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MODELING AND FORECASTING NIGERIAN NAIRA/US DOLLAR AND THE GAMBIAN DALASI/US DOLLAR EXCHANGE RATES: A COMPARATIVE STUDY

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ABSTRACT: *This paper compares the predictive performance of time series forecast methods on the Nigerian Naira/US Dollar (NGN/USD) and The Gambian Dalasi/US Dollar (GMD/USD) exchange rates. The forecast methods—Autoregressive Integrated Moving Average (ARIMA), Simple Exponential Smoothing (SES), Holt's Linear Trend, and Damped Holt—were applied to the annual Nigerian Naira and Gambian Dalasi against the US Dollar for the period 1960–2020. The best model for forecasting exchange rates in both countries was selected based on Root Mean Squared Error (RMSE), Mean Absolute Error (MAE), Mean Absolute Percentage Error (MAPE), and Mean Absolute Scaled Error (MASE). The findings in this study revealed that both Naira/US Dollar and Gambian Dalasi/US Dollar exchange rate distributions are positively skewed and ARIMA (0,2,2) model was selected as the most appropriate model for forecasting both exchange rates. The results also showed that by 2030, the Nigerian Naira/US Dollar exchange rate will rise by 37.06 percent while the Gambian Dalasi/US Dollar will rise by 23.18 percent. This study suggests that both countries should adopt tighter fiscal, monetary, and supply-side policies.*

KEYWORDS: Exchange rate, Nigerian Naira, The Gambian Dalasi, ARIMA, Simple exponential smoothing, Holt's linear, Damped holt.

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INTRODUCTION

In the world today exchange rate has become a significant variable because of its significant impact on many macroeconomic variables such as unemployment, interest rate, and economic growth and its effect on financial policy makers [1]; its evolution is important for several outstanding issues in international economics and finance, such as foreign exchange risk management, currency options pricing, international portfolio management, international trade and capital flows [2]. It is one of the major financial markets in the world today. Many countries, especially the developing countries, have been putting more effort to see to it that their local currencies are boosted. Exchange rate market is one of the important and major financial markets in the world that has been trading non-stop, twenty-four hours a day; billions of dollars of several domestic currencies are transacted every minute of the day [3-4]. Transactions in exchange rate is the rate at which one unit of a foreign currency is exchanged in terms of a domestic currency [5], thereby determining the costs of purchasing foreign goods and financial assets. Thus, a country's exchange rate is one of the important indicators that has to be monitored very closely; this is because fluctuations in the exchange rate can cause economic tribulations [6].

Exchange rate is the relative value of the local currency in terms of foreign exchange [7]; it is the rate of the currency of a nation expressed in terms of foreign currency [8]. Exchange rate is often expressed as the amount of domestic currency needed to buy one unit of foreign currency [9]. The exchange rate is a relative price that measures the worth of a domestic currency in terms of another currency [10]. Foreign exchange rate is the price of one currency in terms of another currency [11-12]. Foreign exchange is also the process of trading local currencies for foreign ones at an unstable exchange rate [13].

Thus, when the domestic income of a country increases, the domestic currency of such a country is likely to depreciate, while an increase in foreign income would cause an appreciation of the currency. Any country that depends and focuses more on domestic goods and services is bound to have an appreciated currency, and if the country depends on foreign goods, its currency is likely to depreciate [14]. In addition, if the domestic inflation rate exceeds the global average rate, it will likely lead to its currency's depreciation, but if the domestic inflation rate, in the other way, is less than the global average, then there is a great possibility that the local currency will appreciate [15]. Furthermore, fluctuations in exchange rate exert changes in domestic production costs [16] and also affect the labour market with respect to the channels of appreciation and depreciation of currencies [17]. A depreciation in the exchange rate leads to the growth of local jobs in the manufacturing and non-manufacturing sectors [18], while volatile exchange rates may increase unemployment rate through the reduction of investment in physical capital [19]. However, investment may be reduced because higher volatility usually connotes increased uncertainty [20]. However, maintaining exchange rate stability implies controlling a country's level of unemployment [21] and promoting investment. When the monetary authority allows the exchange rate to be fixed, other macroeconomic variables are volatile, and when exchange rate is allowed to float, it is known that the exchange rate becomes highly volatile in comparison with other macroeconomic variables [22-23].

The Naira per USD exchange rate is the amount of Naira that is needed to acquire one unit of US Dollar. Nowadays, stabilizing the exchange rate is a formidable bedrock of all economic activities. The centrality of exchange rates in the formulation of monetary policy derives from the fact that for most countries, the prevailing objective of monetary policy is price stability.

