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Oil Price Shocks and the Nigerian Economy: A Forecast Error Variance Decomposition Analysis

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Abstract: This study investigates the impacts of oil price shocks on the macroeconomic performance in Nigeria using Vector Autoregression (VAR) approach. Forecast error variance decomposition is estimated using 7 key Nigerian macroeconomic variables, which are real gross domestic product, consumer price index, real oil revenue, real money supply, real government recurrent expenditure, real government capital expenditure and real oil price. An annual data between the periods 1970-2005 were employed. The Johansen cointegration test identifies at least four cointegrating vectors among the variables. The forecast error variance decomposition estimated from the VAR model shows that oil price shocks significantly contribute to the variability of oil revenue and output. On the other hand, the result reveals that oil price shock does not have substantial effects on money supply, price level and government expenditure in Nigeria over the period covered by the study. This is evident, as its contributions to the variability of these variables are very minimal. The study again reveals that the variability in the price level, apart from its own shock, is explained substantially by output and money supply shocks. Also, apart from its own shock, the variability in money supply is also explained by price level and output. This finding confirms, therefore, that oil price shock may not be necessarily inflationary especially, in the case of an open developing economy like Nigeria. The policy implication of this is that fiscal policy can be used more effectively to stabilise the domestic economy after an oil shock.

Key words: Oil price shocks, macroeconomic performance, vector autoregression, variance decomposition

INTRODUCTION

Nigeria is the largest oil producer in the Sub-Saharan Africa and the 5th largest petroleum exporting country in the Organization of Petroleum Exporting Countries (OPEC). In 1963, only about 1.17% shares of GDP can be attributed to the oil sector, while agricultural sector accounted for about 60% share. But since early 1970, energy export began to represent a significant fraction of the trade balance for Nigeria, thus making oil sector a major production sector claiming about 99% of share of export and about 39% shares of GDP, while its share in government revenue accounts for about 86% in 2005.

Fluctuations in oil prices is a development in the global economy, which is posing a great challenge to researchers and policy makers studying the stochastic nature of macroeconomic dynamics. And as one of the oil exporters, Nigeria has benefited both from exporting more crude oil in terms of volume and also from its improvement in its terms of trade due to the rise in oil price. This is of course, evidenced in an upward surge of government revenue from oil sector rising from 26% in 1970 to about 86% in 2005. This persistent oil price shocks could have severe macroeconomic implications and therefore, inducing several challenges for both fiscal and monetary policy making in the oil exporting as well as importing countries (Kim and Loughani, 1992; Cashin *et al*., 2000). Again, given that the oil prices are exogenously determined by OPEC and as one of its members, Nigeria has no control over the price of its crude oil and thus, her oil revenue. And since, oil revenue accounts for a larger percentage of her total revenue, the economy becomes vulnerable to any shock from the international oil market. The question, therefore, is: How would an economy, especially an oil exporting developing one like Nigeria, adjust to the new economic circumstance in the face of oil price shocks?

There have been growing literatures on the impact of oil shocks both on the oil importing and oil exporting countries. Given the advances in the econometrics methodology, different methods of analyses have yielded different results (Hamilton, 1983; Mork, 1989; Semboja, 1994; Ayadi *et al*., 2000; Philip and Akintoye, 2006). Following the pioneering research of Hamilton (1983) on the US economy, where he stated that the correlation between oil price evolution and economic output was not of a historical coincidence for the 1948-1972 periods, thus, the increase in the price of oil has impacted negatively on productivity and output in America, different empirical studies have emerged all trying to reinvestigate the direct and indirect impacts of oil shocks on the macroeconomic performance of different economies.

For instance, while Mork (1989) further confirmed Hamilton's result as to a negative correlation between output growth and oil price increases, Papapetrou (2001), examining the case of Greece and using a Vector Autoregressive (VAR) model, also reports a negative impact of real oil price changes on the industrial production and employment.

Semboja (1994) studied the effects of oil price changes for Kenya, which is a net importer of oil. For this purpose, he calibrates a static computable general equilibrium model to obtain the impact responses, rather than estimating a VAR process to generate the dynamic responses. The impact responses suggest that an increase in oil prices lead to an increase of the trade balance, a decrease of output and of the price index and also a deterioration of the terms of trade.

