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Modeling and Forecasting Naira / USD Exchange Rate In Nigeria: a Box – Jenkins ARIMA approach

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Abstract

In the financial as well as managerial decision making process, forecasting is a crucial element (Majhi *et al*, 2009). Most research have been made on forecasting of financial and economic variables through the help of researchers in the last decades using series of fundamental and technical approaches yielding different results (Musa *et al*, 2014). The theory of forecasting exchange rate has been in existence for many centuries where different models yield different forecasting results either in the sample or out of sample (Onasanya & Adeniji, 2013). A country's exchange rate is one of the most closely monitored indicators, as fluctuations in exchange rates can have far reaching economic consequences (Ribeiro, 2016). The recent financial turmoil all over the world demonstrates the urgency of perfect information of the exchange rates (Shim, 2000). Understanding the forecasting of exchange rate behaviour is important to monetary policy (Simwaka, 2007). One of the important variables that have considerable influence on other socio – economic variables in Nigeria is the Nigerian naira / dollar exchange rate (Ismail, 2009). Owing to the critical role played by exchange rate dynamics in international trade and overall economic performance of all countries in general, the need for a good forecasting tool cannot be ruled out. In this study, we model and forecast the Naira / USD exchange rates over the period 1960 – 2017. Our diagnostic tests such as the ADF test indicate that EXC time series data is I (1). Based on the minimum AIC value, the study presents the ARIMA (1, 1, 1) model as the optimal model. The ADF test further indicates that the residuals of the ARIMA (1, 1, 1) model are stationary and thus bear the characteristics of a white noise process. It is also important to note that our forecast evaluation statistics, namely ME, RMSE, MAE, MPE, MAPE and Theil's U absolutely show that our forecast accuracy is quite good. Our forecast actually indicates that the Naira will continue to depreciate. The main policy implication from this study is that the Central Bank of Nigeria (CBN), should devalue the Naira in order to not only restore exchange rate stability but also encourage local manufacturing and promote foreign capital inflows.

Key Words: ARIMA, Exchange rate, Forecasting, Nigeria

JEL Codes: C53, E37, E47, F31, F37, O24

I. Introduction & Background

Foreign exchange is a major issue in the discussion of world economy (Etuk *et al*, 2016). Modern macroeconomics relies hugely on foreign exchange rate dynamics (Medel *et al*, 2015).

Exchange rate modeling and forecasting is important for policy making (Hina & Qayyum, 2015). Forecasting exchange rate is crucial as it has significant impact on the macroeconomic fundamentals such as oil price, interest rate, wage, unemployment and the level of economic growth (Ramzan *et al*, 2012). Foreign exchange markets are among the most important and the largest financial markets in the world with trading taking place twenty – four hours a day around the globe and trillions of dollars of different currencies transacted each day (Khashei & Bijari, 2011).

The exchange rate¹ is a relative price that measures the worth of a domestic currency in terms of another currency (Nwankwo, 2014). Exchange rate is seen as the relative value of the domestic currency in terms of foreign exchange (Mussa, 1984; Ahmed, 2001). Exchange rate is the currency rate of one country expressed in terms of the currency of another country (Khan & Jain, 2009). The foreign exchange rate is the price of one currency in terms of another currency (Samuelson & Nordhaus, 1998; Usman & Adejare, 2013; CBN, 2016). Foreign exchange connotes the process of trading domestic currencies for foreign ones at varying exchange rates (Oleka *et al*, 2014). Exchange rate is the rate at which two national currencies exchange for each other (Lipsey & Crystal, 1995). Exchange rate is often expressed as the amount of domestic currency needed to buy one unit of foreign currency (Dornbusch *et al*, 2005).

The exchange rate serves as an important price factor in the economy (Klein & Shambaugh, 2012). It is a measurement of the price of country's domestic currency relative to a foreign basket of goods or prices (Gourinchas, 1999). It determines the relative prices of domestic and foreign goods, as well as the strength of external sector participation in the international trade (Mohammed & Abdulmuahymin, 2016). In fact, foreign exchange is the component that is widely used on daily basis for settlement of international transactions and international bills (Oleka *et al*, 2014). The exchange rate of a Naira per US dollar is the amount of Naira required to obtain one unit of US dollar (Jhingan, 2005; Campbell, 2010; Omojolaibi & Gibadebo, 2014). For a country like Nigeria, the price of foreign exchange plays a highly significant role in the ability of the economy to attain optimal productive capacity (Ogiogio, 1996).

Foreign exchange rates are among the most important prices in international monetary markets (Rahim *et al*, 2018). They affect the economic activity, foreign trade and the distribution of wealth among countries (Tan, 2009). The stability of the exchange rate is today a formidable bedrock of all economic activities (Taiwo & Adesola, 2013). 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 (Adeoye & Saibu, 2014). Therefore, central banks should pay special attention to exchange rates and the value of their domestic currency (Dilmaghani & Tehranchian, 2015). The main objectives of exchange rate policy in Nigeria are to preserve the value of the Naira and to maintain enough foreign exchange reserves (Oleka & Okolie, 2016). In Nigeria, the central bank maintains the stability of the Naira exchange rate in order to achieve its objective of maintaining price stability because domestic prices (inflation and interest rates) are very responsive to exchange rate fluctuations (CBN, 2016).

¹ Various definitions of the term “exchange rate” exist. It is clear that there is no apparent consensus on the definition of the term “exchange rate”.

In the modern world, exchange rates of the most successful countries tend to be floating (Sullivan, 2001). Forecasting of the exchange rate is the foremost endeavor of the practitioners and researchers in the spree of international finance, particularly in the case of the exchange rate which is floating (Hu *et al.*, 1999). Economic growth is one of the fundamental macroeconomic policy objectives which countries all over the world continue to strive to achieve and Nigeria is not an exception (Nyoni & Bonga, 2018). 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, 2009). One of the surest way to achieve the afore – stated goal is to pursue vigorously rapid and sustainable economic growth and development via well managed exchange rate policy (Obi *et al.*, 2016). Sustainable economic growth mainly depends on a nation's ability to invest and make efficient and productive use of the resources at its disposal (Nyoni & Bonga, 2017f). The status of a country's economic well being is reflected by the real exchange rate (Arize & Osang, 2000). Poorly managed exchange rates can be disastrous for economic growth (Rodrick, 2008).

When the domestic income of a country increases, then the country's currency is likely to depreciate. However, an increase in foreign income would likely lead to appreciation of the currency. Also when a nation has a crave for domestic goods and services, it will likely to appreciate of the currency, while a crave for foreign goods and services will likely lead to depreciation of its currency (Arize & Osang, 2000). If the domestic inflation rate exceeds the global average rate, it will likely lead to its currency's depreciation. However, if the domestic inflation rate is less than the global average then the chances are that its currency will appreciate (Giovanni, 1988; Islam & Sardar, 2007).