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Moreover, the major objectives of exchange rate policy in Nigeria are to preserve the value of the Naira and to maintain enough foreign exchange reserves. The Central Bank of Nigeria (CBN) maintains the stability of the Naira exchange rate so as to achieve its objective, which is to maintain price stability. Many methods of forecasting have been employed by many researchers to ensure that the best methods are used to forecast Naira-USD exchange rate. Regarding the use of autoregressive integrated moving average (ARIMA) for forecasting Naira-USD exchange rate are these studies: [24] used Naira-USD exchange rate for the period 1972–2017 to model and forecast exchange rate; the study reveals ARIMA(0,1,0) as the best model. [25] employed data for the period 1981–2012; the result presents ARIMA(2,1,2) as the best model. [26] in their study selected ARIMA(0,2,1) as the best model for forecasting Naira-USD exchange rate with the help of annual data for the period 1972–2014.

The Gambian economy is a small open economy in West Africa. The remittances received by many Gambians from abroad is evidence that exchange rate is a significant component of the monetary transmission process in The Gambia [27]. The floating exchange rate introduced in the Gambia in 1986 has created a room for exchange rate against the international currencies, such as the US Dollar, to be obtained by the forces of demand and supply in the currency market. The Gambian Dalasi per USD exchange rate is the amount of Gambian Dalasi that is needed to acquire one unit of US Dollar.

The NGN/USD and GMD/USD exchange rates are one of the important variables that have significant impact on other socio-economic variables in Nigeria and in The Gambia. However, with the significant role being played by exchange rate dynamics in the international trade and economic performance of all the countries in the world, there is perhaps a need for a good forecasting tool for future predictions.

The purpose of this paper is to obtain the most appropriate forecast method that will be used for forecasting Nigerian Naira/US Dollar and as well as The Gambian Dalasi/US Dollar exchange rate. The specific objectives of this study are to model four different linear forecast methods to the exchange rate of the two countries, to obtain the best forecast method among them for each country, and then to compare the two selected methods for Naira/US Dollar and Gambian Dalasi/US Dollar.

MATERIALS AND METHODS

Data Collection/Analysis

The data used in this study are Nigerian Naira/US Dollar (NGN/USD) exchange rate and The Gambian Dalasi/US Dollar (GMD/USSD) exchange rate sourced from the World Bank websites for the period 1960–2020. The linear forecast methods employed in this study are autoregressive integrated moving average (ARIMA), simple exponential smoothing (SES), Holt's linear trend (HOLT) and Damped Holt's linear trend. The Akaike information criterion corrected (AICC) is used in selecting the best ARIMA method among other competing ARIMA methods, while four measures of forecast performances—Root Mean Squared Error (RMSE), Mean Absolute Error (MAE), Mean Absolute Percentage Error (MAPE), and Mean absolute scaled error (MASE)—are used in selecting the best forecast method among the various competing methods.

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Autoregressive Integrated Moving Average (ARIMA) Method

ARIMA model is a time series forecasting approach. It is a combination of AR (autoregressive) process, I (integrated), and MA (moving average) process. ARIMA is usually adopted in non-stationary time series (i.e., series that change with respect to time). The ARIMA process denoted as $ARIMA(p, d, q)$ is written as

$$y_t = \delta + \phi_1 y_{t-1} + \cdots + \phi_p y_{t-p} + \varepsilon_t - \theta_2 \varepsilon_{t-2} - \cdots - \theta_q \varepsilon_{t-q} \quad (1)$$

where p is AR order, q is MA order, d is degree of differencing, $\phi_1, \cdots, \phi_p$ are the autoregressive process parameters, $\theta_1, \cdots \theta_q$ are the moving average process parameters, $y_{t-1}, \cdots, y_{t-p}$ are the past time series at period $t-1, \cdots, t-p$, δ is the drift, ε_t is white noise and $\varepsilon_{t-1}, \cdots, \varepsilon_{t-q}$ are the errors at period $t-1, \cdots, t-p$.

Time series data is changed from nonstationary to stationary by either differencing or transformation. This paper adopts differencing approach. Differencing is obtained using the expression:

$$y_t' = \nabla^d y_t = \sum_{i=0}^{d} (d\ i)(-1)^i y_{t-i} \quad (2)$$

Stationary autoregressive (AR) process is a linear combination of past values of the variable of interest. An autoregressive (AR) model of order p denoted as AR (p) is written as:

$$y_t = \delta + \phi_1 y_{t-1} + \cdots + \phi_p y_{t-p} + \varepsilon_t \quad (3)$$

where $\delta = \mu(1 - \phi_1 - \cdots - \phi_p)$

Stationary moving average (MA) process is a linear combination of past forecast errors. A moving average (MA) model of order q denoted as MA (q) is written as:

$$y_t = \mu + \varepsilon_t - \theta_1 \varepsilon_{t-1} - \cdots - \theta_q \varepsilon_{t-q} \quad (4)$$

In ARIMA modeling, we adopted the Box-Jenkins methodology—model identification, parameter estimation, model adequacy checks, and forecasting.

