Journal of the Nigerian Association of Mathematical Physics
***Volume* 17 (November, 2010), pp 285 - 292**
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Arima Model of Crude Oil Exports In Nigeria

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Abstract

This work discusses the ARIMA model for crude oil export in Nigeria between January 1999 to December 2007. The relevance of this study lies in its ability to provide information on the possible point of dwindling proceeds from oil exports. The transformation suggested by data evaluation was applied to stabilize the variance. The ARIMA (1,1,1) model, with $\mu = 1.9479, \phi = -0.3019$ ***,and*** $\theta = 0.2915$ ***fitted to the transformed series*** $W_t = X^{0.63}$ ***was found to be adequate for describing the pattern in the series. The forecast values for the next 12 months (i.e. for 2008) using this model indicates a high degree of disagreement with the actual values . This was attributed to changes in the circumstances under which the model was constructed. This indicates that the proceeds from oil exports may not be relied upon for too long because of such changes. It is therefore, suggested that efforts geared towards diversification of exports be increased and sustained.***

Keywords: Oil exports, ARIMA model, transformation, forecasting, exports diversification

1.0 Introduction

Oil is a major source of energy not only in Nigeria but the world in general. In Nigeria, oil is the mainstay of the economy and plays a vital role in shaping the economic and political destiny of the country. Nigeria's exports of crude oil and natural gas at a time of peak prices have enabled the country to post merchandise trade and current account surpluses in recent years. According to [6] report, 80 percent of Nigeria energy revenues flow to the government, 16 percent covers operational costs and the remaining 4 percent go to investors. However, the World Bank has estimated that as a result of corruption, about 80 percent of energy revenues benefit only one percent of the population [United Nation Development Program (2007)].

The U.S remains Nigeria's largest customer for crude oil, accounting for about 40% of the country's total oil exports. Nigeria provides about 10% of overall U.S oil imports and ranks as the fifth largest source for U.S imported oil [6] and (UNDP (2007)).

Petroleum production and export play a dominant role in Nigeria's economy and account for about 90% of her gross earnings. This dominant role has pushed agriculture, the traditional mainstay of the economy during the early fifties and sixties to the background. Over the past years, the oil industry (oil exports) has made a variety of contributions to the Nigeria economy. These include the creation of employment opportunities, the supply of energy to industry and commerce, provision of funds for local expenditure on goods and services, contribution to government revenues, to gross domestic product (GDP) and to foreign exchange reserves. In summary it is noteworthy that (i) Nigerian economy depends on proceeds from oil (ii) Proceeds from oil come from both internal and external sources (iii) Proceeds from external sources (oil exports) far exceed those from internal sources. Therefore, (i) once the proceeds from the external sources dwindle or stops, the Nigeria economy may crumble, (ii) the much dependence of the Nigerian economy on oil export demands that the country should have a reliable estimate of future capacity of the export to sustain the economy and the point at which a diminishing return from the source sets in. To what extent and for how long would the proceeds from oil export continue to sustain the Nigerian economy? This and other related issues are what this paper intends to address.

The relevance of this study lies in its ability to provide information on the possible point of dwindling proceeds from oil export. This, in turn will enable the government and policy makers to guard against sudden collapse of the economy. It will also provide policy makers with information on the impact of corruption on Nigeria economy since it has been estimated that about 80% of revenue benefit only one percent of Nigeria through corruption. Government will also be able to assess the level of dependence of the economy on any particular country or group of countries and take necessary steps to reduce over dependence on them. Furthermore, many models are available for the purpose of providing forecasts but none seems to have addressed the issue of the unstable nature of the data on oil exports (in terms of trend and variances) in Nigeria. Hence, there is need for this study.

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The ultimate objective of this study is, therefore, to construct a time series model that would give a reliable forecast of future values of oil exports in Nigeria which may be necessary to determine the onset of diminishing returns from it. Specifically the study (i) evaluated the data to determine the necessity for and choice of appropriate transformation, (ii) affected the transformation suggested by the data evaluation, (iii) determined the characteristics of the transformed data and (iv) fitted the ARIMA model suggested by the characteristics of the transformed data.

