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Time Series Analysis of Nigerian Monthly Crude Oil Price

Abass I. Taiwo[1*], Kazeem A. Adeleke[2], Adedayo, F. Adedotun[3]
[1]Department of Mathematical Sciences, Olabisi Onabanjo University, Ago-Iwoye
[2]Department of Mathematics, Obafemi Awolowo University Ile-Ife
[3]Department of Mathematics, Covenant University, Ota, Ogun State, Nigeria
Corresponding author: *(taiwo.abass@oouagoiwoye.edu.ng)

Abstract
This study is used to discuss and analysed the fluctuations and volatility in Nigeria monthly crude oil price since crude oil is a major determinant that drives Nigerian economic growth and development. The time series model used to model Nigerianmonthly crude oil price is Autoregressive Integrated Moving Average (ARIMA) model. The stationarity of the series was attained at the first difference based on the Augmented Dickey-Fuller (ADF) test. The ACF and PACF were used to identify four models andafter estimation with the ordinary least estimation method, ARIMA(5,1,2) model was selectedas the optimal model based on the values of the Information Criteria. The model is viewed as satisfactory for forecasting Nigerian monthly crude oil price since the ACF and PACF of the residuals do notform any irregular pattern. The forecasted value of Nigerian monthly crude oil price indicated a steadyrise and maybe in-between 71.78 – 200.84 dollar per barrelin the next 10 years. The forecast evaluation metrics values indicated that the forecasted values are relatively accurate. Conclusively, this price rise may take the Nigerian government out of unchartered waters and the worst recession in 40 years. This as well will give the Nigerian government the chance to revive the economy only if they diversify the economy, create job opportunities, combat insurgency, and put in place zero-tolerance measures against corruption and mismanagement of public funds.

Keywords: Crude oil price, volatility, forecasting, time series model building

1. Introduction
Volatility in oil price can be defined as the rate of change in price over a given period(*Englama et al., 2010*). It is computed as the annualized standard deviation of the percentage change in the daily price and the larger the magnitude of the change, the higher the volatility (*French et al., 1987*).The volatility in crude price affects all oil-producing countries around the globe either positively or negatively(*Akinlo and Apanisile, 2015*). In particular, the global crude oil price crash from 2013 to dateaffected Nigerian government revenue negatively since crude oil

exportation is the Nigerian government major source of revenue(*Odupitan, 2017; Adedokun, 2018*). But many years back, crude oil exportation created a robust wealth for Nigeria. Then, the Naira appreciated as foreign exchange influxes offset outflows and Nigeria foreign reserves assets increased (*Akinyemi et al., 2017; Gylych, 2020*). Due to this, productivity declined in all other sectors as the economy of Nigeria solely depends on crude oil exportation and this led to massive migration to cities and widespread poverty in the rural areas. As a result, Nigeria's job market has witnessed a very high degree of unemployment, small wage and pitiable working environments (*Adesina 2013; Okoro, 2014; Okoi, 2019*). From 1970 to 2020, Nigeria's poverty rate increased from 36% to 70% andin 2020 unemployment is at 30.7%. Based on this, it is believed that oil revenue did not seem to add to the standard of living and create job opportunities but causing social and economic challenges to the Nigerian populace (*Englama et al., 2010, Dapel, 2018*). As if the situation is not worse enough, the global economy is further put to a standstill due to the COVID-19 pandemic that cut the whole world unaware since December 2019 till date (*Otache, 2020*). This has crashed the world oil prices and put the Nigerian government in unchartered waters and the worst recession in 40years. The government continues to struggle to revive the economy amidst dwindling oil revenues compounded by unemployment, poverty,insurgency and mismanagement (*Raji et al., 2020, OECD, 2020*).

Having discussedthis, this study will be used to model and forecast historical Nigerian monthly crude oil price from February 1983 to April 2021. This is done in other to have an insight into the future crude oil price which is important future growth and development of Nigeria. A Univariate time series model called Autoregressive Integrated Moving Average (ARIMA) will be used to model and forecastNigerian crude oil price volatility.

