



## Modeling and Forecasting Exchange Rate Values between Naira and US Dollar to Assess the Effect of COVID-19 Pandemic Period on the Rate

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### Authors' contributions

This work was carried out in collaboration between both authors. Author EJO wrote the first draft and managed data collection. Author INI wrote the protocol and managed literature review. Both authors performed statistical analysis as well as read and approved the final manuscript.

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## Abstract

**Aims:** To model exchange rate values between Naira and US Dollar in order to assess the effect of the COVID-19 pandemic period on the rate by examining the forecasts.

**Study Design:** The study design is the longitudinal research design.

**Place and Duration of Study:** Real life data of monthly average Nigerian Naira-US Dollar exchange rates from Jan.1991 to April 2020 obtained from the Data and Statistics publication of Central Bank of Nigeria.

**Methodology:** The traditional time series ARIMA model is employed for forecasting Naira/Dollar exchange rate using Monthly data covering the period January, 1991 to April, 2020. The ACF and PACF plots showed tendency that the differenced exchange rate data behave as both having autoregressive and moving average processes as the ACF has significant peaks at different lags and a gradual decay to zero is indicated by the PACF.

**Results:** Using the AIC, BIC, and HQC as model selection criterion the ARIMA (2, 1, 3) were selected as the model with the best fit for the exchange rate data as compared to the other selected models. The ACF of the residuals is plotted with lags up to 20 and the residuals coefficient did not exceed the 95%

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confidence limit which indicates that the model is a good fit and is appropriate for the data. Plots of in-sample and out-of-sample forecast were also made.

**Conclusion:** The out-of-sample forecast plot for period of 12 months revealed that naira will continue to depreciate on US dollar for the period forecasted with very high tendencies during the COVID-19 pandemic period.

*Keywords: Modeling; exchange rate; ARIMA; stationarity; COVID-19.*

## Acronyms

*ACF* : Autocorrelation function

*PACF* : Partial autocorrelation function

*AIC* : Akaike Information Criterion

*BIC* : Bayesian Information Criterion

*HQC* : Hannan-Quinn information criterion

*ARIMA* : Autoregressive integrated moving average

*COVID* : Coronavirus disease

## 1 Introduction

Exchange rate depicts the ratio at which one currency is exchanged with another currency, for instance, the quote of currency prices. It also states explicitly the extent to which the value of one currency is worth in terms of the other. It is the required amount of units of currency that can buy another amount of units of another currency. It is the price at which one currency is exchanged for another. It ascertains the domestic worth of an economy, especially the currencies of most industrialized countries such as United States of America Dollars, British Pound Sterling, German Duetsche Mark, Japanese Yen, French Franc, Italian Lira and the Canadian Dollar Akpan, [1]. According to Jameela, [2], Exchange rate policy has been identified as one of the endogenous factors that can affect the economic performance of a nation. In Nigeria, the management of the exchange rate is carried out by the Central Bank of Nigeria, following the adoption of the structural adjustment program policy in 1986, the country has moved from a stiff or unbending exchange rate era to a more flexible regime Azeez, Kolapo and Ajayi, [3]. In practice, no exchange rate is “clean or pure float”, that is a situation where the exchange rate is left completely to be determined by the market forces of demand and supply but rather the prevailing system is to manage float whereby the monetary authorities intervene periodically in the foreign exchange market of a country in order to attain some strategic objectives Mordi [4]. Forecasting is also a critical element of financial and managerial decision making Majhi and Sahoo, [5].

Exchange rate is said to depreciate if the amount of domestic currency required in purchasing a foreign currency increases, while the exchange rate appreciates if the amount of domestic currency required in obtaining a foreign currency reduces. It determines the strength of external sector participation in the international trade as well as the relative prices of domestic and foreign goods. A correct exchange rate does have important factors for the economic growth for most developed countries whereas a high volatility has been a major problem to economic of series of African countries like Nigeria.