Fluctuations in a nation's currency or exchange rate exert changes in domestic production costs (Ngandu, 2008) and also affect the labor market based on channels of appreciation and depreciation of currencies (Nucci & Pozzolo, 2010). A depreciation in the exchange rate increases or promotes the growth of local jobs in the manufacturing and non – manufacturing sectors (Yokoyama *et al.*, 2015). Volatile exchange rates may also increase unemployment through lowering investment in physical capital (Belke & Gros, 2001). Investment may be reduced because higher volatility usually entails increased uncertainty (Nyahokwe & Ncwadi, 2013). Therefore, maintaining exchange rate stability implies controlling a country's level of unemployment (Chimnani *et al.*, 2012) and promoting investment. When the monetary authority allows the exchange rate to be fixed, other macroeconomic variables are volatile. However, when exchange rate is allowed to float, it is known that the exchange rate becomes highly volatile in comparison with other macroeconomic variables (Baxter & Stockman, 1989; Flood & Rose, 1999; MacDonald, 2008).

Many authors, for example; Domac & Shabsign (1999), Takaendesa (2006), Miles (2006), Sibanda *et al.* (2013), Korkmaz (2013), Ahmad *et al.* (2013), Uddin *et al.* (2014) and Chipeta *et al.* (2017) agree on the important role played by exchange rates on economic growth. In Nigeria, specifically; authors such as Odusola & Akinlo (2001), Usman (2007), Bakare (2011), Azeez *et al.* (2012), Akpan & Atan (2012), Obansa *et al.* (2013), Rasaq (2013), Fapetu & Oloyede (2014), Eze & Okpala (2014), Anigbogu *et al.* (2014), Oleka *et al.* (2014), Adelowokan *et al.* (2015), Ali *et al.* (2015), Obi *et al.* (2016), Isola *et al.* (2016) and Okonkwo *et al.* (2017) confirm that indeed there is need for proper exchange rate management if economic growth is to be sustained. To move Nigeria on a sustainable economic growth trajectory, policy makers should focus on those

factors that determine economic growth in Nigeria (Nyoni & Bonga, 2018) and foreign exchange rate is one of those factors.

The evolution of the Nigerian foreign exchange market was influenced by such factors as the changing patterns of international trade, institutional changes in the economy and structural shifts in production (CBN, 2011). The oil boom experienced in nineteen seventies led to enhanced foreign exchange receipts; hence the need to develop a local foreign exchange market became paramount (Mojekwu *et al*, 2011). Nigeria, like many other low income open economies, has adopted two main exchange regimes. Direct administrative control exchange rate was used until 1986, when the country changed over to market regulated regime. Nigeria has, and is still experimenting with various market arrangements. As an integral part of Structural Adjustment Programme introduced in 1986, Nigeria adopted the flexible exchange rate through second tier foreign exchange market (Umar & Soliu, 2009). Since then, several variants (Auction System, Dutch Auction System, Wholesale Dutch Auction System and Rental Dutch Auction System) have been operated in determining the exchange rate of naira to US dollar (Mojekwu *et al*, 2011).

Over two decades ago, the Central Bank of Nigeria (CBN) have been intervening in the foreign exchange market (FEM) to support and stabilize the value of the Naira, although the supportive efforts remain temporarily and short – lived (Sanusi, 2004; Adebisi, 2007). For instance, Nigeria had been one of the most active countries in the FEM between 1993 and 1995 (Adebisi, 2007; Omojalaibi & Gibadebo, 2014). In the month of December 2014 alone, the CBN spent about \$2.3 billion to defend the Naira from losing its value (Nweze, 2015). Also, in another effort to strengthen and stabilize the value of the Naira, the CBN conducted another intervention operation in the first quarter of 2015. The process worth the CBN \$4.7 billion (Komolafe, 2015). The main objectives of the central bank interventions in the FEM, especially in countries with floating exchange rates are to prevent exchange rate misalignment, counter disorderly FEM, manage foreign reserve and “lean against the wind” (Basu & Varoudakis, 2013). In most emerging market – oriented economies like Nigeria, preserving a realistic value for the domestic currency is of paramount importance considering the structure of the economy and the desire to balance domestic production and consumption, create and improve the success of foreign exchange earnings and attracts foreign capitals from multi – national corporations (Dayyabu *et al*, 2016).

Timely forecasting of the exchange rates is able to give important information to the decision makers as well as partakers in the area of the internal finance, buy and sell, and policy making (Alam, 2012). For the giant multinational business units, an accurate forecasting of the exchange rate is crucial since it improves their overall profitability (Huang *et al*, 2004). The importance of forecasting the exchange rates in practical aspect is that an accurate forecast can render valuable information to the investors, firms and central banks for use in allocation of assets, in hedging risk and in policy formulation (Tindaon, 2015). The significance of exchange rates forecasting stems from the reality that the findings of a given financial decision made today is conditional on the exchange rate which will be prevailed in the upcoming period. For this reason forecasting exchange rate is essential for various international financial transactions, namely speculation, hedging as well as capital budgeting (Moosa, 2008). In this study, I rely on the Box – Jenkins ARIMA approach to model and forecast the Naira / USD exchange rate in Nigeria over the period 1960 – 2017. The rest of the paper is structured in chronological order as follows:

literature review, materials & methods, diagnostic tests & model evaluation, results: presentation, interpretation & discussion and conclusion & policy implications.

II. Literature Review

Theoretical Literature Review

While there are a number of theories of exchange rate determination, in this study we will briefly discuss only five most popular ones and these are namely: the Mint Parity Theory, the Quantity Theory of Money, the Tightening Monetary Policy Theory, the Purchasing Power Parity Theory and the Balance of Payment Theory.

The Mint Parity Theory (MPT)

The MPT is associated with the working of the international gold standard (Brown, 2008). Under this system, considering the period 1955 – 1970, when the exchange rates were pegged into gold under the Bretton Woods System, the currency in use was made of gold or was convertible into gold at a fixed rate. In this case, the value of the currency unit was defined in terms of certain weight of gold and the central bank of the country concerned was always ready to buy and sell gold at the specified price. The rate at which such currency could be converted into gold is called the mint price of gold (Oleka *et al*, 2014).

The Quantity Theory of Money (QTM)

Hinged on the monetarist school of thought, the QTM is one of the simplest models for determining long run equilibrium exchange rate. In their diagnosis of the QTM, as noted by Nyoni (2018k); monetarists finalize that any change in the quantity of money affects only the price level, leaving the real sector of the economy totally unaffected. In the context of international economics, or simply the so – called international version of the QTM, the increase in money supply also manifests through a proportionate increase in the exchange rate. As noted by Oleka *et al* (2014), the exchange rate can be viewed as determined by the demand for money, which is in turn influenced positively by the rate of growth of the real economy and negatively by the inflation rate. Therefore, we cannot rule out the fact that the growth of the real economy impacts significantly on a nation's currency position. According to Ude (1999), a defect of the international QTM is that it cannot account for fluctuations in the real exchange rate as opposed to simply the nominal exchange rate.