Again, Ayadi *et al.* (2000) studied the effects of oil production shocks for Nigeria as a net exporter of oil over the 1975-1992 periods. The study revealed the positive response of output after a positive oil production shock. Moreover, the impact response of output is less than one fifth of that of oil production, but the response of output after a year is slightly larger than that of oil production. The response of inflation is negative after a positive oil production shock. To the extent that an oil price increase leads to an oil production increase, the responses suggest that output increases; inflation decreases and the national currency depreciate following a positive oil-price shock.

This study, intend to contribute to this discussion by analyzing Nigeria's oil dependence using Vector Autoregression (VAR) modeling in investigating the impacts of oil price shocks on key macroeconomic variables in Nigerian. This can be done through, the identification of how oil price shocks impact these variables and their dynamic responses, respectively both in the long-run. The motivation for this study, therefore, lies in its attempt to look at the core question: How vulnerable is Nigerian economy to changes in world energy (especially oil) market in spite of its major economic and financial reform initiatives? The overriding objective of this study, therefore, is to examine the dynamic effects and relative importance of oil price shocks on the Nigerian macroeconomic performance.

MATERIALS AND METHODS

Data definition and sources: The 1st step in developing a VAR model is to make a choice of the macroeconomic variables that are essential for the analysis. In this study, therefore, in investigating the impact of oil price shocks on the Nigerian macroeconomic performance, the variables employed consist of the following: Oil price, gross domestic product, oil revenues, government recurrent expenditure, government capital expenditure, money supply and consumer price index. All variables are real and expressed in log form. Data employed in this study, are mainly sourced from the Central Bank of Nigeria (CBN) Statistical Bulletin, 2005.

Oil price trend and the Nigerian oil export value (1980-2005): As a result of the development of its oil sector since 1960s and coupled with the increase in the global energy demand, Nigeria's oil export has been on the rise. The role of oil exports in the external sector development depicts another dimension of the importance of oil in the Nigerian economy. Propelled by the rapid crude oil production and export and of course moderately favorable but volatile world oil price development, oil export value (revenues) rose rapidly and substantially too from 1973-1981. Meanwhile, the value of oil exports fell from about \$27 billion in 1980 to about \$6 billion in 1988. This is due to the fact that the international oil price fell drastically from \$38.82 in 1980 to \$15.09 in 1988 (Fig. 1).

Oil price trend and economic growth in Nigeria (1985-2005): Nigerian crude oil proven reserves as of Jan., 2007 amounted to 36.2 billion barrels, while that of proven natural gas reserves total 182 trillion cubit feet in the same period (World Energy Outlook, 2007). With this natural resource endowment, Nigeria has been playing a dominant and, of course, prominent role in the world energy market. There has been a high correlation between macroeconomic trends in Nigeria and development in the world oil market represented by oil price (Fig. 2). This is due to the fact that in the early 1970s when Nigeria became a major world oil exporter there was a sharp escalation in the price of oil in the world market.

Meanwhile, the collapse of the oil boom around 1983-1989 as a result of negative oil price shock had major impacts on the economy of Nigeria. This is evidenced as the real GDP growth collapsed to 1.8% during the period (Fig. 2). Both economic and social conditions drastically deteriorated as compared to the 1970s. Eventually, there was a recovery in the 1990s as annual economic growth averaged about 4%. In the same period, the percentage share of oil exports to the total exports was still on the increase with about 97%. Meanwhile the noticeable real output growth of about 10% in 2003 was due to the rise of the oil price in the same year to almost \$30.

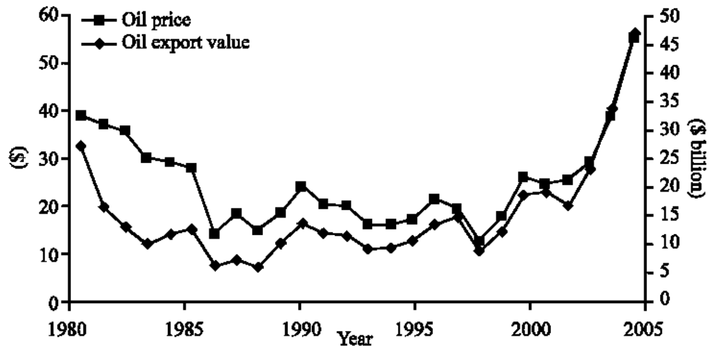

Fig. 1: Crude oil price and oil export value per US$ (1980-2005). Note: The left (Y axis) represents the Nigerian bonny light oil price expressed in US$/barrel, while the right (Y axis) stands for the oil export value also expressed in US$ million. Source: CBN Statistical Bulletin, 2005 data

