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An Empirical Analysis of Crude Oil Price, Consumer Price Level and Exchange Rate Interaction in Nigeria: A Vector Autoregressive (VAR) Approach

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Abstract This work investigated the interaction of Crude Oil Price, Consumer Price Level and Exchange Rate in Nigeria using the Vector Autoregressive (VAR) Model. A monthly data (January, 2007-February, 2015) obtained from the Central Bank of Nigeria was used for the analysis. The analysis showed that all the variables were integrated of order one I (1) and no long-run relationship existed among them. The work also revealed that a shock on crude oil price had a negative impact on exchange rate. More so, variation in exchange rate was substantially caused by crude oil price. Furthermore, a shock on exchange rate had a negative effect on consumer price level. Therefore, government was advised initiate policies that will diversify the income stream of Nigeria's economy. Similarly, a policy that will promote an enabling environment for local investors to produce goods locally so as to conserve foreign exchange was equally encouraged.

Keywords Vector Autoregressive Model, Consumer Price Level, Impulse Response Function and Variance Decomposition

1. Introduction

Nigeria discovered crude oil in 1956 and it became an export commodity in 1958. Prior to the discovery of crude oil, the export commodities were agricultural products. The production level of crude oil in the country has fluctuated over the years due to OPEC's quota and socio-political instability. Following its discovery, crude oil has become major source income and foreign exchange for the country, thereby contributing to over 80% of the federal government's revenue. Recently, the global price of crude oil dwindled in the international market; this led to a shock on the foreign exchange rate of the country and thereby affected consumer prices. Invariably, Exchange rate is the price for which the currency of a country can be exchange for another country's currency [5]. Exchange rate is said to depreciate if the amount of domestic currency required to buy foreign currency increases, while the exchange rate appreciates if the amount of domestic currency required to buy a foreign currency reduces. An appreciation in the real exchange rate may create current account problems because it leads to overvaluation. Overvaluation in the turn makes imports artificially cheaper while export relatively expensive, thus reducing the international competitiveness of a country [12]. Exchange rate volatility refers to the swings of fluctuations in the deviations from a benchmark or equilibrium exchange rate [8]. Therefore, for an import dependent country like Nigeria, there is a need to understand the interaction existing among crude oil price, consumer price level and exchange rate. Thus, how does exchange rate react to a shock on crude price? To what extent does consumer price level reacts to a shock on exchange rate due to crude oil price jolt?

2. Literature Review

[9] studied the effect of oil price shock on aggregate economic activities in Nigeria using quarterly data from 1970 to 2003. Volatility was measured as the conditional variance of the percentage change of the normal oil price. The five variables used for the empirical study were gross domestic product (real GDP) as proxy for industrial production index, domestic money supply, the real effective exchange rate, the inflation rate, and real oil price. The findings showed that while oil price significantly influenced exchange rate, it did not have significant effect on output and inflation in Nigeria. He concluded that an increase in the price of oil results in wealth effects which appreciates the exchange rate.

[6] employed a vector autoregressive model (VAR) to compare the effects of oil price and real effective exchange rate on the real economic activity in Russia, Japan and China.

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He first applied a lag Augmented VAR (LA-VAR) approach causality test to investigate whether the oil price shock and exchange rate volatility ganger-cause the economic growth in Russia, Japan and China. In addition, cointegration technique was used to examine how the real GDP of Russia, Japan and China are affected by changes in oil prices and the exchange rate in the long-run. To get the short-run of the model, a vector error correction model (VECM) was employed to analyze the short-run dynamics of the real GDP for the three countries. His findings indicated that oil price increases impact negatively on economic growth of Russia.

[2] assessed the impact of oil price shock and real exchange rate volatility on the real gross domestic product in Nigeria using quarterly data that span the period 1986-2007. He used the Johansen VAR-based cointegration technique to examine the sensitivity of real GDP to change in oil prices and real exchange rate volatility in the long-run while the vector error correction model was used in the short-run. The result of the long-run analysis indicated that a 10.0 percent increase in crude oil prices increased the real GDP by 7.72 percent, similarly a 10.0 percent appreciation in exchange rate increased GDP by 0.35 percent. The short-run dynamics was found to be influenced by the long-run equilibrium condition. He recommended the diversification of the economy and infrastructural diversification.

