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Petroleum exploration and the oil price dynamics: A case study of Nigerian petroleum industry

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In this paper, we described changes expected to occur in the upstream petroleum exploration industry's activities in response to oil price dynamics. We observed that an increase in oil price accelerates production activities and expand profit margins but, for some reasons, does not imply increase in new oil well exploration. Applying statistical Vector Autoregressive Model on annual data obtained from Nigerian petroleum industry, we empirically ascertained that oil price increase could lead to higher crude production but does not simultaneously translate to more well-drilling and appraisal. Therefore, while oil price may affect the return, viability of exploration and production ventures, it should not be a key strategic factor in deciding on petroleum exploitation policies by host governments.

Key words: Nigerian petroleum industry, exploitation strategy, oil price dynamics, vector autoregressive model.

INTRODUCTION

Petroleum has become an essential part of today's global economy and a key component of many national economies. Hence, the existence of petroleum in meaningful quantities can have important economic, developmental, and strategic consequences for a country. While a country's petroleum resource base is a gift of nature, translating this resource into saleable crude oil requires investment and efforts. Whether governments choose to invest directly or allow private investors to do so, the primary concern should be to maximize the social benefits derived from the exploitation of the resource base (Fee, 1988; Tordo, 2010). In order to exploit their natural resources efficiently many governments adopt strategies aligned to their economic and political ideologies. A petroleum exploration strategy is defined as the series of policies relating to licensing, taxation, royalty and general legal instruments developed by the state in order to ensure orderly development of petroleum exploration and production.

There are six factors identified in Fee (1988) that could have influence on the development of a country's petroleum exploitation strategy. These factors are: level of resource base; access to capital; level of technological development; oil price, oil company exploitation policy and international aid institution lending policy. The last three factors are exogenous; and inasmuch as they contribute to oil companies' production and gross profit rates, their influence on policy choice for host governments exploitation strategies may be minute.

Among the exogenous factors mentioned, this paper particularly discusses oil price and its role in exploration activities; and empirically test its relationship to production and new well drilling and appraisal using data from Nigerian petroleum industry. Our purpose is to ascertain whether in designing new petroleum exploitation strategy, governments need or need not consider oil price as a priority.

The remainder of this paper is organized as follows: the impact of oil price fluctuation on petroleum exploration activities; Nigerian petroleum industry and the major players in the industry; the method adopted for the empirical analysis and the data used; presentation and discussion of the results obtained from the analysis; finally, policy recommendation and conclusion.

PETROLEUM EXPLORATION AND THE OIL PRICE

According to Michot (2000), oil prices have been one of

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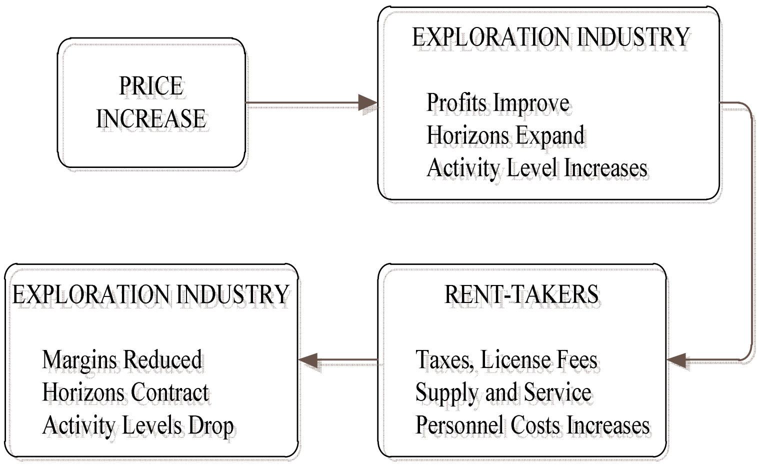

Figure 1. Response to oil price increase.

the main fulcrums of exploration industry's decision making. Over the past 25 to 30 years, oil prices worldwide have been highly volatile and speculation in trading is often blamed for the price cycles that have had such pronounced negative impacts on the exploration business. As a result, in risk management, the use of financial hedging to moderate unexpected swings in oil price has become one of the most important tools for managing overall risk and uncertainty and securing financing for exploration projects.

