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STATISTICS OF EXCHANGE RATE REGIMES IN NIGERIA

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ABSTRACT

The three distinct exchange rate regimes of Nigeria were subjected to Autoregressive Integrated Moving Average (ARIMA) modeling in order to compare them with respect to model structure. It was found that the three regimes admit different models. Regime one admits Moving average model of order 2, Regime two admits Random walk model while Regime three admits Autoregressive Moving Average, ARMA (1,1) model. The implication of the study is that exchange rate data need to be considered differently according to regimes in order to bring out the essential statistical features.

KEY WORDS: Exchange rate regime; ARIMA model, Stationarity, Random walk model.

INTRODUCTION

Exchange rate has been defined as the price of one currency in terms of another. It can be expressed in one of two ways: as units of domestic currency per unit of foreign currency; or units of foreign currency per unit of domestic currency. But since transactions are made in national (domestic) currencies, the former is generally applied for exchange (Mordi, 2006).

The main objectives of exchange rate are the preservation of the external value of the domestic currency and maintenance of healthy balance of payment. Exchange rate is also regarded as a veritable instrument of economic management and therefore an important macroeconomic indicator used in assessing the overall performance of the economy. Indeed, its movements are known to have ripple effects on other economic variables.

Two concepts of exchange rate are usually distinguished: nominal exchange rate and real exchange rate. The nominal exchange rate (NER) measures the relative price of two moneys while the real exchange rate (RER) measures relative price of two goods. The two concepts are, nonetheless, related in that changes in NER can cause short-run changes in RER. For instance, a NER depreciation/ devaluation will have the effect of depreciating RER. This paper is focused on NER (Units of Naira per Dollar) with the exchange rate data in Nigeria divided into three regimes : 1970-1985,1986-June2002 and July2002-2005.

Granted, several studies Osagie (1985), Ajayi (1988), Adubi et al (1999), Mordi (2006), Obadan (2006) and Odusola (2006) have been carried in recent times on exchange rate and/or exchange regimes in Nigeria. However, none of these works considered the model structure of the different regimes. In this paper, attempt is made to use Autoregressive Integrated Moving Average (ARIMA) model to study exchange rate data according to regimes and make comparisons.

METHODOLOGY

Let $Y_t,\ t = 1, 2, \dots\dots, n$ be the observed data for a given exchange rate regime; which may or may not be stationary. To make the observed series stationary, we difference d times, usually $d = 0, 1, 2,$ (Box,

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Jenkins & Reinsel (1994)). The differenced series $X_t,\ t = 1, 2, \ldots\ldots, n-d$ is given by

$$X_t = \nabla^d Y_t = (1-B)^d X_t \qquad (2.1)$$

where

$$B^j Y_t = Y_{t-j} \qquad (2.2)$$

A time series X_t is said to follow an autoregressive moving average model of order p, q (ARMA (p, q)) if it satisfies the difference equation;

$$X_t - \phi X_{t-1} - \cdots - \phi_p X_{t-p} = e_t - \theta_1 e_{t-1} - \cdots - \theta_q e_{t-q} \qquad (2.3)$$

or

$$\phi(B) X_t = \theta(B) e_t \qquad (2.4)$$

where,

$$\phi(B) = 1 - \phi_1 B - \ldots\ldots\ldots - \phi_p B^p \qquad (2.5)$$

$$\theta(B) = 1 - \theta_1 B - \ldots\ldots\ldots - \theta_q B^q \qquad (2.6)$$

and

e_t (the error term) is generally assumed to be independent and identically distributed random variable from a normal distribution with mean zero and variance, $\sigma^2 < \infty$.

For the process (2.4) to be stationary, we require that the roots of $\phi(B) = 0$ lie outside the unit circle. To be invertible, we require that the roots of $\theta(B) = 0$ lie outside the unit circle. We assume that $\phi(B) = 0$ and $\theta(B) = 0$ share no common roots.

Procedures for choosing p and q often known as model identification as well as estimation of time series models can be found in Box, Jenkins & Reinsel (1994), Chatfield (2004).

Model Estimation and Diagnosis.

Autocorrelation function (ACF) and Partial autocorrelation function (PACF) of the difference series are used for model identification. After which Least Square Method was used to estimate the parameters of the model. All computations (ACF, PACF, estimation of parameters, Box & Ljung Q Statistic) in this work were done using MINITAB.

(a) Regime One (1970 – 1985), n = 192

The ACF and PACF for Y_t and $X_t = \nabla Y_t$ are given in Table 1. It is obvious from Table 1 that Y_t is not stationary. However, $X_t = \nabla Y_t$ is stationary. A close examination of the ACF and PACF of X_t suggests an ARMA (0,2) model; which may or may not be a zero mean process.