The Tightening Monetary Policy Theory (TMPT)

The TMPT argues that an increase in the real interest rate due to a tightening monetary policy causes the currency to appreciate more in the short run than it will in the long run. Given that the rate of return on domestic assets may be higher because of the monetary tightening; international investors may be willing to hold foreign assets, especially if they anticipate the value of the domestic currency to fall in the future. Oleka *et al* (2014) argues that an advantage of the TMPT over the international QTM is that it can account for fluctuations in the real exchange rate.

Purchasing Power Parity Theory (PPPT)

This is an economic theory used in determining the relative value of currencies, estimating the amount of adjustment needed in the exchange rate between countries, in order for the exchange rate to be equivalent to each currency's purchasing power (CBN, 2011). This theory recognizes inflation levels and trends as important determinants of exchange rate of a currency both in emerging and developed economies (Scott, 2008). PPPT avers that a currency will lose value if there is a high level of inflation in the country or if inflation levels are perceived to be going up. This is attributed to the fact that inflation erodes the purchasing power, thus demand for that specific currency. According to Oleka *et al* (2014), a currency may sometimes strengthen when inflation rises due to expectations that the central bank of the country concerned will raise short – term interest rates to combat rising inflation. PPPT, as noted by Obadan (2006); concludes that the equilibrium exchange rate between two invertible paper currencies is determined by the equality of their purchasing power (that is, their relative prices).

Balance of Payment Theory (BOPT)

This theory stipulates that under free exchange rates, the exchange rate of the currency of a country depends upon its balance of payment position (Oleka *et al*, 2004). A favourable balance of payment raises the exchange rate, while an unfavorable balance of payments reduces the exchange rate (Jhingan, 2004). Thus the theory implies that the exchange rate is determined by the equilibrium in the balance of payment (Oleka *et al*, 2014).

Empirical Literature Review

The table below shows a summary of the reviewed empirical studies done in Nigeria and elsewhere:

Table 1

Author	Year	Country	Study Period	Method	Key Findings
Mojekwu <i>et al</i>	2011	Nigeria	1974 – 2008	AR (1); ARIMA (1, 1, 1); MA (1); IMA (1, 1); SARIMA (0, 0, 0)(1, 1, 1) ₁₂ ; Simple, Double, Linear, Damped – trend Linear and Seasonal Exponential Smoothing; Winters Method.	Central Bank of Nigeria exchange is the most stable while Bureau de change and inter – bank exchange rates to US dollar fluctuate over the period under investigation.
Etuk	2012	Nigeria	January 2004 – December 2011	SARIMA models	SARIMA (0, 1, 1)x(1, 1, 1) ₁₂ model was found adequate.
Etuk	2013	Nigeria	January 2004 – December 2011	SARIMA models	The (0, 1, 1)x(1, 1, 1) ₁₂ SARIMA is the best fit model.
Osarumwense & Waziri	2013	Nigeria	January 1990 – December 2010	ARIMA models	ARIMA (0, 1, 1) is appropriate.
Onasanya & Adeniji	2013	Nigeria	January 1994 – December 2011	ARIMA models	The best fit model is ARIMA (1, 2, 1) model.
Nwankwo	2014	Nigeria	1982 – 2011	ARIMA models	The best fit model is ARIMA (1, 1, 0).
Etuk	2014	Nigeria	8 December 2012 – 30 March 2013	SARIMA models	SARIMA (0, 1, 1)x(0, 1, 1) ₇ model is the best fit model.
Musa <i>et al</i>	2014	Nigeria	June 2000 – July 2011	GARCH models	GJR – GARCH & TGARCH models show the existence of statistically significant asymmetry effect.

Mbaga & Olubusoye	2014	Nigeria	18 April 2007 – 3 September 2012	FROEXNN and ARIMA models	FOREXNN models are superior to ARIMA models.
Olatunji & Bello	2015	Nigeria	January 2000 – December 2012	ARMA & ARIMA models	ARIMA (1, 1, 2) and ARMA (1, 1) models are optimal.
Mohammed & Abdulmuahymin	2016	Nigeria	1972 – 2014	ARIMA models	ARIMA (0, 2, 1) is the best fit model.
Chamalwa <i>et al</i>	2016	Nigeria	1981 – 2012	ARIMA models	ARIMA (2, 1, 2) is the best fit model.
Etuk <i>et al</i>	2016	Nigeria	22 September 2015 – 16 March 2016	SARIMA models	SARIMA (1, 1, 0)x(1, 1, 0) ₇ model is the best fit model.
Ajao <i>et al</i>	2017	Nigeria	1972 – 2017	ARIMA models	ARIMA (0, 1, 0) is the optimal model.
Khashif <i>et al</i>	2008	Pakistan	1 July 2001 – 30 June 2007	ARIMA, GARCH and State Space models	The State Space model provides the best performance among all the models.
Kadilar <i>et al</i>	2009	Turkey	3 January 2005 – 28 January 2008	ANN, ARIMA and ARCH models	ANN is more accurate than ARIMA and ARCH models
Botha & Pretorius	2009	South Africa	1990 quarter 1 – 2006 quarter 4	Various univariate and multivariate models	The multivariate models outperformed the univariate models (except for random walk model) in the short – run forecasts, one step ahead, while the multivariate models, performed better in the longer – run forecasts.
Fat & Dezsi	2011	Romania	3 January 2011 – 22 April 2011	Exponential smoothing and ARIMA models	Romanian Leu is appreciating against other currencies.
Appiah & Adetunde	2011	Ghana	January 1994 – December 2010	ARIMA models	ARIMA (1, 1, 1) model is the most appropriate model.
Ramzan <i>et al</i>	2012	Pakistan	July 1981 – May 2010	ARMA, ARCH and GARCH models	GARCH (1, 2) is found to be best in removing persistence in volatility while EGARCH (1, 2) successfully overcome the leverage effect in the exchange rate returns under study.
Alam	2012	Bangladesh	3 July 2006 – 30 April 2010	AR and ARMA models	Both the ARMA and AR models jointly outperform other models, in terms of in – sample data set.
Nanayakkara <i>et al</i>	2014	Sri Lanka	1 January 2007 – 18 November 2011	Time series and Neural Network approaches	ANN performs better than GARCH models.
Pedram & Ebrahimi	2014	Iran	1 November 2010 – 30 June 2013	Neural Networks	Neural Network is far much better than ARIMA.
Babu & Reddy	2015	India	January 2010 – April 2015	ARIMA, Neural Networks and Fuzzy Neurons	In predicting exchange rate market in India, ARIMA model does better than complex non – linear models such as Neural Networks and Fuzzy Neurons.
Chi <i>et al</i>	2015	China	25 July 2005 – 25 March 2014	ARFIMA, SVM and BPNN	The prediction performance of the nonlinear combination model is better than the single models.
Etuk & Natamba	2015	Uganda	July 1990 – November 2014	SARIMA models	SARIMA (0, 1, 1)x(0, 1, 1) ₁₂ is the optimal model.
Ayekple <i>et al</i>	2015	Ghana	January 2004 – February 2015	ARIMA models	The exchange rate of the Ghana Cedi to the American Dollar will increase continuously for the years 2016, 2017 and 2018.
Biswajit	2015	India	August 1994 – April 2014	ARIMA, ARCH and GARCH models	The random walk model outperforms ARIMA and ARCH/GARCH models for

