akaike's Information Criterion (AIC), Schwartz Information Criterion (SIC), and Hannan Quinn Criterion (HQC). The objective is to select a model that effectively describes the data while maintaining simplicity by minimizing the number of parameters. For example, if an AR (2) model does not surpass an AR (1) model based on a predefined threshold or criteria, the simpler AR (1) model is chosen. In general, the selected model is the one that minimizes the corresponding criterion's value.

Akaike's Information Criterion (AIC),

It aims to choose an appropriate model for inference based on the principle of parsimony. AIC suggests utilizing the relative entropy or the Kullback-Leibler (KL) information as a fundamental aspect for model selection. An appropriate estimator of the relative KL information is employed, which comprises two components. The first component measures the model's lack of fit, while the second serves as a "penalty" for increasing the model's size, ensuring parsimony in the number of parameters. The AIC criterion that needs to be minimized can be expressed as

$$\text{AIC (n)} = \log(\delta_2^q) + \frac{2n}{T} \quad (5)$$

where n represents the model's dimensionality δ_2^q, is the maximum likelihood estimate of the white noise variance, and T denotes the sample size.

Schwarz's Bayesian Information Criterion (BIC)

BIC was developed within a Bayesian context and possesses the property of being "dimension consistent" as it aims to accurately estimate the model's dimension. It assumes the presence of a true model among the potential models, thus requiring a considerable sample size to achieve effectiveness. The BIC Criterion, which requires minimization, is the main goal.

$$\text{BIC (n)} = \log(\delta_2^q) + \frac{n\log T}{T} \quad (6)$$

where n denotes the model's dimensionality, is the maximum likelihood estimate of the white noise variance, and T represents the sample size.

The Hannan-Quinn (HQ) Criterion

HQ was derived from the iteration logarithm's law, presenting another dimension-consistent model that differs from AIC and BIC primarily in terms of the "penalty term." The HQ Criterion that needs to be minimized can be written as

$$\text{HQ(n)} = \log(\delta_2^q) + \frac{2n\log(T)}{T} \quad (7)$$

where n stands for the model's dimensionality, is the maximum likelihood estimate of the white noise variance, and T represents the sample size. Hannan and Rissanen later substituted the term log with log to expedite the convergence of HQ.

Stationary Test

Test for the stationarity of data is essential in time series analysis. Initially, examining scatter plots can provide insight into the issue at hand. However, the most widely accepted method for assessing stationarity is through the unit root test. This test is crucial in determining the integration order of nonstationary variables, which can influence their inclusion in regression models. Common unit root tests include the Augmented Dickey Fuller (ADF) test and the Phillips-Perron (PP) test.

Augmented Dickey fuller test

The model of the regression for the test is given as

$$\Delta z_t = \partial z_{t-1} + \beta y_{t-1} + \delta_1 \Delta z_{t-1} + \delta_2 \Delta z_{t-2} + \ldots + \delta_p \Delta z_{t-p} + \varepsilon \qquad (8)$$

The hypothesis testing

H_0 : $\partial = 0$ (the series contain unit root(s))

H_1: $\partial < 0$ (the series is stationary)

Test statistic

$$t_\partial = \frac{\partial}{s_e(\partial)} \qquad (9)$$

here

Δz_t= the series of the difference

Δz_{t-1}= the observation immediately preceding

$\delta_1, \ldots, \delta_p$= the parameter representing the delayed changed factor up to p

y_t= the most suitable exogenous regressor that can either be constant or exhibit constant Trend

∂ and β = parameters that needs estimation.

Decision rule:

Reject H_0 if t_∂ is less than asymptotic Critical values.

Data Used

The secondary data utilized in this research study comprises empirical data on monthly exchange rate, which was acquired from the Central Bank of Nigeria (CBN) website, accessible at www.cbn.gov.ng. The period covered by the data spans from January 2000 to December 2019.

RESULTS AND ANALYSIS

We present the result of the analysis obtained from Nigeria's foreign exchange rate.

