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STRUCTURAL EQUATION MODELLING OF NIGERIA CRUDE OIL

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ABSTRACT

Crude oil markets have been subjected to shocks and consequently have been highly volatile. Demand and supply shocks cause large movements in oil prices, which are followed by a dynamic response in both energy demand and supply and in the energy exploration and development activities. Modeling crude oil markets is of paramount importance, not only because of the influence of energy on macroeconomic activity but also because of the role of energy in the investment plans of households and firms. Energy cost and efficiency have become a prime concern in these plans. The study attempted to model Nigeria crude oil on gross domestic product (GDP) using Structural Equation Modelling (SEM) for period 1979 to 2013. To avoid spurious regression, the data were tested for stationarity using the Augmented Dickey-Fuller test and the test indicated that the variables were all stationary. This finding establishes that about 53.8% of the total variation in oil export is jointly explained by oil production, crude oil price and real GDP. Oil export would continue to be under upward pressure so long / inflation rate, real gross domestic product and oil production keep falling. The model was examined for long run relationship using cointegration techniques and the study indicates that there is long run disequilibrium.

Keywords: *crude oil,modelling, Structural Equation Modelling, Augmented Dickey-Fuller test, cointegration techniques.*

1.1 Background of the Study

Crude oil market has recently been faced with different shock and consequently has been highly volatile. Demand and supply shocks cause large movements in oil price, which are followed by a dynamic response in both energy demand and supply and in the energy exploration and development activities. In 2004, the production of crude oil stood at 84 million barrels a day (2) (mbd), increasing at an average rate of 1.3 percent per year during 1974-2004, compared with an average growth rate of 7.2 percent per year during 1918-73. OPEC's output stood at an all time peak of 84mbd in 2004 (2) and above the peak of 31mbd reached in 1973. Non-OPEC production stood at 50 mbd in 2004, increasing steadily at 2.2 percent a year during 1974-2004, compared with 5.8 percent during 1918-73.

The sharp deceleration in world crude growth in the aftermath of the first oil shock may be seen as a long-term response of demand to dramatic jumps in oil prices. In addition to these jumps, many importing countries have introduced high taxes, with rates ranging between 200 percent and 400 percent of the import price of petroleum products, with a view to curbing petroleum demand and appropriating part of the producer's surplus. The demand response to high prices of petroleum products was in the form of inter-energy substitution and increasing efficiency in energy use.

The behavior of crude oil prices, both nominal and real, can be viewed over two distinct subperiods: 1918-73 and 1974-2004. In the initial period, prices exhibited a remarkable long term stability, implying that demand and supply of crude oil were moving in harmony, as markets cleared without sizable excess demand or supply that could have entailed jumps in prices. In addition, the faster pace in natural gas supply kept the emergence of excess demand for crude oil in check.

Since oil is a very important product for everyone in every corner of the world, changes in oil price and their causes are subject of great interest for economists. There are three schools of thought in relation to the determination of changes in oil prices causes, but none have been entirely successful in predicting the path of oil prices. The first school examines the interaction between the marketplace forces of demand and supply in the determination of fuel. Microeconomic theory states that if demand grows or if a disruption in supply occurs, there will be upward pressure on prices. By the same token, if demand falls or there is an oversupply of product in the market, there will be downward pressure on prices. The presence of excess supply or demand is evidenced in crude oil inventories. Zamani (2004) presented a short-term quarterly forecasting model of the real World Trade Index (WTI) price that accounts for both the role of OPEC and the physical oil availability of relative inventory levels, the author included in his model OPEC quotas, overproduction and non-Organization of Economic Co-operation and Development (OECD) demand as explanatory variables. Ye *et al*. (2002, 2005 and 2006) used relative oil inventory levels to forecast oil prices.