The Nigerian economy ambitiously aspires to become one of the twenty largest economies in the world by 2020 and the 12th largest economy by 2050 CBN, [6]. A feat not duly achieved as earlier stated. One of the surest paths to achieve the aforesaid goal is to pursue vigorously rapid and sustainable economic growth and development via well managed exchange rate policy (Obi et al, 2016). However, the outbreak of COVID-19 pandemic in the world is having enormous negative effects on emerging markets and whereas, the Nigerian economy is very vulnerable, it is not an exception. Nigerian economic growth or otherwise has always depended on crude oil export amongst others while most sectors of the economy depend on imports. The outbreak has impacts on exchange rates because with sharp drop in oil prices, border closures, non-existent

buffers, lean sovereign wealth funds, depletion in Nigeria's excess crude account, financial conditions have tightened and the exchange rate is under excess pressure. The existence of underlying economic conditions makes the impact of the COVID-19 shocks more severe for the economy. Businesses are experiencing liquidity challenges in the foreign exchange (FOREX) market, costs are escalating as a consequence of exchange rate depreciation, foreign credit lines are being cancelled, industrial capacity utilization has plummeted purchasing power and job losses are on the increase.

The success of ARIMA model against Monetary Model, fitting the United State Dollar and Turkish Lira rate with the monthly observations taken from the dates between January 1980 and July 2001 was compared by Vergil and Özkan [7]. ARIMA (3,1,2) was the most appropriate model for the series and in conclusion is more efficient in fitting United State Dollar and Turkish Lira rate compared to Monetary Model. Further work was carried out by Appiah and Adetunde [8] on forecasting exchange rate between the Ghana cedi's and the US dollar using time series analysis for the period January 1994 to December 2010. The findings reveal that rates predicted were consistent with the depreciating trend of the observed series and ARIMA (1, 1, 1) was found to be the best model to such series and an out-of-sample forecast for two years were made for a period of two years and a depreciation of Ghana cedi's against the US dollar was found.

Onasanya and Adeniji [9] used time domain model for forecasting Nigerian Naira and US Dollar, in this research, a time domain model (fundamental approach) which uses Box Jenkins approach was applied to forecast the naira/dollar exchange rate for the period January 1994 to December 2011 using ARIMA model. The result reveals that there is an upward trend and the 2nd difference of the series was stationary. Employing the selection criterion AIC and BIC, the best model that explains the series was found to be ARIMA (1, 2, 1). A diagnosis check on the model was conducted, the error was white noise, presence of no serial autocorrelation and a forecast for period of 12 months terms was made which indicates that the naira will continue to depreciate with these forecasted time period. Nwankwo [10] analyzed Naira to Dollar exchange rate using Autoregressive Integrated Moving Average (ARIMA) model within the periods 1982-2011, through Box-Jenkins methodology an AR(1): order one was generated model is preferred as it was shown through the diagnostic rate of Naira-Dollars based on its potentials for better prediction and computational requirements.

The Box and Jenkins (fundamental) approach has been considered as the earliest of all approaches and will generate equilibrium exchange rate. The ARIMA model has come to play a very important role in the modeling of non-stationary time series data and takes into consideration the serial correlation found in time series dataset. In recent studies, a number of related formal models for time varying variance have been developed, so in this paper, we are incorporating a univariate model to justify truly whether past values of Nigeria (naira) against the US (dollar) can predicts its current value and its future value using time modeling technique ARIMA which is a fundamental approach.

## 2 Methodology

The availability, quality and reliability of the data used in developing and running the proposed system are critical to its success. For the implementation of forecasting, data for this research are real life data of monthly average Nigerian Naira-US Dollar exchange rates from Jan.1991 to April 2020 obtainable from the Data and Statistics publication of Central Bank of Nigeria retrievable from the website <http://www.cenbank.org/>. The statistical package to be used for this analysis is the R-package.

