MODELING THE GROWTH PATTERN OF RESERVE CURRENCY IN NIGERIA

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Abstract: The reserve currency is regarded as the currency held in significant amounts by governments and financial institutions in order to help conduct transactions in the global market. In this research study, secondary data on month ly reserve currency was obtained from the Central bank of Nigeria database from January, 2000 to December, 2015. Using the Box-Jenkins (ARIMA) methodology to fit the best model to the series, the data was (Logarithmic) transformed and non-seasonally differenced in order to achieve series stationarity. The results showed that Seasonal ARIMA (1, 1, 1) $(0, 0, 1)_{12}$ model with drift had the least information criteria with AIC of -412.83, AICc of -412.50 and BIC of -396.56 and was chosen as the best fit model that best describe the growth of the reserve currency. The diagnostics test on the model residuals using the Ljung-Box and ARCH-LM tests revealed that the model is free from both autocorrelation and ARCH effects. This model will definitely assist the Apex bank in forecasting the monthly future values of the reserve currency in Nigeria.

Keywords: Autocorrelation, differencing, growth pattern, reserve currency, SARIMA.

Introduction

The reserve currency (Monetary base) is the currency held in significant amounts by governments and institutions in order to help conduct transactions in the global market. Reserve currency is also regarded as the portion of the commercial banks reserves that are maintained in accounts with the Central bank including the total currency circulating in the public and the banks vault cash. Reserve currency (monetary base) should not be confused with money supply which consists of the total money circulating in the public including the non-commercial bank deposits (Mankiw, 2002). Monetary reserve plays a very important role in settling transactions involving different counter parties and the trading in foreign exchange and commodity market. The reserve currency and monetary policies are controlled by either the finance ministry or the Central bank and the government controlled institutions change reserve currency through open market transactions. The monetary base is called high-powered because its increase will basically result in a much larger increase in the supply of demand deposit through banks' loan-making, a ratio called the money multiplier (Cagan, 1965). The growth in reserve currency aids in keeping commodity prices stable as productivity increases in a country. When a country experiences serious inflations, the growth in money needs to be lowered in other to checkmate its effect and control it (Nasiru & Solomon, 2012). Thus, in a country like Nigeria where double digit inflation figure is sometimes experienced and not much significant growth in development and productivity, the growth pattern of the reserve currency (Monetary base) needs a close investigation.

There are a large number of studies which have been conducted by different researchers on monetary base using series of methods depending on the area of interest. (Peter 2005) talked about how monetary transmission mechanism describes how policy-induced changes in the nominal money stock or the short-term nominal interest rate impact real variables such as aggregate output and employment. (Albert *et al*., 2013) modelled the monthly currency in circulation in Ghana using Seasonal Autoregressive Integrated Moving Average (SARIMA) model. (Nasiru & Solomon, 2012) modelled the pattern of Reserve money growth in Ghana while (Mohamed & Bulat, 2014), examined the question of whether monetary rules or ad hoc monetary policies were followed during the early stages of transition and in response to the global financial crisis. Also, Seth & Selva (2010) explored the institutional structure of the transmission mechanism beginning with open market operations through to money and loans. They undertook the empirical analysis of the relationship among reserve balances, money, and bank lending using aggregate as well as bank-level data in a VAR framework and document that the mechanism does not work through the standard multiplier model or the bank lending channel. The purpose of this study is to investigate the growth pattern of the reserve currency in Nigeria.

Material and Methods

The data used for this research study are secondary data on monthly reserve currency (monetary base) in Nigeria obtained from the Central Bank of Nigeria (CBN) database over the periods of January, 2000 to December, 2015 (CBN, 2016).

