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A Combination of ARIMA Models and Neural Networks in Forecasting Nigerian Exchange Rate

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Abstract

Over the years, the United States Dollar, European Euro, and the British Pound Sterling exchange rate to Nigerian Naira has been on the increase. It has become pertinent to identify robust models that will help to cope with the variability associated with the increase in exchange rate. Several studies showed the ARIMA method to be highly useful in modelling and forecasting exchange rates. However, not much work has been done on modelling and forecasting Nigerian Exchange rate using machine learning models which is the focus for this study. The models we used in the study are; the Autoregressive Integrated Moving Average (ARIMA), Artificial Neural Network (ANN), and ARIMA-ANN models. Secondary data obtained from Central Bank of Nigeria (CBN) were used. The results showed that the most appropriate model out of the three time series models considered for these exchange rates is the ARIMA-ANN which produced a better forecast compared to ARIMA and ANN. This conclusion was based on the lowest standards of prediction accuracy which ARIMA-ANN produced the lowest Mean Absolute Error (MAE), Root Mean Square Error (RMSE), and Mean Absolute Percentage Error (MAPE) values for the three different currencies we compared against the naira. Based on the continuous increase in the Nigerian Exchange Rate, the Government and

policymakers should take economic measures to avoid the persistent downfall of the Nigerian Naira.

Keywords: Exchange rate, ARIMA, Neural Networks, Artificial Neural Networks

INTRODUCTION

National currency is used by economist to make and receive payments within a country. However, when carrying out international trade, domestic residents make use of foreign currencies. In exchange rate market, domestic currencies are converted into foreign currencies and vice versa. Exchange rate is defined as the value of a country's currency in terms of the currency of another country. It assumes relevance because of cross-border flows of goods, services, financial assets, and funds transfer. The efficiency of an economy can be determined by fluctuations in exchange rates. Hence, attaching importance to planning economic policies based on the predictions of exchange rates is necessary.

ARIMA (Autoregressive Integrated Moving Average) model is a combination of the AR (Autoregression) and MA (Moving Average) models and differencing parameter 'Integration' that makes the process stationary which is used to predict future value based on past values. A neural network (NN) on the other hand is a computing system made up of a number of simple, highly interconnected nodes or processing elements, which process information by its dynamic state response to external inputs. Neural Network is extensively used for financial forecasting in stock markets, foreign exchange trading, commodity futures trading and bond yields because of its ability to approximate nonlinear functions and offers a novel technique that doesn't require pre-specification during the modelling process.

This research attempts to combine ARIMA and ANN models to forecast the Nigerian exchange rate using American Dollar, British Pound, and European Euro. The combination of these two models (ARIMA and ANN) will bring about good forecasting power. The statistical software used for the analysis is R Software.

Literature Review

Modelling and predicting Exchange rates has been a challenging task for traders in modern financial markets. Statistical and econometric models have been extensively used in the analysis and prediction of foreign exchange rates. Alshaimaa (2015), investigation showed that the combination of the models between NN and ARIMA models gave a better prediction of index of the stock market EGX30. He suggested that the combination of the two models brought about the flexibility of the time series and the power of artificial neural networks, where one of the models compensates for the shortage of the other model. Roneda et al (2017) based their research on the exchange rate in Albania using three types of forecasting models (ARIMA, NAR, and ARIMA-ANN). They found that exchange rate is influenced by many factors like political factors, psychological factors, and economic factors, which makes it difficult to identify a unique kind of model that will yield a stable forecast. The empirical analysis showed that the hybrid model which is ARIMA-ANN had the best prediction performances with the lowest RMSE, MAPE, MAE, and MPE. Yohana and Olubosoye (2014) in publication "A Comparative Analysis of Foreign Exchange Neural Network (FOREXNN) and ARIMA models" showed that Foreign Exchange Neural Networks (FOREXNN) models with backpropagation training algorithm using descent gradient optimization technique and logistic activation function were was compared to ARIMA based on their predictive performance, FOREXNN model outperforms ARIMA model. Katerina Z. (2023) investigated exchange rate forecasting with Artificial Intelligence comparing the Albanian lek to the European Euro. He found out that, the NARNN (Nonlinear Autoregressive Neural Network model) model was preferred over the other linear forecasting models. It was chosen based on MAPE value, as it had the lowest value among all the forecasting models.

This study will contribute to existing literature by providing a suitable model order of ARIMA combined with ANN, to predict future trends of Nigerian Exchange rates.

