Available online www.jsaer.com

***Journal of Scientific and Engineering Research*, 2017, 4(6):170-175**

Research Article

ISSN: 2394-2630
CODEN(USA): JSERBR

Interrupted Time Series Analysis of Daily Amounts of Nigerian Naira Per Ugandan Shilling

Ette Harrison Etuk[1], Richard Chinedu Igbudu[2], Anthony Ike Wegbom[3]

[1]Department of Mathematics, Rivers State University, Port Harcourt, Nigeria
[2]Department of Computer Science, Kenule Beeson Saro_Wiwa Polytechnic, Bori, River State, Nigeria
[3]Department of Statistics, Port Harcourt Polytechnic, Pivers State, Nigeria

Abstract This research is about an intervention on daily exchange rates of the Nigerian Naira (NGN) and its Ugandan counterpart, the Shilling (UGX) observed on 22nd June 2016. The realization of this time series studied spans from 19th May 2016 to 17th November 2016. There is an abrupt jump in the amount of Naira exchanged for a shilling from 0.0509 to 0.0609 from 20th June to 21st June 2016 and then to 0.0840 the next day. Instead of coming down it has been moving up. The proposal of an intervention or interrupted time series model to explain this trend of events is the aim of this work. The pre-intervention exchange rates show an initial downward trend up to 26th May 2016 and then an upward trend. They are adjudged to be non-stationary by the Augmented Dickey Fuller (ADF) test, necessitating their first order differencing. These differences are now stationary and are observed to have a random error fit. Post-intervention forecasts are made on the basis of this pre-intervention model. The difference between post-intervention observations and forecasts is modelled to obtain the transfer function of the intervention. This transfer function is observed to be statistically significant. This shows that the model is adequate. Intervention forecasts are observed to closely fit the post-intervention observations. Intervention measures may therefore be based on the proposed model.

Keywords Ugandan Shilling, Nigerian Naira, intervention, exchange rates, ARIMA modelling

Introduction

Exchange rates of national and international currencies are the basis of national and international transactions. Nigerian-Ugandan trade relations are based on the exchange rates of the currencies, the Nigerian naira (NGN) and the Ugandan shilling (UGX). The relationship between the NGN and the UGX has been the subject of inquiry of many researchers in the recent past. For instance Etuk *et al.*(2016a), (2016b) and (2017) have fitted an additive SARIMA model, a subset SARIMA model and a SARIMA$(0,1,0)\times(1,1,0)_7$ model, respectively, to their daily exchange rates [1-3].

It is observed in this study that the daily amounts of NGN per UGX from 19th May 2016 to 17th November 2016 experienced an abrupt jump on 22nd June 2016 and has not reduced from that day onwards and not even after the Central Bank of Nigeria (CBN) has been pumping dollars into the Foreign Exchange Market as a remedial measure early 2017. It is being speculated that this trend is brought about by the current economic recession bedevilling the Nigerian nation. This is an intervention analysis problem, the intervention being the economic recession and the point of intervention being 22nd June 2016. This work is aimed at proposing an intervention model to explain the effect of economic recession on the NGN/UGX exchange rates. We shall employ the Box-Tiao (1975) approach of interrupted time series analysis [4].

This approach is based on autoregressive integrated moving average (ARIMA) modelling of the pre-intervention series. Many scholars have successfully applied this approach to account for the impact of interventions to the movements in some time series. For instance, Hipel *et al.* (1975) used intervention analysis to study the effect of Aswan dam on the average flow of the Nile River. They concluded that a significant drop in the flow took place in 1903 when the dam was brought into operation [5]. Sakthivadivel *et al.* (1998) observed that the intervention of an irrigation system in India was not effective because of certain factors [6]. Darmanin (2016) in her Master of Science (Statistics) seminar studied the effect of the introduction of low-cost airlines on Maltese tourism patronage [7]. Classical and Bayesian approaches to time series intervention analysis have been compared and contrasted by Santos *et al.* (2017) with the inference that the former is the better approach in explaining intervention on some Brazillian economic time series [8]. Wiradinata *et al.* (2017) have concluded that in Riau Province of Indonesia forest fires, peat land and illegal burning impact negatively on the number of domestic airline flights. These are to mention only a few cases [9].

Materials and Methods

Data:

The data of this study are daily amounts of NGN per UGX form 19th May 2016 to 17th November 2016, retrieved from the website www.exchangerates.org.uk/UGX-NGN-exchange-rate-history.html

The website was accessed for this purpose on 18th November 2016. The data are also listed in the Appendix.