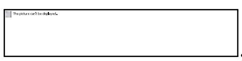
The second school of thought posits that commodity markets are generally efficient and holds the view that futures prices have the power to forecast realized spot prices. A widely supported approach was taken by Chinn *et al*. (2001) who postulated that the best predictor of future spot prices is futures prices. While they found that futures prices are unbiased predictors of future spot prices, the prediction error was large. Taback (2003) also found similar results but found that the explanatory power of futures prices was low for changes in spot prices. Merino and Ortiz (2005), extending the various works of Ye *et al*. (2002, 2005 and 2006), investigated whether some explanatory variables can account for the fraction of oil price variations that is not explained by oil inventories. The authors acknowledge as possible sources of variation: the difference between spot and futures prices; speculation defined as the long-run positions held by non commercials of oil, gasoline and heating oil in the NYMEX futures market; OPEC spare capacity along with the relative level of US commercial stocks, different long-run and short-run interest rates. Exploiting causality and cointegration tests, the authors identified the importance of the speculation variable which, among others appears to add systematic information to the model. A different approach in forecasting oil prices was proposed by Lalonde*et al*. (2003), who tested the impact of the world output gap and the real US dollar effective exchange rate gap on WTI prices. A comparison with a random walk and with an AR (1) specification suggests that both variables play an important role in explaining oil price dynamics. Sanders *et al*. (2009) investigated the empirical performance of the Environmental Impact Assessment (EIA) model for oil price forecasting at different time horizons. The model is a mixture of structural and time series specifications, which includes supply and demand as the main factors driving oil prices, and takes into account the impact of past forecasts. The authors found that EIA three-quarter ahead oil price forecasts are particularly accurate.

2.0 Material and Method

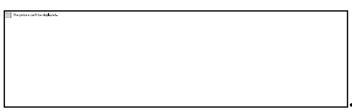
The methodology for this study is the structural (iii) equations models (SEM). As the name makes clear, the heart of this class of models lies in a data generation process that depends on more than one equation interacting together to produce the observed data.

Unlike the single-equation model in which a dependent (y) variable is a function of independent (x) variables, other y variables are among the independent variables in each SEM equation. The y variables in the system are jointly (or simultaneously) determined by the equations in the system.

Compare the usual single equation GDP,

,

to a simple, two-equation SEM:

.

Notice that the first equation in the system has a conventional x variable, but it also has a dependent variable (y_2) on the right-hand side. Likewise, the second equation has a dependent variable (y_1) as a right-hand side variable. In a simultaneous equations system, variables that appear only on the right-hand side of the equals sign are called exogenous variables. They are truly independent variables because they remain fixed. Variables that appear on the right-hand side and also have their own equations are referred to as endogenous variables. Unlike exogenous variables, endogenous variables change value as the simultaneous system of equations grinds out equilibrium solutions. They are endogenous variables because their values are determined within the system of equations.

2.1 Model Specification

A simultaneous demand and supply model for crude oil market is specified. The hypothesis of rational expectations is adopted, given the role of market information in determining the supply behavior (Muth, 2005).

Crude oil export: $y_1 + \delta_{12} y_2 + \gamma_{11} z_1 + \gamma_{14} z_4 = u_1$

Crude oil production: $y_1 + \delta_{22} y_2^e + \delta_{23} y_3 + \gamma_{22} z_2 + \gamma_{24} z_4 = u_2$

where the definitions below apply; output, prices, and real GDP are in logarithm form:

y_1= crude oil output, in millions of barrels per day;

y_2= crude oil nominal price, in U.S. dollars per barrel;

y_2^e = expected nominal price for crude oil, in U.S dollars per barrel;

z_1= real GDP index

z_4= dummy variable for large swings in oil prices;

z= a constant term.