### 2.1 Non-seasonal ARIMA model

A non-seasonal ARIMA model is denoted by ARIMA (p, d, q), where p is the order of AR component, d is the difference and q is the order of MA component respectively. The autoregressive process of order p or an AR (p) satisfies the equation

$$y_t = m + \phi_1 y_{t-1} + \phi_2 y_{t-2} + \dots + \phi_p y_{t-p} + \varepsilon_t \quad (2.1)$$

$$y_t = m + \sum_{k=1}^p \phi_k y_{t-k} + \varepsilon_t \quad (2.2)$$

where  $m$  is some constant.

A moving average process of order  $q$  or an MA ( $q$ ) is of the form

$$y_t = m' + \varepsilon_t - \theta_1 \varepsilon_{t-1} - \theta_2 \varepsilon_{t-2} - \dots - \theta_q \varepsilon_{t-q} \quad (2.3)$$

$$y_t = m' + \varepsilon_t - \sum_{j=1}^q \theta_j \varepsilon_{t-j} \quad (2.4)$$

where  $m'$  is some constant (Tsay, 2005) [11].

The process in (2.2) and (2.4) will form an ARMA ( $p, q$ ) process given as

$$y_t - \sum_{k=1}^p \phi_k y_{t-k} = m' + \varepsilon_t - \sum_{j=1}^q \theta_j \varepsilon_{t-j}, \quad t \geq 0$$

If  $\{y_t\}$  is stationary and for each  $t$  the following relation holds

$$\phi_p(B)y_t = \theta_q(B)\varepsilon_t \quad (2.5)$$

where  $B$  is the backward shift operator defined by  $B^i y_t = y_{t-i}$  where  $i = 1, 2, \dots$  and  $\{\varepsilon_t\}$  is white noise  $\sim N(0, \sigma^2)$ .

A time series  $\{X_t\}$  is said to follow an integrated autoregressive moving average model if the  $d$ th difference if  $W_t = \nabla^d X_t$  is a stationary ARMA process. If  $\{W_t\}$  follows an  $ARMA(p, q)$  model we can say that  $\{X_t\}$  is an  $ARIMA(p, d, q)$  process. For practical purposes we take  $d = 1$  or at most 2.

Consider an  $ARIMA(p, 1, q)$  process with  $W_t = X_t - X_{t-1}$ , we have that,

$$W_t = \phi_1 W_{t-1} + \phi_2 W_{t-2} + \dots + \phi_p W_{t-p} + e_t - \theta_1 e_{t-1} - \theta_2 e_{t-2} - \dots - \theta_q e_{t-q} \quad (2.6)$$

we can also write (2.6) in terms of observed series

$$X_t - X_{t-1} = \phi_1 (X_{t-1} - X_{t-2}) + \phi_2 (X_{t-2} - X_{t-3}) + \dots + \phi_p (X_{t-p} - X_{t-p-1}) + e_t - \theta_1 e_{t-1} - \theta_2 e_{t-2} - \dots - \theta_q e_{t-q} \quad (2.7)$$

from (2.7) we have

$$X_t = (1 + \phi_1)X_{t-1} + (\phi_2 - \phi_1)X_{t-2} + (\phi_3 - \phi_2)X_{t-3} + \dots + (\phi_p - \phi_{p-1})X_{t-p} - \phi_p X_{t-p-1} + e_t - \theta_1 e_{t-1} - \theta_2 e_{t-2} - \dots - \theta_q e_{t-q} \quad (2.8)$$

we call (2.8) the difference equation form of the model.

The general  $ARIMA(p, d, q)$  model using the backshift can be expressed concisely as

$$\phi(B)(1-B)^d X_t = \theta(B)e_t \tag{2.9}$$

where  $\phi$  and  $\theta$  are the autoregressive and moving average polynomials respectively,  $B$  is the backward shift operator and  $e_t$  is the white noise.

