World Wide Journal of Multidisciplinary Research and Development

WWJMRD 2017; 3(7): 108-113
www.wwjmrd.com
Impact Factor MJIF: 4.25
e-ISSN: 2454-6615

Ette Etuk
Department of Mathematics, Rivers State University, Port Harcourt, Nigeria

Azubuike Agbam
Department of Banking and Finance, Rivers State University, Port Harcourt, Nigeria

Imo Moffat
Department of Mathematics/Statistics, University of Uyo, Nigeria

Correspondence:
Ette Etuk
Department of Mathematics, Rivers State University, Port Harcourt, Nigeria

Interrupted Time Series Analysis of Nigerian Monthly Distribution of Petroleum Products

Ette Etuk, Azubuike Agbam, Imo Moffat

Abstract
This work is about an intervention model for monthly distribution of petroleum products in Nigeria. A look at the time plot of the distribution from 2009 to 2015 reveals an abrupt jump in the distribution in January 2013 which continued to 2015. The intervention is believed to be the deregulation of the downstream sector of the Nigerian oil industry which took place January 1, 2012. This means that the impact was not immediate but came twelve months afterwards. It has been noticed that this jump is statistically significant. The pre-intervention distribution is adjudged as non-stationary by the Augmented Dickey Fuller test. Therefore it has been differenced and the differences are stationary. An AR(2) model is found the best for modeling them. Post-intervention forecasts have been obtained on the basis of the ARIMA(2,1,0) model. The difference between post-intervention observations and forecasts is modeled for the intervention transfer function. A close agreement is observed between post-intervention observations and intervention forecasts. Intervention measures may therefore be based on the intervention model so computed.

Keywords: Petroleum, distribution, intervention, Nigeria, Arima modelling

Introduction

Crude oil remains the mainstay of the Nigeria economy. A look at monthly distribution of crude oil in Nigeria from 2009 to 2015 reveals an abrupt jump in January 2013 and this new level continued till 2015. It has been speculated that deregulation of the downstream sector of the Nigerian crude oil industry on 1 January 2012 has been responsible for this development. The aim of this study is to propose an interrupted time series (or intervention) model to explain this change occasioned by the deregulation.

The approach to take is the Box-Tiao[1] ARIMA approach. Since its introduction in 1975, it has gained popularity as many researchers have used it to model interventions. For example, Hipel *et al.* [2] studied the effect of the Aswan dam on the average flow of the Nile River and concluded that a significant drop in the flow occurred in 1903 when the dam was built. Increased speed limit to 65 miles per hour in April 1987 was observed by Chang *et al.* [3] to raise the number accident casualties phenomenally. Yin and Newmann [4] observed that hurricane Hugo caused a gradual die-down stumpage price effect. Sridharan *et al.* [5] have shown the deterrent impact of a new legislation which abolished parole for felony offenders in the Commonwealth of Virginia. Etuk et al.[6] have modeled the intervention effect of Nigerian economic recession on the Chinese Yen/Nigerian naira exchange rates.

The structure of this write-up is like this. This current section introduces the work. Section 2 introduces the materials and methods. Section 3 discusses the results of the data analysis. Then section 4 is the conclusion. Data analyzed are listed in the appendix.

Materials and methods

Data

The data used for this work were obtained from the website of the Nigerian National Petroleum Corporation (NNPC) http://nnpcgroup.com/. They are expressed in metric tonnes and have been listed in the appendix.

Interrupted Time Series Modelling

Let $\{X_t\}$ denote a time series with an intervention (i.e. a perturbation) at time t = T. Box and Tiao[1] proposed that an autoregressive integrated moving average (ARIMA) model be fitted to the pre-intervention data. Suppose this ARIMA model is of order p, d and q. That is,

$$Y_t - a_1 Y_{t-1} - a_2 Y_{t-2} - \ldots - a_p Y_{t-p} = \varepsilon_t + \beta_1 \varepsilon_{t-1} + \beta_2 \varepsilon_{t-2} + \ldots + \beta_q \varepsilon_{t-q} \quad (1)$$

Or

$$A(L)Y_t = B(L)\varepsilon_t \quad (2)$$

where $Y_t = \nabla^d X_t$ and

$A(L) = 1 - \alpha_1 L - \alpha_2 L^2 - \ldots - \alpha_p L^p$ and

$B(L) = 1 + \beta_1 L + \beta_2 L^2 + \ldots + \beta_q L^q$ and L is the backshift operator defined by $L^k X_t = X_{t-k}$ and ∇=1-L and $\{\varepsilon_t\}$ is a white noise process.

