APPLICATION OF LINEAR STOCHATIC MODELLING FOR NIGERIAN MONTHLY CRUDE OIL EXPORTS

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ABSTRACT:
This research is concerned with autoregressive integrated moving average (ARIMA) modelling of monthly crude oil exports of Nigeria. The realization covered is from January 2006 to November 2016. The time plot reveals an initial generally negative trend up to mid-2009, and then a positive trend up to mid-2010 and then a negative trend up to 2016. An examination of the data reveals a measure of twelve monthly seasonality. The Augmented Dickey Fuller (ADF) Test adjudges the series as stationary but its autocorrelation structure shows the involvement of a secular trend in the series. This means that the series is still non-stationary. A non-seasonal differencing makes the series stationary. The correlation structure of these first differences suggest an ARIMA(1,1,1) fit. A twelve monthly differencing of the original series was done also. The correlogram of these seasonal differences shows evidence of secular trend in them. A non-seasonal differencing rids the seasonal differences of the trend. The autocorrelation structure of the resultant series gives evidence of twelve-monthly seasonality and suggests a SARIMA(1,1,0)x$(0,1,1)_{12}$ fit. However it is observed that on the basis of AIC, the ARIMA(1,1,1) fit is the more adequate model. Hence, forecasting or simulation of the export series may be done on its basis.
Keywords: *Nigerian Crude Oil Exports, ARIMA Modelling, SARIMA modelling*

INTRODUCTION:

Crude oil is the mainstay of the Nigerian economy. Data from the Nigerian Bureau of Statistics(NBS), show that more than 80% of the nation's exports was accounted for by crude oil in the first quarter of 2016 (Eboh, 2016). Destinations of these exports in recent times are in their order of importance India, United State of America (USA), Spain, the Netherlands, France, South Africa, Brazil, China, Italy and Japan. These exports involve unrefined crude oil and are cheap compared to the refined oil imported back into the country at comparatively exorbitant costs (Onwuemenyi, 2017). The end of year is usually the peak period because it ushers in the festive Yuletide period when demand for all commodities is on the increase.

LITERATURE REVIEW

This study is aimed at modelling Nigerian monthly crude oil exports with a view to forecasting the 2017 amounts. The approach adopted is the autoregressive integrated moving average (ARIMA) approach of Box and Jenkins (1976). Since its introduction in 1976, it has been extensively applied by researchers, and successfully too, to model time series. For instance, Stevenson (2007) has shown that ARIMA models are useful in explaining variation in broad market trends. Intervention effects on some infectious diseases have been prevented by ARIMA modelling by Sato (2013). An ARIMA(2,1,2) model has been fitted to Square Pharmaceutical Data Limited Data in Bangladesh by Paul *et al.* (2013). Adebiyi *et al.* (2014) proposed a stock price predictive model and applied it to data from New York Stock Exchange and Nigerian Stock Exchange. Adams *et al.* (2014) fitted an ARIMA(1,2,1) to Nigerian Consumer Price Index. Nochai and Nochai (2015) have fitted ARIMA models to oil palm prices in Thailand. Vietnam dong / United States Dollars exchange rates have been modelled by ARIMA techniques by Ngan (2016). Kumar and Raj (2016) have shown the usefulness of ARIMA models in modelling book borrowing data in libraries. Jelena *et al.* (2017) forecasts unemployment rates in the European Union for the future by Box-Jenkins (1976) methods. This is to mention a few.

MATERIALS AND METHODS:

Data: The data for this investigation are monthly crude oil exports of Nigeria from January 2006 to November 2017 published by the Central Bank of Nigeria (CBN) in its website www.cenbank.org(Acessed: 14/06/2017) They are expressed in millions barrels per day (mbp).