Under model identification, the necessary points involved are time plot of the data, estimating the sample autocorrelation function (ACF) and partial autocorrelation function (PACF). The data is first of all checked for stationarity either by visualizing the time plot or by visualizing the ACF and PACF plots.

Simple Exponential Smoothing (SES) Method

This is a linear forecast method that is applied to time series data, when the trend or seasonal pattern is not present in the time series. Under SES, the forecasts are obtained using the weighted averages. The simple exponential smoothing (SES) method is written as:

$$\hat{y}_t = \alpha y_t + \alpha(1 - \alpha) y_{t-1} \quad (5)$$

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where the weight is given by the smoothing parameter, α which lies between zero and one, i.e., $0 < \alpha < 1$.

Holt's Linear Trend Method

This is a special kind of single exponential smoothing used in forecasting time series developed by Holt (1957) that is suitable when there is trend and no seasonal pattern. It involves a forecast equation, a smoothing equation for the level and for the trend. These equations are

$$l_t = \alpha y_t + (1-\alpha)(l_{t-1} - T_{t-1})\ T_t = \beta(l_t - l_{t-1}) + (1-\beta)\ T_{t-1}\ \hat{y}_t = l_t + T_t \} \quad (6)$$

where α is the smoothing factor of data series $(0 < \alpha < 1)$ and β is the trend smoothing factor $(0 < \beta < 1)$; l_t is the estimate of the level of the series at time t; T_t is the estimate of the trend of the series at time t., and $\hat{y}_t$ is Holt's forecast equation.

Damped Holt's Linear Trend Method

This is a special type of Holt's linear trend method that introduces a parameter that dampens [20] the increasing or decreasing trend line by flattening it at some time in the future. This method is written as:

$$l_t = \alpha y_t + (1-\alpha)(l_{t-1} - \varphi T_{t-1})\ T_t = \beta(l_t - l_{t-1}) + (1-\beta)\varphi\ T_{t-1}\ \hat{y}_t = l_t + (\varphi + \varphi^2 + \cdots + \varphi^k)T_t \} \quad (7)$$

where α is the smoothing factor of data series $(0 < \alpha < 1)$ and β is the trend smoothing factor $(0 < \beta < 1)$; φ is the damping parameter $(0 < \varphi < 1)$; l_t is the estimate of the level of the series at time t; T_t is the estimate of the trend of the series at time t., and $\hat{y}_t$ is the Damped Holt's forecast equation.

Measures of Forecast Accuracy

This is used to compare the forecast errors of two or more linear models. The model with the least measure of forecast is considered the best forecasting model among others. This paper adopts the following measure of forecast accuracies:

$$RMSE = \sqrt{\frac{1}{N}\sum_{t=1}^{N} \quad (y_t - \hat{y}_t)^2}\ MAE = \frac{1}{N}\sum_{t=1}^{N} \quad |y_t - \hat{y}_t|\ MAPE = \frac{1}{N}\sum_{t=1}^{N} \quad 100.\left|\frac{y_t - \hat{y}_t}{y_t}\right|\ MASE = \frac{1}{N}\sum_{t=1}^{N} \quad \frac{|y_t - \hat{y}_t|}{\frac{1}{N-1}\sum_{t=2}^{n} \quad |y_t - y_{t-1}|} \} \quad (8)$$

This paper adopts Akaike information criterion corrected (AICC) to select the ARIMA model from candidate ARIMA models.

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$$AICC = AIC + \frac{2p(p+1)}{n-p-1};\ AIC = -2lnL + 2p \quad (9)$$

where L is the likelihood of the data, p is the number of fitted model parameters, and n is the sample size.

RESULTS

Figure 1 shows the time plot for Nigerian Naira/US Dollar and The Gambian Dalasi/US Dollar Exchange Rate for the period 1960–2020. The plot shows that both exchange rates are not stationary, that is, they are affected by time. In addition, the Nigerian Naira/US Dollar exchange rate shows a high increase in trend compared to the Gambian Dalasi/US Dollar exchange rate. In both cases, the high exchange rate is being experienced in 2020.