METHODS

The ARIMA (Autoregressive Integrated Moving Average) model:

The Basic ARIMA Equation

Let Y^* be the dependent series transformed to stationarity. Then the general form of the model is:

$$Y_t^* = \phi_1 Y_{t-1}^* + \phi_2 Y_{t-2}^* + \cdots + \phi_p Y_{t-p}^* + \varepsilon_t - \theta_1 * \varepsilon_{t-1} - \theta_2 * \varepsilon_{t-2} - \ldots - \theta_q * \varepsilon_{t-q} \quad (1)$$

Y^* is predicted by its past values along with current and past errors.

Artificial Neural Network (ANN)

The three basic components of the artificial neuron are:

1. The synapses or connecting links that provide weights, w_j, to the input values, x_j, for $j = 1, 2, , \ldots, m$.
2. An adder that sums the weighted input values $v = w_0 + \sum_{j=1}^{m} w_j x_j$; where w_0 is the bias associated with the neuron, considered as the weight for an input x_0 (equal one) so that $v = \sum_{j=1}^{m} w_j x_j$;
3. An activation function g which maps v to $g(v)$ the output value of the neuron which dampens or bounds the neuron's output.

ANN model for the input observations $(y_{t-1}, y_{t-2}, y_{t-3}, \ldots, y_{t-p})$ to the output value (y_t) i.e.,

$$zy_t = a_0 + \sum_{j=1}^{q} a_j f(w_{oj} + \sum_{i=1}^{p} w_q y_{t-i}) + \varepsilon_t \quad (2)$$

Where, a_j $(j = 1, 2, , \ldots, q)$ is a bias on the j[th] unit

$w_{ij} =$ (i = 0, 1, 2,..., p; j=0, 1, 2,..., q) $=$ the connection weights between layers of the model,

$f(.) =$ the transfer function of the hidden layer,

$p =$ the number of input nodes and q is the number of hidden nodes (Lai et al., 2006).

The activity function for the neurons of the hidden is given by

$$f(x) = \frac{1}{1+ e^{-x}} \quad (3)$$

The gradient descent method is given by:

$$\text{SSE} = \frac{1}{2}\sum(y_k - \hat{y}_k)^2 \quad (4)$$

Where, y_k and $\hat{y}_k$ are the true and predicted output vector of the k[th] output mode.

Combined ARIMA and Artificial Neural Network (ARIMA-ANN)

Suppose the time series contains two main parts, one linear and the other non-linear, the model will be as follows:

$$Y_t = f(L_t, N_t) \quad (6)$$

$Y_t =$ Observation of time series at time t

$L_t =$ Linear part of ARIMA model

$N_t =$ Non-Linear part of ANN

This model is built according to the following steps:

1. Build ARIMA model for time series data Y_t

$$Y_t = \sum_{i=1}^{p} \Phi_i y_{t-i} + \sum_{j=1}^{q} \theta_j e_{t-j} + e_t = \hat{L}_t + e_t \quad (7)$$

where $\hat{Y}_t$ = estimation values

e_t = residual resulting from the linear part of ARIMA

2. Build a training ANN using the observation, residuals resulting from ARIMA

$$N_t^1 = f^1\left(e_{t-1}, e_{t-2,\ldots,} e_{t-q}\right) \quad (8)$$

$$N_t^2 = f^2\left(y_{t-1}, y_{t-2,\ldots,} y_{t-p}\right) \quad (9)$$

$$N_t = f(N_t^1, N_t^2) \quad (10)$$

3. So the combination model will be as follows:

$$y_t = f\left(N_t^1, \hat{L}_t, N_t^2\right) \quad (11)$$

$$y_t = f\left(e_{t-1}, e_{t-2,\ldots,} e_{t-q}, \hat{L}_t, y_{t-1}, y_{t-2,\ldots,} y_{t-p}\right) \quad (12)$$

where f = the non-linear function by ANN

RESULTS AND DISCUSSION

This section provides the results of the analysis carried out in the study. Three-time series models were used which are: Autoregressive Integrated Moving Average (ARIMA), Artificial Neural Network (ANN) and the combined ARIMA-ANN model. The data modelled are the Naira-Dollar exchange rate, Naira-Euro exchange rate and the Naira-pounds exchange rate and which span from December 2001 to April 2023 collected from the database of Central Bank of Nigeria. The analysis is sectioned into explanatory data analysis, Unit root test, ARIMA modelling, ANN modelling, ARIMA-ANN modelling and model performance comparison.