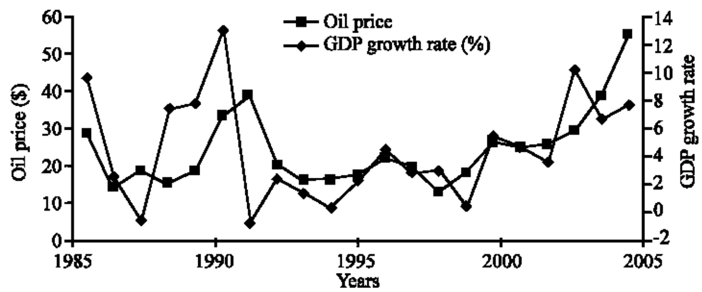

Fig. 2: Oil price and GDP annual growth rate (1985-2005). Note: The left (Y) axis represents the Nigerian bonny light oil price expressed in US$/barrel, while the right (Y) axis stands for the Nigerian GDP annual growth rate. Source: CBN Statistical Bulletin, 2005 data

Vector Autoregressive (VAR) model: To capture the impact of oil price shocks on the macroeconomic performance in Nigeria, this study shall employ the Vector Autoregressive (VAR) model pioneered by Sims (1980). Here, the focus is on the joint behaviour through time of a vector of economic variables. The model is specified thus:

$$y_t = c + \phi_i y_{t-1} ......+ \phi_k y_{t-p} + \mu_t \qquad (1)$$

Where, $y_t = (y_{1t}, \ldots, y_{kt})$, ϕ_i are $(K \times K)$ coefficient matrices and $\mu_t = (\mu_{1t}, ... \mu_{kt})$. This is K-dimension white noise with zero means that is $E(\mu_t) = 0$ and contemporaneous covariance matrix $E(\mu, u') = \Sigma_\mu$. Σ_μ is a diagonal matrix where diagonal elements are the variance of the structural disturbances and off-diagonal elements are zero (structural error terms are assumed to be mutually uncorrelated). Equation 2 can thus, be compactly written as:

$$y_t = c + \sum_{i=0}^{p} \phi_i y_{t-i} + \mu_t \qquad (2)$$

As earlier stated, y_t is a (7×1) vector of observations at time t on the economic variables under consideration (i.e., OILP = Oil Price, GDP = Gross Domestic Output, OILR = Oil Revenue, CPI = Consumer Price Index, MS = Money Supply, GRE = Government Recurrent Expenditure and GCE = Government Capital Expenditure. $c = (c_1, \ldots, c_7)$ is the (7×1) intercept vector of VAR. Φ_i is a sequence of (7×7) matrix of autoregressive coefficients for I = 1, 2,... p and $\mu_t = (\mu_{1t}, \ldots, \mu_{7t})$ the (7×1) generalization of a white noise process or vector of disturbances to the system. It is assumed here that the dynamic behavior of y_t is governed by the following structural model:

$$B(L) = y_t = c + \mu_t \qquad (3)$$

Where, B(L) is a 7th order matrix polynomials in the lag operator L such that:

$$B(L) = B_0 - B_1L - B_2L^2 - \ldots B_7L^7 \qquad (4)$$

B_0 is a non-singular matrix normalized to have one on the diagonal and summarizes the contemporaneous relationship between the variables contained in the vector y_t. Also, μ_t is a vector of structural disturbances and is serially uncorrelated.

Forecast error variance decomposition: One of the ways of characterizing the dynamic behaviour of a VAR system is through Forecast Error Variance Decomposition (FEVD). FEVD separates the variation in an endogenous variable into the component shocks to the VAR. It simply apportions the variance of forecast errors in a given variable to its own shocks and those of the other variables in the VAR. However, the recursive ordering of the variables in the VAR system for this study follows this order. Oil price equation is ordered 1st because the reduced form residuals in this equation, are unlikely to be contemporaneously affected by any other shocks except their own shocks. This restriction implies that oil prices do not respond to contemporaneous changes from other variables in the system because it is determined outside the model. On the other hand, all other variables in the system are contemporaneously affected by change in oil prices.

Oil revenues equation is ordered next to oil price equation. This ordering reflects the fact that the oil price and oil revenues have an influence on all the other variables in the model but their own behaviour is least determined by other variables included in the model. This is an assumption based on the fact that the oil prices and hence, oil revenues are largely determined by the world energy market conditions rather than conditions within the Nigerian economy. Similarly, this ordering assumes that the government expenditure is largely determined by the level of oil revenues, which again is quite a plausible assumption. The money supply equation is ordered next because it is reasonable to assume that monetary shocks have contemporaneous effect on all the remaining domestic variables in the system. The price index equation is ordered 6th because contemporaneous shocks in all nominal variables in the system are likely to affect the residuals in the price index equation. The output equation is ordered last by assuming that output is contemporaneously affected by all shocks in the system.