ARIMA MODELLING:

An ARIMA model is a linear stochastic model introduced by Box and Jenkins (1976). Suppose that $\{X_t\}$ is a stationary time series. It is said to follow *an autoregressive moving average model of order p and q,* designated ARMA(p,q), if

$$X_t = \alpha_1 X_{t-1} + \alpha_2 X_{t-2} + \cdots + \alpha_p X_{t-p} + \beta_1 \varepsilon_{t-1} + \beta_2 \varepsilon_{t-2} + \cdots + \beta_q \varepsilon_{t-q} + \varepsilon_t \quad (1)$$

where $\{\varepsilon_t\}$ is a *white noise process* and the α's and β's are constants such that the model is stationary as well as invertible. Model (1) may be written as

$A(L)X_t = B(L)\varepsilon_t$ (2)

where $A(L) = 1 - \alpha_1 L - \alpha_2 L^2 - \ldots - \alpha_p L^p$ and $B(L) = 1 + \beta_1 L + \beta_2 L^2 + \ldots + \beta_q L^q$ are the autoregressive (AR) and the moving average (MA) operators respectively and L is the backshift operator such that

$L^k X_t = X_{t-k}$.

If $\{X_t\}$ is non-stationary, Box and Jenkins (1976) further propose that differencing the time series to an appropriate order d can make it stationary in which a replacement of X_t with its d^{th} difference $\nabla^d X_t = (1-L)^d X_t$ in (1) yields an *autoregressive integrated moving average model of order p, d, q* denoted by ARIMA(p, d, q). Therefore an ARIMA(p,d,q) may be written as
$A(L)\nabla^d X_t = B(L)\varepsilon_t$ (3)

If in addition $\{X_t\}$ is seasonal of period s, Box and Jenkins proposed that it might be modelled by
$A(L)\Phi(L^s)\nabla^d \nabla_s^D X_t = B(L)\Theta(L^s)\varepsilon_t$ (4)

where $\Phi(L) = 1 + \phi_1 L^s + \phi_2 L^{2s} + \ldots + \phi_P L^{Ps}$ and $\Theta(L) = 1 + \theta_1 L^s + \theta_2 L^{2s} + \ldots + \theta_Q L^{Qs}$ are the seasonal AR and MA operators respectively. The symbol ∇_s^D represents the seasonal difference operator. Then (4) is to be a *seasonal autoregressive integrated moving average model of order (p,d,q)X(P.D,Q)$_s$* , designated SARIMA(p,d,q)X(P,D,Q)$_s$.

Estimation of (1) begins with determination of the differencing order d. To test for data stationarity the Augmented Dickey Fuller (ADF) Test shall be used. Putting d=1, stationarity of the data is tested. If the data are stationary, then d=1. Otherwise d = 2 and so on. After determination of d, the autoregressive order p and the moving average order q are determined by the cut-off points of the partial autocorrelation function (PACF) and the autocorrelation function (ACF) respectively of the differences $\{\nabla^d X_t\}$. The α's and β's are, thereafter, estimated by the least squares or maximum likelihood procedure.

If the series is seasonal the seasonal differencing order D, the AR order P and the MA order Q are estimated in a way similar to their non-seasonal counterparts. Generally d + D < 3. P and Q are determined as seasonal cut-off lags of PACF and ACF respectively. Model comparison is on the basis of Akaike Information Criterion (AIC).

COMPUTER PACKAGE:

The statistical and econometric package Eviews 7 is used for all computations. The least squares procedure is used for model estimation in this software.

RESULTS AND CONCLUSION:

The time plot of the exports in Figure 1 shows an initial negative trend to 2009 and then an upward trend to mid 2010 and then a generally downward trend to 2016. The seasonal movement is evident too. inspection of the series on annual basis reveals that yearly minimums tend to lie in the first half of the years and the maximums in the second half of the years. This corroborates Onwuemenyi's (2017) opinion that the end of year is a peak period for the exportation of the Nigerian crude oil. With a test statistic value of -3.24 and 1%, 5% and 10% critical values of -3.48, -2.88 and -2.58, the ADF test adjudges the exports to be stationary. However its correlogram in Figure 2 gives evidence of the existence of secular trend.

