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Arima Intervention Modelling of Daily West African Franc (XOF) – Nigerian Naira (NGN) Exchange Rates

Ette Harrison Etuk*
Department of Mathematics,
Rivers State University
Nigeria

Love Cherukei Nnoka
Department of Mathematics/Statistics,
Port Harcourt Polytechnic
Rivers State, Nigeria

Idorenyin Augustine Etukudo
Department of Mathematics/Statistics
Akwa Ibom State University
Ikot Akpaden, Nigeria

Abstract— A look at the time-plot of daily exchange rates of West African Franc (XOF) and the Nigerian Naira (NGN) from 19th May 2016 to 13th November 2016 reveals a sharp rise in the amount of Naira from 0.35 to 0.49 per XOF from 21st to 22nd June 2016. From that point onward the naira keeps reducing relatively. This is an intervention case. This means that the point of intervention is 22nd June 2016. It is believed that this intervention is the current Nigerian economic recession which is bedevilling the country. This paper is aimed at proposing an intervention model to explain this phenomenon. The method to adopt is the autoregressive integrated moving average (ARIMA) method. The pre-intervention exchange rates are non-stationary. Differencing it once makes it stationary. Its partial autocorrelation and autocorrelation structures suggest a random noise fit. The difference between post-intervention forecasts and observations is modelled for the intervention transfer function. This is observed to be statistically significant and the forecasts based on it are very closely in agreement with the corresponding observations.

Keywords— XOF, NGN, exchange rates, Intervention analysis, ARIMA modelling

I. INTRODUCTION

An examination of the exchange rates of the West African Franc (XOF) and the Nigerian Naira (NGN) from May 2016 to November 2016 shows an abrupt jump in the amount of NGN per XOF on 22 June 2016. Thereafter it has not reduced. It is speculated that the intervention is the recession in the economy of the Nigerian country. The point of intervention is therefore 22 June 2016. The purpose of this paper is to build an intervention model to explain the behaviour of this time series.

The XOF is the currency of the West African region involving these countries: Benin, Burkina Faso, Chad, Cote d'Ívoire, Senegal, Togo and Mali. It was introduced in the year 1945. On the other hand, the NGN was introduced to the Nigerian populace in the year 1973. International trade between the two geopolitical regions is on the basis of the exchange rates between the currencies. The relationship between the XOF and the NGN has engaged the attention of some researchers. For instance Etuk *et al.* {1] fitted a seasonal autoregressive integrated moving average (SARIMA) model of order $(0,1,1)x(0,1,1)_7$ to their daily exchange rates.

The approach to the intervention modelling of the exchange rates shall be the autoregressive integrated moving average (ARIMA) approach introduced by Box and Tiao [2]. This approach is well tested and successfully applied by many scholars. For instance, Hull *et al.* [3] observed that fluoxetine was effective in the treatment of a long-term personal disorder. The Perch Solar City program in Australia was evaluated by the use of six interventions, namely: living smart, home eco-consultancy, in-home display, solar photovoltaic systems, power-shift and solar hot water systems (See Data Analysis Australia, [4]). It was found that most of these interventions impacted on total household electricity consumption. Pridemore *et al.* [5] noted a reduction of male suicide cases following the introduction of Russian alcohol policy implemented in January 2006 to reduce alcohol consumption. The positive effect of the re-introduction of dichlorodiphenyltrichloroethane in the lowering of malaria incidence was observed by Ebhuoma *et al.* [6] using ARIMA intervention analysis. Rezeki *et al.* [7] studied the impact of monetary crisis and gambling prohibition policy on tourism in Batam, Indonesia.

This work has the following structure: section II is concerned with the materials and methods used, section III involves the results and discussion and section IV concludes it. After the conclusion cited references are listed. Then the data used are listed in the Appendix.

II. MATERIALS AND METHODS

Data: The data for this write-up are daily XOF/NGN exchange rates from May 19, 2016 to November 13, 2016 from the website www.exchangerates.org.uk/XOF-NGN-exchange-rate-history.html accessed on 14 November 2016. These are read as the amount of NGN in one XOF. The data are listed in the appendix.

Arima Intervention Analysis: Suppose a time series $\{X_t\}$ experiences an intervention at time t = T. Box and Tiao (1975) proposed that the pre-intervention data be modelled as an ARIMA model. This means that at time t < T,

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

where

$A(L) = 1 + \alpha_1 L + \alpha_2 L^2 + ... + \alpha_p L^p$

and $B(L) = 1 + \beta_1 L + \beta_2 L^2 + ... + \beta_q L^q$.

Here L is the backshift operator defined by

$L^k X_t = X_{t-k}$

and the α's and β's are constants such that model (1) is invertible as well as stationary. ∇ is the difference operator such that ∇= 1-L and d is the order of differencing so that the series $\{\nabla^d X_t\}$ is stationary. The sequence $\{\varepsilon_t\}$ is a white noise process. The ARIMA model (1) is said to be of order (p, d, q).