DISCUSSION

Table 1 displays the positive mean and a considerable difference of 652.9 between the minimum and maximum values, which is deemed substantial. However, it does not provide evidence of outliers; rather, it indicates that the CBN exchange rate has been consistently increasing, resulting in a depreciating exchange rate. Additionally, it is evident that the exchange rate exhibits significant variability, indicating a lack of stability in the variance of the time series data. Consequently, we can conclude that the time series data is non-stationary. Moreover, figure 1 confirms that the time plot also indicates a lack of stationarity in the time series data, as it displays an upward trend, suggesting that the mean of the CBN EXCHANGE RATE changes over time. Additionally, the significant variation in the exchange rate further supports the notion of instability in the variance of the time series data. Thus, we can reiterate that the time series data is non-stationary.

Table 1: Descriptive Statistics of Original Data

Estimate	Mean	Median	Minimum	Maximum	Count	1st quartile	3rd quartile	Range
Value	294.1	305.7	152.4	805.3	156	162.2	380.0	652.9

Fig 1: Time plot of Nigeria foreign exchange rate from January 2011 to 2023

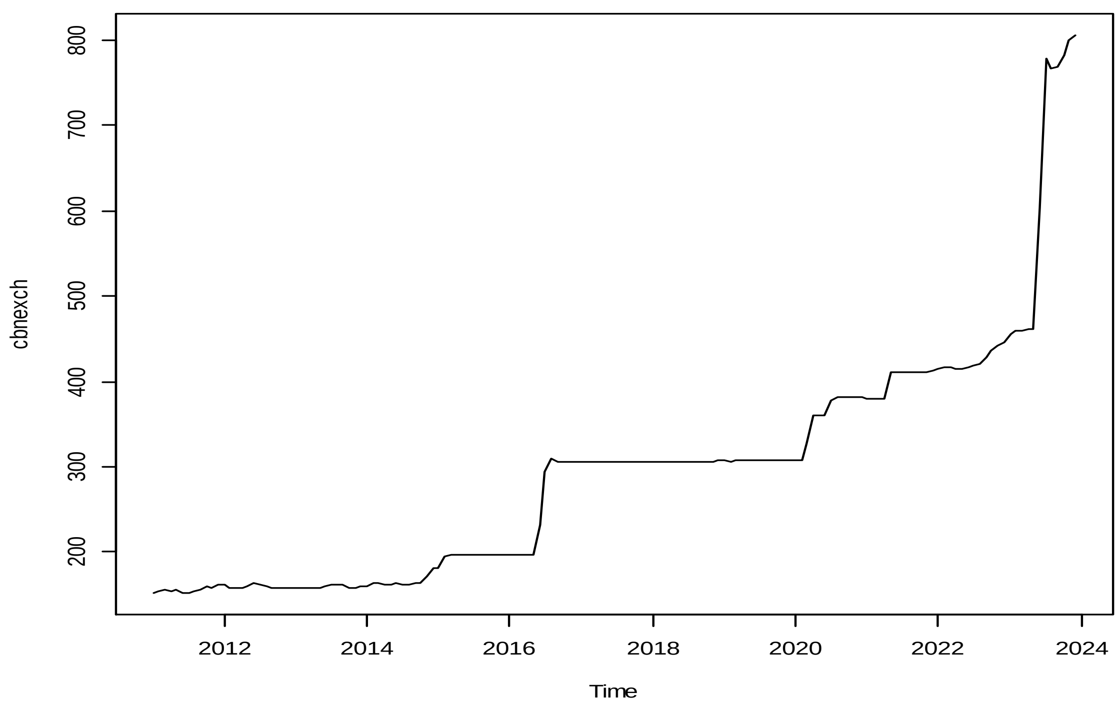
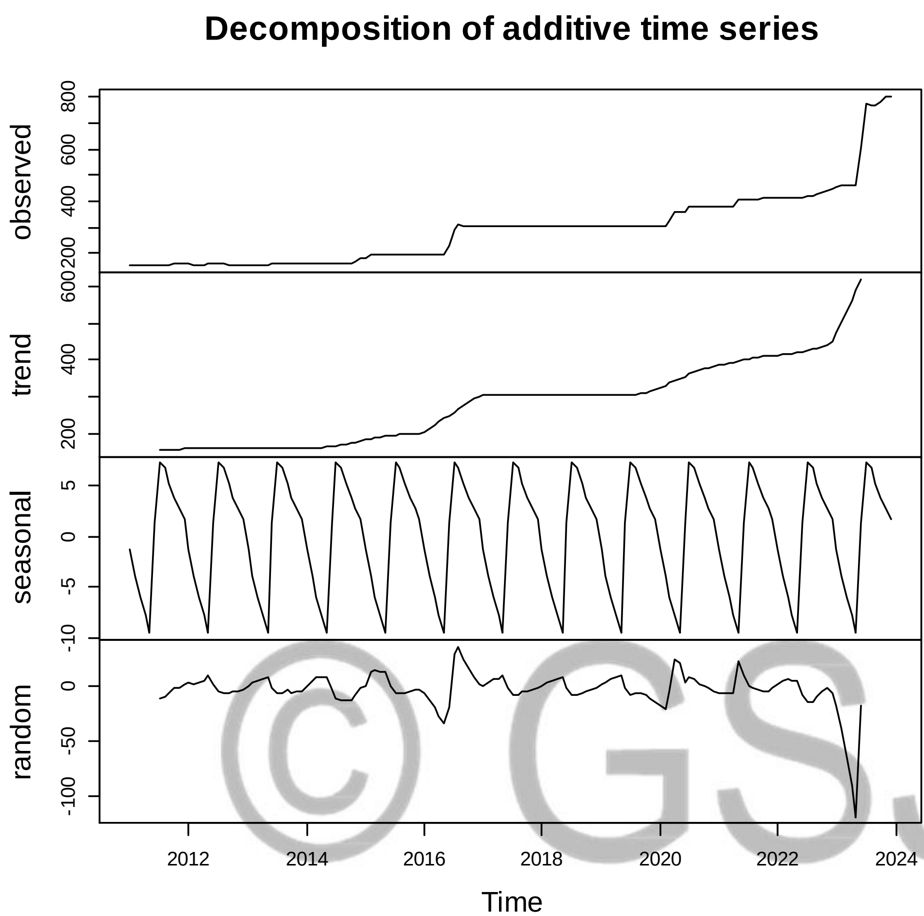