Modelling of (1) invariably begins with the estimation of the differencing order d. This is done by testing for the stationarity of $\{X_t\}$. If it is found stationary than d=0. If not, the series is differenced once; if found stationary then d=1 but if not, the process continues. The Augmented Dickey Fuller (ADF) test shall be used for the testing of series stationarity. To determine p and q the autocorrelation function (ACF) and the partial autocorrelation function (PACF) of the differenced series Y_t are computed and plotted. Their respective cut-off points, if any, are estimates of q and p. Then the α's and the β's can be estimated by the least squares or the maximum likelihood technique.

On the basis of this model, forecasts are made in the post-intervention period. Let these forecasts be given by F(t), t ≥ T. Then $Z_t = X_t - F(t)$ is modeled to give the transfer function of the intervention as

$$Z_t = \frac{c(1)*(1-c(2)\wedge(t-T+1))}{1-c(2)}, \ t \geq T \quad (3)$$

(The Pennsylvania State University[7]). Then the overall intervention model is given by

$$X_t = \frac{B(L)\varepsilon_t}{A(L)\nabla^d} + Z_t I_t \quad (4)$$

where $I_t = 0$, t < T and equal to 1, for t ≥ T.

Computer Software

The statistical and econometric package Eviews 7 was used for all computational work in this research. It uses the least square criterion for model estimation.

Results and Discussion

The time plot in Figure 1 shows an initial slight overall negative trend up to December 2012 after which there is an abrupt rise in January 2013 which continued till 2015. This means that the intervention came in in January 2013 so that T = 49. Figure 2 is the time plot of the pre-intervention series. Figure 3 is the correlogram of the pre-intervention series; it shows that there indeed is a trend in the series. Figures 4 and 5 are the histograms of the pre-intervention and post-intervention oil distributions respectively. A student's t-test comparison of the pre-intervention and post-intervention means based on the histogram data is highly significant (p < 0.001), showing the intervention impact is statistically highly significant.

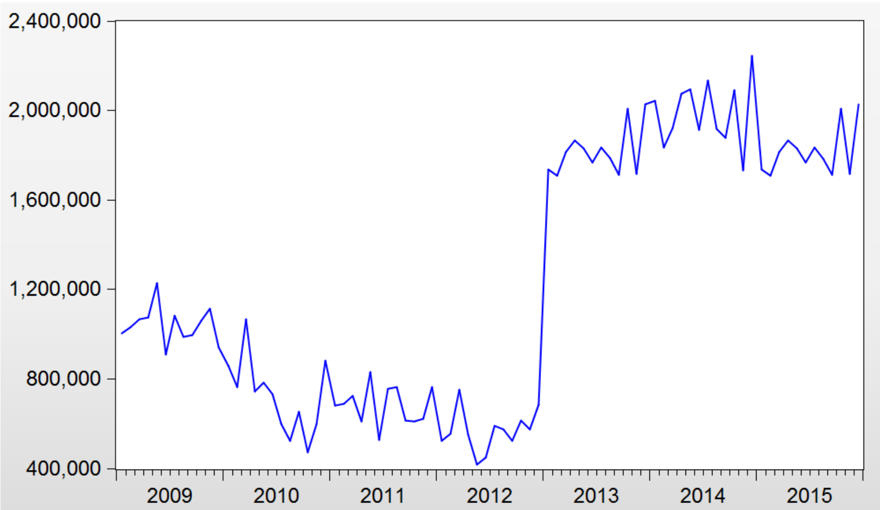


Fig. 1: Nigerian Petroleum Distribution

The ADF test on the pre-intervention data, with a test statistic value of -2.90 and 1%, 5% and 10% critical values of -3.58, -2.93 and -2.60 respectively, certifies them as non-stationary. Differencing them once yields a stationary process on ADF test ground with a test statistic of -8.53. That means that d = 1. The time plot and the correlogram of the series are in Figures 6 and 7 respectively. Based on the observed ACF and PACF one of the best models suggestive is the ARIMA(2,1,0) estimated in Table 1 as