The equation (1) can be written as

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

For a practical time series model (1) or (2) may be fitted by first of all estimating the orders p, d and q. The differencing order is put initially equal to zero. If the series is adjudged stationary, d = 0. Otherwise try d=1. Test for stationarity is done. If the series is stationary then d = 1 and so on. The Augmented Dickey Fuller (ADF) Test shall be used to test for stationarity. Once stationarity has been ascertained, the autoregressive order p is estimated as the lag after which the partial autocorrelation function (PACF) ceases to be statistically significant. The same thing applies to the moving average order q with respect to the autocorrelation function (ACF). Thereafter the estimation of the α's and β's may be done by the least squares approach.

Box and Tiao [2] further proposed that on the basis of the pre-intervention ARIMA(p, d, q) (1) or (2) forecasts be made for the post-intervention period (i.e. for t ≥ T). Suppose these forecasts are F(t), t ≥ T. Let $Z(t) = X_t - F(t)$, t ≥ T.

$$Z(t) = C(1) * \frac{(1 - C(2)^{t-T+1})}{1 - C(2)} \qquad (3)$$

represents the transfer function for the intervention model (Pennsylavania State University, [8]). The model (3) may be estimated by the least squares approach.

Computer Package: The statistical and econometric software Eviews 7 shall be used for all data analysis done herein. It is based on the least (error sum of) squares approach to model estimation.

III. RESULTS AND DISCUSSION

The time plot of the exchange rates in Figure 1 shows an initial fairly horizontal trend (i.e. of the pre-intervention period) and then an abrupt jump on 22 June 2016 which ushers in the post-intervention period. The intervention point is therefore 22 June 2016 or T = 35. The pre-intervention data has an overall slightly positive trend with a peak at the middle (See Figure 2). The ADF test, with the test statistic value of -0.15 and 1%, 5%, 10% critical values of -3.65, -2.95, -2.62 respectively, adjudges it as non-stationary. Therefore it was necessary to difference it once. This first difference has a fairly horizontal trend with a zero mean and a near zero standard deviation as evident from its time plot in Figure 3 and its histogram in Figure 4. With an ADF test statistic value of -3.68 and the same critical values as given above, it is certified to be stationary. Its correlogram of Figure 5 shows an autocorrelation structure of a random error fit, none of the autocorrelations and partial autocorrelations being statistically significant. This implies from equation (2) that

$$X_t = \frac{\varepsilon_t}{1 - L} \qquad (4)$$

On the basis of this model forecasts are made for the post-intervention period. The difference between the post-intervention original data and the corresponding forecasts is modelled by equation (3). As summarized in Table 1, C(1)=0.017929 and C(2)=0.900182. Hence the intervention transfer function is given by

$$Z_t = \frac{0.017929 * (1 - 0.900182^{t-34})}{1 - 0.900182}, \ t \geq 35 \qquad (5)$$

Combining (4) and (5) yields the overall intervention analysis as

$$Y_t = \frac{\varepsilon_t}{1 - L} + 0.17962 * I_t * (1 - 0.900182^{t-34}) \qquad (6)$$

where $I_t = 0$, t < 35, $I_t = 1$, t ≥ 35. Observed is a very close agreement between the post-intervention observations and their corresponding forecasts as can be seen in Figure 6.

