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ARIMA Modeling of Nigeria Crude Oil Production

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Abstract
This study discussed the ARIMA Model for crude oil production in Nigeria from January 2006 to March 2015. The relevance of this study lies in the fact that the quantity of crude oil produced determines the quantity to be either refined and sold or exported as crude which is the main stay of the Nigerian economy. Having a pre knowledge of the quantity of crude oil that may be produced with adequate budgeting can help the country have a viable economy. Multiplicative SARIMA $(1,1,1)(0,1,1)_{12}$ model was proposed as the best model to be fitted to the crude oil production data. The forecast values from the fitted model agreed with the actual values therefore suggesting that the model could be used for forecasting future quantity of crude oil that may be produced in the country.
Keywords: ARIMA model, Seasonality, Differencing, Crude oil Production.

1.0 Introduction
Crude oil is a vital commodity in the world market. Despite the crusade for green energy and other sources of power. Crude oil is still an expensive commodity in the international market. Crude oil, which is the most dominant source of energy in Nigeria was discovered in 1908, at Araromi in the present Ondo State. The United States remains Nigeria's largest customer for crude oil, accounting for about 40% of the country's total crude oil exports. (Nwogu,2010). With the discovery of large deposits in Oloibiri in1958, Shell Petroleum Development Company of Nigeria continued further exploration and export. As a result of the tremendous revenue realized from crude oil, other exploration companies were attracted to the industry (Udosen *et al*, 2009). Nigeria was able to reap instant riches from its oil production (Odularu,2008). Also NNPC report had it that Nigeria petroleum industry is the main generator of Gross domestic product (GPD) with statistics that oil revenue has totalled $ 340 billion in exports since the 1970s. In the 1970s, the production of crude oil was intensified up to the tune of 2.4million barrels per day (Udosen *et al.,* 2009). This was attributed to the crisis in the Middle East which paved way for the increase in demand of oil from Nigeria, but by early 80s, there was slight reduction in the amount of crude oil produced. This was orchestrated by excess production by various OPEC member countries resulting to drop in the price of crude oil. However, the production picked up again from 90s and by 2001, the production was averaging 2.2 million barrels of oil per day (Odularu, 2008). Owing to the huge revenue generated from crude oil, other areas such as agriculture and mining of solid minerals were neglected. This made the Nigerian economy to depend wholly on oil. It is reported that oil and gas exports accounted for more than 98% of export earnings and about 83% of the total revenue that accrued to the federal government in 2000. In Nigeria, the government relies on the income generated from crude oil for day to day running of governmental functions, provision of infrastructure and other social amenities for the citizenry but the income generated depends on the quantity of crude oil produced as well as the price per barrel. Thus, it is necessary to provide a time series model that can be used to forecast quantity of crude oil produced for the purpose of making reliable budget for the sustainance of the economy.

Etuk *et al.(*2013) modeled Nigeria monthly crude oil domestic production from January 2006 to August 2012. They proposed the Multiplicative SARIMA $(0,1,1)(0,1,1)_{12}$ model as the best model. However we noted in the course of carrying out this research that literature on modeling crude oil production was scarce. Most other works were on crude oil exportation.

2.0 Methodology
The data used for this study are secondary data on crude oil production in Nigeria from January 2006 to March 2015. The data was collected from the official website of the Central Bank of Nigeria (CBN). In analyzing the data we employed the multiplicative seasonal autoregressive moving average model. Stationarity is a basic requirement for the application of Box Jenkins methodology. The mean function and variance function of the stationary time series were constant over time. It then followed that a time series is non stationary if at least one of its mean or variance depends on time. A stationary time series with time varying mean can be converted into a stationary time series when the time series has a stochastic trend. The mth order difference of the series takes the form

$$\nabla^m X_t = X_t - X_{t-m}$$

For seasonal differences, we have

$$\nabla_D^s X_t = X_t - X_{t-s}$$

Where S is the seasonal length. The seasonal length for monthly data is S = 12.
The order of differencing can be determined by visual inspection of the time series plot, Continuous inspection

of the time series plot of the differenced series and plot of the ACF after each stage. Stationary time series are expected to have constant variance over time. When the variance is not stable, an appropriate transformation can be applied to stabilize the variance (Iwueze et al,2013).
For seasonal time series with period "s", Box & Jenkins (1976) have generalized the autoregressive integrated moving average (ARIMA) model and defined a general multiplicative seasonal model in the form

$\emptyset(B)\emptyset(B^S)W_t=\theta_0+\theta_q(B)\theta_Q(B^S)e_t$ ……………………………………(2.1)