This study is divided into five sections. Section 1 contains the introduction; Section 2 presents the study methodology, while the Section 3 focuses on the need for and choice of appropriate transformation for the crude oil export data. Section 4 contains the estimation of the parameters of the ARIMA model for crude oil export in Nigeria while the forecasts and study conclusions are contained in Section 5.

2.0 Methodology

The method of analysis adopted in this study is the Box, Jenkins and Reinsel (1994) procedure for fitting autoregressive integrated moving average (ARIMA) model. The Box, Jenkins and Reinsel multiplative time series model is given by

$$\phi_p(B)\Phi_p(B^s)(1-B)^d(1-B^s)^D\omega_t = \theta_q(B)\theta_Q(B^s)e_t \qquad (2.1)$$

Where

$$\phi_p(B) = 1-\phi_1 B - \phi_2 B^2 - \ldots - \phi_p B^p \qquad (2.2)$$

$$\theta_q(B) = 1-\theta_1 B - \theta_2 B^2 - \ldots - \theta_q B^q \qquad (2.3)$$

$$\Phi_P(B^S) = 1-\Phi_1 B^S - \Phi_2 B^{2S} - \ldots - \Phi_P B^{PS} \qquad (2.4)$$

$$\Theta_Q(B^s) = 1-\Theta_1 B^s - \Theta_2 B^{2s} - \ldots \Theta_Q B^{QS} \qquad (2.5)$$

Equations (2.2) and (2.3) are polynomials of B with no common roots, while (2.4) and (2.5) are polynomials of B^s with no common roots. The roots of these polynomials lie outside the unit circle.

e_t is the zero mean white process with constant variance $\sigma^2 < \infty$.

$(1-B)^d$ is the regular differencing to remove the stochastic trend (if any) in the series

$(1-B^s)^D$ is the seasonal differencing operator

The Equation (2.1), which can be written in short form as ARIMA (p, d, q) x (P, D, Q)^s model contains both seasonal component:

$$\Phi_P(B^S)(1-B^S)^D W_t = \Theta_Q(B^s)b_t \qquad (2.6)$$

and non – seasonal component

$$\phi_p(B)(1-B)^d W_t = \theta_q(B)a_t \qquad (2.7)$$

In (2.6) and (2.7) $\{a_t\}$ and $\{b_t\}$ are the residuals which may not be white noise. In a series that contains only the non – seasonal part, Equation (2.7) can be rewritten as

$$\phi_P(B)(1-B)^d(1-B_S)^D W_t = \theta q(B)e_t \qquad (2.8)$$

Where e_t is now a white noise. This is equivalent to the expression in (2.1) with

$$\Phi_P(B^S) = \Theta_Q(B^S) \equiv 1 \qquad (2.9)$$

When there is no seasonal differencing this further reduces to

$$\Phi_P(B)(1-B)^d W_t = \theta_q(B)e_t \qquad (2.10)$$

The value of d is determined by the number of regular differencing required to completely isolate the trend from the series. Complete isolation of the trend is indicated by the nature of the graph of the autocorrelation function (acf) (or the correlogram). The autocorrelation function (acf) and partial autocorrelation (pacf) of a stationary series (that has no trend) and seasonal effect), may show spike(s) at the first and / or second lags and cuts off thereafter. For a stationary autoregressive (AR) process, the pacf cuts off after the first and / or second lag, while for a stationary moving average (MA) process there is a cut off in the acf after the first and / or second lags. When there is a cut off in both acf and pacf, we may consider the ARMA process. For the series under study, the estimates of the parameters which meet the stationarity and invertibility conditions were obtained using the MINI TAB Software.