Methodology overview

The framework used for this study is the (Box & Jenkins; 1976, Box *et al*., 1994) approach which houses the Autoregressive Integrated Moving Average (ARIMA) models. The approach involves three stages namely the identification stage, parameter estimation stage and diagnostic checking stage. But before these stages are carried out the descriptive statistics of the data series was explored in order to ascertain the presence of some basic facts about the series distributional properties. Hence, the first stage of the Box-Jenkins approach, known as the identification stage involves the use of graphical time series plots and the autocorrelation Function (ACF) and Partial Autocorrelation Function (PACF) to check for stationarity, seasonality including the test for unit root using the ADF or KPSS test statistics and also to identify the order for both the non-seasonal and seasonal components of the ARIMA (p, d, q) (P, D, Q) model. The second stage called the model parameter estimation stage involves estimation of the parameters after identifying the tentative models. Three information criteria: the Akaike Information Criterion, the Corrected Akaike Information Criterion proposed by (Akaike, 1974) and the Schwarz

Bayesian Information Criterion elaborated by Bumham & Anderson (2002) was used. The model with the lowest information criteria values is chosen as the best fitted model from the set of tentative models. The model parameters are estimated using the Maximum likelihood estimation method and the significance of the estimated parameters of the chosen model is tested using the t-student test with $(n-k)$ degrees of freedom at 5% significance level. The third stage known as the diagnostic stage is used to examine whether the selected model adequately represents the reserve currency (Monetary base) in Nigeria. The overall checking of the model adequacy was made using the Ljung-Box test, the standardized residuals series plot and Autocorrelation function plot to ascertain that the residuals series are uncorrelated random shocks (White noise). Furthermore, an ARCH-LM test and Durbin Watson test were performed on the fitted model residuals in order to check for homoscedasticity and autocorrelation of the model residuals.

Autoregressive (AR) models

The autoregressive (AR) structure is regarded as a stochastic process that assumes that the present value Y_t can be modelled as a weighted summation of past values $Y_{t-1}, Y_{t-1}, \ldots, Y_{t-p}$ and a certain error term ε_t . The term 'auto' regression indicates that it is a regression of the variable against itself and the error term ε_t is assumed to be purely random with a zero mean and a constant variance.

$$Y_t = c + \phi_1 Y_{t-1} + \phi_2 Y_{t-2} + \phi_3 Y_{t-3} + \ldots + \phi_p Y_{t-p} + \varepsilon_t \quad \ldots. (1)$$

Where $\phi_1, \phi_2, \ldots \phi_p$ the parameters of the model are, C is a constant and ε_t is the random term. The above equation can be equivalently written in terms of the backshift operator (B) as:

$$Y_t = c + \sum_{i=1}^{p} \phi_i B^i Y_t + \varepsilon_t \quad \ldots\ldots\ldots.. (2)$$

The autoregressive models are restricted to stationary data and some stationarity constraints on the coefficients of the model parameters which are estimated using the Maximum likelihood estimation or the unconditional/conditional least square estimation methods are required.

- The AR (1) model is stated as $Y_t = \phi_1 Y_{t-1} + \varepsilon_t$ with parameters constrained within $-1 < \phi_1 < 1$.
- The AR (2) model is stated as $Y_t = \phi_1 Y_{t-1} + \phi_2 Y_{t-2} + \varepsilon_t$ with parameters constrained within $-1 < \phi_2 < 1$, $-1 < \phi_1 + \phi_2 < 1$ and $-1 < \phi_2 - \phi_1 < 1$

Moving average (MA) models

A Moving-average model is a linear regression of the current value of the series against current and previous unobserved random shocks. The random shocks at each point in the series are assumed to be mutually independent and identically distributed with zero mean and constant variance. The MA (q) refers to a moving average model of order (q) and it is expressed mathematically as:

$$Y_t = \mu + \varepsilon_t + \theta_1 \varepsilon_{t-1} + \theta_2 \varepsilon_{t-2} + \theta_3 \varepsilon_{t-3} + \ldots + \theta_q \varepsilon_{t-q} \quad \ldots\ldots (3)$$

Where μ the mean of the data series is, $\theta_1, \theta_2, \ldots, \theta_q$ are the model parameters which are constraint within the invertibility bounds while $\varepsilon_t, \varepsilon_{t-1}, \varepsilon_{t-2}, \ldots, \varepsilon_{t-q}$ are the white noise error terms. The above equation can be equivalently written in terms of the backshift operator (B) as:

$$Y_t = \mu + (1 + \theta_1 B + \theta_2 B^2 + \ldots + \theta_q B^q)\varepsilon_t \quad \ldots\ldots.. (4)$$

The moving average model is a finite impulse response filter applied to white noise. The random shocks are propagated to future values of the series directly and the model shocks affect the Y values for the current period and q periods into the future. The choice of the order is determined by where the autocorrelation function (ACF) of the MA (q) process becomes zero at lag $q+1$ and greater. So the appropriate maximum lag for estimation is determined by the examining the sample ACF to see where it becomes insignificantly different from zero for all lags beyond a certain lag, which is designated as the maximum lag q. The Moving-average models invertibility constraints are similar to the stationarity constraints.