Where B is the back shift operator on the index of the time series such that

$B^S X_t = X_{t-s}$, s is the number of seasons; θ_0 is a constant;

$\emptyset_p(B) = 1-\emptyset_1 B-\emptyset_1 B^2 -,\ldots\ldots, \emptyset_P B^p$

$\emptyset_p(B) = 1-\emptyset_1 B^s - \emptyset_2 B^{2s} -,\ldots\ldots, \emptyset_{PS} B^{ps}$

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

$\theta_Q(B^S) = 1-\theta_s B^s - \theta_{2s} B^{2s} - \theta_{Qs} B^{Qs}$;

$\{e_t\}$ is a purely random process with zero mean and variance σ^2.

The variables $\{W_t\}$ are formed from the original series $\{X_t\}$ by differencing to remove both trend and seasonality by

$W_t=(1-B)^d(1-B^S)^D X_t$………………………………………………(2.2)

The values of the integers d and D do not usually need to exceed one. Equation (2.1) is called a multiplicative seasonal autoregressive integrated moving average (SARIMA) model of order $(p,d,q)x(P,D,Q)_{12}$

3.0 Results and Discussion

In this section we analyze the crude oil production in Nigeria using Box and Jenkins procedure. A time plot of the data for crude oil production is displayed in figure 3.1.

Visual inspection of time plot showed that the series was not stationary.The autocorrelation function of the data displayed in figure 3.2. From the figure 3.2 we observed that the ACF showed that there was trend in the series. Since the ACF had large values at lags 12, 24 and 36 it therefore implied that the data was seasonal. Therefore, we carried out a nonseasonal differencing of order 1and a seasonal differencing at lag 12 to remove both trend and seasonality. From the ACF and PACF plot of the non seasonal and seasonally differenced data we observe that there is a cut off at lag 1 and lag 12 with negative value. The proposed model was multiplicative Seasonal ARIMA $(1,1,1)(0,1,1)_{12.}$

The parameter estimates given by MINITAB software is $\emptyset$ =0.3813, θ_1 =0.6931, θ_2 =0.8649. their respective standard errors are 0.2012,0.1536 and 0.0809. We then carry out a diagnostic test to ascertain the adequacy of the fitted model. Figure 3.11 and 3.12 shows the ACF and PACF of the residuals of the fitted model.

From figures 3.12 and 3.12 above, all the ACF and PACF of the fitted model lies within the 95% confidence interval showing that the model is adequate. From table 3.2 below we can observe that error sum of squares is quite low while comparing the forecast with the actual values of the Nigeria crude oil production.

4.0 Forecasting

Having fitted a time series model to the Nigeria crude oil production series and proven from diagnostic tests that the model could be used for forecasting. We then make a twelve month forecast of Nigeria crude oil production.

Table 3.2: Monthly Actual and Forecasts from period April 2014 to March 2015

Lead	**Months**	**Forecast**	**Actual**	**Error**	**Error^2**
K	t_{0+k}	$\hat{X}_{to(k)}$	X_{t_0}	$\hat{e}_{t_0}$ (k)	$\hat{e}_{t_0}^{\,2}$ (1)
100	April	2.18667	2.22000	0.03333	0.0011109
101	May	2.18315	2.33000	0.14685	0.0215649
102	June	2.14323	2.16000	0.01677	0.0002812
103	July	2.23580	2.06000	-0.17580	0.0309056
104	Aug	2.27658	2.20000	-0.07658	0.0058645
105	Sept	2.28163	2.10000	-0.18163	0.0329895
106	Oct	2.29936	2.21000	-0.08936	0.0079852
107	Nov	2.16141	2.18000	0.01859	0.0003456
108	Dec	2.17258	2.23000	0.05742	0.0032971
109	Jan-15	2.23287	2.20000	-0.03287	0.0010804
110	Feb-15	2.24424	2.21000	-0.03424	0.0011724
111	Mar-15	2.17120	2.07000	-0.10120	0.0102414

From table 4.11 above we can observe that error sum of squares is quite low while comparing the forecast with the actual values of the Nigeria crude oil production.

5.0 Summary and Conclusion

This work discusses fitting of ARIMA model to monthly Nigeria crude oil production for the period January 2006 to march 2015 obtained from the official website of the Central Bank of Nigeria (CBN). The ultimate objective is to construct a statistical model which may be used to obtain forecasts of future values of Nigeria crude oil production necessary for budgeting and planning. The data was non seasonally differenced to remove trend and make the data stationary. The result of the analysis shows that the appropriate model is multiplicative ARIMA $(1,1,1)(0,1,1)_{12}$. This showed slight difference from the work done by Ette et al.(2012). The slight variation could be attributed to the additional period of the data used. The forecasts of the twelve months of April 2014 to march 2015 using the fitted model agreed with the actual values at 95% confidence interval. The model is therefore recommended for use.