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The Box, Jenkins and Reinsel Procedure outlined above assumes that (i) the underlying distribution of the series under study is normal, (ii) the variance is constant and (iii) that the relationship between the seasonal and non – seasonal components is multiplicative as indicated in Model (2.1). When one or all these conditions are violated the fitted model may be inadequate for the series under study. In order to determine the suitability of the study series for the ARIMA modeling procedure the series was evaluated for these assumptions. The normality assumption was investigated by looking at the histogram and the properties of the series (including the mean, median and measures of skewness and kurtosis). Furthermore, the Box – Cox transformation procedure which jointly investigates the need for and determines the appropriate transformation was also adopted to check the stability of variances. For details of the Box – Cox transformation procedure see Bartlett (1947) and Akpanta and Iwueze (2007). However, as noted by Iwu (2009), when data is transformed, the original form of the data, as well as the unit of measure are altered.

3.0 Choice of appropriate transformation for the Crude Oil data

The monthly record of crude oil export in Nigeria from January 1999 – December 2008 (in hundreds of thousands of naira) is shown in Appendix A while the corresponding time plot is shown in Figure1. As Figure 1 shows, the series is moving in upward direction in what appears like a linear trend. This is further strengthened by the annual means from the Buys – Ballot table, given in Table 1, which increased from about 1286.1 in 1999 to about 5839 in 2006.

According to the months, the mean ranged from about 3006 in February to about 3581 in August, indicating that there might be no seasonal effect. Furthermore, the annual standard deviation ranged from about 296.6 in 2001 to about 688.0 in 2005 while the monthly standard deviation ranged from about 1490 in May to about 2172 in August indicating that the variance is not stable. The overall mean (3275.34), the median (2695.00), the measures of skewness (0.38721) and Kurtosis (-1.32208) and the histogram of the original data indicate that the series may not have come from a normal population. In summary there are indications that the underlying distribution may not be normal and the variance may not be stable and hence, that the data needs transformation.

In order to implement the Box – Cox transformation, the slope (β) of the regression equation of the logarithm of the group standard deviations ($\log \hat{\sigma}_x$) on the logarithm of the group means ($\log \bar{x}$) of the series given in Table 1 was obtained and used to determine the appropriate transformation to be adopted. This was found to be equal to be $\hat{\beta} = 0.369 \approx 0.37$ with standard error 0.1298 and coefficient of determination $R^2 = 0.537$. This slope $(\hat{\beta} = 0.37)$ lies between 0 (when no transformation is required) and 0.5 (when square root transformation is required). Since this value (0.37) appears closer to 0.5 than to zero, we examine the suitability of the square root transformation. Thus the null hypothesis tested is $H_0 : \beta = 0.5$ (and the appropriate transformation is the square root) against the alternative $H_1 : \beta \neq 0.5$ (and the appropriate transformation is not square root). When the calculated t-value (-1.009) is compared with the tabulated value (2.365) at α = 0.05 level of significance and 7 degree of freedom, it appears that the square root transformation may be the appropriate transformation.

The square root of the original data was taken to obtain the transformed series: $\left(Y_t = \sqrt{X_t}\right)$. The transformed series was also checked for the adequacy of this transformation, following the whole process of choice of appropriate transformation. The slope $(\hat{\beta})$ of the regression equation of log of the group standard deviation ($(\log \hat{\sigma}_y)$ on the log of the group means on $(\log_e \bar{y})$ is -0.294882 with standard error, s = 0.2005 and coefficient of determination, $R^2 = 0.172$. In comparison, these values of the slope $(\hat{\beta})$ and R^2 appear quite high and indicate that the square root transformation may not have achieved the desired transformation. Therefore, the option lies between further transforming Y_t and using the exact transformation,

$$W_t = X_t^{1-\beta} \qquad (3.1)$$

(where $\beta = 0.369 \approx 0.37$). From the results of the exact transformation, the estimate of the slope ($\hat{\beta}_w$) of the regression equation of $\log_e \hat{\sigma}_{wt}$ on $\log_e \bar{w}_t$ is -0.022 with standard error s = 0.2029 and R^2 = 0.002. Thus the exact transformation appears to be more appropriate for the series.