					forecasting exchange rates of Indian Rupee under the in – sample and the out – of – sample period.
Ngan	2016	Vietnam	January 2013 – December 2015	ARIMA models	ARIMA model is absolutely suitable for forecasting.
Mustafa <i>et al</i>	2017	Malaysia	1 November 2010 – 30 August 2016	Hybrid ARIMA – EGARCH models; hybrid ARIMA – GARCH models.	ARIMA – EGARCH model fits the data better and also performs better in terms of capturing volatility clustering and leverage effects in the series.
Varenius	2017	Sweden	January 2000 – December 2015	ARIMA and VAR models	VAR (1) generates the most accurate forecasts during a 1 – month horizon, while the ARIMA (1, 1, 0) is the more suitable model during a 3 – month horizon. Both models outperform a random walk.

III. Materials & Methods

Empirical Modeling & Estimation

The Moving Average (MA) Process

Given that μ_t is a purely random process with mean zero and variance σ^2 and where ℓ is the lag operator and EXC_t is the Naira / USD exchange at time t ; a process defined by equation [1] below is called an MA (z) process.

$$EXC_t = \sum_{i=1}^z \beta_i \ell^i \mu_t + \mu_t \dots \dots \dots [1]$$

Or

$$\beta(\ell) = k(\ell) \dots \dots \dots [2]$$

where:

$$k(\ell) = 1 + \beta_1 \ell + \dots + \beta_z \ell^z \dots \dots \dots [3]$$

The Autoregressive (AR) Process

Equation [4] below is known as an AR (r) process.

$$EXC_t = \sum_{i=1}^r \alpha_i \ell^i EXC_t + \mu_t \dots \dots \dots [4]$$

Or

$$\alpha(\ell) EXC_t = \mu_t \dots \dots \dots [5]$$

where

$$\alpha(\ell) = \lambda(\ell) \dots \dots \dots [6]$$

where

$$\lambda(\ell) = 1 - \alpha_1 \ell - \alpha_2 \ell^2 \dots \dots \alpha_r \ell^r \dots \dots \dots [7]$$

The Autoregressive Moving Average (ARMA²) Process

Box & Jenkins (1976) combined the autoregressive and moving average terms in order to come up with an ARMA model (Nyoni, 2018i). Combining equations [1] and [4], an ARMA (r, z) process is specified as follows:

$$\lambda(\ell)EXC_t = k(\ell)\mu_t \dots\dots\dots [8]$$

where $\lambda(\ell)$ and $k(\ell)$ are polynomials of orders r and z respectively, simply defined as in equations [3] and [7].

The Autoregressive Integrated Moving Average (ARIMA³) Process

The ARIMA modeling approach proposed by Box & Jenkins (1976) is recognized as a benchmark technique in modeling and forecasting methods because of its structured modeling basis and acceptable forecasting performance (Goh & Teo, 2000). ARIMA models are a set of models that describe the process as a function of its own lags and white noise process (Box & Jenkins, 1974). Making prediction in time series using univariate approach is best done by employing the ARIMA models (Alnaa & Ahiakpor, 2011). A stochastic process EXC_t is called an ARIMA (r, d, z) process if it is I (d) and the d times differenced process has an ARMA representation. If the sequence, $\Delta^d EXC_t$ satisfies an ARMA (r, z) process; what it implies is that the sequence of EXC_t also satisfies the ARMA (r, d, z) process such that:

$$\Delta^d EXC_t = \sum_{i=1}^r \alpha_i \Delta^d \ell^i EXC_t + \sum_{i=1}^z \beta_i \ell^i \mu_t + \mu_t \dots\dots\dots [9]$$

Where Δ is the difference operator, vector $\alpha \in \mathbb{R}^r$ and $\beta \in \mathbb{R}^z$

Model Specification

The ARIMA (1, 1, 1) model, chosen based on table 8; is specified below:

$$(1-\ell)EXC_t = \alpha \ell EXC_t + (1-\beta_1 \ell)\mu_t + \mu_t \dots\dots\dots [10]$$

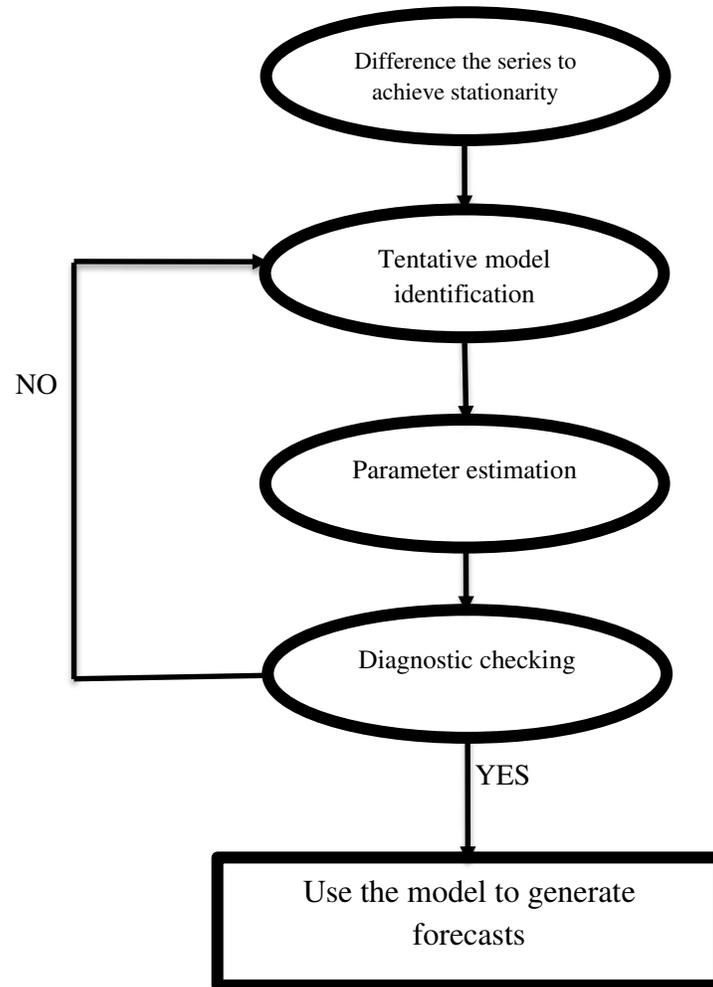
The Box – Jenkins Methodology

² The ARMA (r, z) can only be used for stationary time series data. However, in reality, many time series are non – stationary since they usually contain trends and or seasonal patterns. This implies that, from an application point of view; ARMA models are not appropriate for describing non – stationary time series (Nyoni, 2018i). The family of univariate time series models is not complete without a third element, orders of integration (Wang, 2009).

