

Interrupted Time Series Analysis Of South Africa Rand (Zar)/ Nigeria Naira (NGA) Exchange Rate

Wobo Omezuruike Gideon & Nwaigwe Echendu.

Department of Statistics,

Port Harcourt Polytechnic Rumuola, Port Harcourt

Omezuruike.wobo@portharcourtpoly.edu.ng, echendunwaigwe@yahoo.com

Abstract

The plot of the daily South-Africa rand (ZAR)/ Nigeria naira (NGN) exchange rate showed a downward trend and later upward. An intervention point was noticed from 17th Dec, 2017. The pre-intervention series is found to be non-stationary, and became stationary after the first difference. The Augmented Dickey-Fuller (ADF) test statistics result of -7.279482 is less than the critical values of -3.548208, -2.912631 and -2.594027, the p-value (0.0000) is less than 0.05 which implies stationarity. The ACF and PACF of the differenced series is found to be stationary, hence ARIMA (0, 1, 0) is fitted which is a simple random walk. Forecast was made on the basis of the stationarity of the differenced series and a comparison of the intervention forecast and post-intervention rates revealed strong agreement between both series, hence the overall intervention model $X_t = \frac{\varepsilon_t}{1-B} + 3.67531819(1 - 0.947528^{t-60})I_t$ is found to be adequate. This is clearly seen from the R-squared and adjusted R-squared which is approximately 77%.

Keywords: Exchange rate, Arima intervention model, Forecasting

Introduction

There is a popular saying that the world is a global village. The internet affords people and various countries the opportunity to exchange goods and services which have great impact on the economy of each country. One of the most popular segments of the world's business is exchange rate, which is the value of one country's currency in relation to another currency (O'Sullivan and Steven, 2003). Forecasts are essential in both short-term and long-term plans. However, making such forecasts implies developing a model showing how the business world operates. Time series analysis has widely been applied in various fields of study since the publication by Box and Jenkins (1970, 1976). Various research papers have become available and applied to vast real life problems such as: Etuk et al (2017), Herbury et al (2013), Amadi and Aboko (2013), Dobre et al (2008), Abbas and Allan(2004), Etuk et al (2017), Jerffrey and Eric (2011),Nihan et al (2005), Ismail et al (2009), Abdalla (2006), Yakubu et'al (2013), Nelson (2000), Zheng et al (2015), Krishnamurthi et al (1986), Yin and Newman (1999), Yang (2004) Onasanya and Adenyi (2013) Sharma and Khare (1999), Chang and Lin (1997),. Hilson (1984), Noland et al (2008), Amadi and Etuk (2017), Sastri and Valdes (1989). We will consider the exchange rate between South Africa rand and Nigeria naira using the intervention model approach proposed by Box and Taio (1975)

Materials and methods

The data for this research work is obtained from the website of the central bank of Nigeria (CBN) www.cbn.gov.ng/exrate.asp from the 16th day of October, 2017 to the 13th day of April, 2018. This research work will make use of time series Arima-Intervention approach to analyze the dynamics of the changes, variations and the interruption in the naira-rand exchange rate.

Arima-intervention model.

The ARIMA-Intervention model was introduced by box and Tiao (1975). The ARIMA-intervention method is used to ascertain the impact of the intervention on a time series. A simple intervention model with a single spike in the series is given by:

$$X_t = W_t + N_t \quad (1)$$

Where W_t is the intervention effect modeled as a transfer function that makes use of the pulse and step function to access the degree of the intervention, N_t is the pre-intervention process which is as an ARIMA model derived from box-Jenkins approach. W_t is assumed to be zero before intervention.

Suppose that X_t follows an ARIMA given by:

$$X_t - \mu = \frac{\Phi(B)\epsilon_t}{\Pi(B)} \quad (2)$$

And at time $t=T$ there is intervention to X_t which changes the mean level of X_t , assuming the ARIMA structure of X_t in (2) holds before and after the intervention.

