Intervention Analysis of Daily Indian Rupee/Nigerian Naira Exchange Rates

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Abstract: Time series plot of a realization of daily exchange rates of Indian Rupee and Nigerian Naira from 18th March, 2017 to 10th September, 2017 shows the occurrence of an intervention on 4th August, 2017. This research work has an aim of proposing an intervention model to explain the impact of this intervention believed to be due to the economic recession in Nigeria. Pre-intervention series is observed to be stationary by the Augmented Dickey Fuller Test. Following the shown autocorrelation structure of the series, an adequate subset ARMA(13, 12) model is fitted to it. On the basis of this model forecasts are made for the post-intervention period. Difference between these forecasts and their corresponding actual observations are modeled to obtain the intervention transfer function and the desired overall intervention model. Management of these exchange rates may be made on the basis of this model.

Keywords: Indian Rupee, Nigerian Naira, Exchange Rates, Arima Modelling, Intervention Analysis.

1. Introduction and Literature Review

India uses the Rupee as its legal tender and it has as acronym INR (for Indian Rupee). On the other hand Naira is the Nigerian currency and is denoted by NGN (for Nigerian Naira). Exchange rates between the two currencies are the basis for international trade between the two nations and may be used as proxy for relative performance of their economies. The purpose of this work is to propose an intervention model for their exchange rates. This is sequel to an observation that on 4th August, 2017, there was a sharp and abrupt decrease in the comparative value of the Naira and it has not recovered since then. The data analyzed started from 18th March to 10th September 2017. It is believed that this intervention situation is due to the current economic recession in Nigeria. The approach is that of Box and Tiao (1975) which is based on ARIMA methodology and it has been extensively applied on many time series successfully.

For instance, Masukawa et al. (2014) studied the impact of the introduction of a rotavirus vaccine on rates of hospitalization of children less than 5 years old for acute diarrhea. Valadkhani and Layton (2004) examined the effect of goods and services tax on inflation in Australia. They observed a transitory effect. Ismail (2009) has noticed a significant impact of fiscal and political instability on the Naira/US Dollar exchange rates. Etuk et al. (2017) has fitted an intervention model to the Euro/British Pound exchange rates occasioned by Brexit. An intervention study has been conducted by Etuk and Eleki (2017) on the exchange rates of the Central African Franc and the Nigerian naira still due to the current economic recession in Nigeria. Impact of subprime mortgage crisis in the United States of America on the exports and the manufacturing industry of China has been investigated by Chung et al. (2009), to mention but a few.

2. Materials and Methods

2.1. Data

The data analyzed in this work are daily INR/NGN exchange rates from 18\textsuperscript{th} March, 2017 to 10\textsuperscript{th} September, 2017 from the website www.exchangerates.org.uk/INR-NGN-exchange-rate-history.html. They are read as the amounts of NGN per INR. They are listed in the appendix.
2.2. Intervention Modeling

Let \( [X_t] \) be a time series encountering an intervention at time \( t=T \). Box and Tiao (1975) proposed that the pre-intervention part of the series be modeled by ARIMA techniques. That is, for \( t < T \), suppose that the ARIMA(\( p, d, q \)) model

\[
\nabla^d X_t = \alpha_1 \nabla^d X_{t-1} + \alpha_2 \nabla^d X_{t-2} + \cdots + \alpha_p \nabla^d X_{t-p} + \epsilon_t + \beta_1 \epsilon_{t-1} + \beta_2 \epsilon_{t-2} + \cdots + \beta_q \epsilon_{t-q}
\]

(Where \( \nabla X_t = X_t - X_{t-1} \)) is fitted. Model (1) may be put as

\[
\Phi(L)(1-L)X_t = \Theta(L)\epsilon_t
\]

(2)

Where \( L^k X_t = X_{t-k} \), \( \Phi(L) = 1 - \alpha_1 L - \alpha_2 L^2 - \cdots - \alpha_p L^p \) is the autoregressive (AR) operator and \( \Theta(L) = 1 + \beta_1 L + \beta_2 L^2 + \cdots + \beta_q L^q \) is the moving average (MA) operator. The \( \alpha \)'s and \( \beta \)'s are chosen such that the zeroes of \( \Phi(L) = 0 \) are outside of the unit circle for model stationarity and the zeroes of \( \Theta(L) = 0 \) are outside of the unit circle for model invertibility.

From (2) the noise part of the intervention model is

\[
V_t = \frac{\epsilon_t}{\sigma(L)(1-L)^d}
\]

(3)

On the basis of the model forecasts are obtained for the post-intervention part of the time series. Suppose these are \( F_t \), \( t \geq T \). Then for \( t \geq T \)

\[
Z_t = X_t - F_t = \frac{(1+c(2)-T+1)/(1+c(2)))}{(1-c(2))}
\]

(4)

This is the transfer function of the intervention model. The model is then given by combining (3) and (4) to have

\[
Y_t = \frac{\epsilon_t}{\sigma(L)(1-L)^d} + I_t Z_t
\]

(5)

Where \( I_t \) is an indicator variable such that \( I_t = 1 \) in the post-intervention period and zero otherwise.