Interrupted Time Series Analysis:

Consider a time series $\{X_t\}$. Suppose that it experiences an intervention at time t=T. Box and Tiao (1975) [4] propose that the pre-intervention part of the series be modelled by an ARIMA model. Let this model be an ARIMA(p,d,q). That is,

$$A(L)\nabla^d X_t = B(L)\varepsilon_t \quad (1)$$

where $A(L) = 1 - \alpha_1 L - \alpha_2 L^2 - \ldots - \alpha_p L^p$ and $B(L) = 1 + \beta_1 L + \beta_2 L^2 + \ldots + \beta_q L^q$ are the autoregressive (AR) and the moving average (MA) operators respectively. The α's and β's are constants such that the model (1) is stationary as well as invertible. L is the backshift operator defined by $L^k X_t = X_{t-k}$ and the symbol ∇ is the differencing operator defined as $\nabla = 1\text{-}L$. The sequence of random variables $\{\varepsilon_t\}$ is a white noise process. Model (1) may be described as an autoregressive moving average (ARMA) model of the d^th difference $\{\nabla^d X_t\}$ of the time series $\{X_t\}$. Equivalently

$$X_t = \frac{B(L)\varepsilon_t}{A(L)\nabla^d} \quad (2)$$

On the basis of model (1) forecasts are obtained for the post-intervention period. Suppose these are F_t, $t \geq T$. Suppose $Z_t = X_t - F_t$, $t \geq T$. Then

$$Z_t = \frac{C(1)*(1-C(2)^{t-T+1})}{(1-C(2))}, t \geq T \quad (3)$$

gives the intervention transfer function [10].

Hence the overall intervention model is given by

$$Y_t = \frac{B(L)\varepsilon_t}{A(L)\nabla^d} + \frac{c(1)*(1-c(2)^{t-T+1})I_t}{(1-c(2))} \quad (4)$$

where $I_t = 1$, $t \geq T$ and 0 otherwise.

The estimation of model (1) invariably begins with the determination of the orders p, d and q. The differencing order is the minimum order of differencing such that the pre-intervention series is stationary. Stationarity shall be tested using the Augmented Dickey Fuller (ADF) Test. The AR order p and the MA order q may be estimated by the cut-off lags of the partial autocorrelation function (PACF) and the autocorrelation function (ACF), respectively, of $\{\nabla^d X_t\}$. The α's and β's and c(1) and c(2) may be estimated by the least squares technique.

Computer Package: The eviews 7 package is used for all computational work for this study. It employs the least square procedure of model estimation.

Results and Discussion

The time-plot of the 183-point exchange rates in Figure 1 shows an horizontal trend up to 22nd June 2016 after which there is a sharp rise in the amount of Naira which is exchange for the shilling. The plot has a peak in the third and fourth weeks of August 2016.

The pre-intervention exchange rates are plotted in Figure 2. It has an initial downward trend and a generally upward trend. Needless to say, this is not a stationary time series. To confirm, the ADF Test statistic is equal to -2.07 and the 1%, 5% and 10% critical values are -3.65, -2.96 and -2.62 respectively.