Let W_t be the magnitude of the change at time $t=T$, and let

$$I_t = \begin{cases} 1 & t \geq T \\ 0 & t < T \end{cases} \quad \text{Then at time } t=T, \text{ the overall model becomes:}$$

$$X_t = W_t + \mu + \frac{\Phi(B)}{\Pi(B)}\epsilon_t \quad (3)$$

The following pattern and model could be followed by W_t at time $t \geq T$, That is the intervention period.

i) Indefinite constant change at the mean level

In this case there is a change either upward or downward to each value of the series after T. Let I_t be an indicator variable defined by:

$$I_t = \begin{cases} 1 & t \geq T \\ 0 & t < T \end{cases} \text{ then } W_t \text{ can be modeled as } W_t = \beta_o I_t$$

Hence $W_t = \begin{cases} \beta_o & t \geq T \\ 0 & t < T \end{cases}$ β_o is estimated from the data. The pattern is shown in figure1 below.

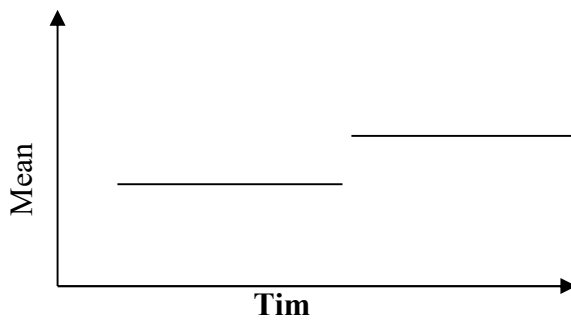


Figure 1: Indefinitely Constant

ii) Transient constant change for a period d times past T

In this case, the change is temporary lasting d times past the intervention period T. Define W_t by:

$$W_t = \beta_o(1 - B^d)I_t. \text{ Or we can redefine } I_t \text{ to be } I_t = \begin{cases} 1 & T \leq t \leq T + d \\ 0 & \text{for all other } t \end{cases}$$

And $W_t = \beta_o I_t$. Hence $W_t = \begin{cases} \beta_o & T \leq t \leq T + d \\ 0 & \text{for all other } t \end{cases}$

The pattern is given in the figure2 below.

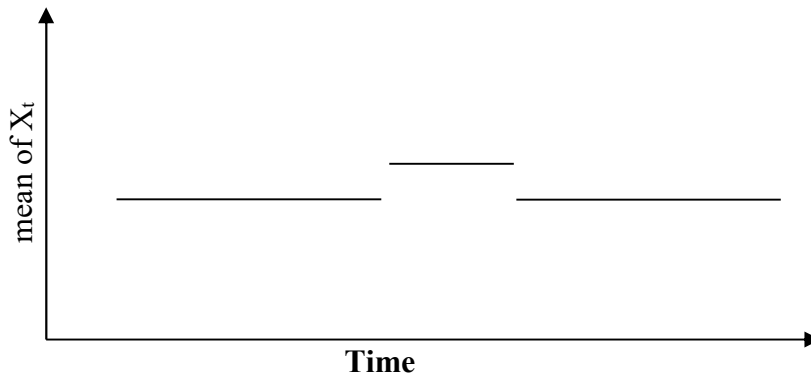


Figure 2: Transient Constant Change for a period d

iii) A progressive increase that eventually becomes constant

In this case the change increases gradually and levels off. We define W_t

By: $W_t = \frac{\beta_o}{1 - k_1 B} I_t = k_1 W_{t-1} + \beta_o I_t$

For $I_t = \begin{cases} 1 & t \geq T \\ 0 & t < T \end{cases}$ assume $|k_1| < 1$, then W_t can be modeled as:

$$W_t = \begin{cases} \frac{\beta_o}{1 - k_1} = k_1 W_{t-1} + \beta_o & t \geq T \\ 0 & t < T \end{cases}$$

W_t May be written in terms of β_o and k_1 as $W_t = \frac{\beta_o(1 - k_1^{t-T+1})}{1 - k_1}$

Where k_1 and β_o are estimated from the data. The pattern is shown in figure3 below.