RESULTS AND DISCUSSION

Stationarity/unit root test: The aim here is to determine the underlying properties of the process that generate the time series variables employed in this research that is, whether the variables are stationary or non-stationary. To this end, Augmented Dickey Fuller (ADF) and Phillip-Perron (PP) tests are employed. The results are presented in Table 1. As shown in Table 1, the ADF and PP tests are reported with and with out the assumption of no significant drift. Examination of test results shows that all the time series data employed in this research, are stationary at first difference with the exception of oil revenue, which is stationary at level. The null hypothesis of 2 unit roots is rejected for all variables at the 5% significance level. Thus, the evidence suggests that first differencing is sufficient for modeling the time series considered in this study.

Cointegration analysis: A vector of variables integrated of order one is cointegrated if there exists linear combination of the variables, which are stationary. In this study, following the approach of Johansen (1991), 2 likelihood ratio test statistics, the trace and maximal eigenvalue test statistics, were utilized to determine the number of cointegrating vectors. The results of the trace and maximal eigenvalue test statistics are presented in Table 2. The null hypothesis, Ho, states that there are no cointegrating vectors. A rejection of the hypothesis would lead to testing the alternative hypothesis, H_A. The test statistics indicate that the hypothesis of no cointegration among the variables, Ho, can be rejected. The results reveal that at least 4 cointegrating vectors exist among the variables of interest. Since, the variables are cointegrated, there is, therefore, a long run relationship among the variables.

Variance decomposition results

Variance decomposition interpretation: The estimation of a VAR model firstly requires the explicit choice of lag length in the equations of the model. In this study, the

Table 1: Unit root test

	ADF				PP			
	Without trend		With trend		Without trend		With trend	
	Level	FD	Level	FD	Level	FD	Level	FD
Oilp	-0.003	-4.616	-2.379	-4.587	-0.214	-4.616	-2.385	-4.593
Ms	-0.995	-5.019	-3.111	-5.958	-1.244	-5.815	-2.091	-5.746
Oilr	-3.331	-6.148	-3.601	-6.015	-3.330	-6.23	-3.615	-6.077
Gce	-0.215	-6.188	-0.422	-5.086	-0.022	-5.020	-0.660	-5.088
Gre	-0.110	-6.574	-2.516	-3.747	-0.271	-3.122	-1.910	-3.759
CPI	-0.525	-3.297	-1.137	-6.446	-0.525	-6.188	-1.137	-6.446
GDP	-2.852	-5.814	-2.849	-6.472	-2.766	-6.574	-4.593	-6.472

Note: ADF = Augmented Dickey Fuller; PP = Phillip-Perron; FD signifies First Difference

Table 2: Johansen (1991) cointegration test

Trace test k = 2					Maximum eigenvalues test k =2				
			Critical values (%)					Critical values (%)	
Ho	H_A	(λ trace)	5	1	Ho	H_A	(λ max)	5	1
r ≤ 0	r > 0	180.3**	124.2	133.6	r = 0	r = 1	63.8**	45.3	51.60
r ≤ 1	r > 1	116.5**	94.2	103.2	r = 1	r = 2	46.2**	39.5	45.10
r ≤ 2	r > 2	80.3**	68.5	76.1	r = 2	r = 3	37.6*	33.5	38.80
r ≤ 3	r > 3	49.6*	47.2	54.5	r = 3	r = 4	30.8*	27.1	32.20
r ≤ 4	r > 4	24.8	29.7	35.7	r = 4	r = 5	15.0	21.0	25.50
r ≤ 5	r > 5	9.8	15.4	20.0	r = 5	r = 6	7.0	14.0	18.63
r ≤ 6	r > 6	2.8	3.8	6.7	r = 6	r = 7	2.8	3.8	6.70

Note: r represents the number of cointegrating vectors, while k represents the number of lags in the unrestricted, VAR model; *(**) denotes rejection of the null hypothesis at the 5 (1%) level