First order differencing of the exports yields a series with no trend (See Figure 3). With a test statistic value of -15.22 and the same critical as mentioned above, the ADF test adjudges these differences as stationary. Their correlogram of Figure 4 is suggestive that p = q = 1. The ARIMA(1,1,1) model is estimated in Table 1 as

$$\nabla X_t + 0.3833\, \nabla X_{t-1} + 0.7744\varepsilon_{t-1} = \varepsilon_t \qquad (5)$$

Twelve-monthly differences of the exports are plotted in Figure 5. They are certified as stationary with an ADF Test statistic of -4.73. However their correlogram of Figure 6 shows evidence of non-stationarity (secular trend). Non-seasonal differencing rids the series of non-stationarity as evident from their time plot of Figure 7 and their correlogram of Figure 8. Moreover the correlogram suggests a SARIMA(1,1,0)x$(0,1,1)_{12}$ for the exports. Estimation of this model in Table 2 yields

$$\nabla\nabla_{12} X_t + 0.3358\nabla\nabla_{12}\mathrm{X}_{t-1} + 0.8599\varepsilon_t \qquad (6)$$

It is observed that model (5) is better the seasonal model (6) on the grounds of minimum AIC.

CONCLUSION:

It might be observed that the ARIMA(1,1,1) model is more adequate than the SARIMA(1,1,0)X$(0,1,1)_{12}$ model on AIC grounds. It may be used for forecastin and simulation of the Nigerian crude oil exports.

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RESULTS:

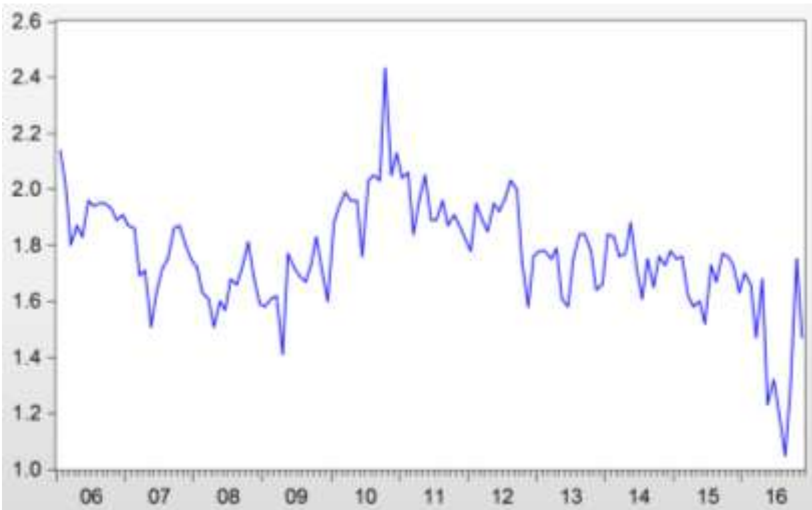
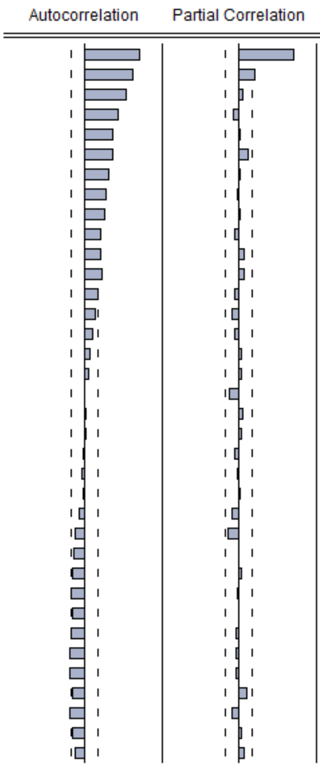