Each residual $u_1$and $u_2$is assumed to be serially uncorrelated, independently and identically distributed with a mean of zero and standard error $\sigma_i, i = 1, 2$, and uncorrelated with the predetermined and exogenous variables. It may be further assumed that demand and supply disturbances are uncorrelated, implying $E(u_1 u_2) = 0$. The expected variables y_2^e and y_4^e are predetermined, and rationally form: $y_2^e = E_{t-1}(y_2 | I_{t-1})$ is the information set in period $t-1$ on which expectations $E_{t-1}(y_i | I_{t-1})$ were based. Demand for crude oil is a function of its price and an indicator for world economic activity, which here is approximated by the real GDP. The supply of crude oil is a function of its expected price at time $t-1$, the output of natural gas,and a dummy variable for shocks to oil prices. The demand for natural gas is a function of its price and real GDP. The supply of natural gas is a function of its expected price at time -1 , the output of crude oil, and a dummy variable for shocks to the natural gas price. Following McCallum (2002) the actual and expected prices are expressed as: $y_2 = y_2^e + \eta_2$,$\eta_2$is forecast errors that are uncorrelated with I_{t-1}.

The model is identified: no one equation can be obtained as a linear combination of two or more equations. Given the dynamics of adjustment in demand and supply, lagged variables have to be introduced. Tests on the length of the lag seem to indicate that the optimal lag would be three or four periods. The model is estimated by a two-stage least-squares method to obtain short-run estimates. To strengthen confidence in these estimates, the model is reestimated in an error correction model (ECM). Long-run elasticities are estimated with the help of the ECM and with cointegration analysis; these two methods are appropriate for finding long-run relations in each identified equation of the model.

4.0 Data Analysis

In view of different theories and literature reviewed in previous chapters of this study and different opinions and findings from various authors, it can be seen that there is a need to establish the relationship between crude oil Production, crude oil export, and crude oil price. The data were collected from OPEC annual report and CBN statistical bulletin of relevant variables from year 1979-2013 which will be put to test accordingly for different objectives stated in the introductory part of this research work. Hence, the result of various estimations and consequent analysis of such findings for the purpose of the study is presented.

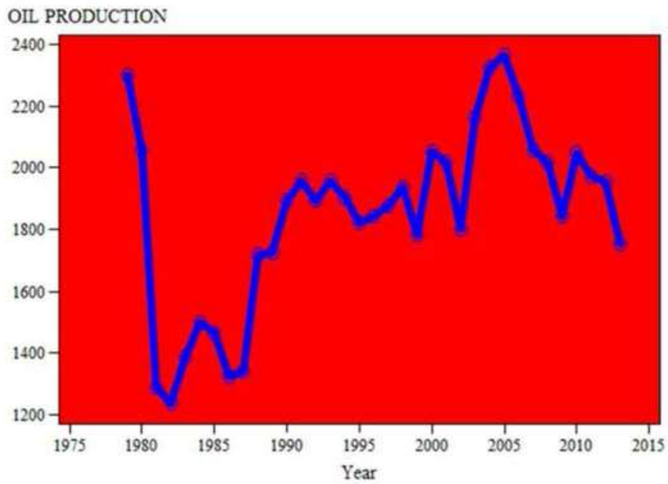
4.1 Data Used

The data used in this project was obtained from OPEC Annual Statistical Bulletin 1999-2014, Statistical Bulletin of the Central Bank of Nigeria (CBN), Annual Abstract of Nigeria Bureau of Statistics, 2013.

4.2 Trend of Data

This section captures the first objective of the study, which is used to analyze the trend of crude oil production, crude oil export, crude oil price, and real gross domestics products (RGDP) from 1979-2013.

Figure1

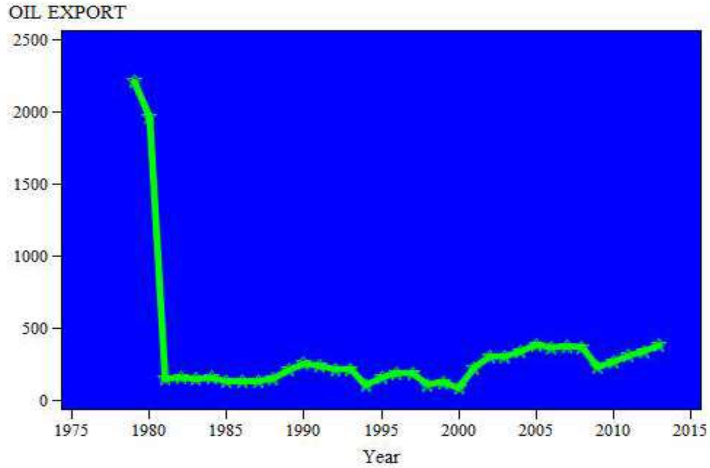


SAS 9.3 software

Figure 1 shows the trend of crude oil production from 1979 to 2013. The chart revealed that there was a steady increase in the production of crude oil until 2010, while there has been continuous decline in the production of crude oil since 2011 till date.