2.Materials and Methods

2.1 Time plot

Time plot will be used to obtain simple descriptive measures of the main property of the series via a visual inspection of the time series plot. This may reveal seasonal, trend, cycle and irregular variations.

2.2 The Augmented Dickey-Fuller (ADF) Test

The Augmented Dickey-Fuller (ADF) test will be used to attain stationarity,and this involves checking through and testing the three sets of models:

$$\Delta x_t = (\lambda - 1)x_{t-1} + \sum_{j=1}^{j} \beta_j \Delta x_{t-j} + w_t (1)$$

$$\Delta x_t = \alpha + (\lambda - 1)x_{t-1} + \sum_{j=1}^{j} \beta_j \Delta x_{t-j} + w_t \quad (2)$$

$$\Delta x_t = \alpha + \delta_t + (\lambda - 1)x_{t-1} + \sum_{j=1}^{j} \beta_j \Delta x_{t-j} + w_t \quad (3)$$

where equation (1) is a pure random walk model,equation (2)contains an intercept term and equation(3) contains both the drift and linear trend. Unit root test involves equations 1 to 3, the associated standard errors and comparing the test statistic with the appropriate values in the Dickey-Fuller table will be used to determine the stationarity of the series.

2.3. Autoregressive Integrated Moving Averages (ARIMA) Models

ARIMA model is aUnivariate model that consists of an autoregressive polynomial, an order of integration(d), and a moving average polynomial. A process (x_t) is said to be an autoregressive integrated moving average process,$ARMA(p,d,q)$if it is written as

$$\emptyset(B)\nabla^d x_t = \theta(B)w_t \qquad (4)$$

where $\nabla^d = (1-B)^d$ with $\nabla^d x_t$and $d$is the consecutive differencing.

2.3.1.Model Identification

The Autocorrelations function (ACF) and partial autocorrelation functions (PACF) will be used for model identification. The ACF will be used to measure the amount of linear dependence between observations in the time series. While partial autocorrelation function will be used to determine the possible order of seasonal autoregressive, non-seasonal autoregressive, moving average and seasonal moving average that should be incorporated in the model(*Box and Jenkins, 1976*). The Autocorrelations function (ACF) denoted by

$$\rho_k = \frac{E[(x_t-\bar{x})(x_{t-k}-\bar{x})]}{E[x_t-\bar{x}]^2} \qquad (5)$$

and partial autocorrelation functions (PACF) is given as

$$x_t = \rho_0 + \sum_{k=1}^{K} \rho_{kk} x_{t-k} \qquad (6)$$

whereρ_{kk} is the k^{th} autoregressive coefficient, $k = 1,2,\dots,K$.After theidentification stage, the appropriate and optimal model will be chosen based on the smallest values of Akaike Information criteria (AIC), Schwartz Bayesian Information criteria (SBC) and Hannan Quinn Information criteria (HQC).

2.3.2Parameter Estimation

After choosing the most appropriate model, the ordinary least squares estimation method will be used to estimatethe coefficients of the model.The coefficient will be obtained using

$$\hat{\emptyset} = \frac{\sum_{t=2}^{n} x_{t-1}x_t}{\sum_{t=2}^{n} x_{t-1}^2} \qquad (7)$$

2.3.3Diagnostic Checking

The estimated model will be diagnosed and validated by computing thevalues of the sample ACF and PACF of the residuals to see whether they do not form any pattern, and all are statistically significant, that is, within two standard deviations with $\alpha = 0.05$ (*Box et al., 2015*). Therefore, the appropriate model will be used to obtain forecast values for the time series, $x_{t+m}, m = 1,2,\dots$ based on the data collected to the present, $x = \{x_t, x_{t-1}, \dots\}$.

2.3.4Forecasting

There are two kinds of forecast,and these are sample period forecasts and post-sample period forecasts. The former will be used to develop confidence in the model and the latter will be used to generate genuinely desired forecasts. In forecasting, the goal is to predict future values of a time series, $x_{t+m}, m = 1,2,\dots$ based on the data collected to the present, $x = \{x_t, x_{t-1}, \dots, x_1\}$. (*Olatayo and Alabi 2011*), and (*Taiwo and Olatayo 2013*).