### 2.2 Model diagnosis

The conformity of white noise residual of the model fit will be judge by plotting the ACF and the PACF of the residual to see whether it does not have any pattern or we perform Ljung Box Test on the residuals. The null hypothesis is:

$H_0$  : There is no serial correlation;  $H_1$  : There is serial correlation

The test statistic for Ljung-Box is

$$Q = n(n+2) \sum_{k=1}^m \frac{\rho_k^2}{n-k} \dots\dots\dots \chi^2(m)$$

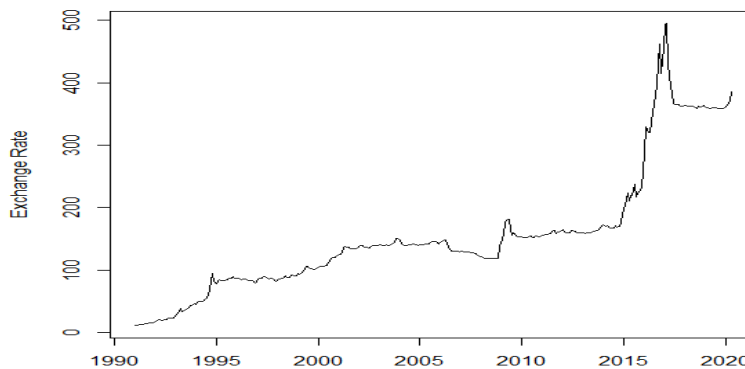
where  $n$  is the sample size,  $m =$  lag length and  $\rho$  is the sample autocorrelation coefficient.

**The decision:** if the  $Q$  is less than the critical value of  $\chi^2$ , then we do not reject the null hypothesis. These means that a small value of Ljung-Box statistic will be in support of no serial correlation or that the error are normally distributed. Tsay, [11].

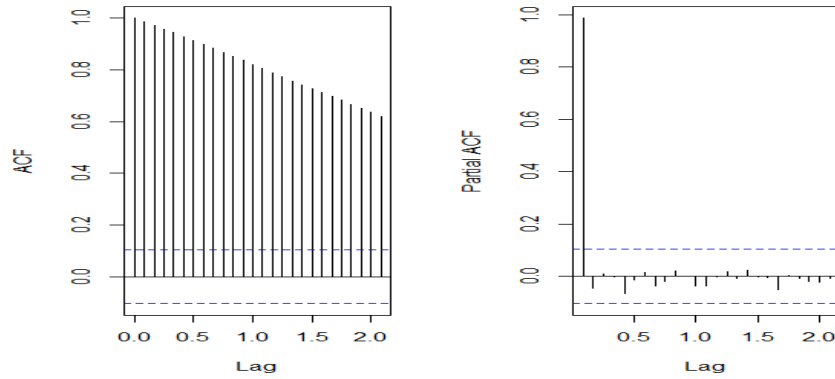
## 3 Results and Discussion

### 3.1 Empirical results

Data obtained were plotted as shown in Fig. 1 and the plot reveals an upward trend over time and series non-stationary. Fig. 2 shows plots of ACF and PACF of the original series which confirms features deduced from time plot of original series.

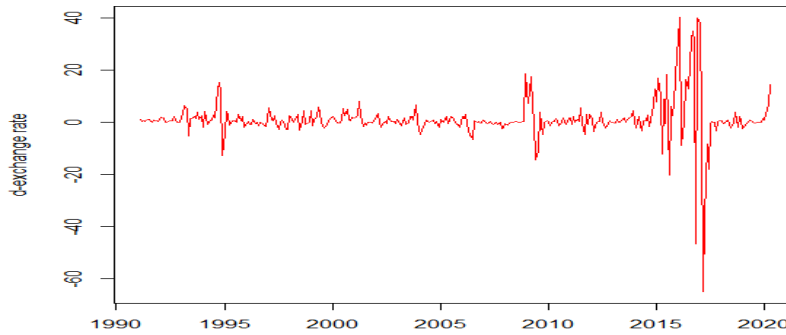


**Fig. 1. Time series plot of monthly Naira/Dollar exchange rate (Jan. 1991- Apr. 2020)**



**Fig. 2. ACF and PACF Plot before differencing**

The series is differenced to achieve stationarity and the time plot of the differenced series is shown in Fig. 3 revealing stationarity though subject to confirmation using the Augmented Dickey Fuller (ADF) test.



