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Time Series Analysis on Nigeria Foreign Exchange Reserve

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ABSTRACT

Time series analysis was carried out on Nigeria External Reserves for the period of 1960 – 2018. An empirical investigation was conducted using time series data on Nigeria External Reserve for a period of 58 years. The techniques of estimation employed in the study include Phillips-Perron unit root test, Dickey-Fuller's test, the Autocorrelation function and the Partial Autocorrelation function for the model selection. The Box-Jenkins ARIMA methodology was used for forecasting the monthly data collected from 1960 to 2018. Result of the analysis revealed that the series became stationary at first difference. The diagnostic check showed that ARIMA (1, 1, 2) is appropriate or optimal model based on the Loglikelihood (LogLik), Akaike's Information Criterion (AIC), as well as the small standard error of the AR(1), MA(1) and MA(2) parameters. The performance of "forecast.Arima()" function in R gives the best model for Nigeria external reserve. Testing for other ARIMA models is necessary in order to establish the best. The downward movement in the forecasts of Nigeria external reserve would be helpful for policy makers in Nigeria.

Keyword: External reserve, ARIMA, stationarity, model selection, forecasts

1 Introduction

External reserves, also known as International Reserves, include international reserve assets of the monetary authority but exclude the foreign currency and the securities held by the public including the banks and corporate bodies. External reserves are needed to guard against possible financial crisis. Zubair and Olarenwaju (2014) tentatively identified ARIMA (1,2,2) model as a suitable model for modelling and forecasting Nigeria's external reserves using a monthly 50 years' data (January, 1960 – December, 2008). The Nigeria's external reserves was found to be on the increase and the paper further called on the Nigerian government to exercise fairness, justice, and equity in order to strengthen her economy. The model was fitted with over differenced log-transformed series which could affect the forecasting power of the ARIMA (1,2,2) model, therefore, the ARIMA (1,1,2) model would have been preferred since a single ordinary difference would have rendered the series stationary. Akpanta and Okorie (2015) identified ARI (5,1,0) model as a suitable model for modeling and forecasting the Nigeria's external reserves. Nigeria's 54 years' external reserve data from January, 1960 to December, 2013 was used to perform analysis in R. The ARI (5,1,0) model with the smallest AIC and BIC statistics was found to out-perform the ARIMA (5,1,1) model. One-year forecast was made with the best ARI (5,1,0) model and the Nigeria's external reserves was trending upwards. From the paper, the point forecast values are higher than the observed values. Interestingly the observed values are found to lie within the 90% confidence intervals. Iwueze et al, (2013)

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recommended the Auto Regressive integrated moving average (ARIMA) process of order (2,1,0) for forecasting the natural log-transformed Nigeria's external reserves, using II years data (from January, 1999 – December, 2008), where the Nigeria's foreign reserves were found to be on the increase. However, the point forecast from this model shows a large discrepancy from the observed and was attributed to the fall in income from petroleum products which is the main source of the Nigeria's external reserves. In the paper the ARIMA (2,1,0) though a candidate model could not have been the best, instead the ARIMA (2,1,2) would have been considered because the ACF plot of the first ordinary differenced log-transformed series showed a significant spike at lag 2 and cut-off thereafter. Ohakwe et al, (2013) modeled Nigerian External Reserves from the period of 1960 – 2010 using descriptive time series technique and Box-Jenkins (ARIMA) model. Etuk et al, (2013) identified and established the adequacy of the seasonal ARIMA (5,1,0)(0,1,1). For modeling and forecasting the amount of monthly rainfall in Port Harcourt, Nigeria. This paper therefore attempts to identify and construct a more reliable Box-Jenkins ARIMA (p,d,q) model that would best explain the underlying generating process and make forecast into the future of the Nigerian External Reserves. Sinha (2010) evaluate the state of the Indian economy throughout recession by analyzing different macro-economic factors such as External Reserves, inflation, exchange rate, fiscal deficit and capital markets. This study forecast some of the major economic variables by ARIMA modelling and presents a depiction of the Indian economy in the coming years. The results indicate that Indian economy is stimulating after a slowdown in the phase of global recession. It was forecasted that External reserves, fiscal deficit, capital markets and foreign investments will increase in 2010-2011. Giavazzi and Pagano (1990) studied the external reserves in Denmark and Ireland in the 1980s and showed that in these countries a drastic cut in public deficits led to a sharp increase in private consumption. The empirical studies that focus on the debt overhang effects of budget deficits try to analyse the nonlinear relationship between public spending and public debt with the growth rate of the economy. Borensztein (1990) provided a major and interesting attempt to test the debt overhang effect empirically. Using data for the Philippines, he found that the debt overhang hypothesis was largely valid. Specifically, he found that debt overhang had an adverse effect on private investment. The effect was strongest when private debt, rather than total debt, was used as a measure of debt overhang. Fairly similar results were obtained in another study carried out by Alfredo and Francisco (2004). They explored the relationship between external debt and growth for a number of Latin American and Caribbean economies. The result of their study showed that lower total external debt levels were associated with higher growth rates, and that this negative relationship was driven by the incidence of public external debt levels, and not by private external debt levels.