The measures of accuracy of forecast considered in this study aremean absolute error (MAE) defined as

$$MAE = \frac{1}{h+1}\sum_{t=s}^{h+s}\left(\hat{X}_t - X_t\right)^2 \qquad (8)$$

root mean square forecast error (RMSE) defined as

$$RMSE = \sqrt{\frac{1}{h+1}\sum_{t=s}^{h+s}(\hat{X}_t - X_t)^2} \quad (9)$$

and the mean absolute percentage errordefined as

$$MAPE = \frac{100}{h+s}\sum_{t=s}^{h+s}\left|\frac{\hat{X}_t - X_t}{\hat{X}_t}\right| \qquad (10)$$

where $t = s, 1+s, \ldots, h+s$.The actual and predicted values for corresponding t values are denoted by $\hat{X}_t$ *and* $X_t$respectively. The smaller the values of *RMSE* and *MAPE*, the better the forecasting performance of the model,(*Olatayo and Taiwo 2015; Olatayo etal., 2014*).

3.Results and Discussion

The data used consist of Nigerian monthly average crude oil price from February 1983 to April 2021 and this was obtained from *the Central Bank of Nigeria data portal (2021) and U.S. Energy Information Administration(2021).*The time plot of Nigerian monthly crude oil price is depicted in Figure 1. This exhibits a continuous trend with a sharp fall in the price of crude oil in 2008, 2016 and 2020. The variation present in Nigerian monthly crude oil price suggested that the series is non-stationary. The movement is secular with certain sharp rapid falls over the months.

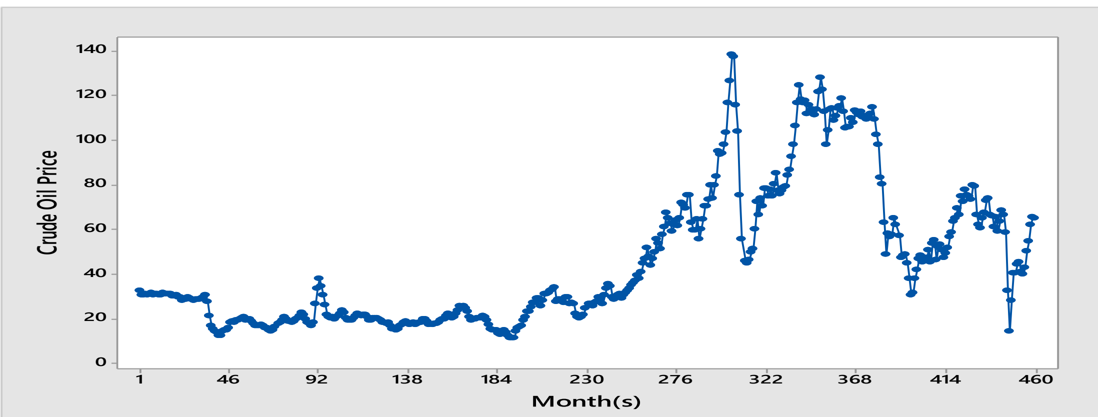

Fig. 1: Time plot of Nigerian monthly crude oil price from February 1983 to April 2021

The Augmented Dickey-Fuller test showed that Nigerian monthly crude oil price is stationary at the first difference that is $I(1)$ at 1%, 5% and 10% level of significance with $p - value = 0.000$. Since the order of integration of the difference series is one (1), then $d = 1$.

The sample autocorrelation (SACF) and sample partial autocorrelationfunction (SPACF) plots in figures 2 and 3were used to obtain tentative models. Based onfigures 2 and 3 whereSACF tailed-off and SPACF cut-off after lag 5 and lag 1 or 2 respectively, then p = 5 and q = 1 or p = 2 and q = 5.Therefore, the four suggested models for analysing Nigerian monthly crude oil price are $RIMA\ (5,1,2), ARIMA\ (5,1,1)$, $ARIMA\ (2,1,5)$ and $ARIMA\ (1,1,5)$.