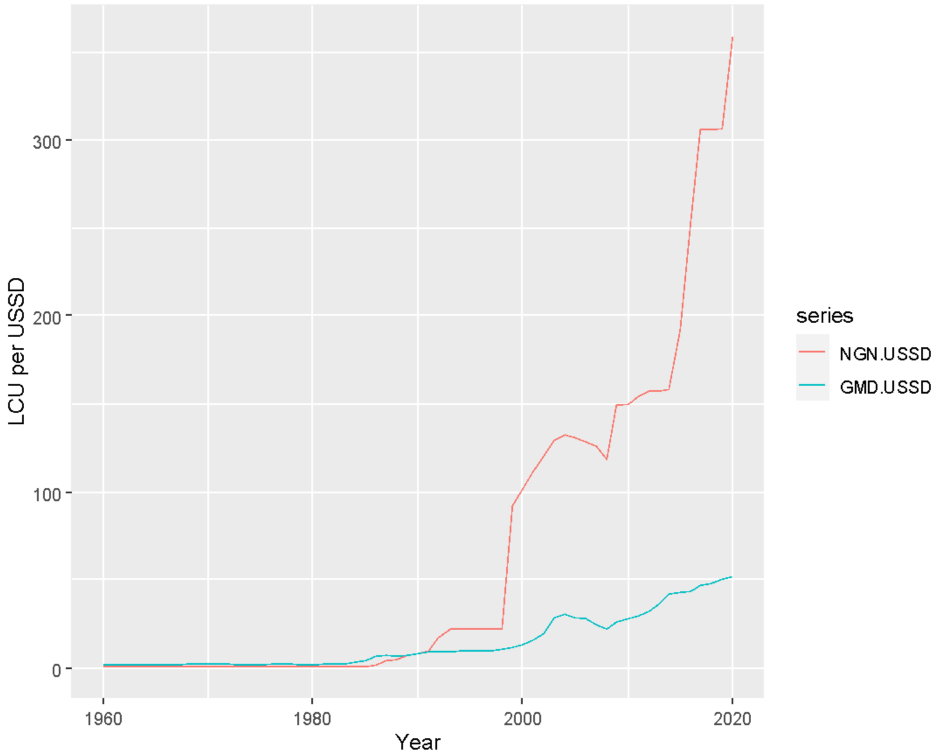

Figure 1: Time plot of Nigerian Naira/USD and the Gambian Dalasi/USD exchange rate for 1960–2020

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Nigerian Naira/USD Exchange Rate Results

Table 1: Descriptive Statistics for NGN/USD Exchange Rate

Mean	Standard deviation	Skewness	Kurtosis	Jarque-Bera	p-value
66.30	94.31	1.47049	1.45649	24.836	4.046e-06

Table 1 shows that the average NGN/USD Exchange Rate for the period 1960–2020 is 66.30 Naira per a US Dollar; NGN/USD is platykurtic (kurtosis is 1.47049 less than 3) and has a positive skewed distribution. Jarque-Bera statistic is 24.836 with p-value less than 0.05; this implies that NGN/USD exchange rate is not normally distributed, and it requires transformation.

Table 2: Augmented Dickey Fuller (ADF) Test for NGN/USD Exchange Rate

Difference	Dickey-Fuller	p-value
0	1.0553	0.9900
1	-3.0684	0.1429
2	-6.3535	0.0100

In Table 2, the actual data gives a Dickey-Fuller of 1.0553 and a p-value value of 0.9900 greater than 0.05; this implies that there is a need for first differencing; the first difference gives a Dickey-Fuller of -3.0684 and a p-value of 0.1429 greater than 0.05, implying that there is need for a second differencing; the second differencing gives a Dickey-Fuller of -6.3535 and a p-value of 0.0100 less than 0.05; this implies that there is no more evidence for further differencing. Figure 2 shows the Autocorrelation Function (ACF) and Partial Autocorrelation Function (PACF) plots for Actual data, first, second, and third differenced NGN/USD Exchange Rate.

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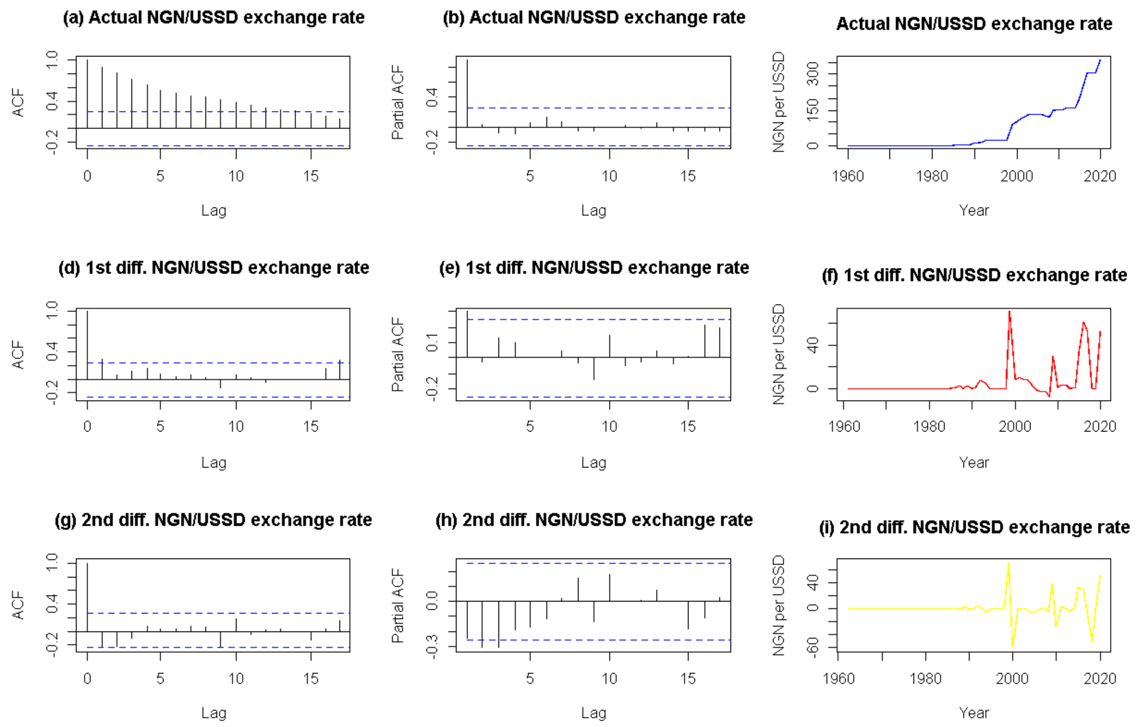