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The time plot of the transformed series (Wt) shown in Figure 2 shows clearly that (a) there is an upward trend moving in a linear form. This is also supported by the annual means shown in Figure 3, which ranged from 90.33 in 1999 to about 235.7 in 2006. (b) the amplitude of the oscillations about the trend has reduced. The annual standard deviations of W_t also shown in Figure 3 appear to be more stable indicating that the variance has been stabilized.

4.0 ARIMA model for Crude Oil Export in Nigeria.

The autocorrelation function (ACF) of the transformed series (W_t) shown in Table 2 decayed reluctantly from about 0.94 at lag 1 to about 0.25 at lag 27 confirming the presence of trend while the corresponding partial autocorrelation function (PACF) has spikes at lags 1 and 2 only. This ACF suggests that the transformed series requires differencing to remove the trend.

The time plot of the differenced series ($U_t = dW_t$) shown in Figure 4 now fluctuates about a line through zero indicating that the trend may have been removed from the series. The ACF and PACF of the differenced series (U_t) also shown in Table 2 also suggest that the differenced series is stationary with one spike each of ACF and PACF at lag 1. These also suggest that the model to be tentatively entertained is the ARIMA (p,d,q) with p= q = d = 1. The suggested model (ARIMA (1,1,1)) was fitted to the transformed series (Wt) and the resultant residuals (e_t) were evaluated to establish the adequacy or otherwise of the fitted model. The ACF and PACF of the residuals from the fitted model shown in Table 3 indicate that the fitted model is adequate to describe the pattern in the transformed series when compared with the 95% confidence bounds ($\pm 2/\sqrt{n}$).

The estimate of the parameters of the fitted model are $\hat{\phi} = -0.3019$ with a standard error of 0.1730, $\hat{\theta}$ = 0.2915 with a standard error of 0.1730 and the constant $\hat{\mu} = 1.9479$ with a standard error of 0.9423. Hence the fitted model is

$$U_t = 1.9479 - 0.3019 U_{t-1} + 0.2915 e_{t-1} + e_t \quad (4.1)$$

or

$$W_t = 1.9479 + 0.6981 W_{t-1} + 0.3019 W_{t-2} + 0.2915 e_{t-1} + e_t \quad (4.2)$$

Where,

$$U_t = (1 - B)W_t \quad (4.3)$$

5.0 Forecasting and Conclusion

The ultimate objective of model building is to provide forecasts of future values. In producing the forecasts using the fitted model, it is assumed that the condition(s) under which the model was constructed would persist in the period for which forcasts are made. If we denote the forecast made at time t_0 for the lead ι by $U_{t0}(\iota)$, then forecast function is given by

$$\hat{U}_{t0}(\iota) = 1.9479 - 0.3019 \hat{U}_{t0}(\iota - 1) + 0.2915 e_{t0}(\iota - 1) + e_{t0}(\iota) \quad (.5.1)$$

If we substitute $U_t = (1-\beta)W_t$ into (5.1), the forecast function in terms of W_t becomes

$$\hat{W}_{t_0}(\iota) = 1.9479 + 0.6981 \hat{W}_{t_0}(\iota - 1) + 0.3019 \hat{W}_{t_0}(\iota - 2)) + 0.2915 \hat{e}_{t_0}(\iota - 1) + \hat{e}_{t_0}(\iota) \quad (5.2)$$

Using the model in (5.2) with $t_0 = 108$ the MINITAB software gave the forecasts $\left(\hat{W}_{t_0}(\iota)\right)$ for the next 12 months (i.e 2008). The corresponding values ($\hat{X}_{t_0}(\iota)$) in terms of Xt, shown in Table 4 were obtained from $\hat{W}_{t_0}(\iota)$ using the relationship in Equation (3.1). That is

$$W_t = X_t^{1-\beta}$$

or

$$\hat{X}_{t_0}(\iota) = \left(\hat{W}_{t_0}(\iota)\right)^{\left(\frac{1}{1-\beta}\right)} \quad (5.3)$$