Oil Export

Figure 2



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According to the chart in Figure 2, it is clearly shown that apart from the significant drop of crude oil exported in 1981, there has been a steady increase in the volume of crude oil exported yearly.

Figure (3)

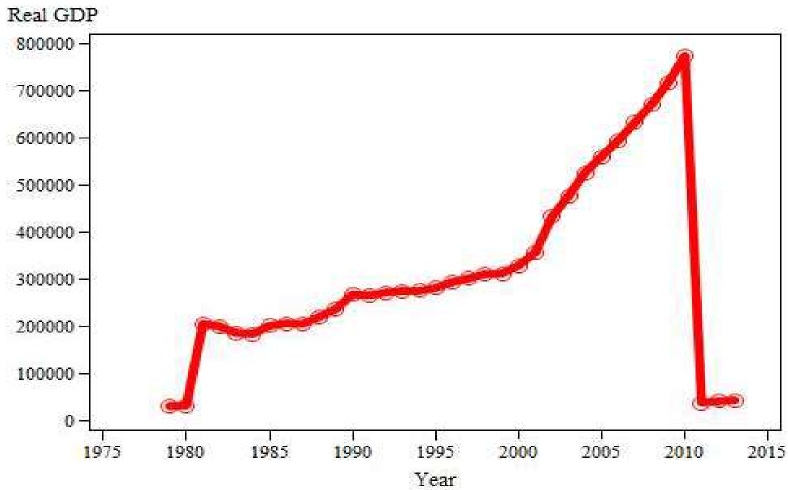

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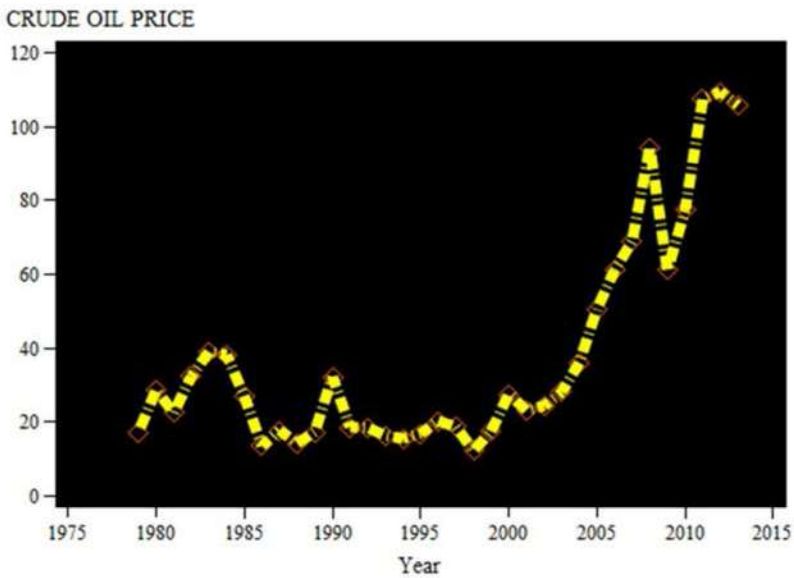
Figure (3) present the trend of RGDP, it clearly shows that there has been a steady growth in the RGDP annually until 2011 when there was a sharp decline in the RGDP of the nation, this equally shows an equal sign of significant decline that occurred in the crude oil production.

Figure 4



SAS9.3 software

Figure (4) shows that the price of crude oil was increasing virtually every year, though on a contrary, decreased in the year 2013.