Fig 2: Time plot of Decomposing time series

The plot below shows the original time series at the top, the estimated component second from the top and third from the top is the seasonal component and the bottom shows the estimated irregular component.



We used the Dickey-Fuller test (ADF test) to determine whether the given time series is stationary or not. Here the P-value is 0.9623 so we have to accept the null hypothesis. So, we conclude the series is non-stationary. Likewise, after differencing the time series data, at first differencing, the P-value is 0.01 so we rejected the null hypothesis and conclude the series is stationary.

Table 3: ADF Test of Nigeria Foreign exchange

ADF Test for Time Series Data

Dickey Fuller	Lag order	p-value
-0.77009	5	0.9623

ADF Test for Time Series Data after Differencing

Dickey Fuller	Lag order	p-value
-5.5952	5	0.01

Fig 3: Time plot of the first difference of Nigeria foreign exchange rate from January 2011 to 2023

Here is a plot displaying the initial discrepancy of Nigeria foreign exchange rate. It has been observed that the plot appears to be approximately constant, indicating that both the mean and variance remains unchanged.

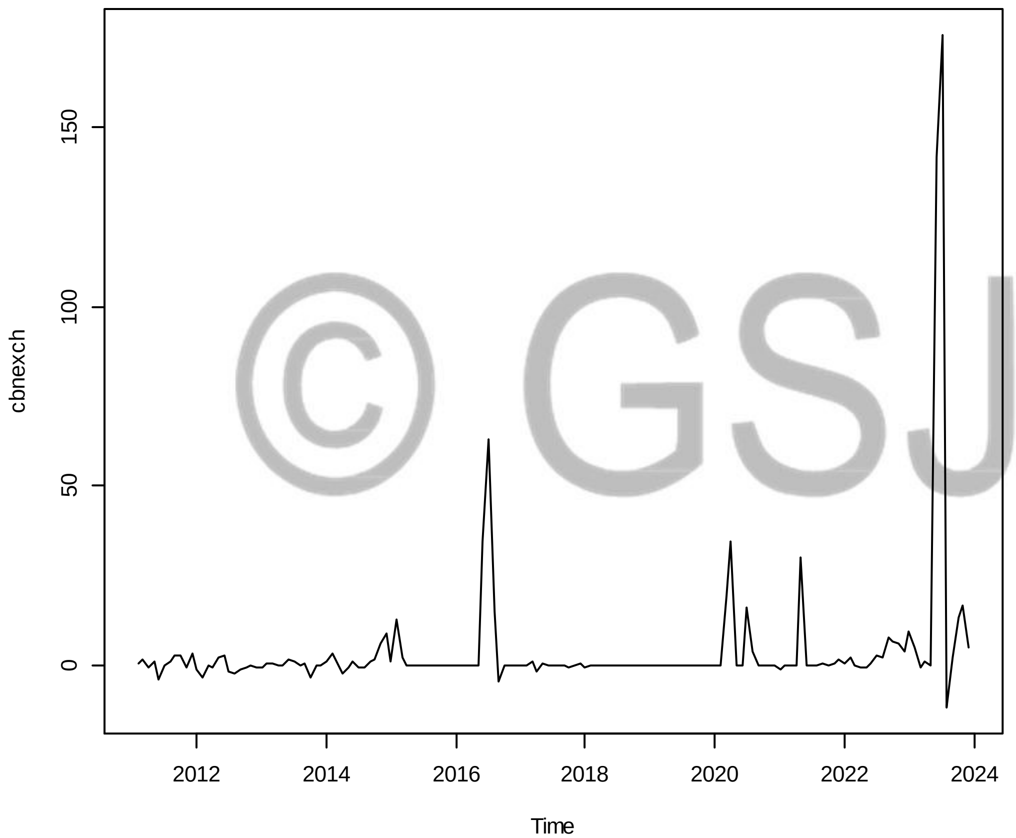


Table 3: Correlogram table of the residuals of Nigeria foreign exchange

Lag	ACF	PACF
0	1	
0.0833	0.427	0.427
0.1667	-0.055	-0.290

0.25	0.013	-0.224
0.3333	0.060	-0.094
0.4167	0.054	0.109
0.5	0.017	0.070
0.5833	0.002	0.055
0.6667	0.014	-0.026
0.75	0.021	0.035
0.8333	0.015	-0.016
0.9167	-0.008	-0.005
1	-0.009	0.000
1.0833	0.000	-0.005
1.1667	-0.011	-0.014
1.25	-0.020	-0.009
1.3333	-0.003	0.013
1.4167	0.005	-0.008
1.5	-0.004	0.001
1.5833	0.001	0.005
1.6667	-0.005	-0.012
1.7500	-0.015	-0.007

ACF and PACF of the series (ARIMA MODEL)

From the analysis of the time plot, it is evident that the mean of the series displays variations over time. Consequently, our attention now shifts towards investigating the autocorrelation functions (ACF) and partial autocorrelation function (PACF) to ascertain the presence of correlations among the data points in the series.