FIGURE1: NIGERIAN CRUDE OIL EXPORTS



	AC	PAC	Q-Stat	Prob
1	0.740	0.740	73.298	0.000
2	0.645	0.217	129.50	0.000
3	0.562	0.065	172.48	0.000
4	0.448	-0.077	200.03	0.000
5	0.382	0.013	220.25	0.000
6	0.371	0.123	239.46	0.000
7	0.329	0.014	254.71	0.000
8	0.292	-0.020	266.77	0.000
9	0.274	0.014	277.46	0.000
10	0.220	-0.049	284.41	0.000
11	0.217	0.071	291.22	0.000
12	0.229	0.079	298.90	0.000
13	0.188	-0.065	304.10	0.000
14	0.145	-0.085	307.25	0.000
15	0.107	-0.052	308.98	0.000
16	0.079	0.030	309.92	0.000
17	0.064	0.032	310.54	0.000
18	0.005	-0.135	310.55	0.000
19	0.019	0.055	310.61	0.000
20	0.018	0.031	310.66	0.000
21	-0.020	-0.060	310.72	0.000
22	-0.030	-0.011	310.87	0.000
23	-0.024	0.017	310.97	0.000
24	-0.069	-0.083	311.75	0.000
25	-0.129	-0.140	314.50	0.000
26	-0.141	0.005	317.80	0.000
27	-0.168	0.028	322.51	0.000
28	-0.174	-0.011	327.61	0.000
29	-0.161	-0.005	332.02	0.000
30	-0.180	-0.036	337.61	0.000
31	-0.192	-0.040	344.01	0.000
32	-0.199	-0.035	350.98	0.000
33	-0.171	0.106	356.19	0.000
34	-0.201	-0.083	363.47	0.000
35	-0.159	0.039	368.08	0.000
36	-0.119	0.066	370.66	0.000

FIGURE 2: CORRELOGRAM OF THE EXPORTS

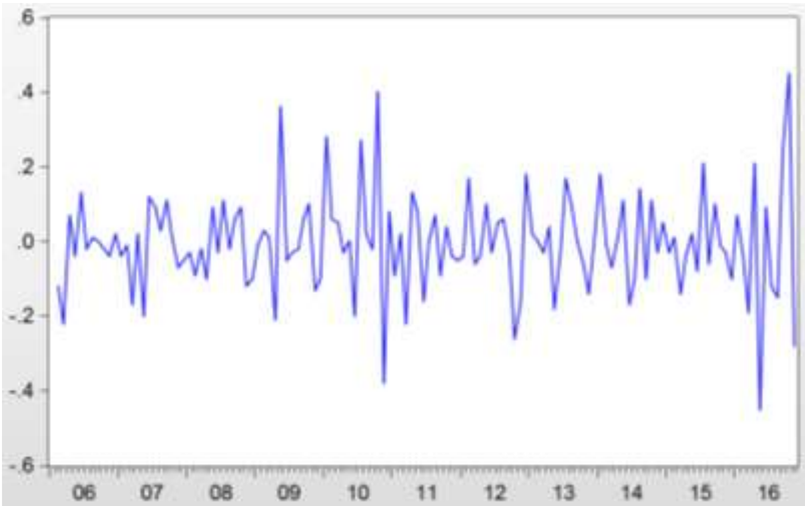
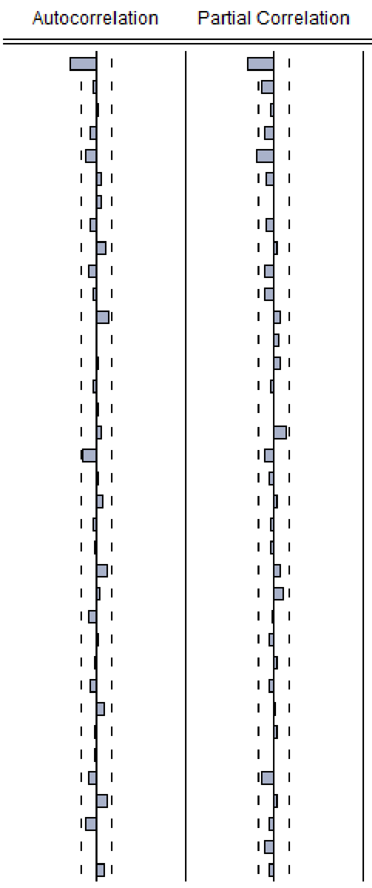