Figure 2: (a) ACF plot for actual NGN/USD exchange rate; (b) PACF plot for actual NGN/USD exchange rate; (c) Time plot for actual NGN/USD exchange rate; (d) ACF plot for 1st differenced NGN/USD exchange rate; (e) PACF plot for 1st differenced NGN/USD exchange rate; (f) Time plot for 1st differenced NGN/USD exchange rate; (g) ACF plot for 2nd differenced NGN/USD exchange rate; (h) PACF plot for 2nd differenced NGN/USD exchange rate; (i) Time plot for 2nd differenced NGN/USD exchange rate.

Table 3: ARIMA Model Selection for NGN/USD Exchange Rate

Models	AICC
ARIMA(2,2,2)	494.9096
ARIMA(0,2,0)	508.0083
ARIMA(1,2,0)	506.0147
ARIMA(0,2,1)	492.236
ARIMA(1,2,1)	492.3592
ARIMA(0,2,2)	491.4559
ARIMA(1,2,2)	493.5906
ARIMA(0,2,3)	493.4016
ARIMA(1,2,3)	495.5636

In Table 3, ARIMA (0,2,2) has the least Akaike information criterion corrected (AICC) of 491.4559 and it is selected as the least parsimonious model among competing ARIMA models.

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Table 4: Model Performance Check for NGN/USD Exchange Rate

	SES	ARIMA (0,2,2)	Holt	Damped Holt
RMSE	16.56404	14.36592	14.72954	14.79925
MASE	0.98414	0.97904	0.99648	1.01108
MAE	6.36183	6.32867	6.44155	6.53598
MAPE	9.43390	8.79848	13.95726	26.88229

In Table 4, ARIMA (0,2,2) forecast method has the least RMSE, MASE, MAE, and MAPE; however, it is selected as the best predictive model among others for NGN/USD exchange rate.