Ndung'u (1998) examined the dynamic impact of external debt accumulation on private investment and growth in Africa. He argued that the external debt problem in Africa has led to an investment pause and has reduced growth performance substantially. To strengthen his argument, he used results from recent empirical work by Elbadawi, et al. (1997) to show the dynamics of the problem and how a country moves from one side of the Laffer curve to the other and the effects on investment and growth. Once a country gets onto the wrong side of the Laffer curve and does not reverse the trend, the accumulated effects further affect growth performance. In another study, Iyoha (1999) adopted a simulation approach to investigate the impact of external debt on economic growth in sub-Saharan African countries. An important in this study was the significance of debt overhang variables in the investment equation, suggesting that mounting external debt depresses investment through both a "disincentive" effect and a "crowding out" effect. Policy simulation was undertaken to investigate the impact of alternative debt stock reduction scenarios (debt reduction packages of 5%, 10%, 20% and 50%) on investment and economic growth. It was found that debt stock reduction would have significantly increased investment and growth performance. Audu (2004) investigated the impact of external debt on economic growth and public investment in Nigeria. Usman and Ibrahim (2010) made a study of external reserves holding with implications for investment, inflation and exchange rate. Using Vector Error Correction (VEC) model they concluded that demand for external reserves in Nigeria "has been driven mainly by current account variability, real exchange rate and opportunity cost of holding reserves (measured by the difference between the real return on reserves and the real return on domestic investments)". They opined that their finding corroborates those of Adam and Leonce (2007) who stated that "demand for international resources in Africa is determined by Export, GDP growth and opportunity cost of holding reserves". Nzotta (2009) attempt to construct a time series model which was utilized to forecast the Nigeria External Reserves to get its future estimations up to fourth quarter of 2015. The study found on the figures collected through secondary sources from 1962 to 2008. ARIMA models were seek on the collected data and to conclude ARIMA (2, 1, 1) is create to be an appropriate model, which is then apply for forecasting purpose. The outcome of the future forecast explains the significant improvement in the fourth quarter of 2015. Usman and Ibrahim in their study say that "changes in external reserves show no significant relationship with inflation in Nigeria". They further added that although "external reserves position for Nigeria has no import on inflation rate but the domestic money supply should be a control variable to regular domestic inflation rate".

2 Materials and Methods

2.1 Autoregressive (AR) Process

The equation below is an example of an Autoregressive process

$$(Y_t - \delta\ ) = \alpha_1\ (Y_{t-1} - \delta) - + u_t$$

Where δ is the mean of *Y* and where u_t is an uncorrelated random error term with zero mean and constant variance σ^2 (i.e., it is *white noise*), then we say that Y_t follows a first-order autoregressive, or AR (1),stochastic process. Here the value of *Y* at time *t* depends on its value in the previous time period and a random term; the *Y* values are expressed as deviations from their mean value. In other words, this model says that the forecast value of *Y* at time *t* is simply some proportion (=α_1) of its value at time (*t* − 1) plus a random shock or disturbance at time *t*; again the *Y* values are expressed around their mean values. But if we consider this model,