Table 3: Oil revenue variance decomposition

Period	SE	OILP	OILR	GRE	GCE	MS	CPI	GDP
1	0.04	38.51	61.49	0.00	0.00	0.00	0.00	0.00
2	0.06	31.89	54.13	0.32	0.04	0.00	5.37	8.25
3	0.07	23.76	52.00	2.58	2.15	2.35	6.80	10.36
4	0.08	24.65	49.41	2.82	2.33	3.25	6.02	11.42
5	0.10	25.10	44.30	3.46	3.19	3.70	7.21	13.04

Table 4: Money supply variance decomposition

Period	SE	OILP	OILR	GRE	GCE	MS	CPI	GDP
1	0.21	2.16	1.42	0.39	0.59	86.44	9.00	0.00
2	0.29	2.75	2.50	0.40	0.18	79.33	7.02	8.00
3	0.38	3.47	2.90	2.85	1.25	76.03	6.21	8.29
4	0.47	3.66	4.58	3.50	2.45	72.18	4.72	8.91
5	0.63	4.62	4.89	3.55	3.24	72.57	3.75	7.38

Table 5: Consumer price index variance decomposition

Period	SE	OILP	OILR	GRE	GCE	MS	CPI	GDP
1	0.48	0.22	2.32	1.63	0.52	7.67	54.64	35.00
2	0.55	1.38	3.28	2.80	2.19	10.08	54.20	26.07
3	0.66	1.77	5.77	3.66	3.93	12.36	52.08	20.43
4	0.83	2.36	6.15	4.24	4.62	13.75	47.50	15.38
5	1.23	4.00	6.41	5.18	6.82	14.49	46.00	13.10

OILP = Oil Price; OILR = Oil Revenue; GRE = Government Recurrent Expenditure; GCE = Government Capital Expenditure; MS = Money Supply; CPI = Consumer Price Index; GDP = Gross Domestic Output

Akaike Information Criterion (AIC) is used to determine the lag length of the VAR model. The AIC criterion is minimized for order 2. This suggests that for this study, the VAR model should be of order 2. Following the selection of the lag order, the 5 years forecasts of the variance decomposition is presented. Since unrestricted VAR assumes recursivity, the ordering of the variance decomposition, therefore, corresponds to the order earlier stated.

In Table 3, the oil revenue variance decomposition analysis reveals that the largest share of shock to oil revenue, apart from its own shock, is oil price, which accounted for about 38% in the 1st year period. Next is the real output contribution, which amounts to about 8% in the 2nd year period, while having about 13% contribution in the 5th year period. Moreover, price level also accounted for about 7% in the 5th year.

Meanwhile, the contributions of government recurrent capital expenditure and also that of money supply shocks remain insignificant through the 5 year period under estimation. The Table 3 also reveals the decreasing trend of the contributions of both oil price and oil revenue shocks, while those of price level and the real output follow increasing trend over time, respectively. This finding also confirms, the earlier assumption being made concerning the exogeneity of both oil price and oil revenue.

Looking at the variance decomposition of money supply (Table 4), it is apparent that the 2 types of government expenditure (recurrent and capital) do not explain a large part of its variations. However, the variance in domestic money supply is significantly explained by the own variance, which accounts for approximately 86% in the 1st year period and about 72% in the 5th period. The contribution of real output amounts to about 9% in the 4th period. The contribution of oil price variance account for about 2% in the 1st year period and exactly 4.62% ni the 5th period. This reveals the insignificant portion of oil price shocks on the variability of money supply. Similarly, the contribution of price level shocks to shocks in money supply amounts to 9% in the 1st year period, though, falling drastically to about 4% in the 5th year period.

Table 5 shows the result of variance decomposition of price level. Apart from its own shock contribution of exactly 54.64% in the 1st year period, real output changes account for the largest share of shock to price level amounting to about 35% in the 1st year period, declining through 20% in the 3rd year to about 13% in the 5th year period. It can also be, noticed from the Table 5 that while money supply changes contributed exactly 14.49% in the 5th year period, oil revenue shock contributed about 6.41 in the 5th year period. However, oil price explained only 0.22% of changes in inflation rate in the 1st year period, rising to 2.36% in the 4th year period and 4% in the 5th year period. This finding therefore, confirms that oil price may not be necessarily inflationary especially, in the case of an open developing economy like Nigeria.