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Appendix

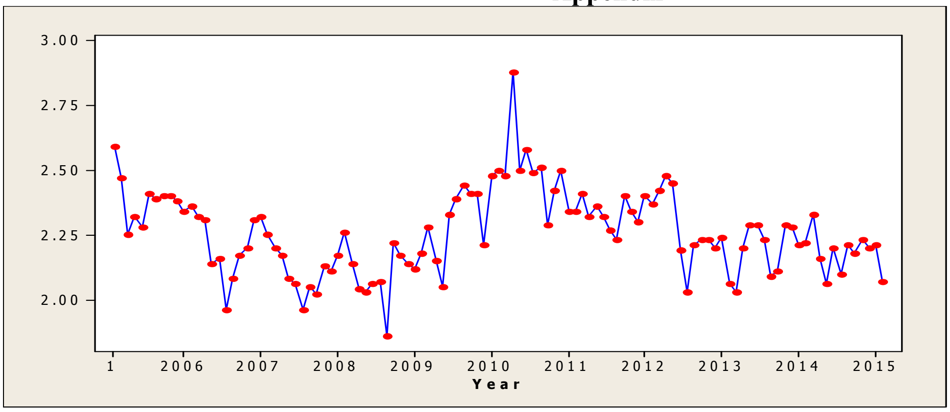

Figure 3.1 Time plot of Nigeria Crude oil production.