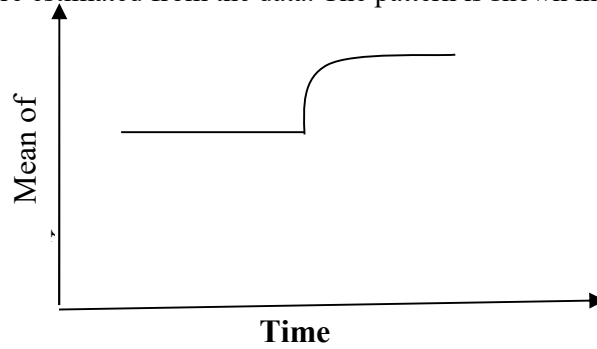


Figure 3: progressive increase that becomes

iv) Instant Change Which Eventually Returns to its original position.

We define $W_t = \frac{\beta_o}{1 - k_1} p_t = k_1 W_{t-1} + \beta_o p_t$

The same condition above for k_1 holds. We define p_t by:

$$p_t = \begin{cases} 1 & t = T \\ 0 & \text{otherwise} \end{cases}, \text{ then } W_t = \begin{cases} k_1 W_{t-1} & t \geq T + 1 \\ 0 & W_{t-1} = 0 \text{ and } t < T \\ \beta_o & W_{t-1} = 0 \text{ and } t = T \end{cases}$$

The pattern is shown in figure3 below

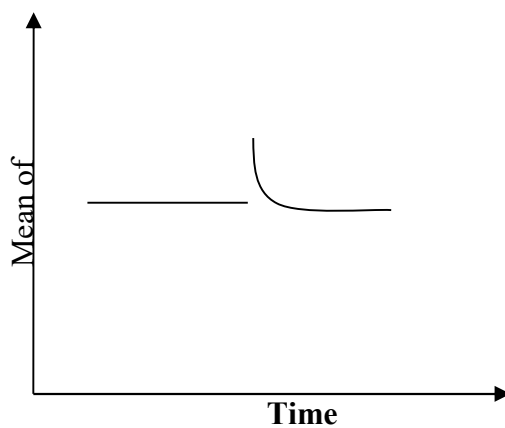


Figure 4: Instant change which returns to its initial position

We used Eviews 7 for all computations of this work.

Results and Discussion

The plot of the exchange rate in figure 1 rise to a certain level after 60 days and did not return, which is an intervention case. The plot of the pre-intervention exchange rate in figure 2 is an indication of a non-stationary series.

A stationarity test shown on table 1 below reveal is in agreement with figure 1 for the t-statistics (-1.921472) is greater than the test critical values (-3.546099, -2.911730, -2.593551) and The probability 0.3205 is greater than 0.05. We differenced the series until it became stationary which is better confirmed from the plot of the differences of pre-intervention rates shown on figure 3 below, the correlogram of the differenced series in figure 4 and the stationarity test on table 2. The t-statistic = -7.279482 is less than the critical values (-3.548208, -2.912631, -2.594027). also the probability is less than 0.05. as shown in table 2. The ACF and PACF shows that the difference of the pre-intervention rate is white noise (see figure 4), hence ARIMA(0,1,0) is fitted, that is

$$\begin{aligned} X_t &= X_{t-1} + \varepsilon_t \\ &= \frac{\varepsilon_t}{1-B} \end{aligned} \quad (4)$$

we have the basis for forecasting the post-intervention period. Let F_t be the forecasts, then $W_t = X_t - F_t$. The graph is shown on figure 5 below and the estimation of the transfer function on table 3.