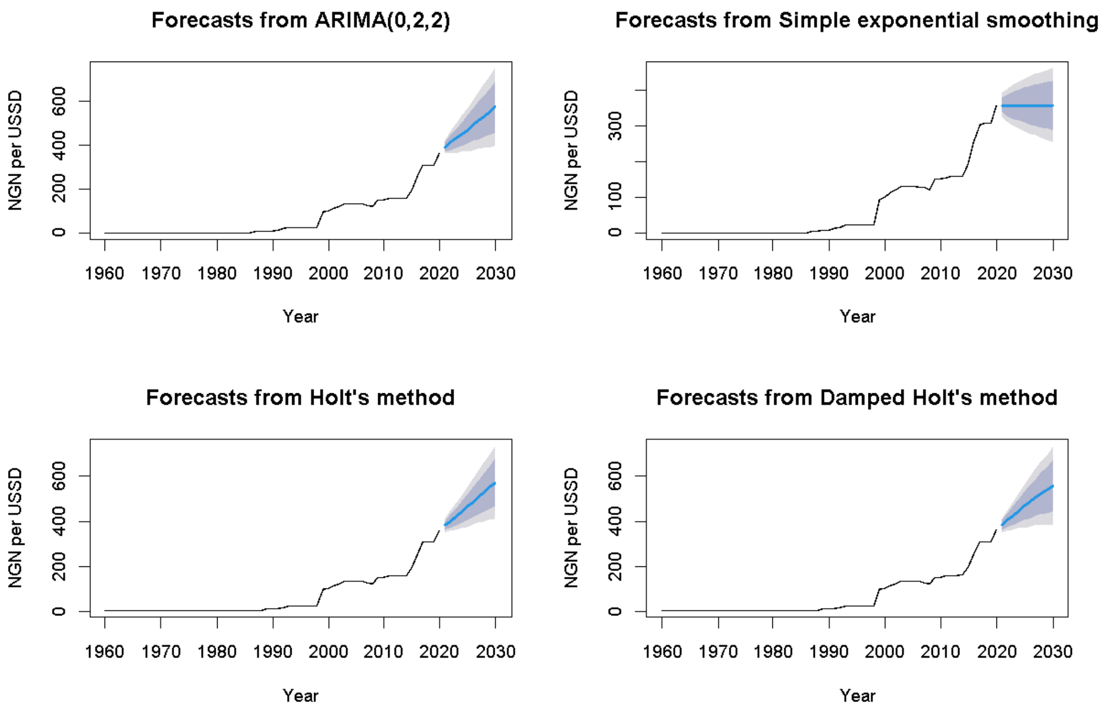

Figure 3: Plots Showing Out-of-sample Forecasts for NGN/USD Exchange Rate

Table 5: Out-of-sample Forecast for NGN/USD Exchange Rate

	Point forecast			
Year	ARIMA(0,2,2)	SES	Holt	Damped Holt
2021	388.9349	358.8048	378.8823	380.3063
2022	409.0644	358.8048	393.9584	401.3763
2023	429.1939	358.8048	419.0344	422.0249
2024	449.3234	358.8048	439.1104	442.2605
2025	469.4529	358.8048	459.1864	462.0913
2026	489.5824	358.8048	479.2624	481.5256

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2027	509.7119	358.8048	499.3384	500.5712
2028	529.8415	358.8048	519.4144	519.2359
2029	549.9710	358.8048	539.4905	537.5272
2030	570.1005	358.8048	559.5665	555.4528

In Table 5, ARIMA (0,2,2), Holt and Damped Holt show an increasing trend in their forecasted NGN/USD exchange rate, while SES shows constant NGN/USD exchange rate which is exactly the same with the exchange rate in 2020. Using the ARIMA (0,2,2) forecast method, the NGN/USD exchange rate by 2030 will rise to 570.1005 Naira for a USSD (showing 37.06% rise in the exchange rate); using Holt forecast method, by 2030, the NGN/USD exchange rate will rise to 559.5665 (showing 35.88% rise in the exchange rate); and using the damped Holt, the NGN/USD exchange rate will rise to 555.4528 (showing 35.40% rise in the exchange rate).

Table 6: Ljung-Box Test for Serial Correlation in the Forecast Errors

Model	Q-statistic	p-value
ARIMA (0,2,2)	6.7357	0.5654
SES	11.2420	0.1883
Holt	7.4335	0.2826
Damped Holt	7.5808	0.1809

ARIMA (0,2,2), SES, Holt and Damped Holt in Table 6 all have p-values greater than 0.05, which implies that they do not have serial correlation left in their respective forecast errors. However, they are all considered good predictive models for NGN/USD exchange rate.

The Gambian Dalasi/USD Exchange Rate Results

Table 7: Descriptive Statistics for GMD/USD Exchange Rate

Mean	Standard deviation	Skewness	Kurtosis	Jarque-Bera	p-value
14.19	15.26	1.11421	-0.03236	12.045	0.002424

Table 7 shows that the average GMD/USD exchange rate for the period 1960–2020 is 14.19 Gambian Dalasi per a US Dollar; GMD/USD is platykurtic (kurtosis is -0.03236 less than 3) and has a positive skewed distribution. Jarque-Bera statistic is 12.045 with p-value less than 0.05; this implies that GMD/USD exchange rate is not normally distributed, and it requires transformation.

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Table 8: Augmented Dickey Fuller (ADF) Test for GMD/USD Exchange Rate

Difference	Dickey-Fuller	p-value
0	-1.0092	0.9292
1	-5.0436	0.0100
2	-5.3271	0.0100

In Table 8, the actual data gives a Dickey-Fuller of -1.0092 and a p-value value of 0.9292 greater than 0.05; this implies that there is need for first differencing. The first difference gives a Dickey-Fuller of -5.0436 and a p-value of 0.0100 less than 0.05, implying that there is no need for a second differencing. But looking at the second differencing, the p-value is equally 0.0100, and it fails to present evidence for further differencing. However, the GMD/USD requires it to be differenced twice before attaining stationarity. Figure 4 shows the Autocorrelation Function (ACF) and Partial Autocorrelation Function (PACF) plots for Actual data, first, second, and third differenced GMD/USD exchange rate.