**Fig. 3. Time series plot of the first difference for monthly Naira/Dollar exchange rate (Jan. 1991- Apr. 2020)**

Table 1 below presents formal Augmented Dickey Fuller statistic for testing the presence of unit root in the series before and after the first difference and second difference.

**Table 1. Augmented dickey fuller (ADF) unit root test**

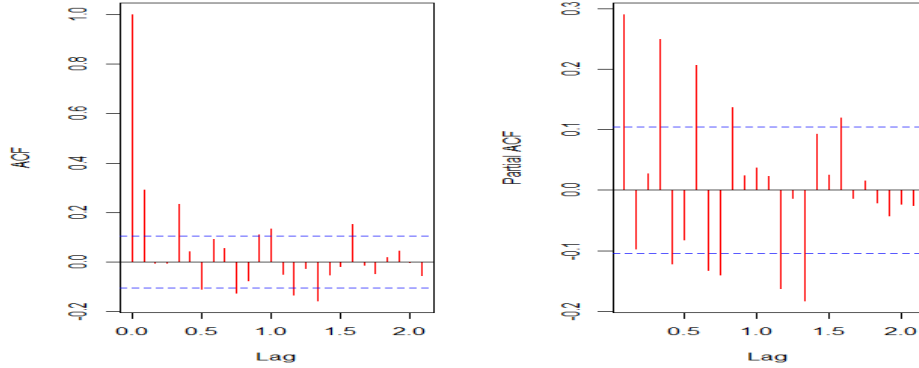
Level of series	Test statistic	P-Value	Decision
Original Series	-2.1911	0.4962	Not Stationary
After First Difference	-5.918	< 0.01	Stationary
After Second Difference	-8.7046	< 0.01	Stationary

The sample ACF and PACF shown in Fig. 4 confirms the tendency of  $\nabla(Y_t)$  to behave as both having autoregressive and moving average processes as the ACF has significant peaks at different lags and the PACF is gradually decaying to zero. This would suggest the exchange rate data follows an ARIMA (p, d, q) process.

### 3.2 The ARIMA model

Several ARIMA models are fitted after examining the ACF and PACF plot of the exchange rate data series at first difference. Table 2. summarizes each of these fitted models showing their AIC (Akaike Information

Criterion), BIC (Bayesian Information Criterion) and HQC (Hannan Quinn Criterion) tests statistic. To select the best suitable model for forecasting, the fitted ARIMA model with lowest of each of the three model selection criterion is chosen.



**Fig. 4. ACF and PACF plot of the exchange rate data series at first difference**

**Table 2. Comparison of selected ARIMA models**

Fitted ARIMA models	AIC	BIC	HQC
ARIMA(0,1,1)	2468.859	2476.581	2471.932
ARIMA(1,1,0)	2552.963	2560.685	2556.036
ARIMA(1,1,1)	2439.323	2450.905	2443.933
ARIMA(1,1,2)	2438.875	2454.318	2445.021
ARIMA(2,1,1)	2438.199	2453.643	2444.345
ARIMA(2,1,2)	2440.151	2459.455	2447.834
ARIMA(1,1,3)	2413.590	2450.895	2439.274
ARIMA(3,1,1)	2455.605	2474.909	2463.288
ARIMA(2,1,3)	2397.615	2420.780	2406.835
ARIMA(3,1,2)	2438.910	2462.075	2448.130
ARIMA(3,1,3)	2399.581	2426.607	2410.337