$$Y_t + 0.5823Y_{t-1} + 0.4117Y_{t-2} = \varepsilon_t \quad (5)$$

which means that

$$X_t = \frac{\varepsilon_t}{(1+0.5823L+0.4117L^2)(1-L)} \quad (6)$$

The adequacy of model (5) or (6) is evident from the

correlogram and the histogram of the residuals of Figures 8 and 9 which show that the residuals are uncorrelated and normally distributed respectively.
Based on model (5) or (6) forecasts F(t) are made for the post-intervention model and $Z_t = X_t - F(t)$ is modelled to yield the transfer function with c(1) = 1056567 and c(2) = 0.1494 as given in Table 2 according to Eq. 3. Figure 10 shows goodness-of fit of the post-intervention forecasts and the observations. Hence the overall intervention model is given by

$$X_t = \frac{\varepsilon_t}{(1+0.5823L+0.4117L^2)(1-L)} + 1056567\, I_t * (1-0.1494\wedge(t-48))/0.8506 \qquad (7)$$

Where $I_t = 0$, $t < 49$, $t = 1$, $t \geq 49$.

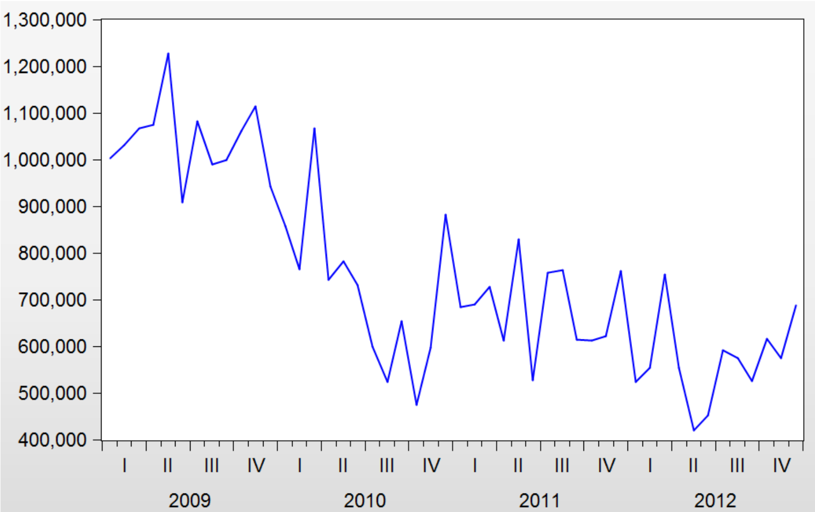
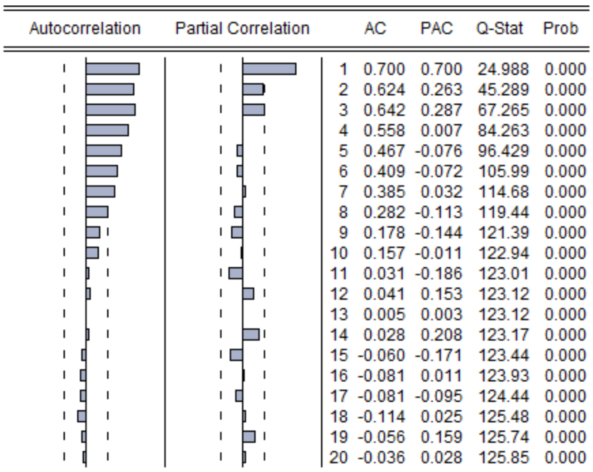