Table 6: Real output variance decomposition

Period	SE	OILP	OILR	GRE	GCE	MS	CPI	GDP
1	0.40	2.56	7.10	1.04	1.25	8.15	5.09	74.01
2	0.47	4.23	9.00	3.07	1.06	16.52	4.12	56.00
3	0.49	7.07	12.77	3.33	2.20	18.13	4.10	53.40
4	0.53	7.66	16.65	4.19	1.37	21.07	2.02	47.04
5	0.73	10.01	17.54	5.31	1.08	24.00	1.06	41.00

Table 7: Government recurrent expenditure variance decomposition

Period	SE	OILP	OILR	GRE	GCE	MS	CPI	GDP
1	0.30	3.00	7.07	89.93	0.00	0.00	0.00	0.00
2	0.33	3.07	9.42	78.00	0.21	0.18	9.12	0.00
3	0.45	2.59	12.32	66.21	3.28	2.38	12.15	0.07
4	0.48	1.01	17.10	60.05	4.01	2.73	13.05	2.05
5	0.52	0.63	20.14	54.09	4.07	3.04	13.00	6.03

OILP = Oil Price; OILR = Oil Revenue; GRE = Government Recurrent Expenditure; GCE = Government Capital Expenditure; MS = Money Supply; CPI = Consumer Price Index; GDP = Gross Domestic Output

For the real output variance decomposition (Table 6), apart from its own shock, which amounts to about 74% in the 1st year period, the largest source of shocks among other variables is changes in money supply, which contributed about 8% in the 1st year, rising to about 18% in the 3rd year period and 24% in the last five year period. Oil revenue contribution follows that of money supply in terms of magnitude by accounting for about 13% in the 3rd year, rising to 17.54% in the 5th year period. The contribution of oil price shock to real output changes is about 4% in the 2nd year period, rising gradually to about 10% in the last 5 year period.

Meanwhile, the contribution of inflation rate shocks declined from about 5% in the 1st year period through 2% in the 4th year period to about 1% in the last 5th year. Also, the government recurrent expenditure accounted for about 5% in the 5th year, while that of government capital expenditure remains insignificant being 1.08% in the same period. The implication of this finding is that both oil revenue and oil price shocks significantly affect real output in Nigeria.

The variance decomposition analysis of government recurrent expenditure (Table 7) shows that apart from the contribution of its own shock, which accounts for the largest portion of the shocks throughout the 5 year period under consideration with about 90% in the 1st year period, it is also observed that oil revenue, followed by price level, account for a significant part of their variance. In the 5th year period, about 20% of the variance in government recurrent expenditures is accounted for by the variations in the oil revenues. The other variable, which also picks up a significant part of the variation in government recurrent expenditure is price level with 13% in the 5th year. Meanwhile, the contribution of the monetary variable (money supply) to the variance in government recurrent expenditure in the model is quite small and almost negligible over a longer period.

CONCLUSION

This study estimated the impacts of crude oil price shocks on the macroeconomic performance in Nigeria using a Vector Autoregression (VAR) model. Seven macroeconomic variables were taken into consideration: Gross Domestic Product (GDP), Consumer Price Index (CPI), Money Supply (MS), Oil Revenue (OILR), Government Recuurrent Expenditure (GRE), government capital expenditure and international crude Oil Price (OILP).

The forecast error variance decomposition is obtained with the aim of assessing how oil price shocks move through major channels of the Nigerian economy and how much of such shocks contribute to the variability of the variables in the system. The result, therefore, shows that crude oil price shocks significantly contribute to the variability of oil revenues by accounting for about 38% in the 1st year period declining to about 25% in the 5th year period. It also contributes significantly to the variability of real output accounting for about 10% in the 5th year period.

On the other hand, the findings presented in this study demonstrate that oil price shocks do not have direct substantial effects on money supply, price level and government recurrent expenditure in Nigeria over the period covered by the study. This is evident, as its contribution to the variability of real money supply only account for about 4.62% in the 5th year period. Again, only about 0.22% of changes in price level can be attributed to the shock in oil price in the 1st year period, rising to 4% in the 5th year period. Meanwhile, the contribution of oil price shock to the variability of government recurrent only accounts for 3% in the 1st year period and an infinitesimal portion of about 0.63 in the 5th year period. The study again reveals that the variability in the price level is explained substantially by the real output and money supply shocks.

This finding also confirms that oil price may not be necessarily inflationary especially, in the case of an open developing economy like Nigeria. From this study, it is found that oil price shocks have produced a small and modest impact on the money supply, suggesting a limited role of monetary policy in influencing economic activity. This may be partially explained by the problem of fiscal dominance, a situation where monetary policy reacts or responds to government fiscal policy. Thus, government expenditure becomes the major determinant of the level of economic activity. Therefore, fiscal policy can be used more effectively to stabilise the domestic economy after an oil shock.

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