Table 1: Descriptive Analysis of the Exchange Rate

Descriptive	Naira-Dollar	Naira-Euro	Naira-Pounds
Mean	210.29	250.53	307.58
CI. Mean 0.95	2.78	2.92	2.98
Median	155.74	207.69	250.33
Standard Deviation	102.59	107.50	109.74
Var	10524.60	11557.19	12043.87
Coef of var	0.49	0.43	0.36
SE.mean	1.42	1.49	1.52
Range	348.65	494.01	422.80
Minimum	112.85	150.73	160.58
Maximum	461.50	509.74	583.37
Sum	1098769.16	137017.55	1605591.28
Count	5225	5217	5220

Naira-Dollar, Naira-Euro and Naira-Pounds have means of 210.29, 250.53 and 307.58 respectively. The table also showed that the minimum and maximum values of the three aforementioned variables in this study are 112.85 and 461.50, 150.73 and 509.74, 160.58 and 583.37 respectively.

Time Plot

The time plot shows the movement over time of exchange rates over time at different period of the years captured.

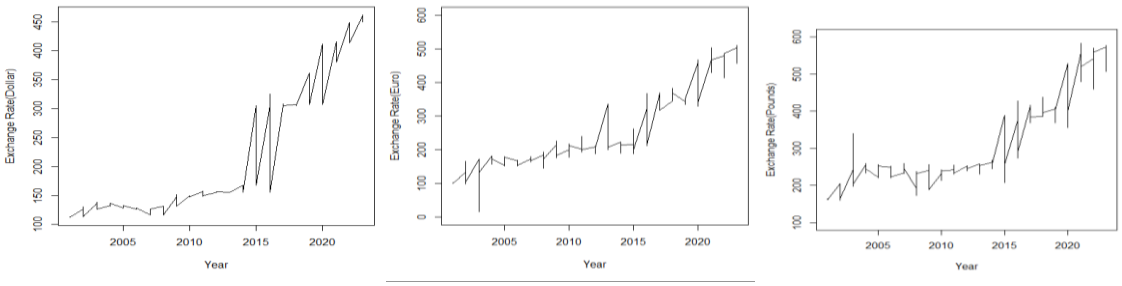

Fig 1:Time plot for Naira – Euro, Naira – Dollar, Naira - Pound Exchange rate respectively.

Unit Root Test

Augmented Dickey-Fuller (ADF) test statistic and Philip-Perron(PP) were used to test for the stationarity of our variables. The result below shows that Naira-Euro is stationary after showing a p-values of 0.02192 and 0.01 for the ADF and PP at a 5% level of significance. Philip-Perron unit root test also shows stationarity for Naira-Pounds with a p-value of 0.02345 at a 5% level of significance.

Table 2: ADF and PP tests for Naira-Dollar

	Statistic	Lag	P-value
ADF	-2.8056	17	0.2372
PP	-17.057	10	0.1587

Table 3: ADF and PP tests for Naira-Euro

	Statistic	Lag	P-value
ADF	-3.7407	17	0.02192
PP	-29.605	10	0.01

Table 4: ADF and PP tests for Naira-Pounds

	Statistic	Lag	P-value
ADF	-3.3158	17	0.06789
PP	-25.238	10	0.02345

ARIMA results for Naira - Dollar exchange rate

Table 5: ARIMA estimate for the Naira-Dollar exchange rate

	Coefficients	s.e.
MA1	0.2384	0.0138

sigma^2 estimated as 135.6: log likelihood=-809.18
AIC=30128.01 AIC=30128.01 BIC=30144.35

The training set error measures:

	ME	RMSE	MAE	MPE	MAPE	MASE	ACF1
Training set	0.80779	4.9248	0.4151	0.01162	0.1772	0.1494	0.000488

Table 5 above shows the estimated value of the Naira-Dollar exchange rate. It produces MA(1) with a coefficient value of 0.2384 and a standard deviation of 0.0138. It also shows its RMSE, MAE and MAPE values to be 4.9248, 0.4151 and 0.1772 respectively.

Forecast of ARIMA (0,1,1) for Naira-Dollar exchange rate

Table 6 below shows the forecast table for the Naira-Dollar exchange rate. It shows the actual, predicted, error values and the error percent. Figure 1 shows the forecast plot of the Naira-Dollar exchange rate using ARIMA (0,1,1) as the model for prediction.