[7] employed basic data from OPEC countries for the period 1975 to 2005 to examine the determinants of equilibrium real exchange rates in some selected oil-dependent countries. The result indicated that oil price had significant effect on real exchange rates in the group of oil producing countries. It showed that higher oil price cause real exchange rate appreciation.

[3] used a multivariate frame work to measure the short-run impact of oil shocks on economic growth, inflation, real wages and exchange rate. Short-run impacts were examined using linear and nonlinear oil price transformation. The generalized impulse responses and error variance decomposition results confirm there is a direct link between net oil price shock and growth and its indirect linkages through inflation and the real exchange rate. The paper thus concluded that oil prices exhibit substantial effects on inflation and exchange rate in New Zealand.

[4] examined whether oil price had an impact on the real exchange rates of three oil-exporting countries namely; Norway, Russia and Saudi Arabia. The authors developed a measure of the real effective exchange rates for Norway and Saudi Arabia (1980-2006) and for Russia (1995-2006). They tested if real oil prices and productivity differentials against 15 OECD countries-influences exchange rate. The results showed that in Russia, there was a positive relationship rate in the long run. In case of Norway and Saudi Arabia, the results indicated that there were no significant impacts of real exchange rates. The results further indicated that different exchange rate regimes for these countries could not explain why the impact of oil prices differs across countries but adduce the development to other policy responses, such as the accumulation of net foreign assets and sterilization, as well as specific institutional characteristics.

3. Methodology

In order to understand the interaction among the three variables, the vector autoregressive model (VAR) was employed to assess the relationship. However, before estimating the model, the properties of the variables were verified in terms stationarity and long term relationship. The econometric tools that were used for these verifications are the Augmented Dickey-Fuller test for stationarity and Johansen co-integration test for long term relationship. In addition, the direction of causality among these variables was ascertained using the Granger Causality test. Nevertheless, impulse response function and variance decomposition were used to evaluate the effects of shocks and variations caused by variable itself and other variables respectively.

The data for this research were obtained from the Central Bank of Nigeria. The scope was a monthly data from January, 2007 to February, 2015, while the variables are:

1. Inflation Rate (INF) – proxy for consumer price level
2. Exchange Rate (EXC)
3. Crude Oil Price (CPR)

3.1. Model Specification

The VAR models to establish the interactions among these variables are:

$$\ln exc_t = \beta_0 + \sum_{i=1}^{p} \beta_1 \ln exc_{t-i} + \sum_{i=1}^{p} \beta_2 \ln \inf_{t-i} + \sum_{i=1}^{p} \beta_3 \ln cpr_{t-i} + \mu_t \tag{1}$$

$$\ln \inf_t = \alpha_0 + \sum_{i=1}^{p} \alpha_1 \ln exc_{t-i} + \sum_{i=1}^{p} \alpha_2 \ln \inf_{t-i} + \sum_{i=1}^{p} \alpha_3 \ln cpr_{t-i} + \nu_t \tag{2}$$

$$\ln cpr_t = \lambda_0 + \sum_{i=1}^{p} \lambda_1 \ln exc_{t-i} + \sum_{i=1}^{p} \lambda_2 \ln \inf_{t-i} + \sum_{i=1}^{p} \lambda_3 \ln cpr_{t-i} + \gamma_t \tag{3}$$

Where:

lninf = natural logarithm inflation rate as a proxy for consumer price level

lnexc = natural logarithm of nominal exchange rate

lncpr = natural logarithm of crude oil price

t = current time

$\alpha_0, \lambda_0, \beta_0$ = parameters of the explanatory variables.