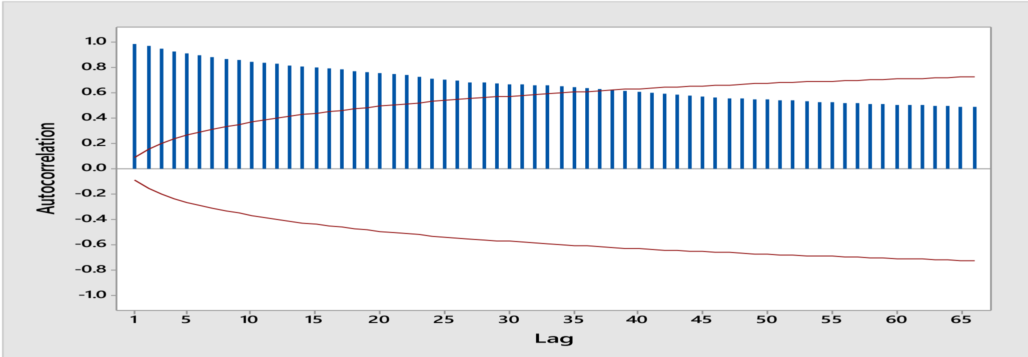

Fig. 2: Sample Autocorrelation function plot of Nigerian Monthly crude oil price

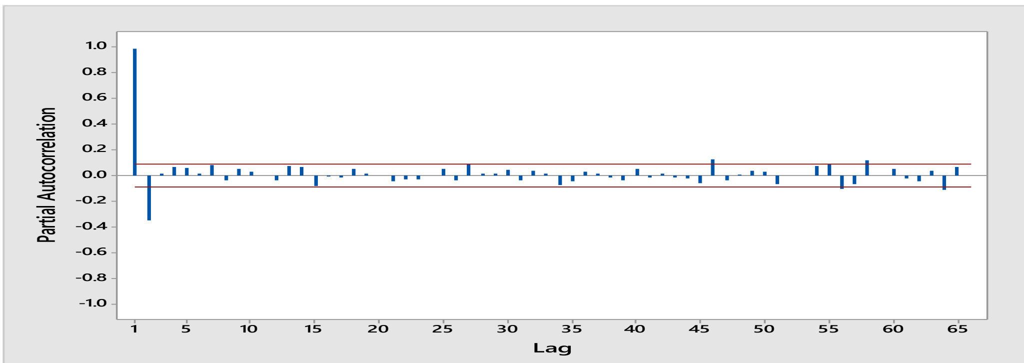

Fig. 3: Sample Partial Autocorrelation function plot of Nigerian Monthly crude oil price

After the estimation of the four suggested models with the ordinary least square estimation method, the values of information criteria in table 1 is used to select $ARIMA\ (5,1,2)$ as this optimal modelsince the model comes with the lowest values of AIC, SBC and HQC. The fitted $ARIMA\ (5,1,2)$model is given as

$$X_t = 0.1713 + u_t$$

$$(1 - 1.3574\ \ L{-}0.2180\ \ L^2 + 0.2519\ \ L^3 - 0.1532\ \ L^4$$

$$= (1 - 1.7369L - 0.8596L^2)\varepsilon_t$$

Table 1: Information Criteria based on the estimated model

Model	AIC	BIC	HQC
$ARIMA\ (5,1,2)$	5.761612	5.832573	5.790495
$ARIMA\ (5,1,1)$	5.763087	5.845053	5.791429
$ARIMA\ (2,1,5)$	5.762289	5.843251	5.794173
$ARIMA\ (1,1,5)$	5.762378	5.844344	5.790719

Figures 4 and 5 is utilized to display the autocorrelation and partial autocorrelationof the residuals of the fitted model. Based on figure 4 and 5, the model is viewed as satisfactory since the ACF and PACF of the residuals do notform any irregular pattern and all statistically significant within two standard deviations with $\alpha = 0.05$.