$(y_t\ - \delta\ ) = \alpha_1\ (Y_{t-1} - \delta) + \alpha_2\ (Y_{t-2} - \delta) + u_t$ then we say that Y_t follows a second-order autoregressive, or AR (2)process. That is, the value of *Y* at time *t* depends on its value in the previous two time periods, the *Y* values being expressed around their mean value δ. In general, we can have

$(Y_t - \delta\ ) = \alpha_1\ (Y_{t-1} - \delta) + \alpha_2\ (Y_{t-2} - \delta)$ +...+ $\alpha_P\ (Y_{t-P} - \delta) +\ u_t$ in which case Y_t is a pth-order autoregressive, or AR(p),process.

2.2 Moving Average (MA) process.

The AR process just discussed is not the only mechanism that may have generated *Y*. Suppose we model *Y* as follows:

$Y_t = \mu + \beta_0 u_t + \beta_1 u_{t-1}$

Where μ is a constant and u is the white noise stochastic error term. Here Y at time t is equal to a constant plus a moving average of the current and past error terms. Thus, we say that Y follows a first-order moving average,or an MA (1),process. But if Y follows the expression

$Y_t = \mu + \beta_0 u_t + \beta_1 u_{t-1} + \beta_2 u_{t-2}$, then it is an MA (2) process.

More generally,

$Y_t = \mu + \beta_0 u_t + \beta_1 u_{t-1} + \beta_2 u_{t-2} + \cdots + \beta_P u_{t-P}$

2.3 Autoregressive Integrated Moving Average (ARIMA) model

The ARMA models, described above can only be used for stationary time series data. However, in practice many time series such as those related to socio-economic and business show non-stationary behavior. Time series, which contain trend and seasonal patterns, are also non-stationary in nature. Thus from application view point ARMA models are inadequate to properly describe non-stationary time series, which are frequently encountered in practice. For this reason, the ARIMA model is proposed, which is a generalization of an ARMA model to include the case of non-stationarity as well. In ARIMA models a non-stationary time series is made stationary by applying finite differencing of the data points. Which is written as ARIMA (p, d, q).

Here, *p*, *d* and *q* are integers greater than or equal to zero and refer to the order of the Autoregressive, integrated, and moving average parts of the model respectively. The integer *d* controls the level of differencing. Generally, *d*=1 is enough in most cases. When *d*=0, then it reduces to an ARMA (*p, q*) model. It is widely used for non-stationary data, like economic and stock price series.

2.4 Box-Jenkins Methodology

After describing various time series models, the next issue to our concern is how to select an appropriate model that can produce accurate forecast based on a description of historical pattern in the data and how to determine the optimal model orders. Statisticians George Box and Gwilym Jenkins developed a practical approach to build ARIMA model, which best fit to a given time series and also satisfy the parsimony principle. Their concept has fundamental importance on the area of time series analysis and forecasting. The Box-Jenkins methodology does not assume any particular pattern in the historical data of the series to be forecasted. Rather, it uses a three step iterative approach of model identification, parameter estimation and diagnostic checking to determine the best parsimonious model from a general class of ARIMA models. This three-step process is repeated several times until a satisfactory model is finally selected. Then this model can be used for forecasting future values of the time series.

3 Data Analysis

The data used for this project is extracted from the bulletin of Central Bank of Nigeria (CBN) and the data is on Nigeria External Reserves (US million) from 1960 to 2017, a period of 58 years. All data analyses were done using R version 3.4.4

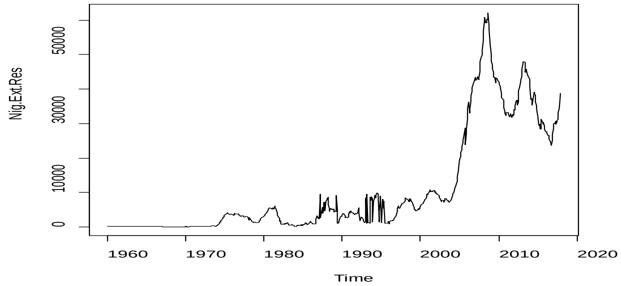

Fig.1: Time plot for Nigeria External Reserve data

From the time plot, it appears that the random fluctuations in the time series are not roughly constant in size over time, there is trend, the time series data does not appear to be stationary in mean and variance, as its level and variance appear not to be roughly constant over time. Therefore, there is need to difference this series in order to fit an ARIMA model. There is an upward movement in the Nigeria External Reserve series data so it is not stationary.