Table 1. Stationarity test of the variables

Level test I(0)		Critical values		
ADF Stat.	Variables	1%	5%	10%
-1.054590	Lnexc	-3.499910	-2.891871	-2.583017
-1.656876	Lninf	-3.499167	-2.891550	-2.582846
-2.706005	Lncpr	-3.499910	-2.891871	-2.583017
Level test l(1)				
-5.627401	Lnexc	-3.499910	-2.891871	-2.583017
-8.792361	Lninf	-3.499910	-2.891871	-2.583017
-6.299812	Lncpr	-3.499910	-2.891871	-2.583017

Author's computation and Eviews 7.1 Output

4. Results

4.1. Unit Root Test

All the variables were tested for stationarity, from table 1 above it showed that they are all integrated of order one I(1) after the first differenced series showed stationarity.

4.2. Cointegration Test

One of the conditions for the use of VAR model is that the stationary variables of order one I(1) must not be co-integrated. Therefore, to verify this condition, if there was a long term relationship existed among these variables, a co-integration test was carried out using the Johansen cointegration test.

Table 2. Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None	0.107041	22.12201	29.79707	0.2918
At most 1	0.085886	11.36668	15.49471	0.1899
At most 2	0.029408	2.835704	3.841466	0.0922

Author's computation and Eviews 7.1 Output

Table 3. Test (Maximum Eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None	0.107041	10.75534	21.13162	0.6717
At most 1	0.085886	8.530972	14.26460	0.3273
At most 2	0.029408	2.835704	3.841466	0.0922

Author's computation and Eviews 7.1 Output

From tables 2 and 3 above showed that there was no co-integration among the three variables. Therefore, no long-run relationship existed among the variables within the period and this has confirmed the use of VAR model.

4.3. Granger Causality Test

The Granger causality analysis presented in table 4 showed that most of the variables did not cause each other. Nevertheless, there was a case of unidirectional causality from crude oil price to exchange rate at 5% significance level.

Table 4. Granger Causality test of the variables

Dependent variable: LNEXC			
Excluded	Chi-sq	df	Prob.
LNINF	9.713496	6	0.1372
LNCPR	78.24317	6	0.0000
All	85.64433	12	0.0000
Dependent variable: LNINF			
Excluded	Chi-sq	df	Prob.
LNEXC	8.011939	6	0.2372
LNCPR	6.774587	6	0.3422
All	11.05246	12	0.5244
Dependent variable: LNCPR			
Excluded	Chi-sq	df	Prob.
LNEXC	8.306601	6	0.2165
LNINF	2.455272	6	0.8734
All	10.42539	12	0.5787

Author's computation and Eviews 7.1 Output

4.4. VAR Lag Order Selection Criteria

In VAR model estimation, the lag length is very important. Therefore, using the lag order selection criteria in table 5, it showed that most of the instruments selected lag length of 6. This lag length will be used in the model estimation and more so, to obtain the minimum values of the information criterion.

Table 5. VAR Lag Order Selection Criteria

Lag	LogL	LR	FPE	AIC	SC	HQ
0	63.52133	NA	5.07e-05	-1.375485	-1.291030	-1.341460
1	371.9354	588.7905	5.62e-08	-8.180350	-7.842531	-8.044251
2	393.1902	39.12816	4.26e-08	-8.458868	-7.867685*	-8.220695*
3	401.3230	14.41718	4.35e-08	-8.439158	-7.594612	-8.098912
4	405.8650	7.742024	4.83e-08	-8.337840	-7.239929	-7.895519
5	421.7323	25.96476	4.16e-08	-8.493916	-7.142641	-7.949521
6	434.3593	19.80135*	3.86e-08*	-8.576347*	-6.971708	-7.929878
7	436.9722	3.919388	4.52e-08	-8.431186	-6.573183	-7.682643
8	440.8231	5.513768	5.16e-08	-8.314161	-6.202794	-7.463544
9	444.2509	4.674295	5.98e-08	-8.187520	-5.822789	-7.234829
10	450.8856	8.594942	6.47e-08	-8.133763	-5.515668	-7.078998

Author's computation and Eviews 7.1 Output

4.5. Model Estimation

The Vector Autoregressive (VAR) model was used to assess the interaction and shocks with respect to the three variables used for this research work using monthly data from January, 2007 to February 2015.