FIGURE 3: DIFFERENCE OF THE NIGERIAN CRUDE OIL EXPORTS



	AC	PAC	Q-Stat	Prob
1	-0.296	-0.296	11.637	0.001
2	-0.047	-0.148	11.938	0.003
3	0.019	-0.045	11.988	0.007
4	-0.077	-0.103	12.795	0.012
5	-0.122	-0.204	14.851	0.011
6	0.055	-0.086	15.264	0.018
7	0.047	-0.001	15.570	0.029
8	-0.069	-0.082	16.238	0.039
9	0.102	0.030	17.712	0.039
10	-0.096	-0.102	19.034	0.040
11	-0.046	-0.112	19.335	0.055
12	0.132	0.073	21.871	0.039
13	0.007	0.064	21.879	0.057
14	0.020	0.077	21.937	0.080
15	-0.037	-0.027	22.141	0.104
16	0.012	0.003	22.162	0.138
17	0.045	0.134	22.468	0.167
18	-0.157	-0.101	26.245	0.094
19	0.023	-0.061	26.329	0.121
20	0.066	0.034	27.008	0.135
21	-0.045	-0.038	27.324	0.160
22	-0.024	-0.039	27.415	0.196
23	0.120	0.068	29.713	0.158
24	0.029	0.108	29.853	0.190
25	-0.083	-0.012	30.985	0.190
26	0.020	-0.054	31.051	0.226
27	-0.014	0.028	31.086	0.268
28	-0.073	-0.052	31.978	0.275
29	0.086	0.008	33.235	0.268
30	-0.012	0.028	33.259	0.311
31	-0.021	0.005	33.333	0.354
32	-0.085	-0.145	34.604	0.345
33	0.117	0.038	37.009	0.289
34	-0.132	-0.063	40.114	0.217
35	-0.004	-0.098	40.117	0.254
36	0.098	-0.058	41.861	0.231

FIGURE 4: CORRELOGRAM OF THE FIRST DIFFERENCES OF THE EXPORTS

TABLE 1: ESTIMATION OF THE ARIMA(1,1,1)MODEL

Dependent Variable: DCOE
Method: Least Squares
Date: 06/12/17 Time: 13:26
Sample (adjusted): 2006M03 2016M11
Included observations: 129 after adjustments
Convergence achieved after 6 iterations
MA Backcast: 2006M02

Variable	Coefficient	Std. Error	t-Statistic	Prob.
AR(1)	0.383319	0.143970	2.662493	0.0088
MA(1)	-0.774392	0.099455	-7.786331	0.0000

R-squared	0.156728	Mean dependent var	-0.004264
Adjusted R-squared	0.150088	S.D. dependent var	0.134099
S.E. of regression	0.123626	Akaike info criterion	-1.327722
Sum squared resid	1.941005	Schwarz criterion	-1.283384
Log likelihood	87.63805	Hannan-Quinn criter.	-1.309706
Durbin-Watson stat	2.015734		