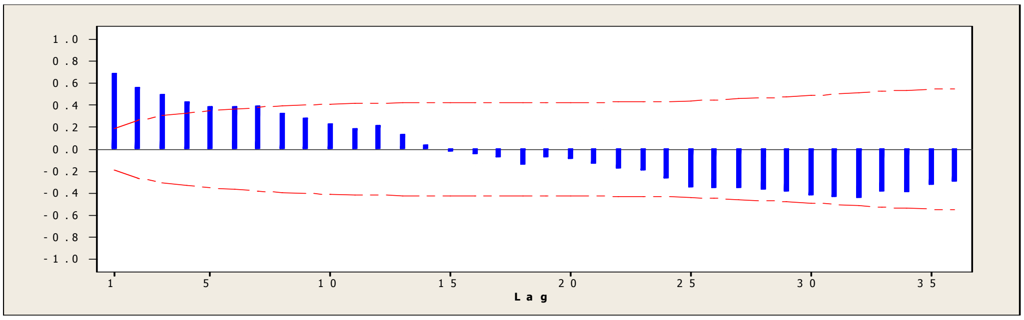

Figure 3.2: ACF of Nigeria Domestic Crude Oil Production

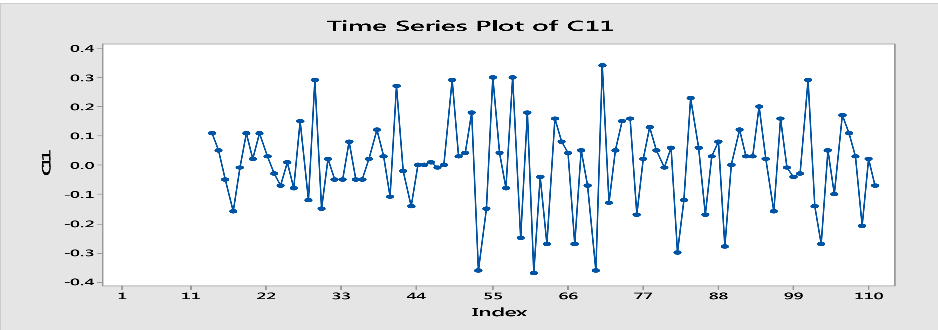

Figure 3.5: Time Plot of Non Seasonal and Seasonally Differenced Series

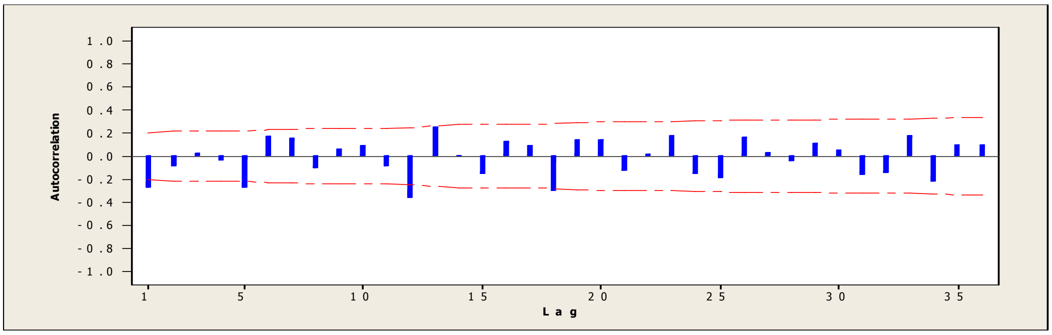

Fig 3.6: ACF of Non Seasonal and Seasonally differenced Series

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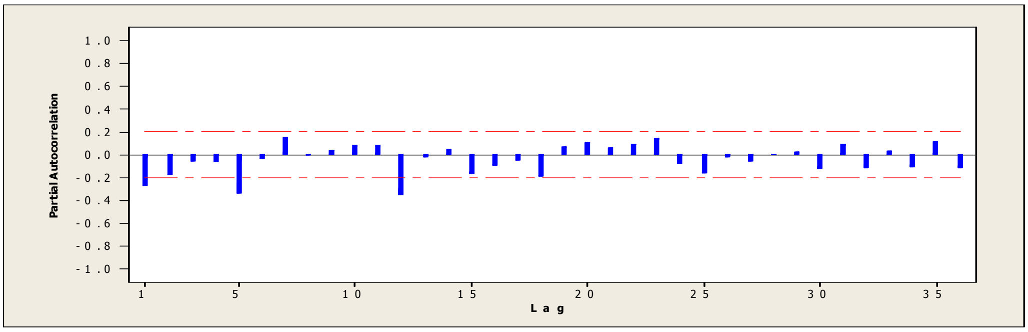

Figure 3.7: PACF of the non seasonal and seasonally differenced Series.

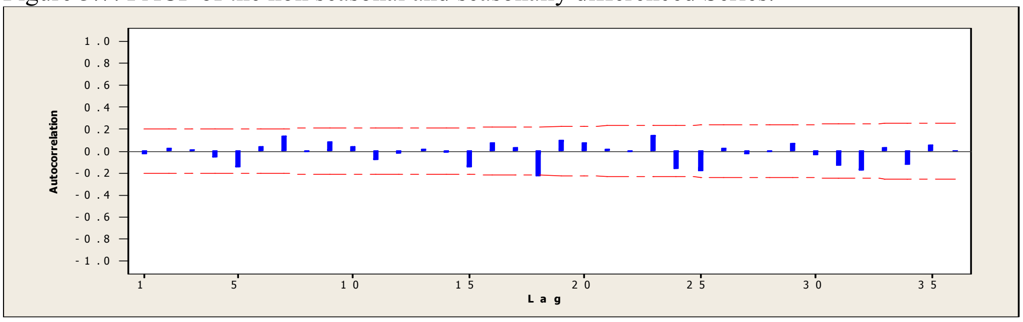

Fig 3.8: ACF of the Residuals of the fitted Model

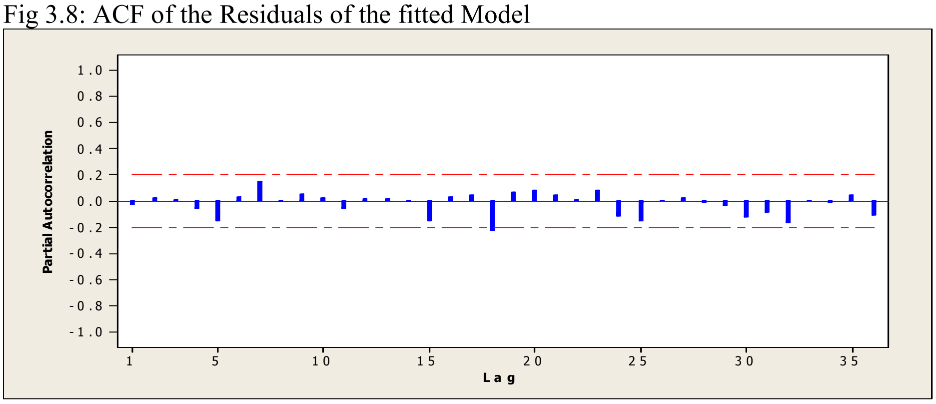

Fig: 3.9 PACF of the Residuals of the Fitted Model