From Table 2, ARIMA (2, 1, 3) is exhibits lowest AIC, BIC and HQC statistic hence chosen as the best suitable model for forecasting while Table 3 shows parameters of the chosen model. From Table 3, the coefficients of ARIMA (2, 1, 3) model were valid and stationary condition was met and satisfied since the coefficients are all less than one (-0.532437, -0.556116, -0.074999, -0.100516 and -0.824480) and all with the exception of MA1 and MA2 are also significant since their p – value are less than 0.05 and 0.01 but the MA2 is significant at 0.1. This means that the overall significance of the coefficients of ARIMA (2, 1, 3) was accepted and hence both AR (2) and MA (3) thus explain the series.

**Table 3. ARIMA (2, 1, 3)**

	Coefficient	Std. Error	z	P-value
AR1	-0.530424	0.077608	-6.8346	<0.00001
AR2	-0.553168	0.067445	-8.2018	<0.00001
MA1	-0.074164	0.061560	-1.2047	0.22830
MA2	-0.101859	0.054382	-1.8730	0.06107
MA3	-0.823976	0.050844	-16.2059	<0.00001

Hence, the ARIMA (2, 1, 3) can be written mathematically as

$$W_t = -0.530424W_{t-1} - 0.553168W_{t-2} + e_t + 0.074164e_{t-1} + 0.101859e_{t-2} + 0.823976e_{t-3} \quad (3.1)$$

with  $W_t = X_t - X_{t-1}$ . The required model will be given as

$$X_t = 0.469576X_{t-1} - 0.022744X_{t-2} + 0.553168X_{t-3} + e_t + 0.074164e_{t-1} + 0.1018596e_{t-2} + 0.823976e_{t-3} \quad (3.2)$$

The ACF of the residuals is plotted with lags up to 20 as shown in Fig. 5. The residuals coefficient did not exceed the 95% confidence limit which indicates that the model is a good fit and is appropriate for the data. Since the series has more than 100 observations we consider using the Box-Pierce Statistic instead of Ljung-Box Statistic. The purpose of the Box-Pierce is to test whether the residuals are independent ( $H_0$ ) or to check for absence of serial auto-correlation. The p-values of the Box-Pierce Statistic in Fig. 5 for various values of the lag shows that the residuals are independent since the p-values fall above the dotted line, which corresponds with p-value of 0.05. If the  $P$ -value was below about 0.05, there would be some cause for concern: it would imply that the terms in the ACF are too large to be a white noise.

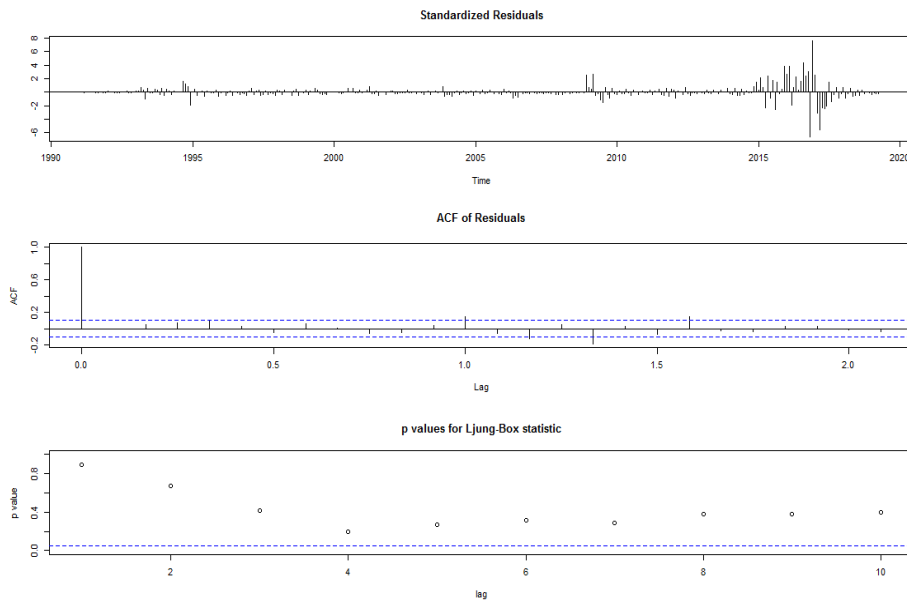
Table 4 shows result of a Box-Pierce test and considering, lag say 10, the p-value of 0.3962 is compared with 0.05, since it is greater than 0.05 we can attest that ARIMA (2, 1, 3) is specified correctly and is adequate.