For X_t, $\bar{X} = 0.0013$, $s_x = 0.0153$, $n - 1 = 191$, *the test statistic is* $t = \frac{0.0013 - 0}{\frac{0.0153}{\sqrt{192}}} = 1.18$. This t- value is not significant even at 10 per cent significant level and thus the deterministic trend μ is not needed. Hence, the model for Regime one is

$$(1-B)Y_t = (1 - \theta_1 B - \theta_2 B^2) e_t \ldots\ldots\ldots \qquad (3.1)$$

Substituting the least square estimates of the parameters ($\theta_1 = 0.25$, $\theta_2 = -0.1623$), we obtain the model:

$$\nabla Y_t = X_t = (1 - \underset{(0.0728)}{0.25}B + \underset{(0.0728)}{0.1623}B^2) e_t \qquad (3.2)$$

with $\hat{\sigma}^2 = 0.0.0002151$

To determine the adequacy of the model (3.2), a diagnostic check of the residual ACF and PACF given in Table 2 was done. Following Chatfield (2004), the first twenty ACF and PACF lie within $\pm \frac{2}{\sqrt{n}} = \pm \frac{2}{\sqrt{192}} = \pm 0.144$, indicating that the model (3.2) is adequate. Similarly, the values of the Q Statistic (Box and Ljung (1978)) are not significant as given in Table 6 confirming that the model (3.2) is adequate.

Table 1: Sample ACF ($\hat{\rho}_k$) and PACF ($\hat{\phi}_{kk}$) for Regime One (1970 – 1985).
$\bar{Y}$= 0.66614, s_y= 0.08207, $\bar{X}$ =0.0013, s_x = 0.0153

	ACF($\hat{\rho}_k$)		PACF($\hat{\phi}_{kk}$)			ACF($\hat{\rho}_k$)		PACF($\hat{\phi}_{kk}$)	
k	Y_t	∇Y_t	Y_t	∇Y_t	k	Y_t	∇Y_t	Y_t	∇Y_t
1	0.95	-0.27	0.95	-0.27	25	0.24	0	-0.03	-0.02
2	0.91	0.2	0.15	0.14	26	0.22	-0.02	-0.02	-0.04
3	0.87	-0.07	-0.06	0.02	27	0.2	0.06	-0.01	0
4	0.84	0.15	0	0.12	28	0.17	0.04	-0.04	0.03
5	0.8	0.03	-0.02	0.11	29	0.14	0.14	-0.04	0.15
6	0.76	0.07	-0.03	0.07	30	0.11	-0.12	-0.06	-0.08
7	0.71	0.03	-0.05	0.05	31	0.09	0.08	0.05	-0.01
8	0.67	-0.02	-0.04	-0.03	32	0.07	0.03	0.03	0.08
9	0.63	0.02	0	-0.03	33	0.05	-0.01	-0.03	-0.05
10	0.59	0.02	-0.01	0	34	0.03	0.02	-0.01	-0.05
11	0.56	0.09	0.03	0.09	35	0.01	-0.02	0	-0.04
12	0.53	-0.01	0.03	0.03	36	0	-0.06	0.03	-0.11
13	0.5	0.08	0.02	0.06	37	-0.01	-0.04	0.01	-0.08
14	0.47	-0.02	-0.01	0.02	38	-0.03	0.02	-0.05	0.02
15	0.45	-0.02	0.03	-0.07	39	-0.04	0.07	-0.04	0.1
16	0.43	0.04	0.02	0	40	-0.06	0	-0.03	0.04
17	0.41	0.05	-0.03	0.05	41	-0.07	-0.03	-0.01	-0.02
18	0.38	0.02	-0.04	0.02	42	-0.09	0.05	0	0.04
19	0.36	0	0	0	43	-0.1	0.04	-0.03	0.1
20	0.34	-0.03	0.01	-0.04	44	-0.12	0.06	-0.03	0.08
21	0.33	0.05	0.02	0.02	45	-0.14	-0.02	-0.03	-0.07
22	0.31	-0.01	-0.02	0	46	-0.15	0.07	0.01	0.01
23	0.29	0.14	-0.01	0.12	47	-0.17	0.03	-0.01	0.1
24	0.27	0	-0.06	0.07	48	-0.18		-0.02	

Table 2: Residual ACF ($\hat{\rho}_k$) and PACF ($\hat{\phi}_{kk}$) from the fitted model (3.2)