Inverted AR Roots	.38
Inverted MA Roots	.77

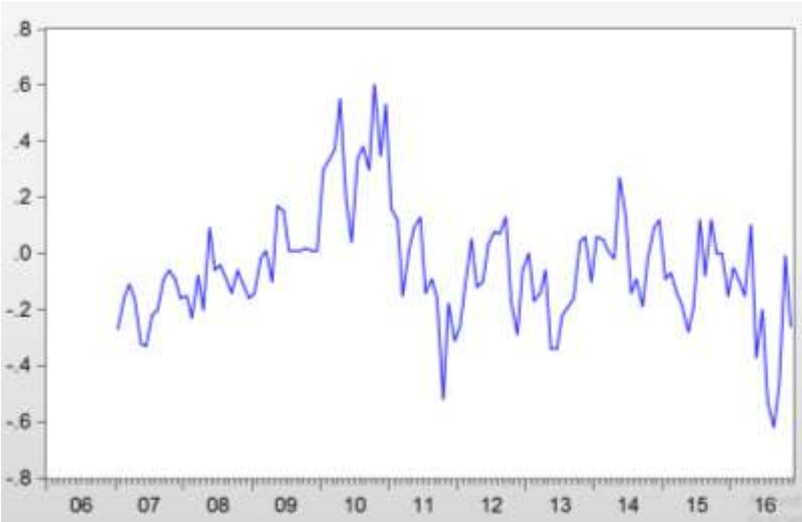
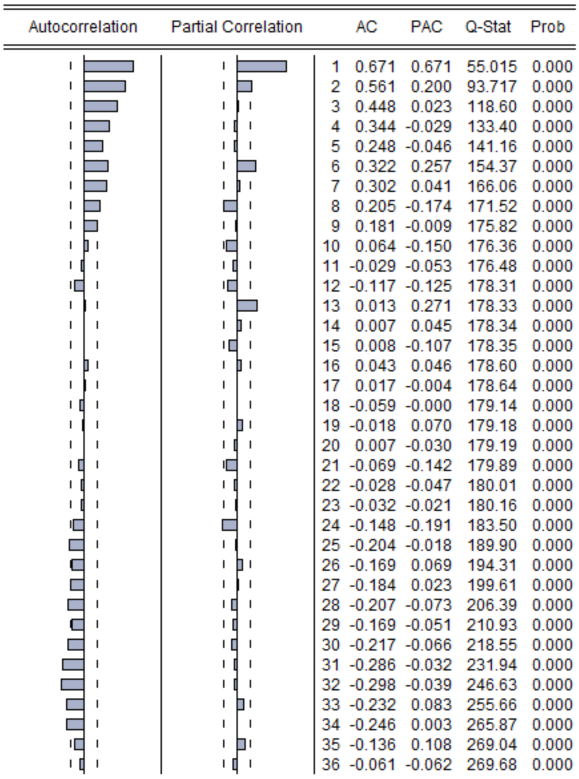


FIGURE 5: SEASONAL DIFFERENCES OF THE EXPORTS



Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.671	0.671	55.015	0.000
		2	0.561	0.200	93.717	0.000
		3	0.448	0.023	118.60	0.000
		4	0.344	-0.029	133.40	0.000
		5	0.248	-0.046	141.16	0.000
		6	0.322	0.257	154.37	0.000
		7	0.302	0.041	166.06	0.000
		8	0.205	-0.174	171.52	0.000
		9	0.181	-0.009	175.82	0.000
		10	0.064	-0.150	176.36	0.000
		11	-0.029	-0.053	176.48	0.000
		12	-0.117	-0.125	178.31	0.000
		13	0.013	0.271	178.33	0.000
		14	0.007	0.045	178.34	0.000
		15	0.008	-0.107	178.35	0.000
		16	0.043	0.046	178.60	0.000
		17	0.017	-0.004	178.64	0.000
		18	-0.059	-0.000	179.14	0.000
		19	-0.018	0.070	179.18	0.000
		20	0.007	-0.030	179.19	0.000
		21	-0.069	-0.142	179.89	0.000
		22	-0.028	-0.047	180.01	0.000
		23	-0.032	-0.021	180.16	0.000
		24	-0.148	-0.191	183.50	0.000
		25	-0.204	-0.018	189.90	0.000
		26	-0.169	0.069	194.31	0.000
		27	-0.184	0.023	199.61	0.000
		28	-0.207	-0.073	206.39	0.000
		29	-0.169	-0.051	210.93	0.000
		30	-0.217	-0.066	218.55	0.000
		31	-0.286	-0.032	231.94	0.000
		32	-0.298	-0.039	246.63	0.000
		33	-0.232	0.083	255.66	0.000
		34	-0.246	0.003	265.87	0.000
		35	-0.136	0.108	269.04	0.000
		36	-0.061	-0.062	269.68	0.000