- The MA (1) model is stated as $Y_t = \theta_1 \varepsilon_{t-1} + \varepsilon_t$ with parameters constrained within $-1 < \theta_1 < 1$.
- The MA (2) model is stated as $Y_t = \theta_1 \varepsilon_{t-1} + \theta_2 \varepsilon_{t-2} + \varepsilon_t$ with parameters constrained within $-1 < \theta_2 < 1$, $-1 < \theta_1 + \theta_2 < 1$ and $-1 < \theta_2 - \theta_1 < 1$

Autoregressive moving average (ARMA) models

The autoregressive moving average (ARMA) models provide a parsimonious description of a weakly stationary stochastic process in terms of two polynomials, one for the auto-regression and the second for the moving average. The model is usually referred to as the ARMA (q, p) model with (p) autoregressive terms and (q) moving average terms. The model contains the AR (p) and MA (q) models. The ARMA (p, q) is mathematically written as:

$$Y_t = c + \varepsilon_t + \sum_{i=1}^{p} \phi_i Y_{t-i} + \sum_{i=1}^{q} \theta_i \varepsilon_{t-i} \quad \ldots\ldots\ldots.. (5)$$

Where the parameters of the ARMA (p, q) model are estimated the same way the parameters of the AR (p) and the MA (q) models are estimated. The error term ε_t are assumed to be independent identically distributed random variables (i.i.d) sampled from a normal distribution with zero mean and constant variance. The ARMA (p, q) model can also be expressed in terms of the Backshift operator (B) as:

$$\left(1 + \sum_{i=1}^{p} \phi_i B^i\right) Y_t = \left(1 + \sum_{i=1}^{q} \theta_i B^i\right) \varepsilon_t \quad \ldots\ldots\ldots.. (6)$$

If the parameters $\phi_0 = \theta_0 = 1$, we have the above formulation become

$$\left(\sum_{i=0}^{p} \phi_i B^i\right) Y_t = \left(\sum_{i=0}^{q} \theta_i B^i\right) \varepsilon_t \quad \ldots\ldots\ldots.. (7)$$

Finding appropriate values of p and q in the ARMA (p, q) model can be facilitated by plotting the partial autocorrelation function for an estimate of p and likewise using the autocorrelation function for an estimate of q. If the series shows evidence of non-stationarity through the sample Autocorrelation function (ACF) and the Partial-autocorrelation function (PACF), the series is differenced. Hence, the Autoregressive Integrated Moving Average model, ARIMA (p, d, q). The model is expressed as:

$$\phi(B)\Phi(B^s)(1-B)^d Y_t = \theta(B)\Theta(B^s)\varepsilon_t \quad \ldots\ldots\ldots (8)$$

If the series is also effected by seasonal variations as a result of seasonality that comes with some monthly times series data, then the ARIMA (p, d, q) is extended to include the seasonal components parameters. Thus the seasonal ARIMA $(p, d, q)(P, D, Q)_s$ can be expressed using the backshift operator as:

$$\phi(B)\Phi(B^s)(1-B)^d (1-B^s)^D Y_t = \theta(B)\Theta(B^s)\varepsilon_t \quad \ldots\ldots (9)$$

Where, $(\phi_i, \Phi_i), (\theta_j, \Theta_j)$ represent the parameters of the non-seasonal and seasonal autoregressive coefficients and the non-seasonal and seasonal moving-average coefficients and ε_t is the white noise error.