K	ACF($\hat{\rho}_k$)	PACF($\hat{\phi}_{kk}$)	K	ACF($\hat{\rho}_k$)	PACF($\hat{\phi}_{kk}$)	K	ACF($\hat{\rho}_k$)	PACF($\hat{\phi}_{kk}$)
1	0	0	18	0.03	0.01	35	-0.03	-0.06
2	0.03	0.03	19	-0.02	-0.01	36	-0.09	-0.13
3	-0.04	-0.04	20	-0.03	-0.04	37	-0.06	-0.06
4	0.14	0.14	21	0.03	0.02	38	0.04	0.04
5	0.09	0.1	22	0.04	0.02	39	0.09	0.09
6	0.09	0.08	23	0.16	0.14	40	0	0.01
7	0.03	0.04	24	0.04	0.04	41	-0.04	-0.01
8	-0.03	-0.04	25	-0.03	-0.03	42	0.05	0.07
9	0	-0.02	26	-0.04	-0.04	43	0.08	0.11
10	0.04	0.01	27	0.06	0.01	44	0.06	0.04
11	0.1	0.08	28	0.11	0.07	45	-0.01	-0.07
12	0.03	0.03	29	0.12	0.1	46	0.08	0.06
13	0.07	0.08	30	-0.11	-0.11	47	0.05	0.07
14	-0.02	-0.01	31	0.04	0.06			
15	-0.03	-0.06	32	0.06	0.06			
16	0.06	0.03	33	0	-0.07			
17	0.08	0.04	34	0.02	-0.02			

(b) Regime Two (1986 – June 2002), n=198

The ACF and PACF for Y_t and $X_t = \nabla Y_t$ are given in Table 3. It is obvious too from Table 3 that Y_t is not stationary. However, $X_t = \nabla Y_t$ is stationary. A close examination of the ACF and PACF of X_t suggests a white noise since almost all the ACF and PACF lie within $\pm\frac{2}{\sqrt{198}}$ = 0.142 indicating randomness.

For X_t, the calculated t–value = $\frac{0.596\sqrt{197}}{4.657}$ =1.8, which indicates that constant term is not significant. We therefore have the model

$$X_t = (1 - B)Y_t = e_t \quad (3.3)$$

with $\hat{\sigma}^2$ = 21.69. Hence, the model for Regime Two is a random walk (Chatfield(2004),pp.35). This indicates that for regime 2, the knowledge of past exchange rate movements cannot help in predicting either the size or the direction of the next exchange rate movement. Rather the exchange rate depends on its immediate past (i.e. February exchange rate will depend on January exchange rate of same year, etc.)

Table 3: Sample ACF ($\hat{\rho}_k$) and PACF ($\hat{\phi}_{kk}$) for Regime Two (1986 – June 2002).

	ACF($\hat{\rho}_k$)		PACF($\hat{\phi}_{kk}$)			ACF($\hat{\rho}_k$)		PACF($\hat{\phi}_{kk}$)	
k	Y_t	∇Y_t	Y_t	∇Y_t	k	Y_t	∇Y_t	Y_t	∇Y_t
1	0.98	0	0.98	0	25	0.42	-0.01	-0.01	-0.01
2	0.96	0	0	0	26	0.39	-0.02	-0.01	-0.02
3	0.93	0.03	-0.01	0.03	27	0.37	0.03	-0.01	0.02
4	0.91	0.06	-0.03	0.06	28	0.34	-0.02	-0.04	-0.02
5	0.89	-0.01	-0.03	-0.01	29	0.32	-0.03	-0.01	-0.03
6	0.86	-0.01	-0.01	-0.01	30	0.3	-0.02	-0.01	-0.02
7	0.84	-0.01	0	-0.02	31	0.27	-0.02	-0.01	-0.02
8	0.82	-0.01	-0.01	-0.02	32	0.25	-0.02	-0.01	-0.01
9	0.8	-0.01	0	-0.01	33	0.23	-0.01	-0.01	-0.01
10	0.77	0.01	-0.02	0.02	34	0.2	-0.01	-0.02	-0.01
11	0.75	0.01	-0.03	0.01	35	0.18	-0.01	-0.02	-0.01
12	0.73	0.01	-0.02	0.01	36	0.16	0.02	-0.02	0.01
13	0.7	0	-0.03	0	37	0.14	-0.01	-0.02	-0.01
14	0.68	0.01	-0.03	0.01	38	0.11	0.02	-0.02	0.02
15	0.65	-0.02	-0.02	-0.02	39	0.09	-0.01	0	-0.01
16	0.63	0	0.01	-0.01	40	0.07	-0.01	0	-0.01
17	0.6	-0.01	-0.02	-0.01	41	0.05	0.02	-0.01	0.01
18	0.58	0.04	-0.02	0.04	42	0.03	-0.01	-0.03	0
19	0.56	-0.05	-0.01	-0.04	43	0.03	-0.01	0.42	0
20	0.53	-0.01	0.02	-0.01	44	0.02	0	0	0
21	0.51	-0.01	-0.01	-0.01	45	0.02	-0.01	-0.01	-0.01
22	0.49	-0.01	-0.02	-0.02	46	0.02	-0.01	-0.02	0
23	0.47	0.05	-0.02	0.06	47	0.02	-0.01	-0.02	-0.01
24	0.44	0.05	-0.06	0.05	48	0.02	-0.01	-0.01	-0.01
					49	0.01	-0.01	0	-0.01