Table 6. Model Estimation Result

	LNEXC	**LNINF**	**LNCPR**
LNEXC(-1)	0.870342	-0.632572	0.796218
	(0.11784)	(0.48723)	(0.44343)
	[7.38589]	[-1.29831]	[1.79558]
LNEXC(-2)	0.045212	0.603700	-0.305490
	(0.17025)	(0.70396)	(0.64068)
	[0.26556]	[0.85758]	[-0.47682]
LNEXC(-3)	-0.063222	-0.640692	0.152547
	(0.17130)	(0.70828)	(0.64461)
	[-0.36907]	[-0.90458]	[0.23665]
LNEXC(-4)	0.051440	-0.141338	-0.779635
	(0.16950)	(0.70085)	(0.63785)
	[0.30348]	[-0.20167]	[-1.22229]
LNEXC(-5)	-0.185405	0.413611	0.140913
	(0.16739)	(0.69213)	(0.62991)
	[-1.10759]	[0.59759]	[0.22370]
LNEXC(-6)	0.216462	0.205416	0.178005
	(0.10223)	(0.42271)	(0.38471)
	[2.11733]	[0.48595]	[0.46270]
LNINF(-1)	-0.057499	0.867084	0.026122
	(0.02705)	(0.11186)	(0.10180)
	[-2.12536]	[7.75160]	[0.25659]
LNINF(-2)	0.064975	0.121537	-0.067916
	(0.03652)	(0.15099)	(0.13742)
	[1.77927]	[0.80493]	[-0.49423]
LNINF(-3)	0.011929	-0.155129	0.034580
	(0.03507)	(0.14499)	(0.13196)
	[0.34017]	[-1.06992]	[0.26206]

	LNEXC	LNINF	LNCPR
LNINF(-4)	-0.066068	0.232515	-0.047325
	(0.03392)	(0.14024)	(0.12763)
	[-1.94794]	[1.65802]	[-0.37080]
LNINF(-5)	0.060454	0.019807	0.032659
	(0.03425)	(0.14162)	(0.12889)
	[1.76501]	[0.13986]	[0.25339]
LNINF(-6)	-0.003331	-0.126972	-0.025819
	(0.02489)	(0.10292)	(0.09367)
	[-0.13381]	[-1.23365]	[-0.27563]
LNCPR(-1)	-0.115326	-0.065621	1.246441
	(0.03274)	(0.13535)	(0.12318)
	[-3.52300]	[-0.48482]	[10.1186]
LNCPR(-2)	0.015637	0.346120	-0.120366
	(0.05701)	(0.23573)	(0.21454)
	[0.27428]	[1.46828]	[-0.56104]
LNCPR(-3)	0.172441	-0.249121	-0.063782
	(0.05643)	(0.23334)	(0.21236)
	[3.05566]	[-1.06765]	[-0.30035]
LNCPR(-4)	-0.214321	-0.208290	-0.253603
	(0.05736)	(0.23717)	(0.21585)
	[-3.73644]	[-0.87825]	[-1.17492]
LNCPR(-5)	-0.013990	-0.038206	0.302113
	(0.06036)	(0.24959)	(0.22715)
	[-0.23176]	[-0.15308]	[1.33000]
LNCPR(-6)	0.151819	0.236256	-0.229338
	(0.04143)	(0.17130)	(0.15590)
	[3.66458]	[1.37923]	[-1.47108]
C	0.326754	0.972922	-0.274981
	(0.13232)	(0.54712)	(0.49794)
	[2.46935]	[1.77826]	[-0.55224]
R-squared	0.972320	0.922267	0.924021
Adj. R-squared	0.965495	0.903100	0.905286
Sum sq. resids	0.035836	0.612651	0.507458
S.E. equation	0.022156	0.091610	0.083376
F-statistic	142.4620	48.11752	49.32176
Log likelihood	230.5845	99.99807	108.6637
Akaike AIC	-4.599664	-1.760828	-1.949210
Schwarz SC	-4.078860	-1.240023	-1.428406
Mean dependent	5.027922	2.323211	4.530711
S.D. dependent	0.119278	0.294296	0.270915
Determinant resid covariance (dof adj.)		2.74E-08	
Determinant resid covariance		1.37E-08	
Log likelihood		441.2679	
Akaike information criterion		-8.353649	
Schwarz criterion		-6.791237	