Fig. 2: Pre-Intervention Petroleum Distribution



	AC	PAC	Q-Stat	Prob
1	0.700	0.700	24.988	0.000
2	0.624	0.263	45.289	0.000
3	0.642	0.287	67.265	0.000
4	0.558	0.007	84.263	0.000
5	0.467	-0.076	96.429	0.000
6	0.409	-0.072	105.99	0.000
7	0.385	0.032	114.68	0.000
8	0.282	-0.113	119.44	0.000
9	0.178	-0.144	121.39	0.000
10	0.157	-0.011	122.94	0.000
11	0.031	-0.186	123.01	0.000
12	0.041	0.153	123.12	0.000
13	0.005	0.003	123.12	0.000
14	0.028	0.208	123.17	0.000
15	-0.060	-0.171	123.44	0.000
16	-0.081	0.011	123.93	0.000
17	-0.081	-0.095	124.44	0.000
18	-0.114	0.025	125.48	0.000
19	-0.056	0.159	125.74	0.000
20	-0.036	0.028	125.85	0.000

Fig. 3: Correlogram of the Pre-Intervention Data

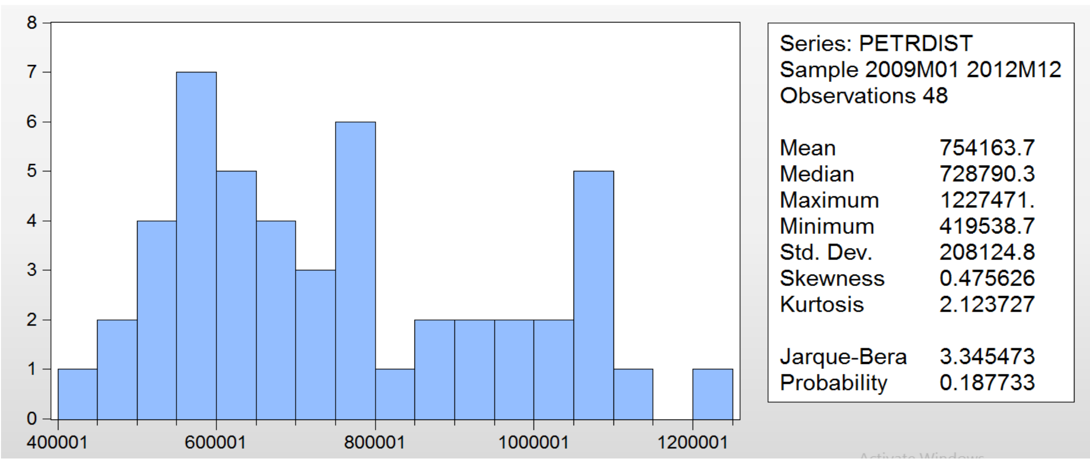


Fig. 4: Histogram of the Pre-Intervention Data

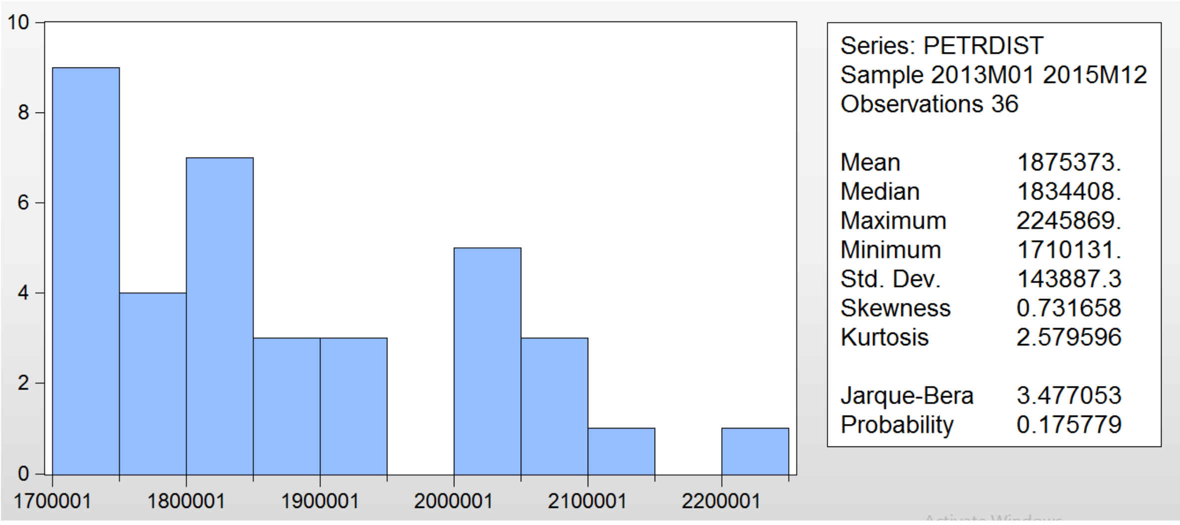


Fig. 5: Histogram of the Post-Intervention Data

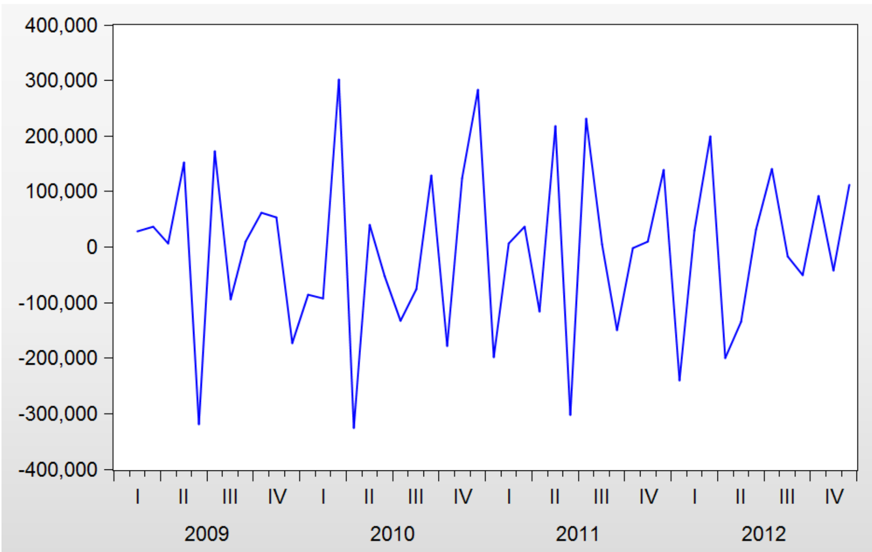
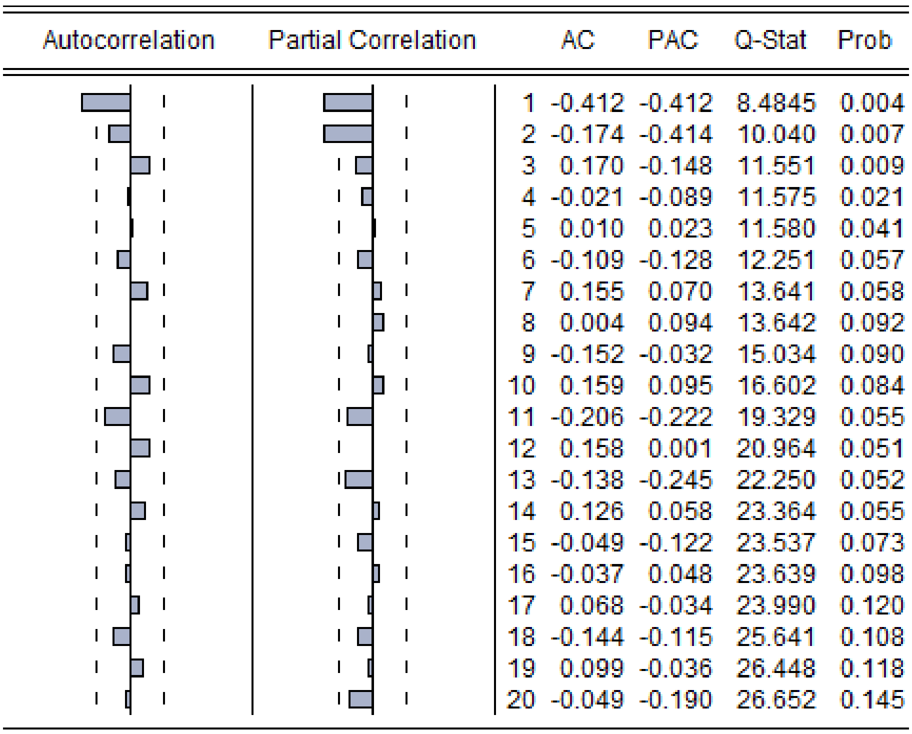