³ One of the most popular and frequently used stochastic time series is the Autoregressive Integrated Moving Average (ARIMA) model (Box & Jenkins, 1970; Hipel & McLeod, 1994; Cochrane, 1997; Zhang, 2003). The popularity of the ARIMA model is mainly due to its flexibility to represent several varieties of time series with simplicity as well as the associated Box – Jenkins methodology (Box & Jenkins, 1970; Hipel & McLeod, 1994; Zhang, 2003; Hamzacebi, 2008). The main advantage of ARIMA forecasting is that it requires data on the time series in question only. First, this feature is advantageous if one is forecasting a large number of time series. Second, this avoids a problem that occurs sometimes with multivariate models. Third, with multivariate models, timeliness of data can be a problem (Meyler *et al*, 1998). ARIMA models frequently outperform more sophisticated structural models in terms of short – run forecasting ability (Litterman, 1986; Stockton & Glassman, 1987). However, ARIMA models are essentially backward looking. As such, they are generally poor at predicting turning points, unless the turning point represents a return to a long – run equilibrium (Meyler *et al*, 1998).

The Box – Jenkins methodology is shown below:

Figure 1



The first step towards model selection is to difference the series in order to achieve stationarity. Once this process is over, the researcher will then examine the correlogram in order to decide on the appropriate orders of the AR and MA components. It is important to highlight the fact that this procedure (of choosing⁴ the AR and MA components) is biased towards the use of personal judgement because there are no clear – cut rules on how to decide on the appropriate AR and MA components. Therefore, experience plays a pivotal role in this regard. The next step is the estimation of the tentative model, after which diagnostic checking shall follow. Diagnostic checking is usually done by generating the set of residuals and testing whether they satisfy the characteristics of a white noise process. If not, then there would be need for model re – specification and repetition of the same process; this time from the second stage. The process may go on and on until an appropriate model is identified (Nyoni, 2018i).

⁴

In this study, we employ the Akaike Information Criterion (AIC).

Data Collection

An extensive time series data is required for univariate time series forecasting (Wabomba *et al*, 2016). More than 50 observations are recommended in order to build a reliable ARIMA model (Chatfield, 1996; Meyler *et al*, 1998). In line with Chatfield (1996), Meyler *et al* (1998) and Wabomba *et al* (2016) amongst others; this study is based on 57 observations of annual Naira / USD⁵ exchange rates (EXC). All the data used in this study was collected from the World Bank.

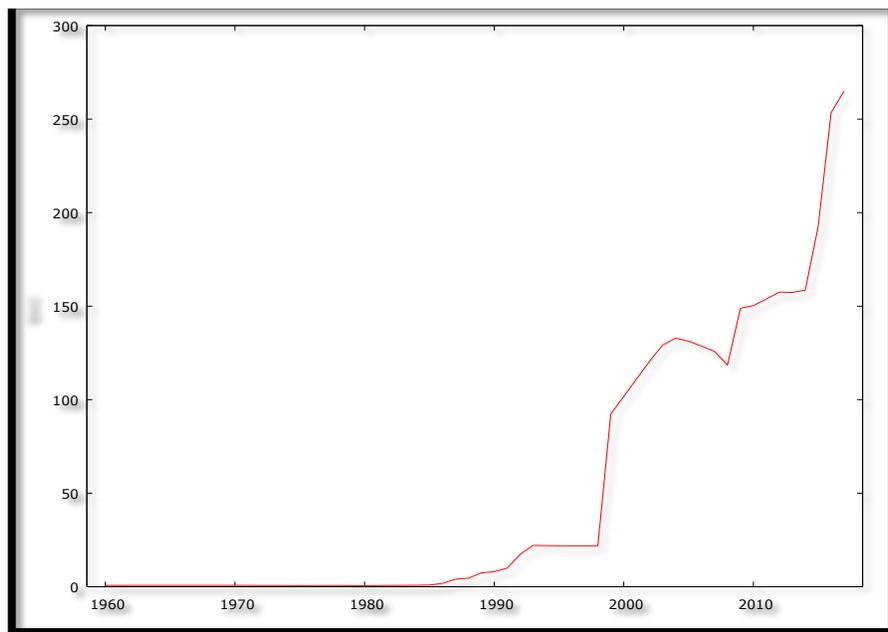
IV. Diagnostic Tests & Model Evaluation

Stationarity (Unit Root) Tests

Graphical Test

Stationarity of a series can be tested graphically, as already shown by Gujarati (2004).

Figure 2



The time plot above indicates that the time series data is not stationary simply because it shows an upward trend which implies that the mean of EXC is changing over time and thus there is no stability in the variance of the time series data.

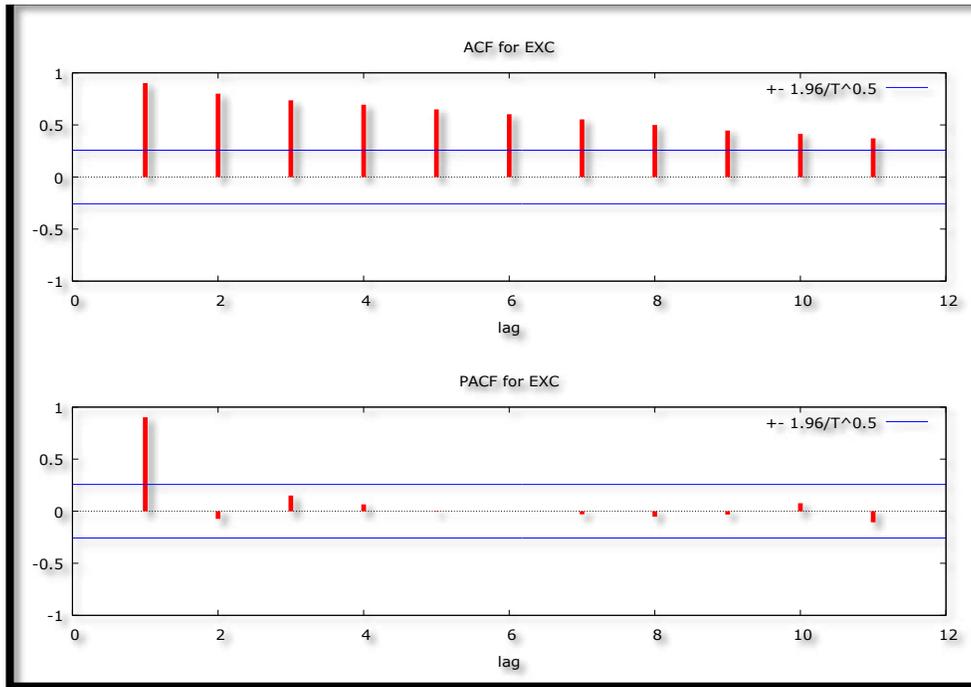
The Correlogram

The correlogram below, presented in graphical form; confirms the non – stationarity of the EXC time series data. The most striking feature of this correlogram is that the autocorrelation coefficients are quite high at various lags and this is typical for non – stationary time series data.