As Figure 5 shows, between 1999 and 2007, the plot of the actual and fitted values of the oil exports indicates a high degree of agreement between the two. However, for the subsequent twelve months (i.e. for 2008), the plot of the forecast and actual values given in Figure 6 shows a great disparity between the actual and forecast, which suggests that circumstances under which the model was constructed may have changed considerably. This is understandable considering the many

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unforeseen circumstances (including the Niger Delta crisis and the constant vandalization of oil pipelines) which became worse during that period. This is indicative that proceeds from oil exports may not continue for too long to sustain the economy of the country. It is therefore, suggested that the efforts geared towards diversification of exports be beefed up and sustained. It is also evident that U S who is the major importer of Nigerian oil may also be looking for alternative sources of energy. When this fully realized the proceeds from oil exports will continue to be unreliable.

Table 1: Marginal and overall means and standard deviations of crude oil exports
Nigeria 1999 – 2007 (N'000,000.00)

Year	Mean ($\overline{X_t}$)	Standard Deviation ($\hat{\sigma}_{xt}$)	Months	Mean $(\overline{X_t})$	Standard Deviation ($\hat{\sigma}_{xt}$)
1999	1286.1	314.0	January	3167	1872
2000	2279.0	412.0	February	3006	1886
2001	1643.5	296.6	March	3160	1787
2002	1665.8	492.0	April	3109	1850
2003	2497.8	341.8	May	3108	1490
2004	3728.0	549.0	June	3301	1803
2005	5211.0	688.0	July	3325	1988
2006	5839.0	572.0	August	3581	2172
2007	5329.0	427.0	September	3277	1682
			October	3503	1946
			November	3344	1737
			December	3422	1805
Overall Mean	3275.3			3275.3	
Overall STD		1752.4			1752.4

$$S_x = \hat{\sigma}_x\ ,\ \overline{X} = \hat{\mu},\ b = \hat{\beta}$$

Table 4: Actual and forecast of monthly crude oil exports
Nigeria 2008 ($x10^6$)

Lead ι	Months	Actual (X_t)	Forecast $\hat{X}_{t_0}(\iota)$	Error $\hat{e}_{t_0}(\iota)$)
1	January	7091.13	5757.63	1333.50
2	February	9236.01	5813.84	3422.17
3	March	8630.39	5873.35	2757.03
4	April	8764.83	5932.15	2832.68
5	May	8151.35	5991.44	2159.91
6	June	7672.40	6050.87	1621.53
7	July	6200.89	6110.54	90.34
8	August	3954.37	6170.42	-2216.05
9	September	4540.89	6230.52	-1689.63
10	October	7091.13	5757.63	1333.50
11	November	9236.01	5813.84	3422.17
12	December	8630.39	5873.35	2757.03
MSE				5439492.00

Table 2. : ACF and PACF transformed (Wt) and Differenced (Ut) series

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Table 3. : ACF and PACF residual series (e_t)

Lag k	W_t		U_t	
	ACF	PACF	ACF	PACF
1	0.937662	0.93766	-0.50096	-0.50096
2	0.918373	0.32423	0.10618	-0.19329
3	0.890239	0.03977	0.01770	-0.02171
4	0.861768	-0.02557	0.05901	0.11196
5	0.831324	-0.04297	-0.09033	-0.00066
6	0.805513	0.01082	0.03342	-0.03219
7	0.782199	0.03455	0.03375	0.02660
8	0.755306	-0.02050	-0.00458	0.04893
9	0.724519	-0.06898	-0.04626	-0.02228
10	0.699761	0.00345	0.09308	0.06057
11	0.673429	0.00135	-0.10367	-0.04963
12	0.648633	0.00521	0.07130	0.00499
13	0.622893	-0.01510	-0.00076	0.04714
14	0.599616	-0.00360	-0.09788	-0.10832
15	0.586891	0.09676	0.14629	0.07122
16	0.554825	-0.11185	-0.20273	-0.14948
17	0.535880	0.00141	0.23322	0.11408
18	0.508422	-0.05136	-0.15232	0.02463
19	0.479547	-0.06299	0.01280	-0.07141
20	0.458195	0.04261	0.05380	0.02875
21	0.426772	-0.07168	-0.06577	-0.05887
22	0.400087	-0.03657	-0.08048	-0.16237
23	0.369536	-0.04525	0.11152	0.00143
24	0.333812	-0.08232	-0.07582	-0.02995
25	0.309063	0.04096	-0.03561	-0.10724
26	0.282810	0.03168	0.01782	-0.00843
27	0.253486	-0.04617		