Fig. 6: Difference of Pre-Intervention Data

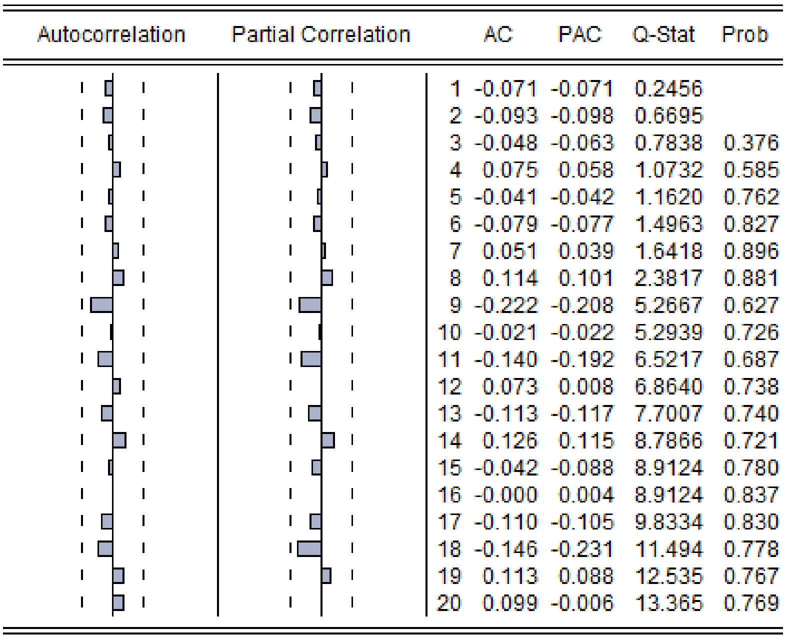


Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	-0.412	-0.412	8.4845	0.004
		2	-0.174	-0.414	10.040	0.007
		3	0.170	-0.148	11.551	0.009
		4	-0.021	-0.089	11.575	0.021
		5	0.010	0.023	11.580	0.041
		6	-0.109	-0.128	12.251	0.057
		7	0.155	0.070	13.641	0.058
		8	0.004	0.094	13.642	0.092
		9	-0.152	-0.032	15.034	0.090
		10	0.159	0.095	16.602	0.084
		11	-0.206	-0.222	19.329	0.055
		12	0.158	0.001	20.964	0.051
		13	-0.138	-0.245	22.250	0.052
		14	0.126	0.058	23.364	0.055
		15	-0.049	-0.122	23.537	0.073
		16	-0.037	0.048	23.639	0.098
		17	0.068	-0.034	23.990	0.120
		18	-0.144	-0.115	25.641	0.108
		19	0.099	-0.036	26.448	0.118
		20	-0.049	-0.190	26.652	0.145

Fig. 7: Correlogram of Difference of Pre-Intervention Data

Table 1: Estimation of the Arima (2, 1, 0) Pre-Intervention Model

Variable	Coefficient	Standard Error	t-Statistic	Probability
AR(1)	-0.582258	0.139573	-4.171707	0.0001
AR(2)	-0.411721	0.139630	-2.948668	0.0051
R-squared	0.307365	Akaike Information criterion 26.52267		
Inverted AR roots	-0.29-0.57i	-0.29+0.57i		



Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	-0.071	-0.071	0.2456	
		2	-0.093	-0.098	0.6695	
		3	-0.048	-0.063	0.7838	0.376
		4	0.075	0.058	1.0732	0.585
		5	-0.041	-0.042	1.1620	0.762
		6	-0.079	-0.077	1.4963	0.827
		7	0.051	0.039	1.6418	0.896
		8	0.114	0.101	2.3817	0.881
		9	-0.222	-0.208	5.2667	0.627
		10	-0.021	-0.022	5.2939	0.726
		11	-0.140	-0.192	6.5217	0.687
		12	0.073	0.008	6.8640	0.738
		13	-0.113	-0.117	7.7007	0.740
		14	0.126	0.115	8.7866	0.721
		15	-0.042	-0.088	8.9124	0.780
		16	-0.000	0.004	8.9124	0.837
		17	-0.110	-0.105	9.8334	0.830
		18	-0.146	-0.231	11.494	0.778
		19	0.113	0.088	12.535	0.767
		20	0.099	-0.006	13.365	0.769

Fig. 8: Correlogram of the Residuals of the Arima (2, 1, 0) Model

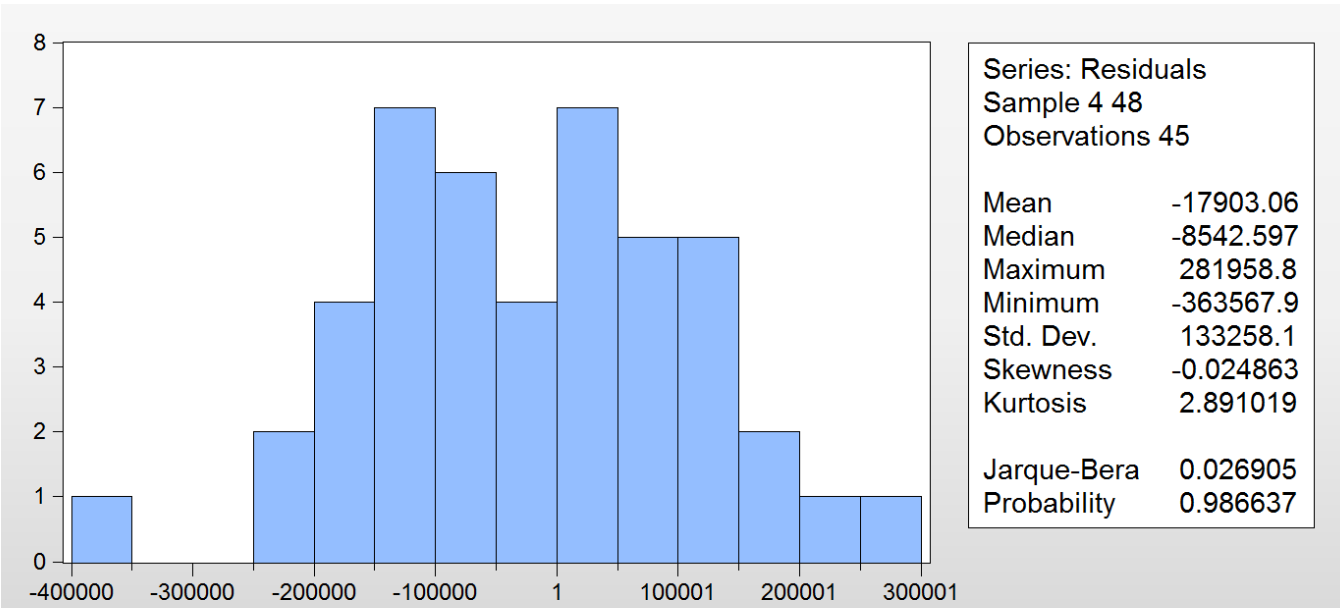


Fig. 9: Histogram of the Residuals of the Arima (2, 1, 0) Model

Table 2: Intervention Transfer Function Estimation

Variable	Coefficient	Standard Error	t-Statistic	Probability
C(1)	1056567	136855.6	7.720306	0.0000
C(2)	0.149398	0.112231	1.331162	0.1920
R-squared	0,035587	Akaike info criterion 26.63266		