In a stable cost/price environment, that is, no real growth in oil prices or costs, the industry will tend to exhaust the population of probable economic targets and areas. In mature provinces, the explorers will already have discovered most of the largest and most attractive fields, and will be increasingly searching for and finding the minimum economic discovery quality (defined in terms of depth, field size and well productivity characteristics). As reserve replacement becomes increasingly difficult, the oil industry will try to maintain its rate of return by reductions in its exploration activities by drilling only highly prospective areas, or will seek to replace its dwindling reserves through takeovers of other companies. A significant increase in oil prices revises the prevailing cost/price environment and changes exploration and production from a maturing to a growth business.

The initial response of the industry to an increase in oil price may not be an increase in exploration activity but a reappraisal of discoveries made in mature provinces which were deemed uneconomic under previous price scenarios (Hannesson, 1998). Price increases have also given rise to an impetus in technological developments aimed at improving the recovery factor of existing fields. The profit potential of increased exploration activity can also be reduced by service industries bidding up the cost of manpower and equipment in a highly competitive exploration climate. Governments may add to this rent-taking by increasing taxes associated with production or by the imposition of a windfall profits tax on oil companies operating within their jurisdiction.

Increased oil prices eventually have impact on pattern of consumption and leads to a serious imbalance in the supply and demand situation. Therefore, while it appears on the surface that significant price increases should lead to an explosion in oil and gas exploration, there are forces within the industry, the government and in the general economic environment that tend to limit the rate of expansion of exploration.

Figure 1 shows graphically the effect of price increases on the exploration and production industry. This series of events is not hypothetical but was in fact observed following the price increases in 1973 and again in 1979 by Fee (1988). The price rise slowdown of the early eighties culminating in falling prices in 1985 and 1986 has affected exploration and production investment decisions made using rising oil price scenarios in the 1979 to 1981 period.

Inversely, Figure 2 shows the effect of price decrease on the petroleum exploration process. As oil prices decrease, industry profits reduce with the consequent limiting of the horizons and reduction of taxes and license fees, as such, the supply and service industry reduces its costs. This reduction in rent-taking leads to improved margins, expanded horizons and a pick-up in activity level. Therefore, while oil price increase and decrease immediately affect exploration/development activity, industry forces tend to push activity back towards the initial equilibrium.

In sum, price increase may improve field economics in the short term but additional rent-taking from government and service suppliers reduces the net effect considerably. Also, price increases lead to a drop in consumption, which in turn places less emphasis on the industry locating new short-term resources. In terms of developing

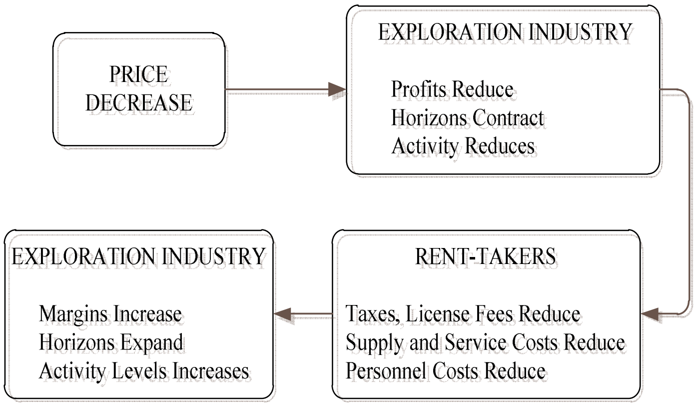

Figure 2. Response to oil price decrease.

Table 1. Liquids production by region ('000 bbl/d) 2001 to 2010.

Location	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Onshore	1205	1034	1149	1229	1204	781	631	645	542	635
Offshore	1149	1024	1161	1336	1392	1282	1187	1083	1045	1072
Deepwater	-	-	8	27	35	358	409	438	644	780
Total Liquids ('000 b/d)	2354	2058	2318	2592	2631	2421	2227	2166	2231	2487

Source: Wood Mackenzie (2007), note: bbl/d = barrels per day.

Table 2. Operating expenditure by region (US$ Million) 2001 to 2010.

Location	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Onshore	1334	1536	1528	1540	1592	1706	2290	2516	2358	2547
Shallow water	1602	1638	1992	2110	2385	2639	2793	2927	2975	3084
Deepwater	-	-	47	77	120	385	403	606	1436	2037
Total	2936	3174	3567	3727	4097	4730	5486	6049	6769	7668

Source: Wood Mackenzie.

a petroleum exploration strategy, it is difficult to see how countries could incorporate an oil price rated factor. Therefore, conducting an empirical investigation for a given petroleum industry, in this case Nigerian petroleum industry, is of utmost importance.