Fig 4: ACF of differenced Nigeria foreign exchange

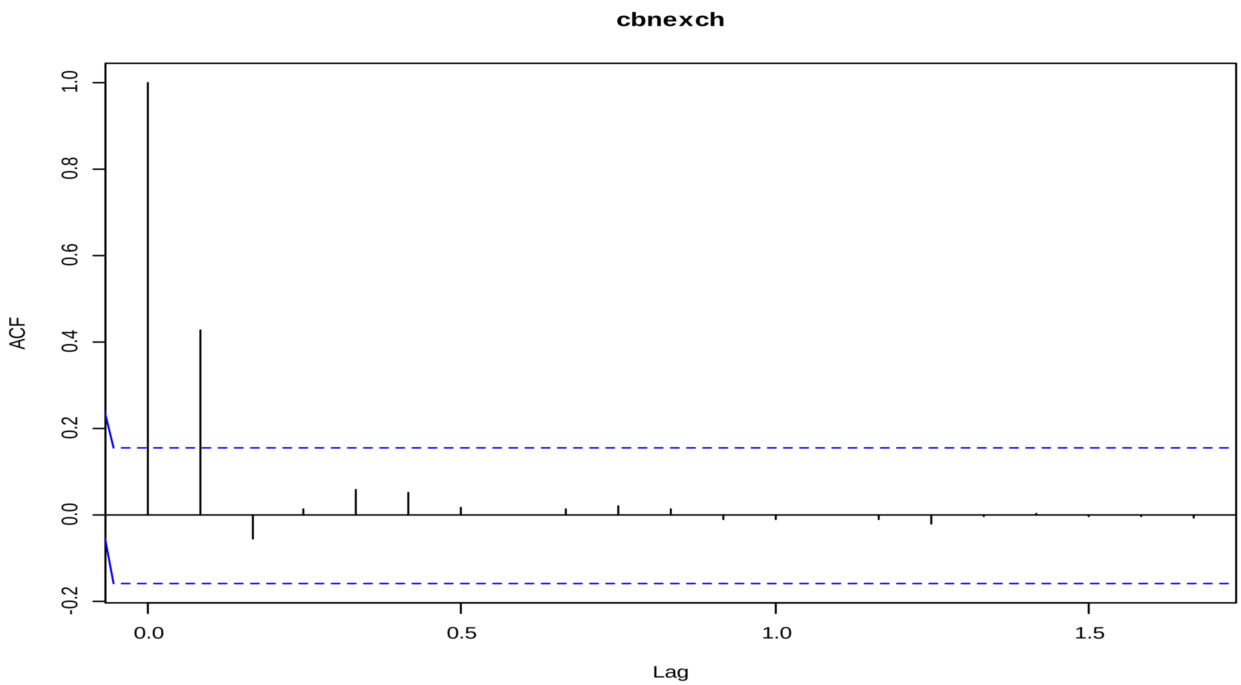
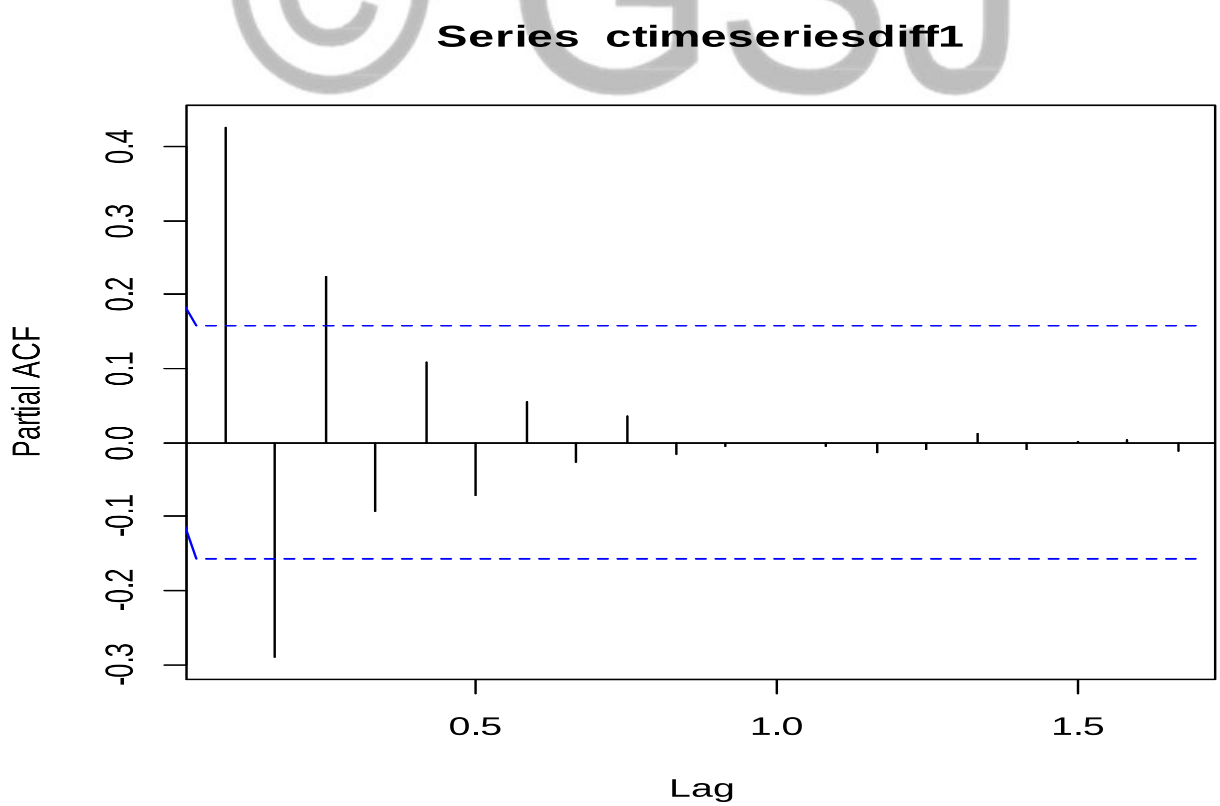