Lag(k)	ACF	PACF)
1	-0.00773	-0.00773
2	-0.00623	-0.00629
3	0.10296	0.10288
4	0.06426	0.06647
5	-0.06305	-0.06139
6	0.01806	0.00681
7	0.06708	0.05467
8	0.00709	0.01720
9	-0.01881	-0.01360
10	0.05170	0.03436
11	-0.04299	-0.05152
12	0.04342	0.05281
13	-0.01624	-0.02244
14	-0.07130	-0.07568
15	0.05271	0.05403
16	-0.07730	-0.08643
17	0.13109	0.15647
18	-0.09349	-0.10349
19	-0.05085	-0.05255
20	0.01468	0.00498
21	-0.12603	-0.13481
22	-0.11247	-0.07866
23	0.03151	0.03253
24	-0.09645	-0.10255
25	-0.09727	-0.06485
26	-0.00159	0.02263

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Appendix: Buys – Ballot table of monthly Oil Export in Nigeria between 1999 and 2008 (x 10^6)

	MONTH													
YEAR	Jan	Feb	Mar	April	May	Jun	July	Aug	Sept	Oct	Nov	Dec	Mean	Std
1999	843.1	703.1	1013.8	1124.2	1204.7	1400.5	1428.8	1419.4	1421.9	1503.1	1630.6	1740.1	1286.1	314.0
2000	2162.4	2545.8	2860.7	2178.4	2635.3	3057.6	2055.2	2140.3	2139.3	2093.1	1780.1	1702.3	2279.2	412.5
2001	2094.9	1659.0	1866.5	1680.2	1936.2	1910.1	1404.0	1786.2	1612.9	1391.7	1155.7	1224.3	1643.5	296.6
2002	1127.7	1084.8	1171.7	1451.9	1490.4	1448.8	1360.0	1857.4	2104.9	1961.4	2463.2	2453.6	1664.7	491.9
2003	2628.1	2793.9	2158.5	1981.0	2754.7	2139.5	2378.9	2205.0	2393.4	2586.0	2862.7	3091.3	2497.8	341.8
2004	3349.5	3043.8	3419.2	3281.2	3208.8	3221.5	4122.3	4194.0	4186.4	4790.7	4130.6	3787.4	3728.0	548.6
2005	4841.3	3991.6	5013.2	4968.9	4846.3	5251.1	5658.0	6548.2	4429.7	5960.0	5440.2	5580.5	5210.7	687.9
2006	5796.5	6796.1	5659.7	5727.7	4904.5	6302.9	5616.7	6939.3	5639.0	5600.6	5606.6	5476.2	5838.8	571.6
2007	5673.5	4435.7	5273.4	5590.3	4988.9	4976.0	5900.3	5142.6	5567.2	5636.5	5026.6	5740.7	5329.3	426.6
2008	7803.8	7194.1	8276.1	7091.1	9236.0	8630.4	8764.8	8151.4	7672.4	6200.9	3954.4	4540.9	7293.0	1646.0
Mean	3632.1	3424.8	3671.3	3507.5	3720.6	3833.8	3868.9	4038.4	3716.7	3772.4	3405.1	3533.7	3677.1	
Std	2294.4	2216.9	2335.8	2150.9	2393.5	2393.9	2544.1	2506.1	2108.9	2023.8	1649.1	1737.8		2115.8

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Acknowledgement

Our sincere gratitude is due to Professors I. S. Iwueze and F.C. Eze of School of Science, Federal University of Technology, Owerri for their continued support

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