Author’s computation and Eviews 7.1 Output

The estimated result in table 6 showed that R^2 of 0.9723 which indicated 97% of total variation in exchange rate can be explained by the explanatory variables. The adjusted R^2 of 0.9655 or 97%, showed that the explanatory variables were robust in explaining the variation in exchange rate. The R^2 for consumer price level and crude oil price were 0.9222 and 0.9240 respectively. While, the adjusted R^2 of 90% and 91% respectively for consumer price level and crude oil price indicated that the level of variations explained by the explanatory variables. Nonetheless, the respective F-statistic was statistically significant at 5% and the model was a good fit. The individual parameters of the variables cannot be interpreted; therefore, a block-F test will be used to verify the collective impact of the explanatory variables.

4.6. Block-F Test

The exclusion test using the block-F test in table 7 above indicated that the parameters of all lag 1 variables were significant and jointly significant as well. Parameters of all lag 2 variables were both individually and jointly insignificant, and this is the same for parameters of lag 5 variables. The parameters of lag 3 variables were only significant in exchange rate model. The parameters of lag 4 and lag 6 displayed the same behavior. Nonetheless, there is no economic theory supporting the impact of these parameters. Therefore, the need for impulse response function (IRF) and variance decomposition for more understanding of the dynamic shock effects of these variables.

4.7. Impulse Response Function (IRF)

The graph of impulse response function in fig. 1 showed that consumer price level had initial negative impact on exchange rate but was able to find its way back to equilibrium path after 7 months. Also, crude oil price had a huge negative impact on exchange rate. In addition, exchange rate affected consumer price level negatively and the price level never returned to equilibrium path. Nevertheless, crude oil price had positive effect on consumer price level. All these effects were significant at 5%.

Table 7. VAR Lag Exclusion Wald Test

Chi-squared test statistics for lag exclusion:

Numbers in [ ] are p-values

	LNEXC	LNINF	LNCPR	Joint
Lag 1	72.70074	61.55987	104.2608	255.8273
	[1.11e-15]	[2.73e-13]	[0.000000]	[0.000000]
Lag 2	3.597429	3.648422	0.850763	9.248781
	[0.308344]	[0.302016]	[0.837291]	[0.414634]
Lag 3	9.767562	3.146422	0.276438	13.88784
	[0.020649]	[0.369596]	[0.964397]	[0.126371]
Lag 4	17.22897	3.702257	2.794036	22.76749
	[0.000634]	[0.295462]	[0.424483]	[0.006740]
Lag 5	4.114948	0.443635	1.811170	6.654440
	[0.249316]	[0.931088]	[0.612507]	[0.673047]
Lag 6	16.52697	4.051035	2.592411	26.53858
	[0.000884]	[0.256006]	[0.458822]	[0.001667]
df	3	3	3	9