4.3 Stationarity Test

Since unit root problem is a common feature of most time series data. Time series properties of all variables used in estimation were examined in order to obtain reliable result. Thus, this exercise was carried out through Augmented Dickey Fuller (ADF) test as articulated. The ADF was used to determine the order of integration, that is, the number of times a variable has to be differentiated before it becomes stationary. In this study, we applied unit root test to check the stationarity of the variables. The null hypothesis in the ADF test was that there is the presence of unit root. Table 4.1 give the results of ADF.

Table 4.1: Augmented-Dickey Fuller (ADF) Test

Variables/Coefficients	ADF Values	Mackinnon Critical Values	Order of Integration	Conclusion
Oil export	-6.0384*	-3.6394	I(0)	Stationary
Oil production	-4.9478*	-3.6463	I(1)	Stationary
Oil price	-6.4793*	-3.6463	I(1)	Stationary
Log(rgdp)	-5.7135*	-3.6463	I(1)	Stationary
Inflation	-7.1883*	-3.6394	I(0)	Stationary
Exchange rate	-5.4342*	-3. 6463	1(1)	Stationary

Source: Author's computation, 2015. ***E-Views7***

From the results of Table 4.1, that is the ADF, showed that Oil export and inflation are stationary at zero level while the other variables oil production, oil price, log(rgdp) exchange rate are stationary at first difference

4.4 The Co integration Analysis Results and Interpretation.

Table 4.2: Johannsen Co-integration

Hypothesized no. of CE(s)	Eigen value	Max- Eigen value	Critical value at 5 percent	Trace statistics
None *	0.9907	154.2581	40.0776	95.7537
At most 1 *	0.6153	31.5239	33.8769	69.8189
At most 2	0.4444	19.3846	27.5843	47.8561
At most 3	0.2802	10.8511	21.1316	29.7971
At most 4	0.1899	6.9488	14.2646	15.4947
At most 5	0.0383	1.2894	3.8414	3.8415

From Table 4.2, we can conclude that there is co-integrating vectors, the trace statistic is greater than the critical value and also both trace test statistic and the max-eigen value test indicate 2 co-integrating equations at 5% level of significance

Thus, we can safely reject the null (H_0) which says there is no co-integration and conveniently accept the alternative hypothesis of the presence of co-integrating vectors. Thus, we can conclude that a long run relationship exists among the variables. This result means that in Nigeria's case, the hypothesis of no co-integration among the variables should be rejected.

4.5 The Structural Equation Modelling of Macroeconomic and Crude Oil.

This section provides the result of objective two which is used to determine the Multi-linear equation of crude oil production, crude oil export, crude oil price, Inflation, exchange rate, and RGDP.

4.5.1 Data Analysis for Two-Stage Least Square Estimation (1979-2013)

Oil Export=β_0 + β_1 oil Production + β_2 Oil Price +β_3 log(RGDP)+ β_4Inflation+ ε_t...... (equation 1)

Oil Production= α_1 Oil Export + α_2 Exchange Rate........... (equation 2)

Model 1: TSLS, using observations 1979-2013 (T = 35)

Dependent variable: OIL_EXP

Instrumented: OIL_PRO

Instruments: const EXCHANGE PRICE l_RGDP INF

Table 4.3

Parameter Estimates

Variable	**DF**	**Parameter Estimate**	**Standard Error**	**t Value**	**Pr > |t|**	**Variable Label**
Intercept	1	3730.930	904.6106	4.12	0.0003	Intercept
Oil_Pro	1	0.396640	0.348095	1.14	0.2635	Crude Oil Production
Price	1	-3.15912	2.250758	-1.40	0.1707	Price Of Crude Oil
log_rgdp	1	-733.740	157.1385	-4.67	<.0001	Log(RGDP)
Inf	1	-3.39593	3.416362	-0.99	0.3282	Inflation