Computer Package: Eviews 10 was used to do all computations in this work.

3. Results and Discussion

The time plot of the realization of the time series used in this work is shown in Figure 1. After three spikes, there is a sudden sharp increase on 4th August 2017 after which there is no fall in the series. This is the point of intervention. Prior to this point the exchange rates, apart from three spikes between time point 100 and 125, exhibit a fairly flat trend (See Figure2). They are adjudged stationary by the Augmented Dickey Fuller Test (See Table 1). Their correlogram of Figure 3 shows evidence of seasonality of order 12. This informs the fitting of an ARIMA(13,12) model estimated in Table 2 as

\[
X_t = 0.5947X_{t-1} + 0.6618X_{t-12} - 0.2564X_{t-13} - 0.3776\epsilon_{t-1} - 0.3661\epsilon_{t-12}
\]

(6)

The autocorrelation structure of its residuals shown in Figure 4 looks like that of white noise, an indication of model adequacy. On its basis the noise component of the model is

\[
V_t = \frac{(1-0.3776L-0.3661L^{13})\epsilon_t}{1-0.5947L-0.6618L^{12}+0.2564L^{13}}
\]

(7)

On the basis of model (6) forecasts \( F_t \) were obtained for the post-intervention period. The transfer function is estimated as summarized in Table 3 as

\[
Z_t = X_t - F_t = \frac{0.842247*(1-(0.108582)^{T-139})}{1.108582}
\]

(8)
giving the overall model as

\[ Y_t = V_t + I_t Z_t \]  \hspace{1cm} (9)

Where \( I_t = 1, \ t \geq 140, \) zero elsewhere. Forecasts and actual observations of the post-intervention period closely agree (See Figure 5).

4. Conclusion

It may be concluded that model (9) adequately explains the impact of the Nigerian-economic-recession induced 4th August 2017 intervention on the daily INR/NGN exchange rates. The model may be used for the management and amelioration of the situation by the Nigerian Government.

References


![Figure 1](image-url)  \hspace{1cm} **Figure 1.** Time plot of daily INR/NGN exchange rates

*Source:* Computation by the authors using Eviews 10.
Figure 2. Time plot of the pre-intervention data

![Time plot of the pre-intervention data](image)

Source: Computation by the authors using Eviews 10.

Table 1. Stationarity test for pre-intervention data

<table>
<thead>
<tr>
<th>Null Hypothesis: Pre-Intervention Data has a unit root</th>
<th>t-Statistic</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Augmented Dickey-Fuller test statistic</td>
<td>-9.550144</td>
<td>0.0000</td>
</tr>
<tr>
<td>Test critical values</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1% level</td>
<td>-3.478189</td>
<td></td>
</tr>
<tr>
<td>5% level</td>
<td>-2.882433</td>
<td></td>
</tr>
<tr>
<td>10% level</td>
<td>-2.577990</td>
<td></td>
</tr>
</tbody>
</table>

Source: Computation by the authors using Eviews 10.

Figure 3. Correlogram of the pre-intervention data

![Correlogram of the pre-intervention data](image)

Source: Computation by the authors using Eviews 10.
Table 2. Estimation of the pre-intervention ARIMA model

<table>
<thead>
<tr>
<th>Variable</th>
<th>ARMA</th>
<th>Maximum Likelihood OPG-BHHH</th>
</tr>
</thead>
<tbody>
<tr>
<td>AR(1)</td>
<td>0.594654</td>
<td>0.159896</td>
</tr>
<tr>
<td>AR(12)</td>
<td>0.661779</td>
<td>0.164040</td>
</tr>
<tr>
<td>AR(13)</td>
<td>-0.256435</td>
<td>0.008483</td>
</tr>
</tbody>
</table>

Source: Computation by the authors using Eviews 10.

Figure 4. Correlogram of the pre-intervention ARIMA model residuals

Table 3. Estimation of the intervention transfer function

<table>
<thead>
<tr>
<th>Coefficient</th>
<th>standard error</th>
<th>t-Statistic</th>
<th>probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>C(1)</td>
<td>0.842247</td>
<td>0.082304</td>
<td>10.23337</td>
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<tr>
<td>C(2)</td>
<td>-0.108582</td>
<td>0.109427</td>
<td>-0.992281</td>
</tr>
</tbody>
</table>

Source: Computation by the authors using Eviews 10.

Figure 5. Post-intervention observations and intervention forecasts

Source: Computation by the authors using Eviews 10.
## Appendix

### DATA

<table>
<thead>
<tr>
<th>Month, 2017</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>September, 2017</td>
<td>5.6363 5.6363 5.5933 5.5988 5.5912 5.6133 5.6034 5.6533 5.6533 5.6533</td>
</tr>
</tbody>
</table>