Author’s computation and Eviews 7.1 Output

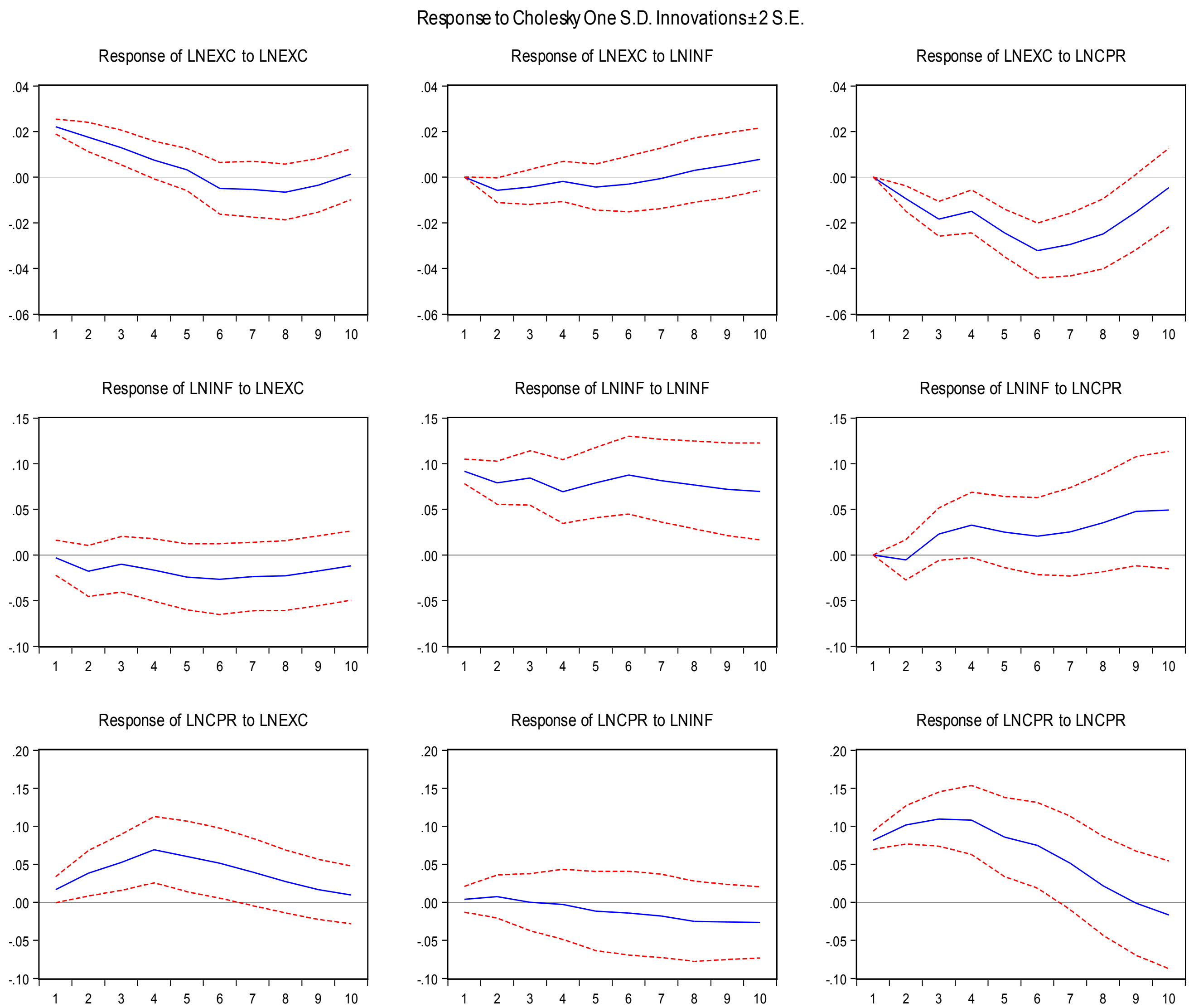

Figure 1. Graph of Impulse Response Function. (Author's computation and Eviews 7.1 Output)