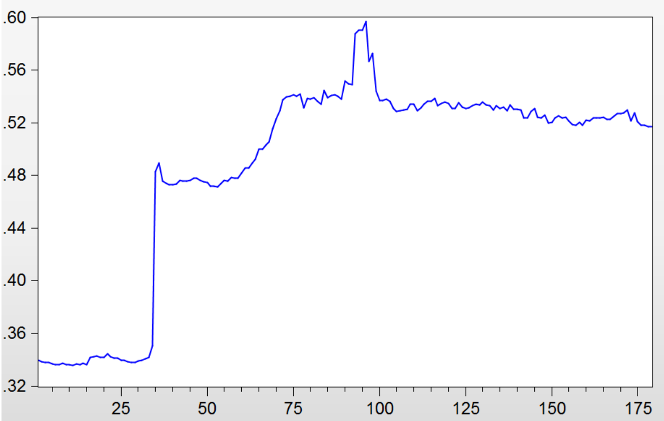


Figure 1: Daily XOF/NGN Exchange Rates

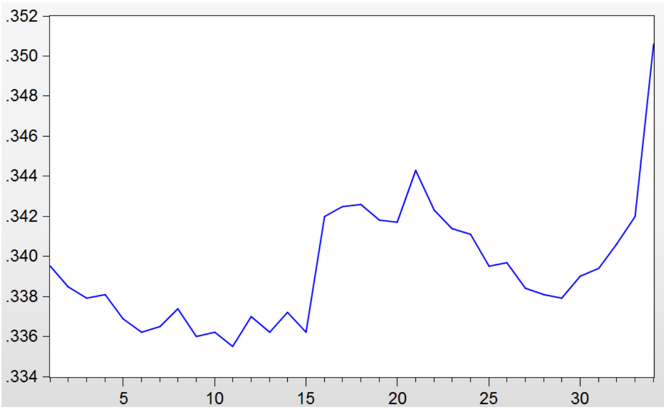


Figure 2: Pre-intervention XOF/NGN exchange rates

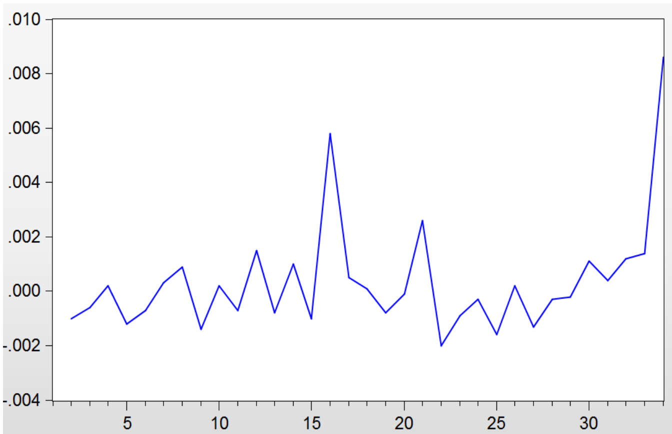


Figure 3: Difference of Pre-intervention exchange rates

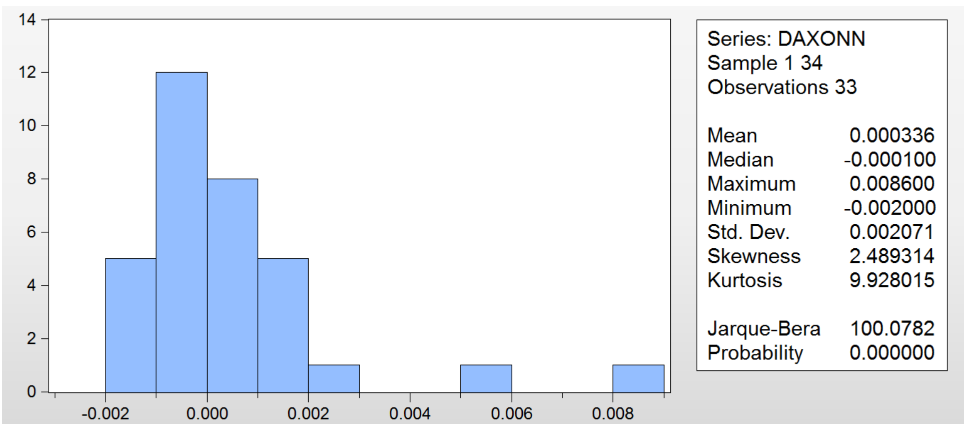
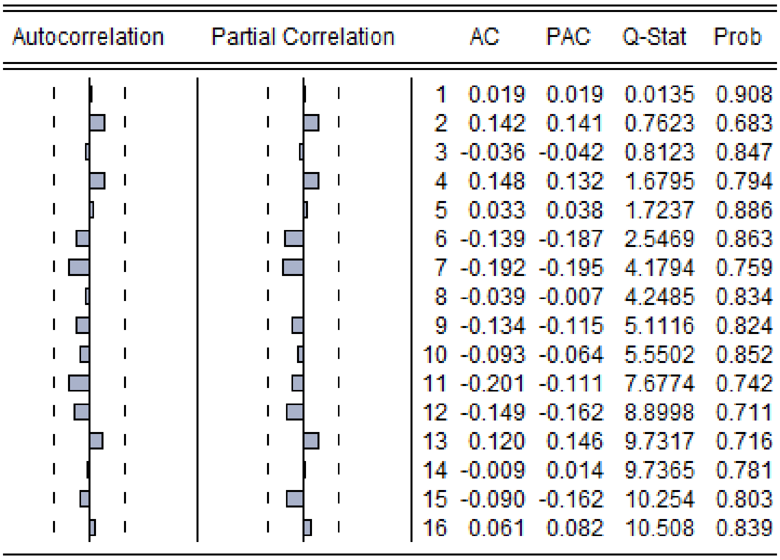