Table 6: Forecast of ARIMA (0,1,1) for Naira-Dollar exchange rate

Actual		Predicted		Error		Error Percent	
420.83	419.19	421	421	0.17	1.81	0.04	0.43
420.46	418.47	421	421	0.54	2.53	0.13	0.60
419.89	418.07	421	421	1.11	2.93	0.26	0.70
419.72	417.48	421	421	1.28	3.52	0.30	0.84
419.37	417.19	421	421	1.63	3.81	0.39	0.91

ARIMA results for Naira - Euro exchange rate

Table 7: ARIMA estimate for the Naira-Euro exchange rate

	ar1	ma1	sar1	sar2
Estimate	0.0123	-0.2732	-0.0034	0.0009
s.e.	NaN	NaN	NaN	0.0164

sigma^2 estimated as 38.93: log likelihood=-16244
AIC=32453.83 AICc=32453.83 BIC=32530.58

The training set error measures:

	ME	RMSE	MAE	MPE	MAPE	MASE	ACF1
Training set	0.08862	6.2364	1.6205	-0.1493	0.8718	0.2528	-0.00027

Table 7 above shows the estimated value of the Naira-Euro exchange rate. It produces ARIMA(1,1,1) (2,0,0)[12] model with coefficients value of 0.0123, -0.2732, -0.0034 and 0.0009 for ar1, ma1, sar1 and sar2 respectively. It also shows its RMSE, MAE and MAPE values to be 6.2364, 1.6205 and 0.8718 respectively.

Forecast of ARIMA(1,1,1)(2,0,0)[12] for Naira-Euro exchange rate

Table 7 below shows the forecast table for the Naira-Euro exchange rate. It shows the actual, predicted, error values and the error percent. Figure 1 shows the forecast plot of the Naira-Euro exchange rate using ARIMA(1,1,1)(2,0,0)[12] as the model for prediction.

Table 8: Forecast of ARIMA(1,1,1)(2,0,0)[12] for Naira-Euro exchange rate

Actual		Predicted		Error		Error_Percent	
426.6185	421.6330	426	426	0.62	4.37	0.14	1.04
426.4887	425.3947	426	426	0.49	2.60	0.11	0.14
424.3469	423.3998	426	426	1.65	2.60	0.39	0.61
421.3248	423.9513	426	426	4.68	2.05	1.11	0.48
422.1994	423.7740	426	426	3.80	2.23	0.90	0.53

ARIMA results for Naira - Pounds exchange rate

Table 9: ARIMA estimate for the Naira-Pounds exchange rate

	ar1	ar2	ar3	ar4	ma1	ma2	sar1
estimate	-0.8654	-0.4270	-0.1188	-0.1067	0.6429	0.2226	0.0004
s.e.	0.1217	0.1469	0.0372	0.0158	0.1221	0.1313	0.0144

sigma^2 estimated as 45.31: log likelihood=-16621.69
AIC=33228.78 AICc=33228.8 BIC=33311.51

The training set error measures:

	ME	RMSE	MAE	MPE	MAPE	MASE	ACF1
Training set	0.09277	6.7258	1.9615	0.0014	0.6545	0.25409	0.00016

Table 9 above shows the estimated value of the Naira-Pounds exchange rate. It produces ARIMA(4,1,2)(1,0,0)[12] model with coefficients value of -0.8654, -0.4270, -0.1188, -0.1067, 0.6429, 0.2226 and 0.0004 for ar1, ar2, ar3, ar4, ma1, ma2 and sar1 respectively. It also shows its RMSE, MAE and MAPE values to be 6.7258, 1.9615 and 0.6545 respectively.

Forecast of ARIMA(0,1,1) for Naira- Pounds exchange rate

Table 10 below shows the forecast table for the Naira-Pounds exchange rate. It shows the actual, predicted, error values and the error percent. Figure 1 shows the forecast plot of the Naira-Pounds exchange rate using ARIMA(4,1,2)(1,0,0)[12] as the model for prediction.