The transfer function is thus given by:

$$\begin{aligned} W_t & \\ &= \frac{\beta_o(1 - k_1^{t-60})}{1 - k_1} \end{aligned} \quad (5)$$

Where $\beta_o = C(1)$ and $k_1 = C(2)$. Substituting β_o and k_1 into (5) where $\beta_o = 0.192873$ and $k_1 = 0.947528$ yeilds

$$W_t = \frac{0.192873(1-0.947528^{t-60})}{1-0.947528} . \quad \text{Simplifying we have that}$$

$$W_t = 3.67531819(1 - 0.947528^{t-60}) \quad (6)$$

Combining (4) and (6), we have the overall intervention model to be

$$X_t = \frac{\varepsilon_t}{1-B} + 3.67531819(1 - 0.947528^{t-60})I_t \quad (7)$$

$$\text{Where } I_t = \begin{cases} 1 & t \geq T \\ 0 & \text{otherwise} \end{cases}$$

Conclusion

An Arima-intervention model is fitted to South Africa Rand/Nigeria Naira exchange rate data. The R-square and adjusted R-square which is 77% shows that the model is a good fit for the data. The pattern for the intervention is a progressive increase that eventually becomes constant. The change increased gradually and levels off which is not favorable to Nigeria’s economy as the change did not return to its original position.