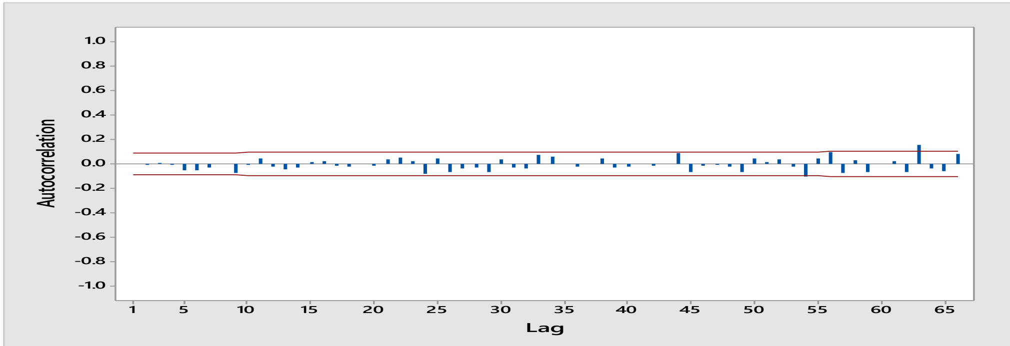

Fig 4. ACF plots of the residuals of ARIMA(5,1,2) model

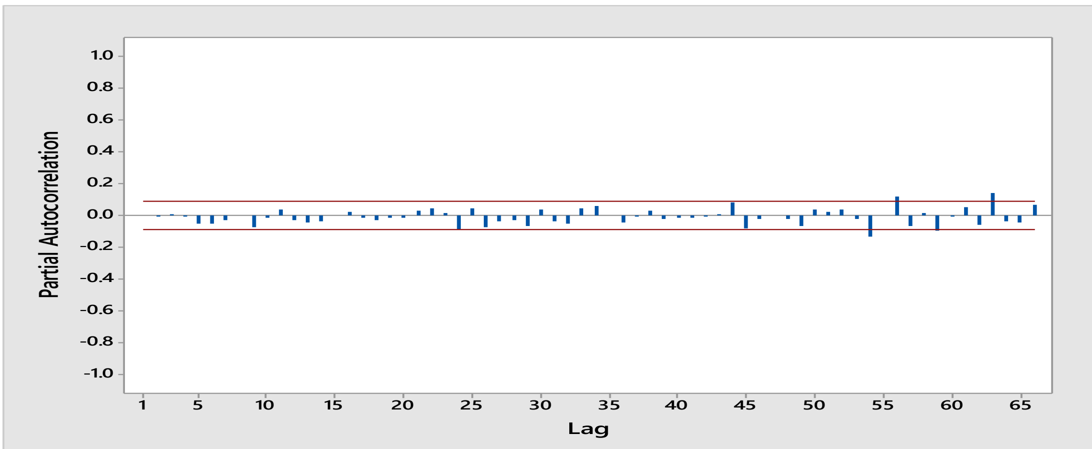

Fig 5. PACF plots of the residuals of ARIMA(5,1,2) model

Fig. 6 is used to present the fitted and predicted values for Nigerian monthly crude oil price for the next 10 years. This was further explained by Table 2 where the Nigerian monthly crude oil price forecast, upper and lower limit values were presented. Based on Fig. 6 and Table 2, Nigerian monthly crude oil price will rise steadily and maybe in between 71.783–200.844 dollar per barrelin the next 10 years. Hence, there is evidence of volatility in actual and forecasted values of Nigerian monthly crude oil price per barrel. Accordingly, the ARIMA models forecast showed a steady price rise in Nigerian monthly crude oil price. This price rise may take Nigeria government out of unchartered waters and the worst recession in 40 years. This has well will give the Nigerian government the chance to revive the economy only if they diversify the economy, create job opportunities, combat insurgency, and put in place zero-tolerance for corruption and mismanagement of public funds.