⁵

United States Dollars

Figure 3



ADF Test

The Augmented Dickey Fuller (ADF test) was used to check the stationarity of the EXC series. The general ADF test is done by running the following regression equation:

$$EXC_t = c_t \gamma EXC_{t-1} + \sum_{i=1}^{p-1} \Delta EXC_{t-i} + \mu_t \dots\dots\dots [11]$$

Where c_t is a deterministic function of the time index t and $\Delta EXC_j = EXC_j - EXC_{j-1}$ is the differenced series of EXC_t . The null hypothesis $H_0: \gamma = 1$ is tested against the alternative hypothesis $H_a: \gamma < 1$ using equation [11] above. If the null hypothesis is rejected, then the time series is stationary. The results of the ADF tests done in this study are shown below:

Levels: intercept

Table 2

Variable	ADF Statistic	Critical Values		Conclusion
EXC	2.531066	-3.550396	@1%	Not stationary
		-2.913549	@5%	Not stationary
		-2.594521	@10%	Not stationary

Levels: trend & intercept

Table 3

Variable	ADF Statistic	Critical Values		Conclusion
EXC	0.089628	-4.127338	@1%	Not stationary
		-3.490662	@5%	Not stationary

		-3.173943	@10%	Not stationary
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Levels: without intercept and trend & intercept

Table 4

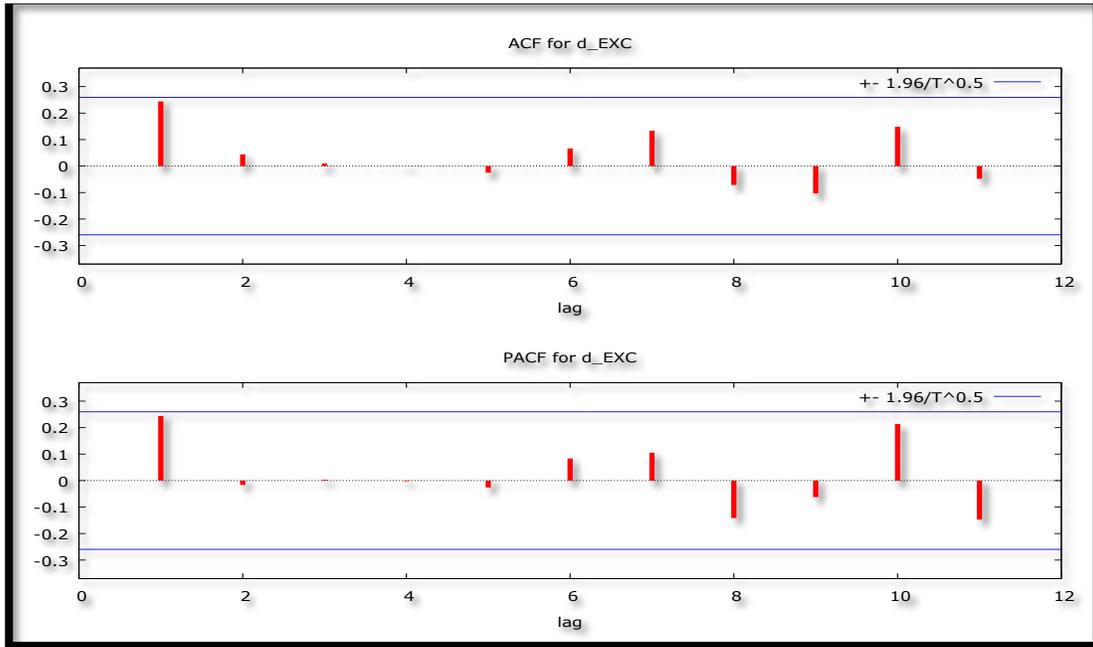
Variable	ADF Statistic	Critical Values		Conclusion
EXC	3.656847	-2.606163	@1%	Stationary
		-1.946654	@5%	Stationary
		-1.613122	@10%	Stationary

Tables 2 and 3 indicate that the EXC series is basically not stationary at levels. Although table 4⁶ indicates that the series is stationary without intercept and trend & intercept, we need to proceed to check for stationarity at first differences as shown in tables 5 – 7 below.

The Correlogram (at First Differences)

For a purely white noise process, the autocorrelations at various lags hover around zero (Gujarati, 2004). The autocorrelations below, especially those between lags 2 nd 12; generally hover around zero, pointing to the conclusion that D (EXC) is stationary. We also note that in the correlogram below, there are no spikes outside the bands; hence confirming that the series is now stationary.

Figure 4



1st difference: intercept

Table 5

⁶ We do not base our analysis much on table 4 since the EXC series exhibits a trend (up – wards sloping).

Variable	ADF Statistic	Critical Values		Conclusion
D(EXC)	-5.713333	-3.552666	@1%	Stationary
		-2.914517	@5%	Stationary
		-2.595033	@10%	Stationary

1st difference: trend & intercept

Table 6

Variable	ADF Statistic	Critical Values		Conclusion
D(EXC)	-6.422545	-4.130526	@1%	Stationary
		-3.492149	@5%	Stationary
		-3.174802	@10%	Stationary

1st difference: without intercept and trend & intercept

Table 7

Variable	ADF Statistic	Critical Values		Conclusion
D(EXC)	-5.253249	-2.606911	@1%	Stationary
		-1.946764	@5%	Stationary
		-1.613062	@10%	Stationary

Tables 5, 6 and 7 show that the EXC series became stationary after first differencing. This means that the EXC series is integrated of order one, that is I (1).

Evaluation of various ARIMA models

Table 8

Model	AIC
ARIMA (1, 1, 1)	462.8502
ARIMA (1, 1, 2)	463.2574
ARIMA (2, 1, 1)	463.3339
ARIMA (1, 1, 3)	465.2568
ARIMA (3, 1, 1)	465.2276

Table 8 above shows that the ARIMA (1, 1, 1) model has the lowest AIC value and is therefore chosen as the optimal model.