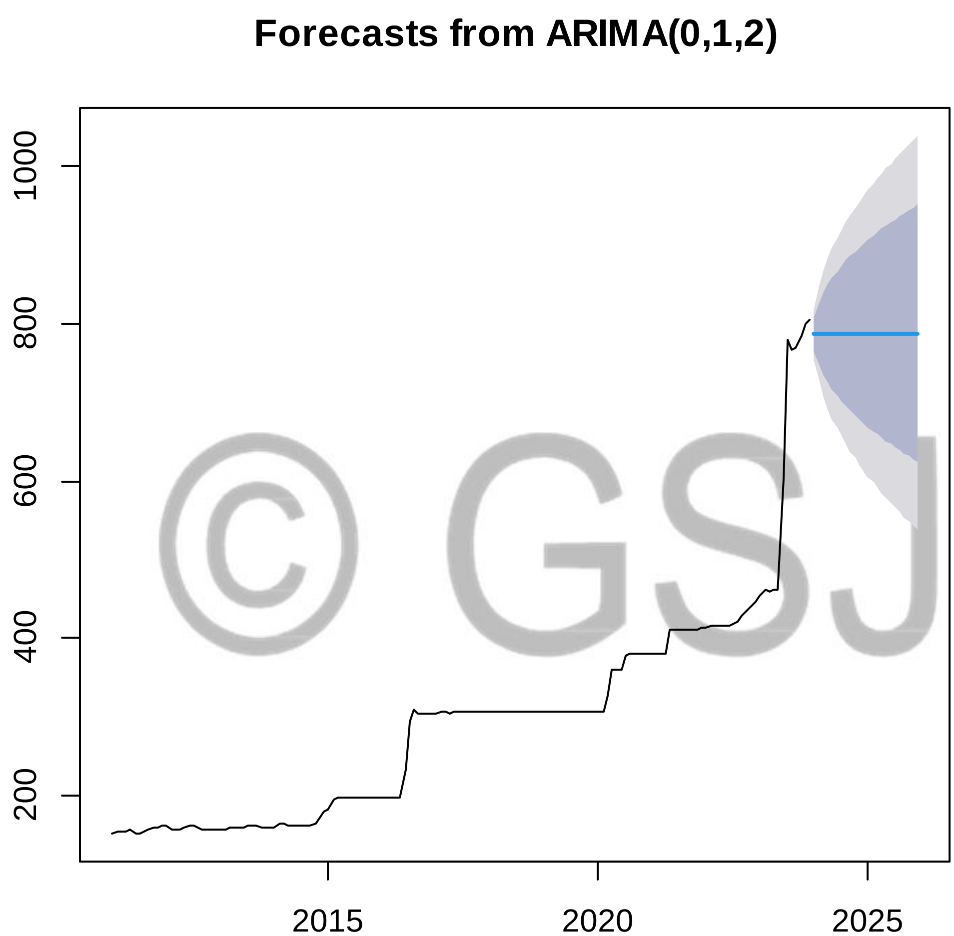
Fig 5: P ACF of differenced Nigeria foreign exchange



ARIMA(0,1,2) has the best AIC of 1307.97 out of the other models, a forecast plot was further made for the model.

The forecast plot showed a reduction in the Nigeria foreign exchange.

Fig 6: Forecast of Nigeria foreign exchange



Recommendation

To enhance a more secure economic environment and mitigate the fluctuations in Nigeria's currency exchange rate, it is essential to consider various strategic actions. The primary focus should be on promptly diversifying the economy and reducing dependence on oil revenues through the reinforcement of fiscal measures. The implementation and maintenance of strong monetary policies are equally crucial in addressing inflationary pressures and maintaining stability in the exchange rate. Moreover, it is imperative to create a favorable atmosphere to attract foreign direct investment and improve trade competitiveness. These diverse recommendations, if rigorously pursued, have the potential to guide Nigeria towards a more resilient and stable currency exchange rate regime, thereby promoting continuous economic growth and stability.

Conclusion

This study concludes by summarizing key findings, emphasizing the significance of exchange rate stability for Nigeria's economic development, and providing recommendations for policymakers to establish a more robust exchange rate framework.

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