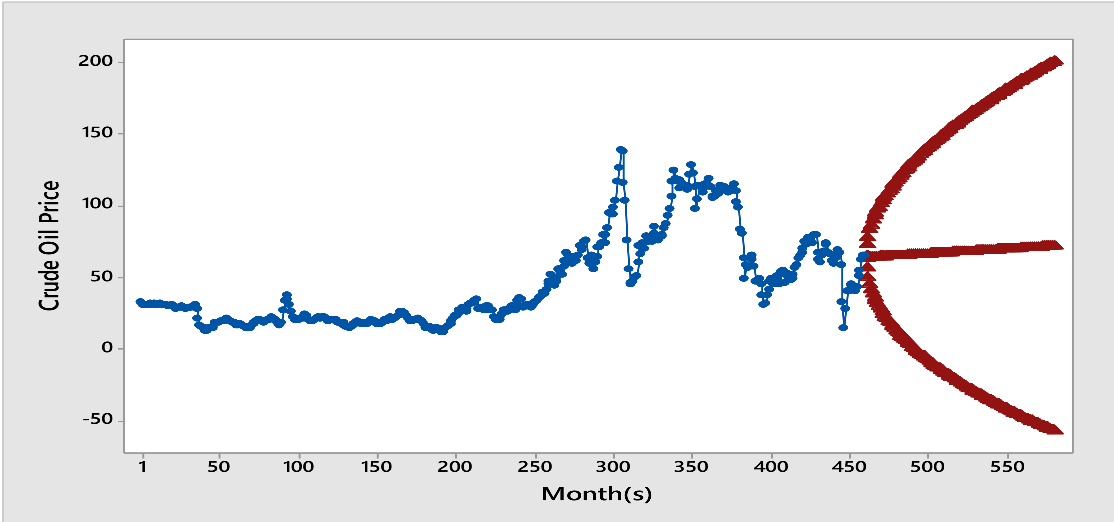

Fig. 6 Time plot of the forecast values of Nigerian monthly crude oil price from February 1983 to May 2030

The forecast evaluation metrics results give in Table 3 shows that the accuracy of the forecasted values was high. Since the mean Absolute Percentage Error (MAPE) is 0.023, the mean absolute erroris 0.018 and the root mean square error is 0.052. This indicates thatthe forecast evaluation metrics are relatively close to zero and this implies that the forecasting inaccuracy is low.

Table 2: Forecast of Nigerian monthly crude oil price from May 2021 to May 2030 with 95% confidence interval.

Month(s)	Forecast Value	Lower Limit	Upper Limit
461	64.740	56.378	73.102
462	63.617	49.370	77.865
463	64.146	45.131	83.161
464	63.689	40.893	86.485
465	64.137	38.427	89.847
466	64.110	35.743	92.477
467	64.107	33.459	94.755
468	64.432	31.571	97.294
469	64.121	29.229	99.012
470	64.615	27.786	101.443
471	64.268	25.580	102.955
472	64.674	24.254	105.094
473	64.518	22.382	106.654
474	64.672	20.946	108.399
475	64.787	19.473	110.101
476	64.693	17.887	111.499
477	65.000	16.723	113.277
478	64.791	15.094	114.489

479	65.126	14.056	116.196
480	64.972	12.545	117.399
481	65.187	11.465	118.909
482	65.194	10.178	120.210
483	65.234	8.981	121.487
484	65.402	7.917	122.888
485	65.317	6.639	123.995
486	65.561	5.709	125.412
487	65.455	4.449	126.461
488	65.666	3.537	127.795
489	65.636	2.389	128.883
490	65.745	1.416	130.073
491	65.827	0.419	131.235
492	65.831	-0.627	132.288
493	65.995	-1.503	133.494

Month(s)	Forecast Value	Lower Limit	Upper Limit
494	65.948	-2.572	134.469
495	66.128	-3.399	135.654
496	66.101	-4.423	136.624
497	66.232	-5.266	137.730
498	66.271	-6.198	138.740
499	66.330	-7.088	139.748
500	66.437	-7.926	140.799
501	66.442	-8.848	141.732
502	66.582	-9.626	142.791
503	66.577	-10.540	143.694
504	66.705	-11.306	144.717
505	66.730	-12.170	145.630
506	66.817	-12.957	146.591
507	66.888	-13.756	147.532
508	66.931	-14.569	148.430
509	67.037	-15.312	149.387
510	67.057	-16.132	150.247
511	67.171	-16.849	151.192
512	67.199	-17.647	152.044
513	67.294	-18.366	152.953
514	67.348	-19.122	153.817
515	67.413	-19.856	154.681
516	67.495	-20.568	155.558
517	67.537	-21.311	156.386
518	67.635	-21.993	157.263
519	67.672	-22.729	158.073