Table 10: Forecast of ARIMA(4,1,2)(1,0,0)[12]] for Naira-Pounds exchange rate

Actual		Predicted		Error		Error_Percent	
505.1122	504.2141	508	508	2.89	3.79	0.57	0.75
508.4906	501.7310	508	508	0.49	6.27	0.10	1.25
509.6810	498.6606	508	508	1.68	9.34	0.33	1.87
509.5769	501.5259	508	508	1.58	6.47	0.31	1.29
505.1412	497.4449	508	508	2.86	10.56	0.57	2.12

Neural Network Result

This section discusses the result obtained using Artificial Neural Network (ANN) model for the Naira-Dollar, Naira -Euro and Naira - Pounds exchange rates. Tables 11, 12 and 13 show the ANN output for the three-time series data.

Table 11: ANN model for Naira - Dollar exchange rate

Model: NNAR(25,1,13)[12] Average of 20 networks, each of which is a 25-13-1 network with 352 weights options were - linear output units

ME	RMSE	MAE	MPE	MAPE	MASE
0.0181	4.52	0.566	-0.03	0.262	0.204

Table 11 above shows that the ANN model Naira-Dollar data as Neural Network Autoregressive model, NNAR(25,1,13)[12] with an average of 20 networks each of which is 25 inputs, 1 hidden neuron and 13 outputs. The table also shows that the model produced RMSE, MAE and MAPE of 4.52, 0.566 and 0.262 respectively.

Table 12: ANN model for Naira - Euro exchange rate

Model: NNAR(36,1,18)[12] Average of 20 networks, each of which is a 36-18-1 network with 685 weights options were - linear output units

ME	RMSE	MAE	MPE	MAPE	MASE
0.0396	5.56	1.59	-0.177	0.849	0.248

Table 12 above shows that the ANN model Naira-Euro data as Neural Network Autoregressive model, NNAR(36,1,18)[12] with an average of 20 networks each of which is 36 inputs, 1 hidden neuron and 18 outputs. The table also shows that the model produced RMSE, MAE and MAPE of 5.56, 1.59 and 0.849 respectively.

Table 13: ANN model for Naira - Pounds exchange rate

Model: NNAR(25,1,13)[12] Average of 20 networks, each of which is a 25-13-1 network with 352 weights options were - linear output units

ME	RMSE	MAE	MPE	MAPE	MASE
0.0457	6.05	1.83	-0.0220	0.607	0.237

Table 13 above shows that the ANN model Naira-Pounds data as Neural Network Autoregressive model, NNAR(25,1,13)[12] with an average of 20 networks each of which is 25 inputs, 1 hidden neuron and 13 outputs. The table also shows that the model produced RMSE, MAE and MAPE of 6.05, 1.83 and 0.607 respectively.

ANN Forecast for Naira - Dollar exchange rate

Table 14 below shows the forecast table for the Naira-Dollar exchange rate. It shows the actual, predicted, error values and the error percent. Figure 1 shows the forecast plot of the Naira-Dollar exchange rate using NNAR(25,1,13)[12] as the model for prediction.

Table 14: Forecast of NNAR(25,1,13)[12] for Naira-Dollar exchange rate

Actual		Predicted		Error		Error_Percent	
420.83	419.19	417.5477	414.5912	3.28	4.60	0.78	1.10
420.46	418.47	416.9205	414.0531	3.54	4.42	0.84	1.06
419.89	418.47	416.3156	413.5488	3.57	4.92	0.85	1.18
419.72	418.07	415.7226	420.1643	4.00	2.09	0.95	0.50
419.37	417.48	415.1442	419.5007	4.23	2.02	1.01	0.48

ANN Forecast for Naira - Euro exchange rate

Table 15 below shows the forecast table for the Naira-Euro exchange rate. It shows the actual, predicted, error values and the error percent. Figure 1 shows the forecast plot of the Naira-Euro exchange rate using NNAR(36,1,18)[[12] as the model for prediction.

Table 15: Forecast of NNAR(36,1,18)[12] for Naira-Euro exchange rate

Actual		Predicted		Error		Error_Percent	
426.6185	421.6330	430.3621	432.9157	3.74	11.28	0.88	2.68
426.4887	425.3947	432.0818	433.3009	5.59	7.91	1.31	1.86
424.3469	423.3998	432.7086	433.5835	8.36	10.18	1.97	2.41
421.3248	423.9513	432.8080	425.7068	11.48	1.76	2.73	0.41
422.1994	423.7740	433.0906	426.6807	10.89	2.91	2.58	0.69

ANN Forecast for Naira - Pounds exchange rate

Table 16 below shows the forecast table for the Naira-Pounds exchange rate. It shows the actual, predicted, error values and the error percent. Figure 1 shows the forecast plot of the Naira-Pounds exchange rate using NNAR(25,1,13)[12] as the model for prediction.