APPENDIX

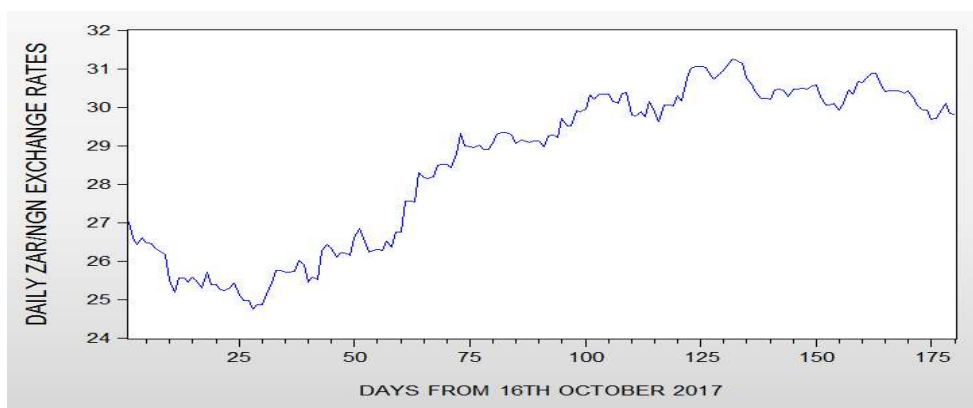


Figure 1: Time Plot of the daily ZAR /NGN exchange rates

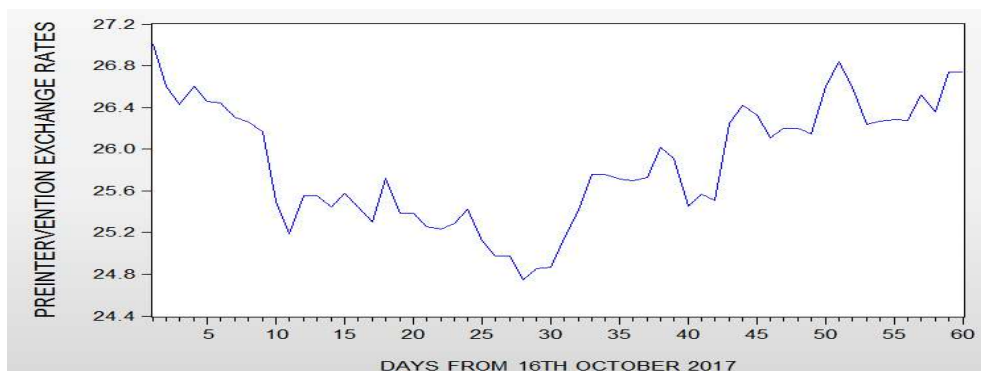


Figure 2: Time Plot of the pre-intervention exchange rates

Table 1: Stationarity test for the pre-intervention

Null Hypothesis: ZARN has a unit root
 Exogenous: Constant
 Lag Length: 0 (Automatic - based on SIC, maxlag=10)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-1.921472	0.3205
Test critical values:		
1% level	-3.546099	
5% level	-2.911730	
10% level	-2.593551	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
 Dependent Variable: D(ZARN)
 Method: Least Squares
 Date: 04/18/18 Time: 11:21
 Sample (adjusted): 2 60
 Included observations: 59 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
ZARN(-1)	-0.104943	0.054616	-1.921472	0.0597
C	2.708171	1.412110	1.917819	0.0601

series

R-squared	0.060833	Mean dependent var	-0.004508
Adjusted R-squared	0.044356	S.D. dependent var	0.242935
S.E. of regression	0.237486	Akaike info criterion	-0.004105
Sum squared resid	3.214780	Schwarz criterion	0.066320
Log likelihood	2.121093	Hannan-Quinn criter.	0.023386

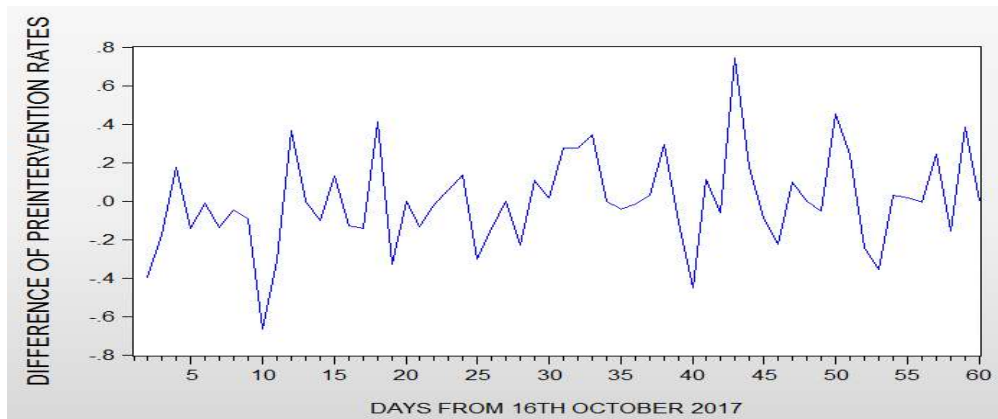


Figure 3: Differences of the pre-intervention rates

Table 2: Stationarity test for the differences of the pre-intervention series

Null Hypothesis: DZARN has a unit root
 Exogenous: Constant
 Lag Length: 0 (Automatic - based on SIC, maxlag=10)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-7.279482	0.0000
Test critical values:		
1% level	-3.548208	
5% level	-2.912631	
10% level	-2.594027	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
 Dependent Variable: D(DZARN)
 Method: Least Squares
 Date: 04/18/18 Time: 11:23
 Sample (adjusted): 3 60
 Included observations: 58 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
DZARN(-1)	-0.948591	0.130310	-7.279482	0.0000
C	0.002541	0.031662	0.080238	0.9363

R-squared	0.486195	Mean dependent var	0.006852
Adjusted R-squared	0.477020	S.D. dependent var	0.333380
S.E. of regression	0.241092	Akaike info criterion	0.026596
Sum squared resid	3.255015	Schwarz criterion	0.097646
Log likelihood	1.228706	Hannan-Quinn criter.	0.054272