In order to establish if the time series data (Nigeria External Reserves) is stationary or not, the Phillips-Perron test for the null hypothesis that series data has a unit root against a stationary alternative is performed:

Table 1: Phillips-Perron Unit Root Test before differencing

Dickey-fuller statistic	P-value	Remark
-1.8498	0.6419	Not stationary

From the output, it can be seen that the p-value is 0.6419, which is greater than 0.05 and this indicates that there is no stationarity in the time series data.

Since the Nigeria External Reserve data is not stationary, there is a need to carry out differencing in order to make the time series data stationary.

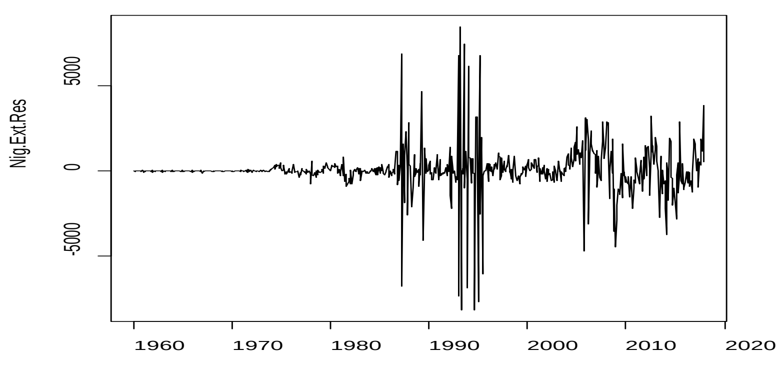

Fig.2: Time plot for Nigeria External Reserve data after first differencing

From the time plot, it appears that the random fluctuations in the time series are roughly constant in size over time, there is no trend, the time series data appears to be stationary in mean and variance, as its mean and variance appear to be roughly constant over time. Therefore, there is no need to difference this series in order to fit an ARIMA model. The Nigeria External Reserve series data is stationary.

Table 2: Phillips-Perron Unit Root Test after differencing

Dickey-fuller statistic	P-value	Remark
-30.6880	0.0100	Stationary

From the output, it can be seen that the p-value is 0.01, which is less than 0.05 and this indicates that the data is stationary.

4 Arima Model Selection

Since the series is stationary after first order differencing, the next step is to choose the ARIMA model that best fit the Nigeria External Reserve data by plotting a correlogram and partial correlogram for lags 1-20 and investigate what ARIMA model to use:

Table 3: Autocorrelations of the series

Lag	1	2	3	4	5	6	7	8	9	10
Autocorrelation	0.165	0.090	0.016	-0.003	0.215	-0.030	0.129	-0.048	0.050	0.118
Lag	11	12	13	14	15	16	17	18	19	20
Autocorrelation	-0.108	0.058	0.009	0.063	-0.041	0.028	-0.056	-0.039	0.141	-0.017

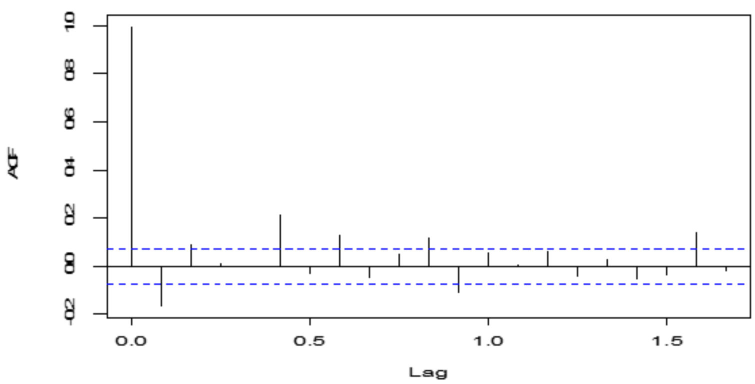

Fig. 3: Autocorrelation for the first differenced data

It can be seen from the correlogram that the autocorrelations from lags 1 and 2 exceed the significance bounds, and that the autocorrelations tail off to zero after lag 18. The autocorrelations for lags 2, 4, 6, 8 and 18 are positive, and decrease in magnitude with increasing lag. The autocorrelation function tails off to zero after lag 1.