ADF test of the Residuals from the ARIMA (1, 1, 1) model

Levels: intercept

Table 9

Variable	ADF Statistic	Critical Values		Conclusion
μ_t	-6.849788	-3.555023	@1%	Stationary
		-2.915522	@5%	Stationary
		-2.595565	@10%	Stationary

Levels: trend & intercept

Table 10

Variable	ADF Statistic	Critical Values		Conclusion
μ_t	-6.793772	-4.133838	@1%	Stationary
		-3.493692	@5%	Stationary
		-3.175693	@10%	Stationary

Levels: without intercept and trend & intercept

Table 11

Variable	ADF Statistic	Critical Values		Conclusion
μ_t	-6.766794	-2.607686	@1%	Stationary
		-1.946878	@5%	Stationary
		-1.612999	@10%	Stationary

Tables 9, 10 and 11 show that the residuals of the ARIMA (1, 1, 1) model satisfy the characteristics of a white noise process. Therefore, the ARIMA (1, 1, 1) model is adequate and can be used for forecasting and control.

V. Results: Presentation, Interpretation & Discussion

Descriptive Statistics

Table 12

Description	Statistic
Mean	52.275
Median	5.95
Minimum	0.55
Maximum	265
Standard deviation	72.958
Skewness	1.1791
Excess Kurtosis	0.27064

As shown in the table above, the mean is positive. The difference between the minimum and maximum is 264.45 and is quite large. However, it does not indicate the existence of outliers but that the EXC series is ever increasing, thus a depreciating exchange rate ever since. The skewness coefficient is positive as shown, implying that our series has a long right tail and is non – symmetric. Nyoni & Bonga (2017h) reiterate that the rule of thumb for kurtosis is that it should be around 3 for normally distributed variables and yet in this study kurtosis has been found to be 0.27064 indicating that the EXC series is not normally distributed.

ARIMA (1, 1, 1) model results

Table 13

Variable	Coefficient	Standard Error	z	p – value
AR (1)	0.978826	0.108807	8.996	0.0000
MA (1)	-0.872319	0.180878	-4.823	0.0000

The model can also be represented as follows:

$$D(EXC_t) = 0.978826D(EXC_{t-1}) - 0.893065\mu_{t-1} \dots\dots\dots [12]$$

p – value (0.0000) (0.0000)

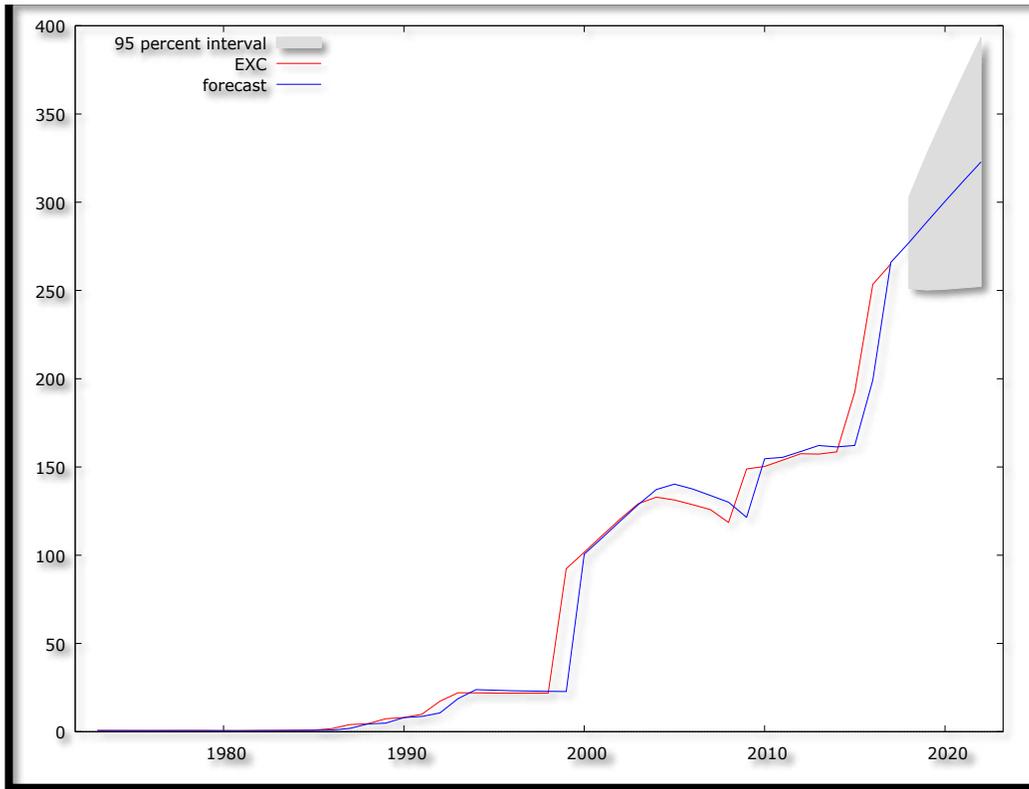
Std. Error (0.108807) (0.180878)

Results Interpretation

Both coefficients of the AR (1) and MA (1) components are statistically significant at 1% level of significance. The coefficient of the AR (1) component is positive while the coefficient of the MA (1) component is negative as conventionally expected. The AR (1) coefficient is 0.978826 and is thus close to one, implying that the series returns to its mean slowly. The MA (1) coefficient is -0.872319 and represents the fraction of last period’s shock⁷ that is still felt in the current period. While these results are not similar to any previous study done in Nigeria, they are indeed consistent with the findings of Appiah & Adetunde (2011) who found that an ARIMA (1, 1, 1) model was the optimal exchange rate forecasting model for Ghana.

Forecast graph

Figure 5

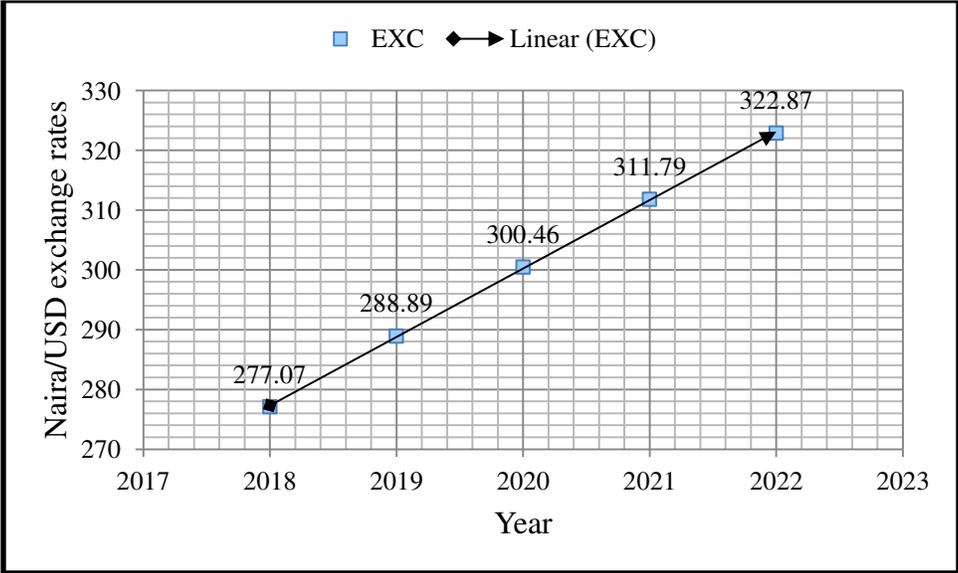


⁷ In the context of Nigeria, such shocks could be things like unpredictable political events (e.g unconstitutional removal of a political administration), droughts, Boko Haram insurgency etc.