FIGURE 6: CORRELOGRAM OF SEASONAL DIFFERENCES OF THE SERIES

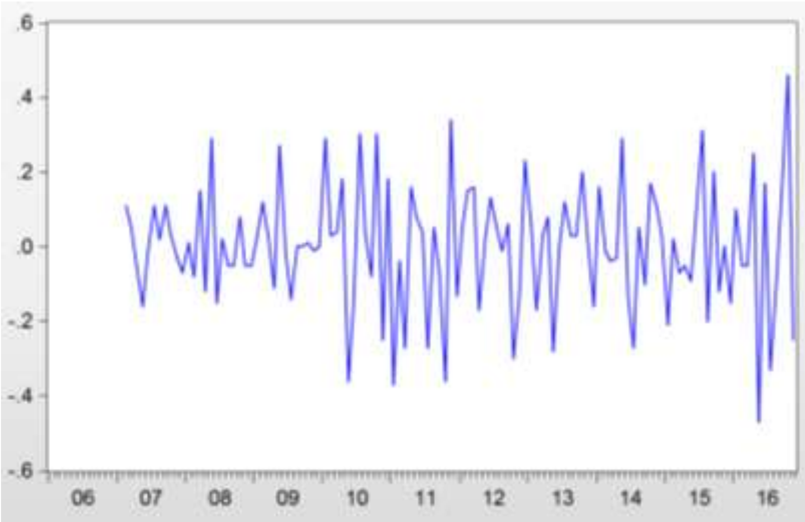


FIGURE 7: DIFFERENCES OF THE SEASONAL DIFFERENCES OF THE EXPORTS

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	-0.317	-0.317	12.188	0.000
		2	-0.023	-0.138	12.252	0.002
		3	-0.027	-0.090	12.345	0.006
		4	-0.018	-0.069	12.383	0.015
		5	-0.245	-0.323	19.933	0.001
		6	0.144	-0.089	22.572	0.001
		7	0.151	0.141	25.478	0.001
		8	-0.122	-0.052	27.403	0.001
		9	0.151	0.114	30.367	0.000
		10	-0.035	0.017	30.531	0.001
		11	-0.021	0.064	30.591	0.001
		12	-0.329	-0.310	45.041	0.000
		13	0.207	-0.082	50.810	0.000
		14	0.006	0.058	50.816	0.000
		15	-0.074	-0.129	51.559	0.000
		16	0.128	-0.019	53.832	0.000
		17	0.047	-0.031	54.146	0.000
		18	-0.188	-0.126	59.154	0.000
		19	0.029	0.019	59.277	0.000
		20	0.157	0.101	62.825	0.000
		21	-0.172	0.027	67.167	0.000
		22	0.065	0.000	67.791	0.000
		23	0.187	0.163	72.996	0.000
		24	-0.095	0.001	74.367	0.000
		25	-0.143	-0.110	77.465	0.000
		26	0.071	-0.059	78.240	0.000
		27	0.011	-0.012	78.258	0.000
		28	-0.081	0.007	79.287	0.000
		29	0.152	0.046	82.974	0.000
		30	0.032	-0.024	83.138	0.000
		31	-0.109	-0.009	85.058	0.000
		32	-0.119	-0.137	87.405	0.000
		33	0.127	-0.018	90.087	0.000
		34	-0.192	-0.138	96.330	0.000
		35	0.043	0.004	96.650	0.000
		36	0.150	0.006	100.55	0.000

FIGURE 8: CORRELOGRAM OF DIFFERENCE OF THE SEASONAL DIFFERENCES

TABLE 2: ESTIMATION OF THE SARIMA(1,1,0)X(0,1,1)12 MODEL

Dependent Variable: DSDCOE
Method: Least Squares
Date: 06/13/17 Time: 21:16
Sample (adjusted): 2007M03 2016M11
Included observations: 117 after adjustments
Convergence achieved after 9 iterations
MA Backcast: 2006M03 2007M02

Variable	Coefficient	Std. Error	t-Statistic	Prob.
AR(1)	-0.335794	0.088230	-3.805913	0.0002
MA(12)	-0.859867	0.029142	-29.50659	0.0000

R-squared	0.425301	Mean dependent var	-0.000855
Adjusted R-squared	0.420303	S.D. dependent var	0.166943
S.E. of regression	0.127107	Akaike info criterion	-1.270633
Sum squared resid	1.857954	Schwarz criterion	-1.223416
Log likelihood	76.33202	Hannan-Quinn criter.	-1.251463
Durbin-Watson stat	2.091466		

Inverted AR Roots	-.34			
Inverted MA Roots	.99	.86+.49i	.86-.49i	.49+.86i
	.49-.86i	-.00-.99i	-.00+.99i	-.49-.86i
	-.49+.86i	-.86+.49i	-.86-.49i	-.99