Mean dependent var	335.2657	S.D. dependent var	447.3463
Sum squared resid	3216551	S.E. of regression	327.4422
R-squared	0.538011	Adjusted R-squared	0.476413
F(4, 30)	5.607774	P-value(F)	0.001711
Log-likelihood	-542.9766	Akaike criterion	1095.953
Schwarz criterion	1103.730	Hannan-Quinn	1098.638
Rho	0.575205	Durbin-Watson	0.574985

Source: SAS9.3 software

R-squared

A close inspection of the table above indicates that the specified model above has a good coefficient of determination, with R-squared value of approximately 53.8% while the adjusted R-squared is about 47.6%. Thus, with the entire variable inculcated in the model the variables can be relied upon to explain total variations in the model (7).

F-statistic

Furthermore, the model specified have F-statistic value of 5.608, this implies that the overall model is statistically significant at 1% level of significance. Hence, all the explanatory variables in the model simultaneously explain the variations in the oil export. In order words, the independent variables can explain the endogenous variable to some extents at 95% confidence interval

Individual Tests of Significance (Student T-Test)

Decision Rule: if $T_{Cal}>T_{Tab}$ or when the P-value is less than 5% - reject H_0 and accept H_1

Critical Values: $T_{0.01}$ = 2.457, $T_{0.05}$ = 1.697 and $T_{0.1}$ = 1.310

The T-statistics for log(rgdp) was greater than all the tabulated value i.e (4.6694) and therefore it can be concluded, that, it is very significant, while on the contrary, other independent variables are not significant even at level of significance of 10%.

Based on the outcome of the above research, the trend revealed clearly that, its as a result of the sudden shock in crude oil hike that happened in the year 2011 to 2013. Therefore, the research considered a time frame of 1979-2010 for appropriate and unit root free data for modelling the simultaneous equation.

4.5.2 Data Analysis for Two-Stage Least Square Estimation (1979-2010)

Oil Export=β_0 + β_1 oil Production + β_2 Oil Price +β_3 log(RGDP)+ β_4Inflation+ ε_t...... (equation 1)

Oil Production= α_1 Oil Export + α_2 Exchange Rate........... (equation 2)

Model 2: TSLS, using observations 1979-2010 (T = 32)

Dependent variable: OIL_EXP
Instrumented: OIL_PRO
Instruments: const PRICE INF EXCHANGE l_RGDP

Table 4.4

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|	Variable Label
Intercept	1	6638.052	610.4118	10.87	<.0001	Intercept
Oil_Pro	1	1.023960	0.151016	6.78	<.0001	Crude Oil Production
Price	1	7.604161	1.821231	4.18	0.0003	Price of Crude Oil
log_rgdp	1	-1541.13	110.9237	-13.89	<.0001	Log(RGDP)
Inf	1	-1.98077	1.715753	-1.15	0.2584	Inflation

Mean dependent var	334.1969	S.D. dependent var	468.3830
Sum squared resid	725340.5	S.E. of regression	163.9038
R-squared	0.904738	Adjusted R-squared	0.890626
F(4, 27)	55.92042	P-value(F)	1.12e-12
Log-likelihood	-461.8206	Akaike criterion	933.6411
Schwarz criterion	940.9698	Hannan-Quinn	936.0704
Rho	0.204464	Durbin-Watson	1.888918

Hausman test -
Null hypothesis: OLS estimates are consistent
Asymptotic test statistic: Chi-square(1) = 14.3487
with p-value = 0.000151882
Weak instrument test -
First-stage F-statistic (1, 27) = 20.8122
Source: SAS9.3 software

Interpretation of Result of Table 4.4

Hausman's Test

The chi-square test statistic of Hausmann test indicate that ordinary least square (OLS) are consistent and the entire instrument are valid. With p-value=0.000151882.

Co-efficient of determination

Adjusted R-squared

The adjusted R-Squared which is always used to penalize those variables that are not really affecting the model, but in this model it shows that all the variables are important in the model for us to have the Adjusted R-Squared to be 89.06% which is not really different from the R-Squared of the model so with all the variable inculcated in the model the variables are still very able to explain 89.06% of the total variations in the model. It is good fit so the model can be relied upon.