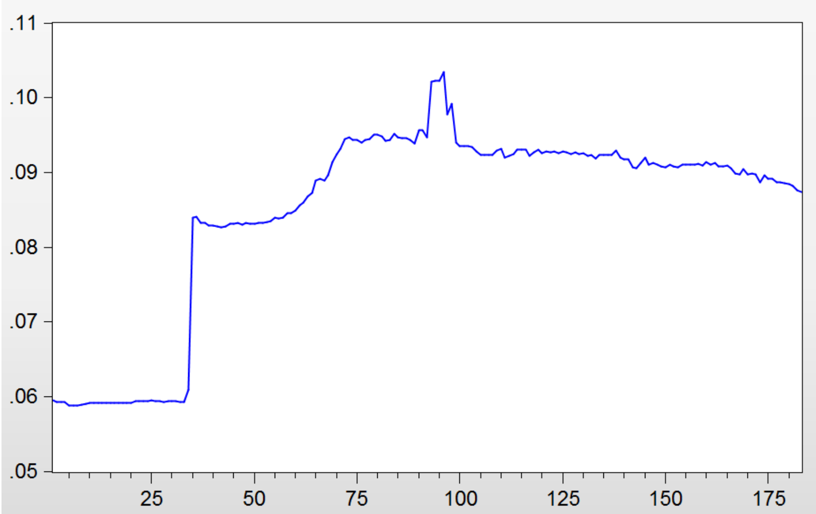


Figure 1: Daily Amount of Naira per Shilling

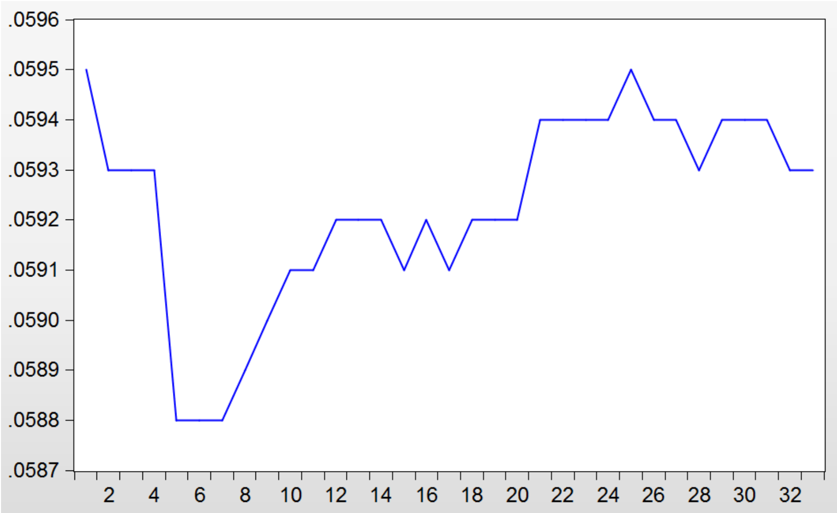


Figure 2: Pre-intervention Exchange Rates

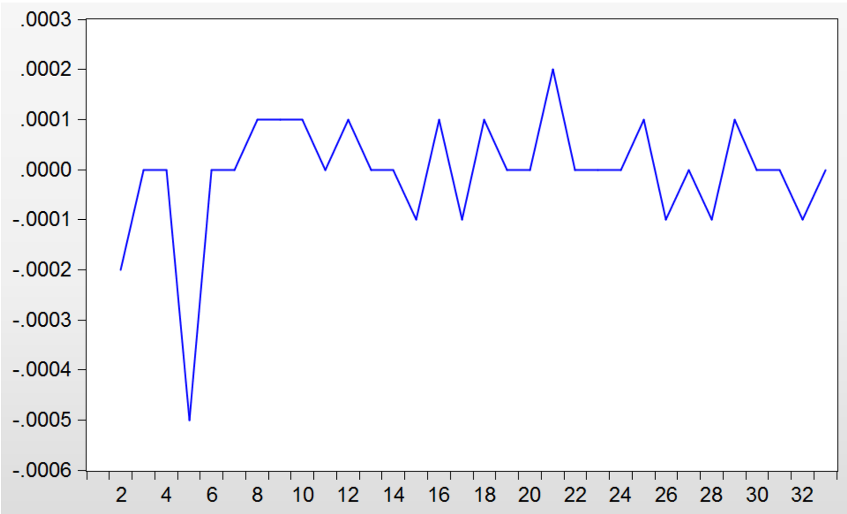


Figure 3: Differnece of Pre-intervention Data

First order differencing of the pre-intervention exchange rates yields a series with generally no .trend (See Figure 3). With an ADF test statistic of -6.01 and the same critical values as listed above, they are adjudged as stationary. Their correlogram in Figure 4 shows that all correlations and partial correlations are not statistically significant. This suggests a random error fit. In support, their histogram in Figure 5 shows a zero mean. Therefore, the pre-intervention exchange rates follow the model

$$(1-L)X_t = \varepsilon_t \quad (5)$$

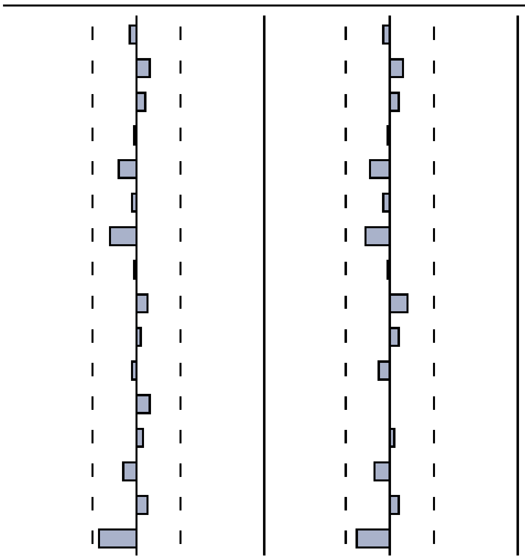
On the basis of model (5) forecasts are made for the post-intervention period. These forecasts are subtracted from the post-intervention observations and the differences modelled as given by equation (3). The estimation of this transfer function is given in Table 1 as