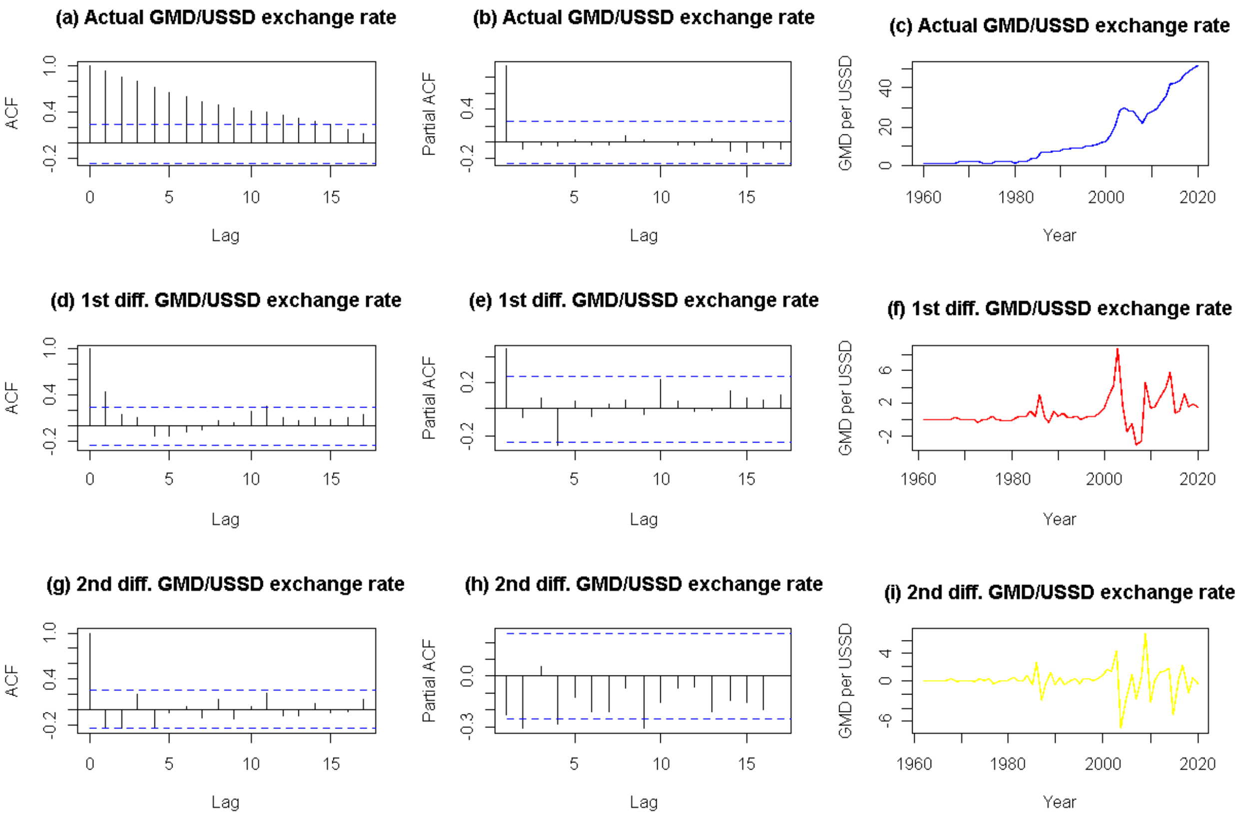

Figure 4: (a) ACF plot for actual GMD/USD exchange rate; (b) PACF plot for actual GMD/USD exchange rate; (c) Time plot for actual GMD/USD exchange rate; (d) ACF plot for 1st differenced GMD/USD exchange rate; (e) PACF plot for 1st differenced GMD/USD exchange rate; (f) Time plot for 1st differenced GMD/USD exchange rate; (g) ACF plot for 2nd differenced GMD/USD exchange rate; (h) PACF plot for 2nd differences GMD/USD exchange rate; (i) Time plot for 2nd differenced GMD/USD exchange rate.

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Table 9: ARIMA Model Selection for GMD/USD Exchange Rate

Models	AICC
ARIMA(2,2,2)	235.214
ARIMA(0,2,0)	245.124
ARIMA(1,2,0)	244.274
ARIMA(0,2,1)	240.310
ARIMA(1,2,2)	233.357
ARIMA(0,2,2)	231.362
ARIMA(0,2,3)	233.485
ARIMA(1,2,1)	233.132
ARIMA(1,2,3)	235.564

In Table 9, ARIMA (0,2,2) has the least Akaike information criterion corrected (AICC) of 231.362 and it is selected as the least parsimonious model among competing ARIMA models.

Table 10: Model Performance Check for GMD/USSD Exchange Rate

	SES	ARIMA (0,2,2)	Holt	Damped Holt
RMSE	1.97225	1.58068	1.74340	1.67231
MASE	0.98374	0.80643	0.83770	0.83388
MAE	1.11638	0.91516	0.95065	0.94631
MAPE	7.68089	6.92765	8.12248	8.20996

In Table 10, ARIMA forecast method has the least RMSE, MASE, MAE, and MAPE; however, it is selected as the best predictive model among others for forecasting GMD/USD exchange rate.

Table 11. Ljung-Box Test for Serial Correlation in the Forecast Errors

Model	Q-statistic	p-value
ARIMA (0,2,2)	12.011	0.1507
SES	21.806	0.0053
Holt	29.498	0.000049
Damped Holt	9.4261	0.09323

In Table 11, the ARIMA (0,2,2) and Damped Holt methods have p-values greater than 0.05, which implies that they do not have serial correlation left in their residuals, and thus considered adequate predictive models for GMD/USD exchange rate. The SES and Holt, on the other hand, have p-values less than 0.05, which implies that they still have serial correlation left in their residuals, thus are not considered adequate for predicting GMD/USD exchange rate.