F-statistic

Furthermore, the model specified have F-statistic value of 55.92, this implies that the overall model is statistically significant at 1% level of significance. Hence, all the explanatory variables in the model simultaneously explain the variations in the oil export. In order words, the independent variables can explain the endogenous variable very well at 95% confidence interval

Individual Tests of Significance (Student T-Test)

Decision Rule: if $T_{Cal} > T_{Tab}$ or when the P-value is less than 5% - reject H_0 and accept H_1

Critical Values: $T_{0.01} = 2.457$, $T_{0.05} = 1.697$ and $T_{0.1} = 1.310$

The T-statistics for oil production was greater than all the tabulated value i.e (6.7805) and therefore it can be concluded that it is significant at any significance level, also, the t-statistics of oil price remained significant at all level of significance as it's t-calculated is 4.1753 which is greater that all the critical values, as the impact of log(rgdp) was also significant because it's calculated value was greater than the tabulated value as it's 13.8939. Only inflation was not significant in the model because it's t-statistics was less than the tabulated value at all level of significance.

Durbin Watson statistics

The value is 1.89 which implies that there is no form of any autocorrelation in the model specified. These shows that the error correction model is free from the problem of serial correlation due to its value of 1.89. It is still within the range of 1.6 to 2.4. As a result of this, our model estimated can be confidently relied upon for making inferences.

Discussion of Result

This section captions the third and the last objective of this research work by establishing the relationship between RGDP, inflation, exchange rate, oil prices, oil export and oil production.

The co-efficient of oil production signifies that there is a positive significant relationship between the crude oil that was produced and exported. As 1.0239 increases in crude oil production leads to 1 unit increase in crude oil export, remembering that there is an intra relationship in them. They both affect each other simultaneously. Crude oil price is another significant variable that contribute positively to oil export this implies that a 7.60416 unit increase in crude oil price will lead to1 unit increase in 1 unit volume increase of crude oil exportation and it is significant at all level of significance, On the contrary, despite the significant impact of real GDP of oil export, there exists a negative relationship between the real GDP and oil export, as the model fitted shows that 669.306 unit decrease in the real GDP led to 1 unit increase in the oil exportation. Finally, the impact of inflation on the crude oil exportation was not significant, as much as the relationship between the two variables are negative, as 1.98 unit decrease in the inflation rate will lead to 1 unit increase in the crude oil exportation.

5.0 Conclusion

The study attempted to model Nigeria crude oil on gross domestic product (GDP). The time plot revealed that there was increase of crude oil price overtime. In the same vein, the plot for oil production indicates fluctuation and therefore instability. The time plot for oil export showed that there was shape decline of export overtime. The plot for real GDP indicated that increase in the real GDP overtime, but an abrupt decline from 2010. To avoid spurious regression, the data were tested for stationarity using the Augmented Dickey-Fuller test and the test indicated that the variables were all stationary. This finding establishes that about 53.8% of the total variation in oil export is jointly explained by oil production, crude oil price and real GDP. In the model, oil production, price of crude oil and inflation rate were said to insignificant, while real GDP is statistically significant. Collectively, all the variables are said to be statistically significant. The Durbin-Watson statistic indicates that there is no serial autocorrelation among the variables. Oil export would continue to be under upward pressure so long inflation rate, real gross domestic product and oil production keep falling.

The SEM, being a structural model, has many potential applications for industry analysts and policymakers. It could simulate over time the impact of a change in an exogenous variable via dynamic multipliers. It can also simulate the impact of random shocks to production and export of crude oil. This, however, would require an identification scheme to define shocks. Oil export operates in the demand function and may arise from shocks to real GDP, and inflation rate. Oil production shocks operate in the supply function and may arise from shocks to actual or capacity output.

Given the stability and reliability of the elasticity estimates, a forecast of oil export using SEM could provide realistic and relevant information for oil market traders. Because the model is estimated in structural form, sensitivity analysis can be performed on one or more structural parameters.

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