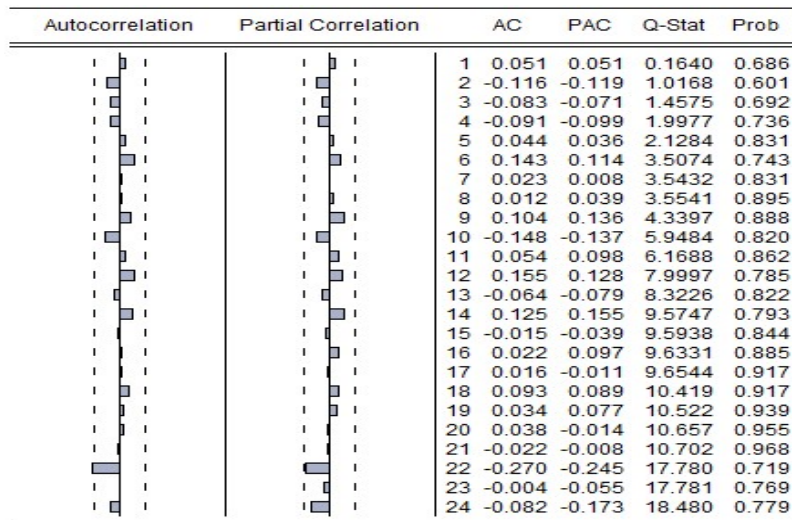


Figure 4: Correlogram of differences of the pre-intervention series

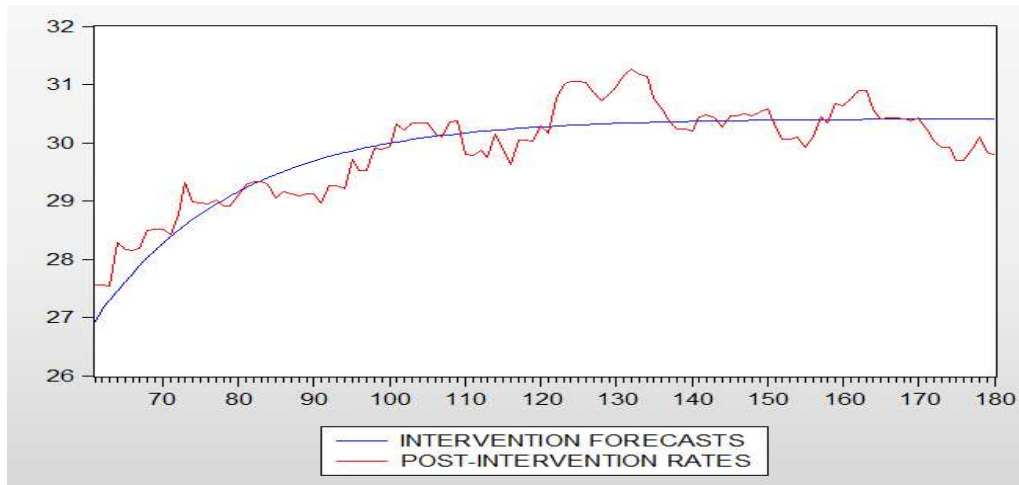


Figure 5: Comparison of the intervention forecasts and post-intervention rates

Table 3: Estimation of the intervention transfer function

Dependent Variable: Z
 Method: Least Squares (Gauss-Newton / Marquardt steps)
 Date: 04/18/18 Time: 12:08
 Sample: 61 180
 Included observations: 120
 Convergence achieved after 14 iterations
 Coefficient covariance computed using outer product of gradients
 $Z=C(1)*(1-C(2)^*(T-60))/(1-C(2))$

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	0.192873	0.010937	17.63560	0.0000
C(2)	0.947528	0.003438	275.6264	0.0000
R-squared	0.768048	Mean dependent var		3.149546
Adjusted R-squared	0.766082	S.D. dependent var		0.826752
S.E. of regression	0.399859	Akaike info criterion		1.021118
Sum squared resid	18.86671	Schwarz criterion		1.067576
Log likelihood	-59.26705	Hannan-Quinn criter.		1.039984
Durbin-Watson stat	0.252915			

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