Source: The data were obtained from CBN Statistical Bulletin, vol. 16, Dec. 2005

(b) Regime Three (July 2002 – 2005), n= 42

The ACF and PACF are given in Table 4. It can be seen from Table 4 that the ACF are dying off while there is a cut off in the PACF after lag1, indicating Y_t to be stationary. A close examination of the ACF and PACF of Y_t suggests an Autoregressive Moving Average - ARMA(1,1) model. For Y_t , $\bar{Y}$ = 130.71, s_y = 3.33, n = 42, *the test statistic is*

$$t = \frac{130.71 - 0}{\frac{3.33}{\sqrt{42}}} = 254.38.$$

This t-value is significant and shows that the constant term is needed.

Thus, the model for regime three is $Y_t = \mu + \phi_1 Y_{t-1} - \theta_1 e_{t-1} + e_t$ (3.4)

Substituting the least square estimates of the parameters, we obtain:

$$\underset{(0.2827)}{Y_t = 7.9598} + \underset{(0.0727)}{0.9382}\, Y_{t-1} + \underset{(0.1540)}{0.3225}\, e_{t-1} + e_t \quad (3.5)$$

with $\hat{\sigma}^2$ = 1.38

Table 4: Sample ACF($\hat{\rho}_k$) and PACF($\hat{\phi}_{kk}$) for Regime Three (July 2002 – 2005).

$\bar{Y}$ = 130.71, s_y = 3.33

k	ACF($\hat{\rho}_k$)	PACF($\hat{\phi}_{kk}$)
1	0.87	0.87
2	0.73	-0.1
3	0.6	-0.04
4	0.48	-0.05
5	0.39	0.04
6	0.32	-0.01
7	0.25	-0.02
8	0.19	-0.02
9	0.13	-0.05
10	0.07	-0.05

Table 5: Residual ACF($\hat{\rho}_k$) and PACF($\hat{\phi}_{kk}$) from the fitted model (3.5)

k	ACF($\hat{\rho}_k$)	PACF($\hat{\phi}_{kk}$)
1	-0.04	-0.04
2	0.02	0.01
3	-0.05	-0.05
4	-0.08	-0.08
5	-0.09	-0.1
6	-0.04	-0.05
7	-0.04	-0.05
8	-0.04	-0.06
9	0	-0.02
10	-0.01	-0.03

Source: The data were obtained froms CBN Statistical Bulletin, vol. 16, Dec. 2005

To determine the adequacy of the model (3.5), a diagnostic check of the residual ACF and PACF given in Table 5 was done. Following Chatfield (2004), the ACF and PACF are close to zero and lie within $\pm \frac{2}{\sqrt{n}} = \pm \frac{2}{\sqrt{42}} = \pm 0.309,$ indicating that the model (3.5) is adequate or fits the data. Similarly, the values of the Q Statistic (Box and Ljung (1978)) are not significant as given in Table 6 confirming that the model (3.5) is adequate.

Table 6: Q Statistic

	k	Q	df	$\chi^2_{0.05}$	Decision
	12	10.7	10	18.31	Not significant
Regime (1)	24	20.8	22	33.92	Not significant
	36	34.2	34	48.60	Not significant
	48	43.3	46	61.66	Not significant
	12	1.2	10	18.31	Not significant
Regime (3)	24	15.8	22	33.92	Not significant
	36	16.3	34	48.60	Not significant
	48	*	*	*	Not significant

DISCUSSIONS

The observed data for the first two regimes were found not to be stationary and had to be differenced to make them stationary; while the observed data for the third regime was stationary. Stationarity is necessary because stationarity condition make it possible to use sample statistics of a realization to estimate the unknown population parameters. Again, the wide variation in estimates of the error variances in the three regimes indicates that errors in the estimation of the model parameters and the errors of prediction are different in the three regimes. Regime 2 has the greatest error in the estimation of the model parameters and in the error of prediction, followed by Regime 3, while Regime 1 has the least error in the estimation of the model parameters and in the error of prediction. The implication of the result is that Regime 1 gives the best estimators of the model parameters.

CONCLUSION

In this research, we have examined the stationarity and model structure of exchange rate data according to regimes. We observed that the regimes exhibited different model structure. The implication of the study is that exchange rate data need to be considered differently according to regimes in order to bring out the essential statistical features.

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