520	67.765	-23.401	158.931
521	67.814	-24.113	159.740
522	67.890	-24.790	160.569
523	67.958	-25.470	161.385
524	68.015	-26.153	162.184
525	68.098	-26.806	163.003
526	68.146	-27.488	163.780
527	68.233	-28.126	164.591
528	68.283	-28.795	165.361
529	68.362	-29.429	166.154
530	68.424	-30.077	166.924
531	68.490	-30.713	167.694
532	68.563	-31.339	168.466
533	68.621	-31.975	169.216
534	68.700	-32.585	169.985
535	68.755	-33.215	170.724

Month(s)	Forecast Value	Lower Limit	Upper Limit
536	68.833	-33.816	171.481
537	68.892	-34.432	172.216
538	68.963	-35.032	172.958
539	69.030	-35.631	173.692
540	69.094	-36.230	174.418
541	69.167	-36.815	175.150
542	69.227	-37.410	175.863
543	69.302	-37.984	176.589
544	69.362	-38.571	177.295
545	69.434	-39.141	178.010
546	69.499	-39.715	178.713
547	69.566	-40.283	179.415
548	69.636	-40.845	180.116
549	69.699	-41.409	180.806
550	69.771	-41.961	181.503
551	69.833	-42.520	182.185
552	69.905	-43.065	182.874
553	69.968	-43.616	183.552
554	70.037	-44.157	184.232
555	70.104	-44.698	184.906
556	70.170	-45.236	185.576
557	70.240	-45.767	186.247
558	70.304	-46.301	186.909
559	70.374	-46.826	187.574
560	70.438	-47.353	188.230

Month(s)	Forecast Value	Lower Limit	Upper Limit
561	70.508	-47.873	188.889
562	70.574	-48.393	189.541
563	70.641	-48.909	190.191
564	70.709	-49.421	190.839
565	70.775	-49.933	191.482
566	70.844	-50.439	192.126
567	70.909	-50.946	192.763
568	70.978	-51.446	193.402
569	71.044	-51.947	194.034
570	71.112	-52.443	194.666
571	71.179	-52.938	195.295
572	71.245	-53.430	195.921
573	71.313	-53.919	196.546
574	71.379	-54.407	197.165
575	71.448	-54.890	197.786
576	71.514	-55.373	198.401
577	71.582	-55.852	199.016
578	71.649	-56.330	199.627
579	71.716	-56.805	200.237
580	71.783	-57.278	200.844

Table 3. Forecasting evaluation metrics for Nigerian monthly crude oil price forecast

Forecast Evaluation metric	Value(s)
Root mean square error	0.052
Mean absolute error	0.018
Mean absolute percentage error	0.023

4. Conclusion

The volatility in Nigerian's crude oil price can be attributed to several factors. Some of these factors are global economic meltdown, exchange rates depreciation, global price crash, poor agricultural production, and COVID-19 pandemic. The Autoregressive Integrated Moving Average (ARIMA) was used to analyse Nigerian monthly crude oil price from February 1983 to April 2021. Autocorrelation and partial autocorrelation function were used to identify four ARIMA models and after estimation of the models with ordinary least square estimation method, ARIMA(5,1,2) was chosen as the optimal model for Nigeria monthly crude oil price based on the values of AIC, BIC and HQC. The model is viewed as satisfactory for forecasting Nigerian monthly crude oil price since the ACF and PACF of the residuals do notform any irregular pattern. The forecasted value of Nigerian monthly crude oil price indicated a steadyrise and maybe in-between 71.78 – 200.84 dollar per barrelin the next 10 years.The forecast evaluation metrics values indicated that the forecasted values are relatively accurate. Conclusively, this price rise may take the Nigerian government out of unchartered waters and the worst recession in 40 years. This will give Nigerian government the chance to revive the economy only if they diversify the economy, create job opportunities, combat insurgency, and put in place zero-tolerance measures against corruption and mismanagement of public funds.

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