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Table 12. Out-of-sample Forecast for GMD/USD Exchange Rate

	Point Forecast	
Year	ARIMA (0,2,2)	Damped Holt
2021	52.83	52.63
2022	54.41	53.53
2023	55.99	54.25
2024	57.57	54.82
2025	59.14	55.28
2026	60.72	55.65
2027	62.30	55.95
2028	63.88	56.18
2029	65.46	56.37
2030	67.04	56.52

In Table 12, ARIMA (0,2,2) and Damped Holt show a slight increase in the predicted GMD/USD exchange rate. Using ARIMA (0,2,2) forecast method, by 2030, the GMD/USD exchange rate will rise to 67.04 (showing 23.18% rise in the exchange rate), and using Damped Holt forecast method, the GMD/USD exchange rate will rise to 56.52 (showing 8.88% rise in the exchange rate).

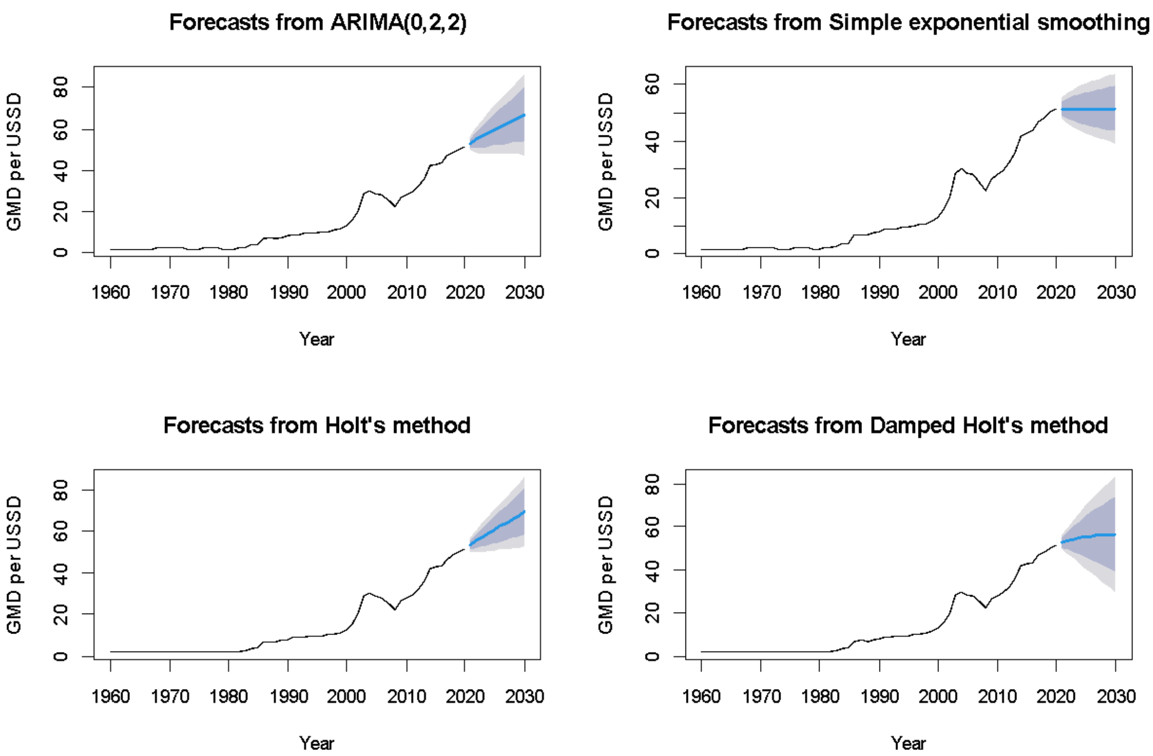

Figure 5: Plots showing out-of-sample forecasts for GMD/USD exchange rate

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CONCLUSION

Numerous researches have been carried out by many researchers on modeling and forecasting of exchange rate for developed and developing countries using different approaches. Exchange rate prediction is one of the demanding applications of modern time series forecasting. Foreign exchange rates are influenced by many economic, political and psychological factors. Despite the strategies the both governments (Nigeria and The Gambia) through their Central Bank have adopted to maintain a stable exchange rate, both the Nigerian Naira and Gambian Dalasi have depreciated throughout the 80's till date (Aliyu, 2011; Benson & Victor, 2012) and our results indicate that both the Nigerian Naira and The Gambian Dalasi will continue to depreciate.

We therefore recommend that both governments—Nigerian and The Gambian governments—should adopts the following:

1. Pursue a tighter fiscal and monetary policies that could lower inflation

2. Adopt supply-side policies that could increase competition and also reduce the cost of production, thereby helping the export industries and increasing the values of the currencies.

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