$$Z_t = \frac{0.004080 * (1 - 0.874601^{t-33})}{(1 - 0.874601)} \quad (6)$$

where t ≥ 34. By formula (4) the overall intervention model is given by

$$Y_t = \frac{\varepsilon_t}{1-L} + \frac{0.004080 * (1 - 0.874601^{t-33}) I_t}{(1 - 0.874601)} \quad (7)$$

where I_t = 1, t ≥ 34 and zero elsewhere.



	AC	PAC	Q-Stat	Prob
1	-0.065	-0.065	0.1505	0.698
2	0.110	0.106	0.5908	0.744
3	0.067	0.081	0.7567	0.860
4	-0.014	-0.017	0.7643	0.943
5	-0.146	-0.168	1.6256	0.898
6	-0.036	-0.062	1.6796	0.947
7	-0.212	-0.189	3.6313	0.821
8	-0.016	-0.012	3.6425	0.888
9	0.091	0.148	4.0300	0.909
10	0.025	0.067	4.0610	0.945
11	-0.042	-0.085	4.1516	0.965
12	0.111	0.005	4.8181	0.964
13	0.042	0.036	4.9215	0.977
14	-0.109	-0.129	5.6373	0.975
15	0.086	0.075	6.1097	0.978
16	-0.307	-0.269	12.499	0.709

Figure 4: Correlogram of Difference of Pre-Intervention Rates

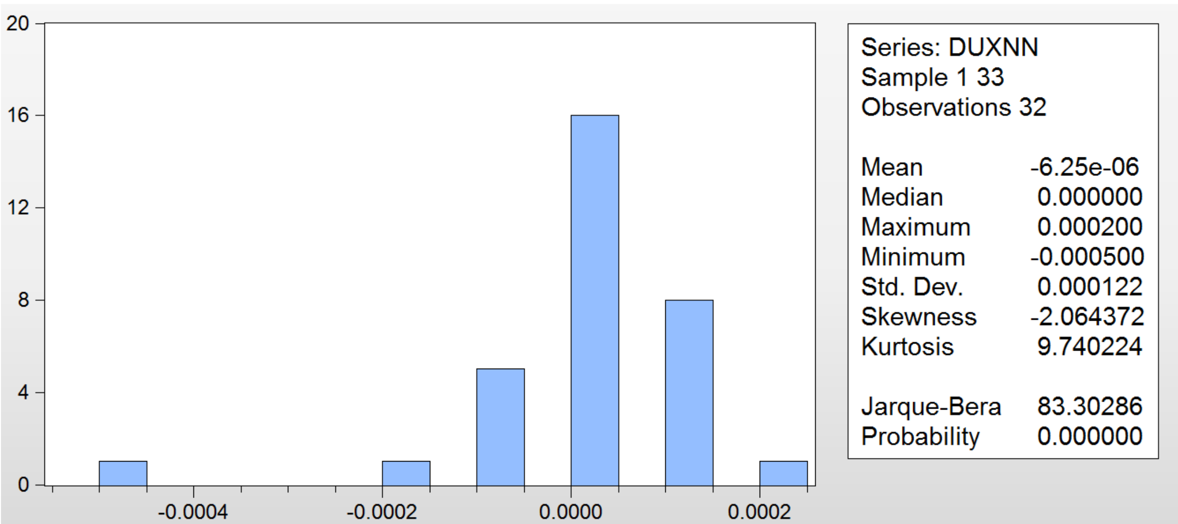


Figure 5: Histogram of Difference of Pre-Intervention Rates

Table 1: Estimation of the Intervention Transfer Function

Dependent Variable: Z
Method: Least Squares
Date: 05/14/17 Time: 15:52
Sample: 34 183
Included observations: 150
Convergence achieved after 12 iterations
Z=C(1)*(1-C(2)^(T-33))/(1-C(2))

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	0.004080	0.000344	11.86246	0.0000
C(2)	0.874601	0.010966	79.75602	0.0000