Table 4: Partial autocorrelations of the series

Lag	1	2	3	4	5	6	7	8	9	10
Autocorrelation	-0.165	0.064	0.042	0.000	0.217	0.040	0.106	-0.023	0.020	0.091
Lag	11	12	13	14	15	16	17	18	19	20
Autocorrelation	-0.090	-0.036	0.033	0.046	-0.067	0.034	-0.069	-0.054	0.110	0.042

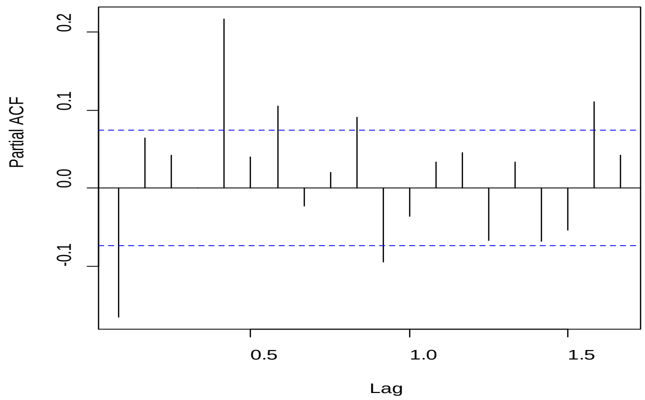

Fig. 4: Partial autocorrelation for the first differenced data

From the partial correlogram, it can be seen that the partial autocorrelation at lag 1 is negative and does not exceeds the significance bounds (-0.165), while the partial autocorrelation at lag 4 is also positive and also exceeds the significance bounds.

Since the correlogram tails off to zero after lag 1, and the partial correlogram is zero after lag 4, the ARIMA models possible for the time series data (Nigeria External Reserve) is $ARIMA(1,1,2)\ where\ p = 1, d = 1\ and\ q = 2$.

The ARIMA model can therefore be written as:

$$y_t = \alpha + \rho_1 y_{t-1} + \theta_1 \in_{t-1} + \theta_2 \in_{t-2} + \in_t$$

Where

5 Parameters Estimation

The ARIMA model chosen for the time series data (Nigeria External Reserve) is $ARIMA(1,1,2)$ and the model is given by $y_t = \alpha + \rho_1 y_{t-1} + \theta_1 \in_{t-1} + \theta_2 \in_{t-2} + \in_t$. The parameters ρ_1, θ_1 and θ_2 are estimated as follows:

Table 5: Parameter estimates from ARIMA (1,1,2) model

	Coef.	Std. error
Constant	65.8838	74.6583
AR		
lag1	0.8441	0.0378
MA		
lag1	-1.2655	0.0595
lag2	0.2819	0.0547

From the result above, the model is obtained as follows: $y_t = 65.8858 + 0.8441 y_{t-1} - 1.2655 \in_{t-1} + 0.2819 \in_{t-2} + \in_t$

It can be seen that the $ARIMA(1,1,2)$ model fitted for the Nigeria External Reserve in US millions from 1960 to 2018 gives a good fit and it is the best selected model based on the small standard error of the AR(1), MA(1) and MA(2).