Unit root test

The unit root test was performed to check if the reserve currency series contains unit root and require differencing. To ascertain whether or not the data series is stationary, the Augmented Dickey-Fuller (ADF) test proposed by (Dickey & Fuller; 1979) is used. The test is based on the assumption that the time series data Y_t follows a random walk. The Augmented Dickey-Fuller (ADF) test, corresponding to modelling a random walk is expressed as:

$$Y_t = \rho Y_{t-1} + \varepsilon_t \quad \ldots\ldots\ldots\ldots (10)$$

Where, if $\rho = 1$ the model is said to be non-stationary which implies the presence of unit root in the series. Thus, first differencing we have $\nabla Y_t = \partial Y_{t-1} + \varepsilon_t$, where $\partial = (\rho - 1)$. The null hypothesis is $H_0 : (\rho = 1$ or $\partial = 0$), against the alternative ($\rho < 1$ or $\partial < 0$). The Augmented Dickey-Fuller (ADF) test, a p-value greater than alpha (α) at 5% level of significance would lead to the none rejection of the null hypothesis which in turn implies the presence of a unit root in the series.

Results and Discussion

The time series plot of the data in Fig. 1, gives an overview of the reserve currency data series. The series shows an increasing trend pattern over the period's in-view and also a sharp increase and decrease at specific periods in each year suggesting some seasonal influence in the series. From Fig. 1, it can be seen that series is not stationary. This was also affirmed from the slow decay in the ACF of the series and a very significant spike at lag 1 of the PACF with marginal spikes at few other lags as shown in Fig. 2. Furthermore, result of the ADF test shown in Table 1 shows that the series is not stationary. Thus, the data was transformed and non-seasonally differenced. As shown in Fig. 3, the series fluctuates about the zero line in the plot confirming that the non-seasonal first differenced series is stationary. Also the result of the ADF test in Table 1 indicates that the data is stationary after the non-seasonal first difference.

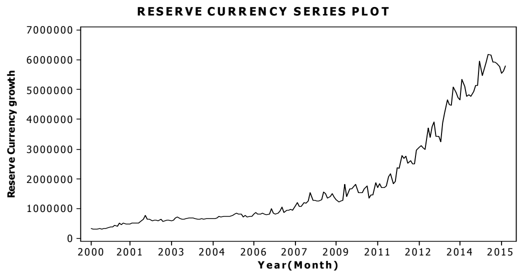

Fig. 1: Time series plot of the data

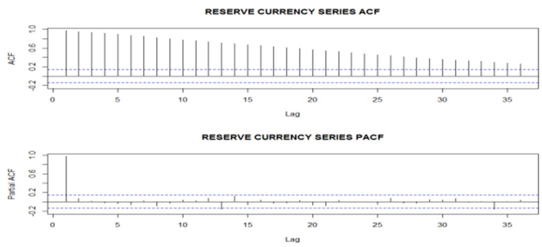

Fig. 2: ACF and PACF of the actual data

Table 3: Estimates of ARIMA (1, 1, 1) (0, 0, 1)$_{12}$ model

Parameter	Model Fit Statistics			
	Coefficients	Standard Error	t-statistics	p-value
Drift (μ)	0.0157	0.0029	5.414	0.00001
AR (1)	0.3796	0.1282	2.961	0.00001
MA (1)	-0.7323	0.0921	-7.951	0.00001
SMA (1)	0.1642	0.0677	2.425	0.00001