### 3.3 Forecast

The forecast table (Table 5) shows the calculated one-step ahead forecast using the fitted ARIMA (2, 1, 3) with 95% confidence limit for the exchange rate data using the 352 original data points. The forecast for 12 months starts from the month of June 2020 and shows the same characteristic of the original series between Naira and US Dollar and clearly indicates that Naira will continue to depreciate against the US Dollar within the next one year.

**Table 4. Box-pierce test**

Q-Statistic	df	P-value
10.520	10	0.3962



**Fig. 5. ACF of residuals and Ljung-box statistic**

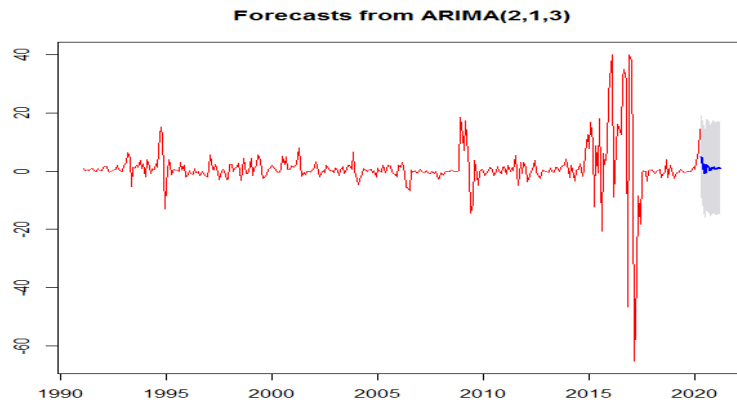


**Table 5. Forecast table**

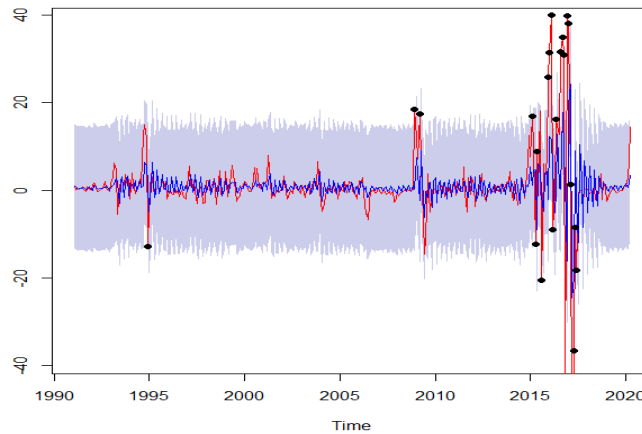
Month/Year	Point Forecast	LCL	UCL
June 2020	5.0211348	-9.197044	19.23931
July 2020	0.5551606	-14.749010	15.85933
August 2020	-0.8347627	-16.166737	14.49721
September 2020	2.3729210	-13.355978	18.10182
October 2020	1.4403488	-14.356294	17.23699
November 2020	0.1606195	-15.687547	16.00879
December 2020	1.3552882	-14.552378	17.26295
January 2021	1.4295124	-14.478631	17.33766
February 2021	0.7292894	-15.198923	16.65750
March 2021	1.0596463	-14.873196	16.99249
April 2021	1.2717580	-14.661497	17.20501
May 2021	0.9765059	-14.961498	16.91451

*\*The UCL and LCL are the upper and lower confidence level respectively*

Fig. 6 depicts the out-of-sample forecast plot between Naira and US Dollar for one year (12 months) while Fig. 7 provides the fitted values for in-sample one-step forecasts. Assuming normally distributed errors with 95% prediction intervals, The plot shows the comparisons between the actual values and predicted values for ARIMA (2, 1, 3).