Table 16: Forecast of NNAR(25,1,13)[12] for Naira-Pounds exchange rate

Actual		Predicted		Error		Error_Percent	
505.1122	504.2141	511.7551	517.3859	6.64	13.17	1.32	2.61
508.4906	501.7310	512.7595	518.1525	4.27	16.42	0.84	3.27
509.6810	498.6606	514.2150	518.4091	4.53	19.75	0.89	3.96
509.5769	501.5259	515.7916	508.9469	6.21	7.42	1.22	1.48
505.1412	497.4449	516.4867	509.7443	11.35	12.3	2.25	2.47

ARIMA-Neural Network Result

This section discusses the result obtained using the ARIMA-Artificial Neural Network (ANN) model for the Naira-Dollar, Naira -Euro and Naira - Pounds exchange rates. Tables 17, 19 and 21 show the ARIMA-ANN output for the three-time series data.

ARIMA-ANN results for Naira - Dollar exchange rate

Table 17: ARIMA-ANN results for Naira - Dollar exchange rate

ARIMA coefficients	Value
ma1	-0.2337267

ANN Summary
Average of 20 networks, each of which is a 1-1-1 network with 4 weights options were - linear output units

RMSE	MAE	MAPE
4.365134	0.4147789	0.1731256

Table 17 above shows that ARIMA-ANN model Naira-Dollar data as ARIMA-Neural Network Autoregressive model, ARIMA(0,0,1)NNAR(1,1,1) with an average of 20 networks each of which is 1 input, 1 hidden neuron and 1 output. The table also shows that the model produced RMSE, MAE and MAPE of 4.365134, 0.4147789 and 0.1731256 respectively.

Forecast results for Naira - Dollar exchange rate using ARIMA-ANN

Table 18 below shows the forecast table for the Naira-Dollar exchange rate using ARIMA(0,0,1)NNAR(1,1,1) model. It shows the actual, predicted, error values and the error percent.

Table 18: ARIMA-ANN Forecast results for Naira - Dollar exchange rate

Actual		Predicted		Error		Error Percent	
429.38	427.76	449.760	449.7616	20.38	22.00	4.75	5.14
429.11	427.43	449.7616	449.7616	20.65	22.33	4.81	5.22
428.81	426.61	449.7616	449.7616	20.95	23.15	4.89	5.43
428.51	490.26	449.7616	449.7616	21.25	40.50	4.96	8.26
428.10	450.55	449.7616	449.7616	21.66	0.79	5.06	0.17

ARIMA-ANN results for Naira - Euro exchange rate

Table 19: ARIMA-ANN results for Naira -Euro exchange rate

ARIMA coefficients	Value
ma1	-0.2589309

ANN Summary
Average of 20 networks, each of which is a 1-1-1 network with 4 weights options were - linear output units

RMSE	MAE	MAPE
5.094977	1.562855	0.8418087

Table 19 above shows that ARIMA-ANN model Naira-Euro data as ARIMA-Neural Network Autoregressive model, ARIMA(0,0,1)NNAR(1,1,1) with an average of 20 networks each of which is 1 input, 1 hidden neuron and 1 output. The table also shows that the model produced RMSE, MAE and MAPE of 5.094977, 1.562855 and 0.8418087 respectively.

Forecast results for Naira - Euro exchange rate using ARIMA-ANN

Table 20 below shows the forecast table for the Naira-Euro exchange rate using ARIMA(0,0,1)NNAR(1,1,1) model. It shows the actual, predicted, error values and the error percent.

Table 20: ARIMA-ANN Forecast results for Naira - Euro exchange rate

Actual		Predicted		Error		Error Percent	
426.6185	421.6330	461.0184	462.1220	34.4	40.49	8.06	9.60
426.4887	425.3947	461.7440	462.1256	35.26	36.73	8.27	8.63
424.3469	423.3998	461.9936	462.1268	37.65	38.73	8.87	9.15
421.3248	423.9513	462.0811	462.1273	40.76	38.18	9.67	9.00
422.1994	423.7740	462.1115	462.1274	39.91	38.35	9.45	9.05

ARIMA-ANN results for Naira - Pounds exchange rate

Table 21: ARIMA-ANN results for Naira -Pounds exchange rate

ARIMA coefficients	Value
ma1	0.2303085

ANN Summary
Average of 20 networks, each of which is a 6-4-1 network with 33 weights options were - linear output units

RMSE	MAE	MAPE
5.964977	1.066428	0.6078308

Table 21 above shows that ARIMA-ANN model Naira-Pounds data as ARIMA-Neural Network Autoregressive model, ARIMA(0,0,1)NNAR(6,4,1) with an average of 20 networks each of which is 6 inputs, 4 hidden neurons and 1 output. The table also shows that the model produced RMSE, MAE and MAPE of 5.964977, 1.066428 and 0.6078308 respectively.