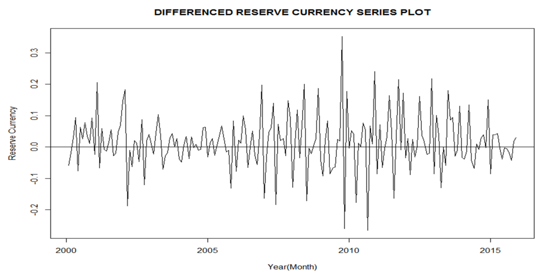

Fig. 3: Time series plot of differenced data series

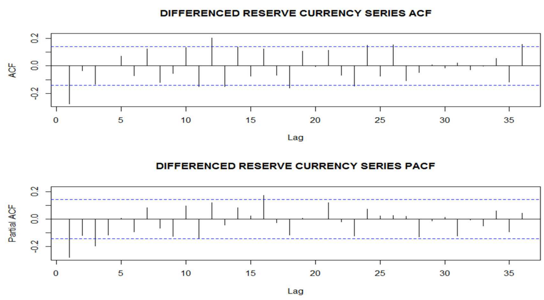

Fig. 4: ACF and PACF of the differenced series

The rapid decay in the ACF and the PACF of the differenced data as shown in Fig. 4 indicates that the data was stationary after the first non-seasonal differencing. From Fig. 4, there was significant spike at lag 12, lag 24 and lag 36 of the ACF which suggests that a seasonal moving average component needs to be added to our model. Hence, different Seasonal ARIMA (p, 1, q) (P, 0, Q)$_{12}$ models were fitted to the data and the best model selected based on the minimum values of AIC, AICc, BIC. From Table 2, seasonal ARIMA (1, 1, 1) (0, 0, 1)$_{12}$ was the best model based on the selection criterion used. The parameters of this model were then estimated using the Maximum likelihood estimation method. As shown in Table 3, all the parameters are significant base on the t-scores at 5% level of significance. The AIC, AICc and BIC penalty statistics have corresponding values of -412.83, -412.50 and -396.56, respectively which penalizes the fitted model based on the principle of parsimony. The Seasonal ARIMA (1, 1, 1) (0, 0, 1)$_{12}$ model is expressed as:

$$(1+0.3796B)(1-B)^d Y_t = 0.0157 + (1-0.7323B)(1+0.1642B^{12})\varepsilon_t \cdots \quad (11)$$

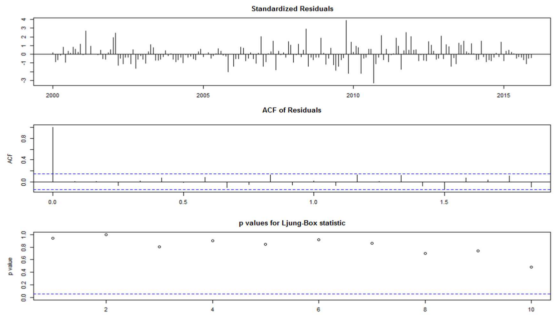

Fig. 5: Diagnostic plots of the residuals of ARIMA (1, 1, 1) (0, 0, 1)$_{12}$ model

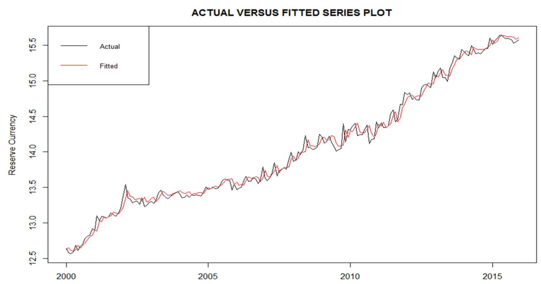

Fig. 6: Actual versus fitted series plot

In addition, the model was diagnosed to see how well it fits the data. It can be seen from Fig. 5 that the ACF of the residuals shows that the residuals are white noise although there was a significant spike at lag 0 of the ACF which could be due to random factor. Furthermore, the plot of the Ljung-Box p-values in Fig. 5 shows that the model is adequate for representing the data as they are above 5% level of significance indicated by the blue line. Also, the Ljung-Box and ARCH LM-test in Table 4 indicates that there was no autocorrelation and conditional homoscedasticity (ARCH) effect in the residuals of the model at the 5% level of significance. Fig. 6 reveals that the model fits the data very well given that it adjusts the data series for trends, seasonality and persistence of the random stocks and more accurately represents the series.

Conclusion

In this study, the growth pattern of the reserve currency was modelled using the Seasonal ARIMA (p, d, q) (P, D, Q). The best fitted model for the reserve currency growth in Nigeria was Seasonal ARIMA (1, 1, 1) (0, 1, 1)$_{12}$. The model residuals were adequately diagnosed using appropriate statistical tests (Ljung-Box and ARCH-LM). Also the model adequacy was confirmed by the graphical plots of the standardized residuals to be uncorrelated random shocks (white noise). The model can be used by the Apex bank in forecasting the monthly future values of the reserve currency in Nigeria, which will greatly assist in monetary policy making.

Conflict of Interest

The authors, O.D.Adubisi and E.C.Okorie declare that there is no conflict of interest regarding the publication of this article; "Modeling the Growth Pattern of Reserve Currency in Nigeria".

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