**Fig. 6. Exchange rate Out-of-sample forecast plot**



**Fig. 7. Exchange rate In-sample forecast plot**

### 3.4 Trend estimation

Plot of original series and the trend is seen in Fig. 8 while Table 6 shows estimate of the trend equation given as  $y = 2.17079 + 0.87065x$  with coefficient of determination  $R^2 = 0.7519$  and corresponding adjusted  $R^2 = 0.7512$ .

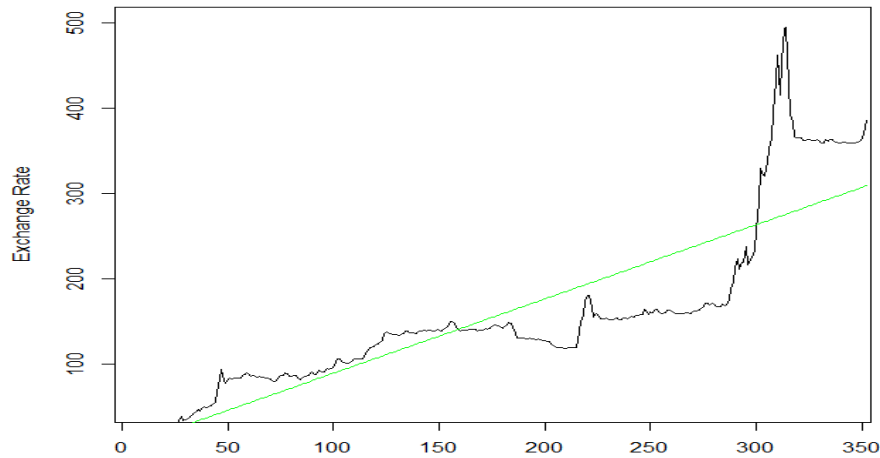


Fig. 8. Plot of the original series with trend

Table 6. Summary of the trend equation

Coefficient	Estimate	Standard Error	t-value	Pr(> t )
Intercept	2.17079	5.44438	0.399	0.69
X	0.02673	0.02673	32.569	< 2e-16

Multiple R-squared: 0.7519, Adjusted R-squared: 0.7512

Residual standard error: 50.96 on 350 degrees of freedom

In this article, we attempt to establish the traditional time series ARIMA model for forecasting Naira/Dollar exchange rate using Monthly data covering the period from January 1991 to April 2020. Stationarity was achieved at first difference, further confirmed with the Augmented Dickey Fuller unit root test. Using the AIC, BIC and HQC as model selection criterion the ARIMA (2, 1, 3) was selected as the model with the best fit for the exchange rate data as compared to the other selected models. The ACF of the residuals is plotted with lags up to 20. The residuals coefficient did not exceed the 95% confidence limit which indicates that the model is a good fit and is appropriate for the data. The Box-Pierce Statistic showed that the residuals are independent and are white noise. In-sample and out-of-sample forecast were carried out. The out-of-sample forecast for period of 12 months showed that the naira will continue to depreciate on US dollar for the period forecasted. The coefficient of determination given in Table 6 with its corresponding adjusted implies that 75.19% of the variation in the exchange rate is explained by time.

### 4 Conclusion

The COVID-19 pandemic will have a negative impact on the Nigerian economy which might see the naira depreciating further against the US dollar. The Nigerian government must put in place structural measures which will adequately diversify the economy to avoid the looming crisis. Continuous devaluation of the Nigerian naira will see the naira depreciate further because of the over dependency on imported goods and will sell at higher rates.”

## Competing Interests

Authors have declared that no competing interests exist.

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