ARIMA-ANN Forecast results for Naira - Pounds exchange rate

Table 22 below shows the forecast table for the Naira-Pounds exchange rate using ARIMA(0,0,1)NNAR(6,4,1) model. It shows the actual, predicted, error values and the error percent.

Table 22: ARIMA-ANN Forecast results for Naira - Pounds exchange rate

Actual		Predicted		Error		Error Percent	
505.1122	504.2141	515.6692	515.6597	10.56	11.45	2.09	2.27
508.4906	501.7310	515.2857	514.5619	6.80	12.83	1.34	2.56
509.6810	498.6606	514.0773	514.4281	4.40	15.77	0.86	3.16
509.5769	501.5259	514.0331	514.4282	4.46	12.90	0.87	2.57
505.1412	497.4449	513.3008	514.3880	8.16	16.94	1.62	3.41

Model comparison among the three models

In this section, we examined the performance comparison of the three models used to model Naira - Dollar, Naira – Euro, and Naira - Pounds exchange rates. Tables 23, 24 and 25 show the model comparison for Naira - Dollar, Naira – Euro, and Naira - Pounds respectively.

Table 23: A model comparison using Naira - Dollar exchange rate

Approach	MAE	RMSE	MAPE
ANN	0.57	4.52	0.26
ARIMA	0.42	4.92	0.18
ARIMA-ANN	0.41	4.34	0.17

Table 24: A model comparison using Naira - Euro exchange rate

Approach	MAE	RMSE	MAPE
ANN	1.59	5.56	0.85
ARIMA	1.62	6.24	0.87
ARIMA-ANN	1.56	5.09	0.84

Table 25: A model comparison using Naira - Pounds exchange rate

Approach	MAE	RMSE	MAPE
ANN	1.83	6.05	0.61
ARIMA	1.96	6.73	0.65
ARIMA-ANN	1.07	5.96	0.61

CONCLUSION

Looking at the Dollar exchange rate time plot in chapter four above, it was discovered that the exchange rates were not stationary and kept on increasing over time. Between 2001 – 2015 there was an increase of 85.15 which is about 43% increase within a 14 years time frame while the from February 2015 – April 2023 there was an increase of 263.03 which accounted for up to 53.1% increase within a 7-year time- frame. The plot also showed that

the exchange rates were also not stationary for Euros, it increased over time. From the year 2001 – February 2015 there was an surge of 122.0672 which is about 55% increase within a 14-year time frame while from February 2015 – April 2023 there an increase of 281.756 which accounted for up to 56% increase within a 7-year period. Also, the plots showed nonstationary for Pounds as it indicated an upward movement. The difference between the exchange rate values from the year 2001 – February 2015 was 144.1023 which is about a 47.1% increase within a 14.3-year time-frame while from February 2015 – April 2023 there was a difference of 266.4921 which accounted for up to 47% increase within a 7-year time-frame. The unit root test revealed that Naira-Euro, and Naira-pounds were stationary at order (1) except Naira-Dollar.

Modelling Naira-Dollar, the predictive performance using the three models revealed that ARIMA-ANN model, had the lowest the MAE (0.41), RMSE (4.34), and MAPE (0.17) compared to ARIMA and ANN. For Naira-Euro, ARIMA-ANN model outperformed ARIMA and ANN models, with MAE, RMSE, and MAPE of 1.56, 5.09, and 0.84 respectively. Comparing the predictive performance for Naira-Pounds using ARIMA, ANN and ARIMA-ANN models, the results revealed that ARIMA-ANN competitively outperformed ANN with MAE, RMSE, and MAPE are 1.07, 5.96, and 0.61 respectively. It is concluded based on this research that ARIMA-ANN is a better predictor of future Nigerian-Exchange rates than the ARIMA of different orders or the ANN. Further research could be done using different models.

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