Figure 4: Histogram of Difference of Pre-intervention exchange rates



	AC	PAC	Q-Stat	Prob
1	0.019	0.019	0.0135	0.908
2	0.142	0.141	0.7623	0.683
3	-0.036	-0.042	0.8123	0.847
4	0.148	0.132	1.6795	0.794
5	0.033	0.038	1.7237	0.886
6	-0.139	-0.187	2.5469	0.863
7	-0.192	-0.195	4.1794	0.759
8	-0.039	-0.007	4.2485	0.834
9	-0.134	-0.115	5.1116	0.824
10	-0.093	-0.064	5.5502	0.852
11	-0.201	-0.111	7.6774	0.742
12	-0.149	-0.162	8.8998	0.711
13	0.120	0.146	9.7317	0.716
14	-0.009	0.014	9.7365	0.781
15	-0.090	-0.162	10.254	0.803
16	0.061	0.082	10.508	0.839

Figure 5: Correlogram of difference of Pre-intervention exchange rates

Table I Estimation of the Intervention Transfer Function

	Coefficient	Standard Error	t-Statistic	Probability
C(1)	0.017929	0.001546	11.59923	0.0000
C(2)	0.900182	0.009043	99.53988	0.0000

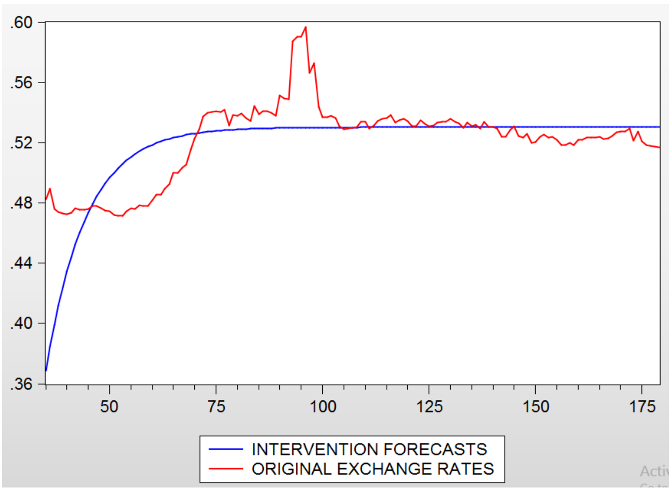


Figure 6: Post-intervention observations and forecasts

IV. CONCLUSION

It may be concluded that the intervention model to explain the change in the level of the exchange rates in favour of the XOF is given in equation (6). The statistical significance of the coefficients is an indication of model adequacy. This model may be employed by policy makers in Nigeria to ameliorate the exchange rates in favour of the country.

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APPENDIX

DATA*

0.3395 0.3385 0.3379 0.3381 0.3369 0.3362 0.3365 0.3374 0.3360 0.3362 0.3355 0.3370 0.3362 0.3372 0.3362
0.3420 0.3425 0.3426 0.3418 0.3417 0.3443 0.3423 0.3414 0.3411 0.3395 0.3397 0.3384 0.3381 0.3379 0.3390
0.3394 0.3406 0.3420 0.3506 0.4862 0.4894
0.4759 0.4740 0.4732 0.4727 0.4733 0.4765 0.4756 0.4757 0.4762 0.4781 0.4781 0.4764 0.4752 0.4745 0.4719
0.4717 0.4715 0.4743 0.4763 0.4758 0.4784 0.4779 0.4779 0.4818 0.4855 0.4856 0.4897 0.4924 0.5001 0.5001
0.5033 0.5054 0.5155 0.5230 0.5290 0.5375 0.5397 0.5403 0.5411 0.5404 0.5417 0.5313 0.5384 0.5379 0.5392
0.5365 0.5343 0.5446 0.5390 0.5410 0.5411 0.5401 0.5378 0.5515 0.5494 0.5488 0.5474 0.5904 0.5903 0.5969
0.5665 0.5727 0.5438 0.5367 0.5368 0.5379 0.5363 0.5308 0.5288 0.5292 0.5297 0.5302 0.5339 0.5339 0.5294
0.5314 0.5343 0.5361 0.5362 0.5386 0.5332 0.5347 0.5357 0.5346 0.5311 0.5309 0.5350 0.5322 0.5309 0.5315
0.5333 0.5339 0.5337 0.5359 0.5337 0.5329 0.5299 0.5333 0.5310 0.5319 0.5293 0.5337 0.5304 0.5303 0.5296
0.5239 0.5239 0.5286 0.5311 0.5243 0.5236 0.5257 0.5198 0.5203 0.5239 0.5252 0.5234 0.5241 0.5217 0.5185
0.5184 0.5201 0.5184 0.5219 0.5217 0.5234 0.5235 0.5235 0.5240 0.5225 0.5227 0.5245 0.5268 0.5272 0.5276
0.5296 0.5215 0.5274 0.5209 0.5184 0.5181 0.5173 0.5169

*Note : The data are to be read row-wise.