The graph above indicates that Naira / USD exchange rate is likely to progress at an increasing rate. The implication is that the Naira is likely to continue depreciating against the USD as shown below in figure 6.

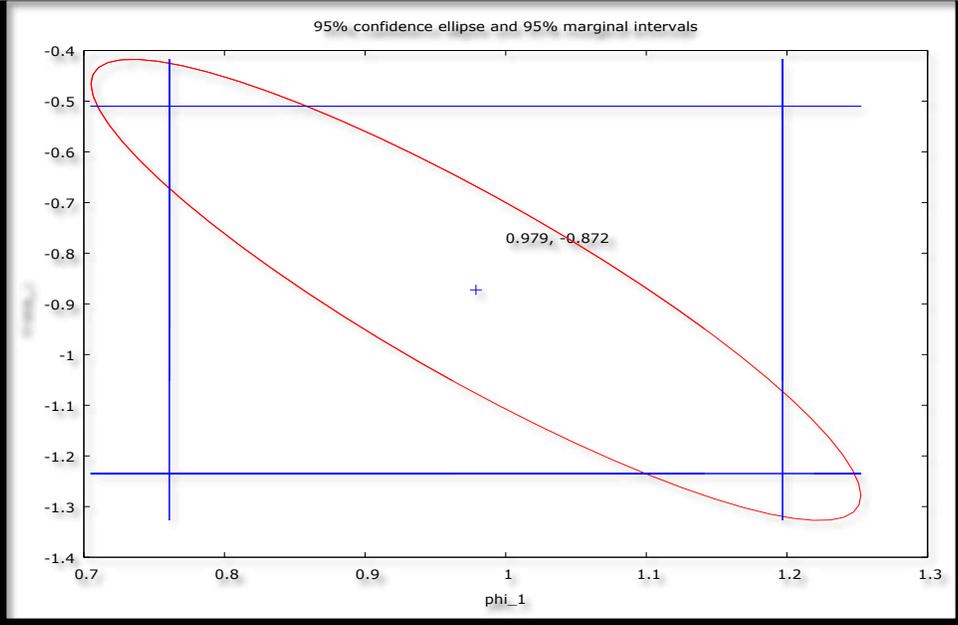
Predicted Annual Naira / USD exchanges over the period 2018 – 2022

Figure 6



Confidence Ellipse

Figure 7



The graph above indicates the region in which the realization of the two test statistics must lie for us not to reject the null hypothesis. The graph apparently confirms the accuracy of our forecast.

Forecast Evaluation Statistics

Table 14

Forecast Evaluation Statistic	Statistic
Mean Error (ME)	2.428
Root Mean Squared Error (RMSE)	13.222
Mean Absolute Error (MAE)	4.6945
Mean Percentage Error (MPE)	5.1282
Mean Absolute Percentage Error (MAPE)	8.6497
Theil's U	0.97215

The ME is a measure of the average deviation of forecasted values from actual ones. Since it shows the direction of the error, it is usually termed as the Forecast Bias. A desirable ME must be closer to zero. Our ME is 2.428 which is not far away from zero, indicating that our forecast is indeed good. The RMSE is nothing but the square root of the calculated MSE and must be as small as possible; our RMSE is 13.222 and is generally acceptable. The MAE measures the average absolute deviation of forecasted values of original ones and for a forecast to be good, the MAE must be as small as possible. In this study the MAE is 4.6945 and is relatively small and acceptable, pointing to the fact that our forecast is good. The MAPE represents the percentage of average absolute error and does not penalize extreme deviations. However, smaller values of the MAPE are desirable. In this study, MAPE is 8.6497 is actually acceptable. The MPE represents the percentage of average error that occurred while forecasting and has similar properties as MAPE. A smaller value of MPE is desirable. In this study, MPE has been found to be 5.1282 and is relatively smaller and desirable. In this study we base our analysis mainly on the Theil's U statistic, which is generally defined as a relative accuracy measure that compares the forecasted results with a naïve forecast. Theil's U must lie between 0 and 1; the closer the value of Theil's U is to zero, the better the forecast method. However, a Theil's U of 1 implies that the forecast is no better than a naïve guess. Since the Theil's U value in this study has been found to be 0.97215, which is apparently between 0 and 1; we conclude that our forecast accuracy is acceptable.

VI. Conclusion & Policy Implications

Most researchers have done a great research on forecasting of exchange rate for developed and developing countries using different approaches (Ajao *et al*, 2017). Exchange rate prediction is one of the demanding applications of modern time series forecasting. The rates are inherently noisy, non – stationary and deterministically chaotic (Box & Jenkins, 1994; Deboeck, 1994; Theodossiou, 1994; Yaser & Atiya, 1996; Chandrasekara & Tilakaratne, 2009). Foreign exchange rates are influenced by many economic⁸, political and psychological factors. Forecasting exchange rates is not a simple task because of these unstable factors (Erdogan & Goksu, 2014). Exchange rate forecasting is, and has been a challenging task in finance (Fat & Dezsi, 2011). Forecasting with a weak set of tools and models will lead to taking wrong adjustments which has an adverse effect on the decision making process (Pedram & Ebrahimi,

⁸ Significant impact of economic growth, trade development, interest rates and inflation rates on exchange rate make it extremely difficult to predict them (Yu *et al*, 2007).

2014). The low ability to predict exchange rate movements appears to reveal a huge need for further research on the issue (Simwaka, 2007). Despite various efforts by the (Nigerian) government to maintain a stable exchange rate, the Naira has depreciated throughout the 80's to date (Aliyu, 2011; Benson & Victor, 2012) and our results indicate that the Naira is likely to continue depreciating. While it is true that Nigeria is an import – dependent country, I still recommend devaluation of the Naira in order to restore exchange rate stability in Nigeria. While this policy stance would make the importation of commodities into Nigeria more expensive, the good part of it is that on the other side of the same coin it would encourage local manufacturing and the much needed inflow of foreign capital.

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