R-squared	0.374609	Mean dependent var	0.031213
Adjusted R-squared	0.370383	S.D. dependent var	0.004919
S.E. of regression	0.003903	Akaike info criterion	-8.240824
Sum squared resid	0.002255	Schwarz criterion	-8.200682
Log likelihood	620.0618	Hannan-Quinn criter.	-8.224515
Durbin-Watson stat	0.256278		

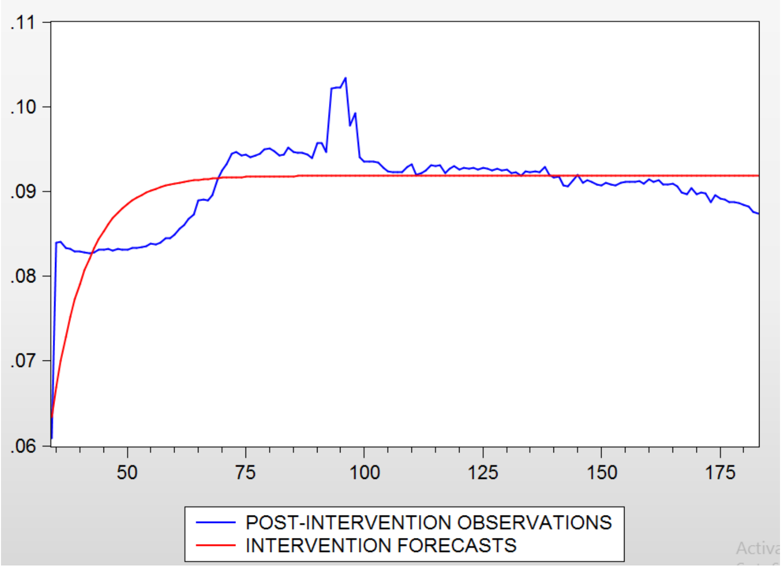


Figure 6: Comparison of Post-Intervention Observations and Forecasts

Conclusion

There is a close agreement between post-intervention observations and the forecasts as may be seen in Figure 6. Hence the intervention model (7) is adequate. The model explains the impact of the economic recession on the amount of Naira which is exchanged for a Ugandan shilling. This is certainly going to assist Nigerian managers and government officials to put up intervention measures to remedy the situation.

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Appendix

Data*

0.0595 0.0593 0.0593 0.0593 0.0588 0.0588 0.0588 0.0589 0.0590 0.0591 0.0591 0.0592 0.0592
0.0592 0.0591 0.0592 0-0591 0.0592 0.0592 0.0592 0.0594 0.0594 0.0594 0.0594
0.0595 0.0594 0.0594 0.0593 0.0594 0.0594 0.0594 0.0593 0.0593 0.0609 0.0840 0.0841
0.0833 0.0832 0.0829 0.0829 0.0828 0.0827 0.0828 0.0831 0.0831 0.0832 0.0830 0.0832
0.0831 0.0831 0.0833 0.0833 0.0834 0.0835 0.0839 0.0838 0.0840 0.0845 0.0845 0.0849
0.0856 0.0860 0.0868 0.0873 0.0889 0.0891 0.0889 0.0896 0.0914 0.0925 0.0932 0.0945
0.0947 0.0943 0.0944 0.0940 0.0943 0.0945 0.0950 0.0951 0.0948 0-0942 0.0944 0.0952
0.0947 0.0946 0.0946 0.0944 0.0939 0.0957 0.0957 0.0947 0.1021 0.1023 0.1023 0.1034
0.0978 0.0992 0.0940 0.0935 0.0935 0.0935 0.0934 0.0928 0.0924 0.0923 0.0923 0.0923
0.0929 0.0932 0.0920 0.0922 0.0925 0.0931 0.0930 0.0931 0.0922 0.0927 0.0930 0.0926
0.0928 0.0927 0.0928 0.0926 0.0928 0.0927 0.0925 0.0927 0.0925 0.0926 0.0922 0.0923
0.0919 0.0924 0.0923 0.0924 0.0923 0.0929 0.0920 0.0917 0.0918 0.0907 0.0906 0.0913
0.0920 0.0910 0.0913 0.0911 0.0908 0.0907 0.0910 0.0908 0.0907 0.0910 0.0911 0.0911
0.0911 0.0912 0.0909 0.0914 0.0911 0.0913 0.0908 0.0908 0.0909 0.0906 0.0899 0.0897 0.0904
0.0897 0.0899 0.0898 0.0887 0.0896 0.0892 0.0891 0.0887 0.0887 0.0886 0.0884
0.0882 0.0876 0.0874

* The data are arranged row-wise.