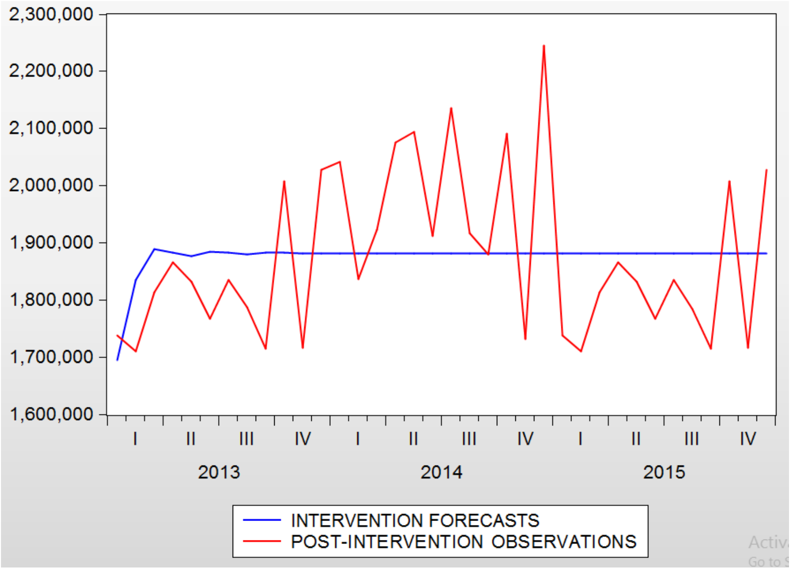


Fig. 10: Post-Intervention Observations and Forecasts

Conclusions

It may be concluded that model (7) is adequate to account for the intervention impact on the distribution of the petroleum products by deregulation of the downstream sector of the Nigerian petroleum industry. Clearly the impact was not immediate but was felt after a year of its introduction. Government functionaries and managers may avail themselves of this model for planning purposes. .

Appendix

Data

	Years						
months	2009	2010	2011	2012	2013	2014	2015
January	1003025	856808.3	683337.1	522913.3	1738231	2041955	1738231
February	1031146	765246.2	689568.9	553682.4	1710131	1836267	1710131
March	1067923	1067817	726433.4	752870.8	1813639	1922385	1813639
April	1074922	743167.2	611549.5	553500.3	1866522	2075285	1866522
May	1227471	782633.4	829860.6	419538.7	1832093	2094790	1832093
June	909015	731147.2	527257.3	451067.5	1767629	1912967	1767629
July	1082330	599084.0	758032.0	591864.6	1834408	2135416	1834408
August	988853.1	523974.1	763304.3	574473.0	1787428	1916416	1784428
September	998302.8	653055.9	613601.7	524961.9	1714157	1879907	1714157
October	1060502	474616.7	611492.5	616389.4	2007766	2090333	2007766
November	1114721	597898.5	622320.2	574996.8	1716488	1732244	1716488
December	942312.6	881543.0	762259.2	687068.2	2027801	2245869	2027801

References

1. Box GEP, Tiao GC. Intervention Analysis with applications to economic and environmental problems. Journal of American Statistical Association, 1975; 70: 70-79.
2. Hipel KW, Lennox WC, Unny TE, McLeod AI. Intervention analysis in water resources. Water Resources Research, 1975; 11(6): 855-861.
3. Chang GL, Chen CH, Carter EC. Intervention analysis for the impacts of the 65 mph speed limit on rural interstate highway fatalities. Journal of Safety Research, 1993; 24(1): 33-53.
4. Yin R, Newmann DH. An Intervention analysis of Hurricane Hugo's effect on South Carloina's stumpage prices. Canadian Journal of forest Research, 1999; 29(6): 777-787.
5. Sridharan S, Vujic S, Koopman SJ. Intervention Time Series Analysis of Crime Rates. https://papers.tinbergen.nl/03040.pdf . 27th June 2017.
6. Etuk EH, Dimkpa YM, Sibeate P, Godwin N. Intervention analysis of daily Yen/Naira Exchange rates. Management and Administrative Science Review, 2017; 6(1): 41-49.
7. The Pennsylvania State University. Welcome to STAT 510! Applied Time Series Analysis. Department of Statistics Online Program. www.onlinecourses.science.psu.edu/stat510/