4.8. Variance Decomposition

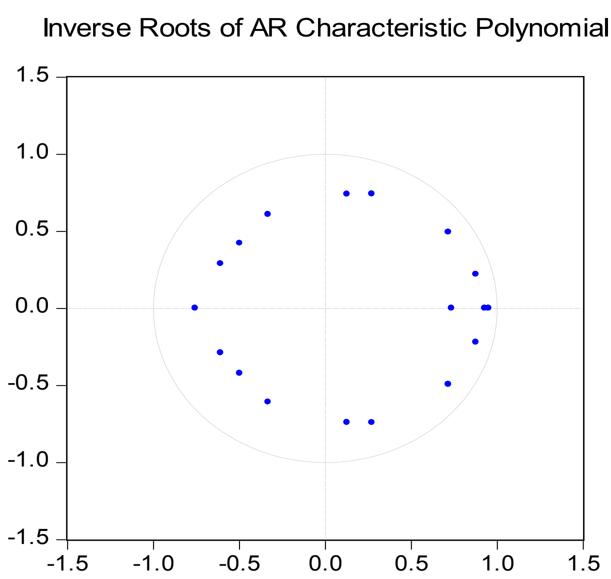

Figure 2. Graph of AR Inverse Root

Table 8. Variance Decomposition of Variables

Variance Decomposition of LNEXC:				
Period	S.E.	LNEXC	LNINF	LNCPR
1	0.022156	100.0000	0.000000	0.000000
2	0.030334	86.79966	3.574042	9.626298
3	0.037989	66.94810	3.613612	29.43829
4	0.041558	59.15654	3.225306	37.61816
5	0.048525	43.84645	3.171986	52.98156
6	0.058538	30.82500	2.438522	66.73647
7	0.065790	25.06927	1.936450	72.99428
8	0.070699	22.56637	1.855474	75.57816
9	0.072614	21.62642	2.274993	76.09859
10	0.073185	21.32113	3.376202	75.30267
Variance Decomposition of LNINF:				
Period	S.E.	LNEXC	LNINF	LNCPR
1	0.091610	0.107223	99.89278	0.000000
2	0.122455	2.150472	97.65828	0.191245
3	0.150753	1.877224	95.69294	2.429841
4	0.169981	2.439143	91.92398	5.636876
5	0.190693	3.552174	90.26155	6.186277
6	0.212471	4.424437	89.65893	5.916634
7	0.230106	4.830855	88.91152	6.257629
8	0.246144	5.077811	87.38887	7.533314
9	0.261431	4.947451	85.03478	10.01777
10	0.275207	4.647187	83.11287	12.23994
Variance Decomposition of LNCPR:				
Period	S.E.	LNEXC	LNINF	LNCPR
1	0.083376	3.957991	0.238895	95.80311
2	0.137172	9.232993	0.384911	90.38210
3	0.183130	13.43211	0.215992	86.35190
4	0.223588	18.55313	0.160335	81.28653
5	0.247187	21.12637	0.348720	78.52491
6	0.263715	22.36287	0.599686	77.03744
7	0.272232	23.11904	1.005498	75.87547
8	0.275585	23.53828	1.809596	74.65212
9	0.277308	23.61643	2.654881	73.72869
10	0.279231	23.41243	3.523957	73.06361
Cholesky Ordering: LNEXC LNINF LNCPR				

Author's computation and Eviews 7.1 Output

The forecast error variance of exchange rate showed that variation was mostly caused by crude oil price after 2 months. In the case of consumer price level, the variation was mostly caused by itself, while, exchange rate marginally caused variation in crude oil price after 4 months.

4.9. Model Stability

The autoregressive inverse root of the VAR indicated that all the polynomial roots were inside the unit circle, which showed that the VAR model is very stable and can be used for policy making.

Table 9. Inverse Root of AR

Root	Modulus
0.950867	0.950867
0.928873	0.928873
0.878590 - 0.220269i	0.905781
0.878590 + 0.220269i	0.905781
0.717068 - 0.492814i	0.870088
0.717068 + 0.492814i	0.870088
0.272976 - 0.742047i	0.790664
0.272976 + 0.742047i	0.790664
-0.754420	0.754420
0.128524 + 0.740112i	0.751189
0.128524 - 0.740112i	0.751189
0.736813	0.736813
-0.331699 - 0.608969i	0.693446
-0.331699 + 0.608969i	0.693446
-0.607655 - 0.289089i	0.672917
-0.607655 + 0.289089i	0.672917
-0.496937 - 0.421861i	0.651853
-0.496937 + 0.421861i	0.651853

Author’s computation and Eviews 7.1 Output

5. Conclusions

The recent global decline in crude oil prices necessitated the need to investigate the interaction of crude oil price, consumer price level and inflation in Nigeria. This work revealed that a shock on crude oil price had a negative impact on exchange rate. This negative impact could be as a result of Nigeria’s dependence on crude oil for both income and foreign exchange; this is line with the work of [9] and [2] in Nigeria. More so, variation in exchange rate was substantially caused by crude oil price. This shows a strong interaction existing between crude oil price and exchange rate in Nigeria. In addition, since the country is a highly import dependent, a shock on exchange rate had a negative effect on consumer price level. Therefore, government should initiate policies that will diversify the income stream of Nigeria’s economy instead of depending mainly on crude oil as source revenue. Equally, a policy that promotes an enabling environment that encourages local investors to produce goods for local consumption and export since this will help to conserve foreign exchange should be implemented.

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