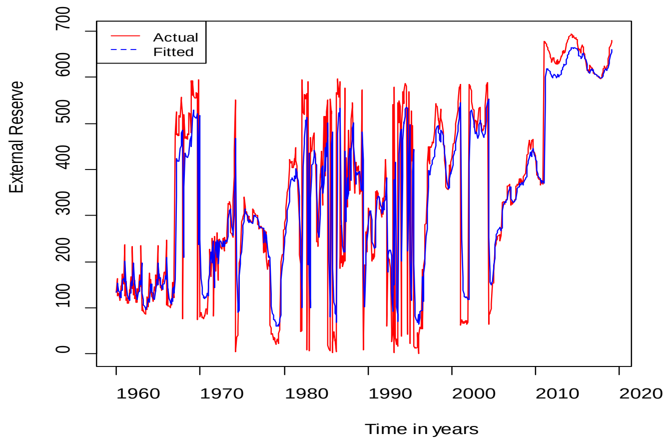

Fig. 5: Actual and the fitted series

Table 6: Parameter estimates from ARIMA (1,1,2) model

Model	Log-likelihood	AIC
ARIMA (2,1,0)	-4347.69	8701.38
ARIMA (1,1,0)	-4353.65	8711.30
ARIMA (0,1,1)	-4342.22	8688.44
ARIMA (2,1,1)	-4327.48	8662.97
ARIMA (1,1,2)	-4325.06	8660.21
ARIMA (0,1,0)	-4388.28	8778.57
ARIMA (1,1,3)	-4333.76	8673.53
ARIMA (1,1,1)	-4326.00	8662.00
ARIMA (0,0,1)	-4559.58	9125.07

6 Making Forecasts

The original time series for the Nigeria External Reserve indicates the reserve for 58 years (1960-2017). The forecast function gives a forecast of the Nigeria External Reserve for the next five years (NER January 2018-December 2022), as well as 80% and 90% prediction intervals for those predictions. The Nigeria External Reserve for December 2017 was 407 US million Dollars (the last observed value in the time series data), and the forecasted Nigeria External Reserve for the next five years is increasing with time as given by the ARIMA model.

The plot of the observed Nigeria External Reserve for the 58 years, as well as the Nigeria External Reserve that would be predicted for the next 5 years using $ARIMA(1,1,2)$ model is given below:

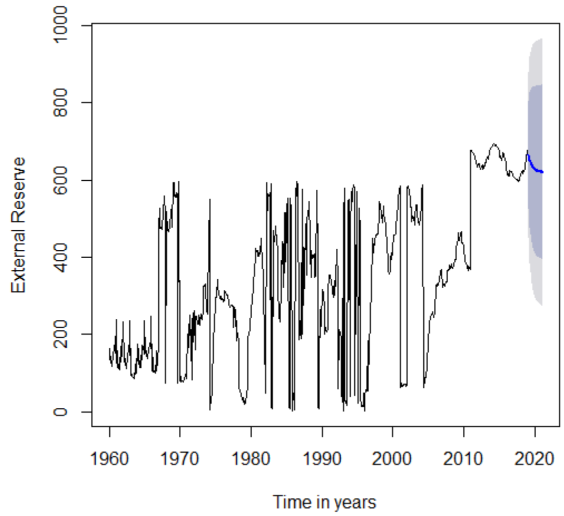

Fig. 6: The actual and the forecasts series

7 Summary and Conclusion

The major aim of this research work is to fit a robust time series model for Nigerian External Reserve. This is done by examining the stationarity in the Nigeria external reserve data. The study carries out an empirical analysis to determine the best ARIMA model for the Nigeria external reserve. This study investigated the Time series analysis of Nigeria External Reserves for the period of 1960 – 2017. The study set out to study the stationarity in the Nigeria External Reserve. An empirical investigation was conducted using time series data on Nigeria External Reserve from 1960 to 2017 a period of 57 years. The techniques of estimation employed in the study include Phillips-Perron unit root test, Dickey-Fuller's test, the Autocorrelation function and the Partial Autocorrelation function for the model selection. The Box-Jenkins ARIMA methodology was used for forecasting the monthly data collected from 1960 to 2018. Result of the analysis revealed that the series became stationary at first difference. The diagnostic checking has shown that ARIMA (1, 1, 2) is appropriate or optimal model based on the Loglikelihood (LogLik), Akaike's Information Criterion (AIC), as well as the small standard error of the AR(1), MA(1) and MA(2) parameters.

RECOMMENDATION

The Nigerian government should promote exportation of domestic products as a high exchange rate will make our goods more attractive in the foreign market and will increase foreign exchange earnings. Time series data analysts are encouraged to explore R package in order to discover better methods.

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