NIGERIAN PETROLEUM INDUSTRY

The petroleum industry is the largest sector and main generator of income for Nigeria. The industry accounts for over 95% of the country's export earnings and about 40% of government revenues. The petroleum industry is primarily located in Nigeria's Niger Delta region. According to EIA (2011) and BP (2011), Nigeria had an estimated 37.2 billion barrels of proven oil reserves as of January 2011. The majority of reserves are found along the country's Niger River Delta and offshore in the Bight of Benin, the Gulf of Guinea and the Bight of Bonny. The current production figures by region are shown in Table 1.

In 2009, total oil production in Nigeria was slightly over 2.2 million bbl/d, making it the largest oil producer in Africa. Crude oil production averaged 1.8 million bbl/d for the year. Recent offshore oil developments combined with restart of some shut-in onshore production have boosted crude production to an average above 2.4 million bbl/d in 2010. The upsurge in offshore oil development activities were mainly as result of the incessant attack by militants in the Niger Delta region on onshore oil facilities and lesser rent-taking by the government because of the increasing risk and cost involve in offshore/deepwater exploration. Table 2 shows the total operating expenditure for exploration and production activities in Nigeria for 2001 to 2010. Clearly, there are rising interests in in shallow and deepwater exploration activities in Nigerian petroleum industry as indicated by the rising expenditure figures in the areas.

Recent developments in the upstream sector include the start up of the Chevron-operated Agbami field in September 2008, which reached its estimated peak production of 250,000 bbl/d in 2009 as well as Eni's startup of the Oyo field in 2009, producing approximately 25,000 bbl/d. Non-crude production was boosted in 2009 with Total's Akpo condensate field that started up in 2009, adding about 180,000 bbl/d of liquids to total production.

Nigerian petroleum industry is predominated by foreign oil companies as more than 85% of its total oil production comes from these foreign companies. Foreign companies operating in form of joint ventures (JVs) or production sharing contracts (PSCs) with the Nigerian National Petroleum Corporation (NNPC) include ExxonMobil, Chevron, Total, Eni/Agip, Addax Petroleum, ConocoPhillips, Petrobras, StatoilHydro, and others. Shell has been working in Nigeria since 1936 and currently operates the most nameplate crude oil production capacity, estimated to be between 1.2 and 1.3 million bbl/d. However, the company has had its hardest hit by the instability as much of its production is onshore. More than half of Shell's crude oil production capacity is currently shut-in, some since early 2006 (EIA, 2011).

The elements of Nigerian petroleum exploitation strategy are rooted in its legal and fiscal system adopted for the industry. Initially, Nigeria adopted concession agreements whereby foreign oil companies were in full control of petroleum assets and production but these systems later evolved into joint ventures (JVs) between the companies and the government. The government represented by the state oil company (NNPC) acquired equity interest in the concessions. The foreign oil companies have continued to operate the JVs with costs and revenues split on an equity basis.

The 1990s saw major changes to the Nigerian upstream industry. Blocks in the inland basins and in the deepwater area of the Niger Delta were made available for open bidding rounds. The awards made in the 1990s were mostly in the form of production sharing contracts (PSCs). The period also saw the government encourage the participation of indigenous oil companies in exploration and production. About 38 indigenous companies were granted licenses between 1990 and 1994. However, many of them lacked the technical and financial resources to operate their exploration licenses. In trying to alleviate this problem, the government entrenched the local content act into their petroleum fiscal system. This act, among other things, mandates the foreign oil companies to develop the skills of their local staff and utilize the services of indigenous oil service companies when necessary.

Lastly, the proposed Petroleum Industry Bill (PIB) currently before the country's National Assembly intends to set out a new legal framework for the organization and operation of the entire oil industry. The bill intends to reduce administrative bureaucracy within government agencies and introduce sliding scale tax revenue collection systems that automatically respond to oil price changes as well as production rate. When passed into law, the bill will establish a more transparent and a balanced business environment for all stakeholders in the industry.

METHOD OF ANALYSIS AND DATA DESCRIPTION

In studying the relationship between oil price and petroleum exploration activities in Nigerian petroleum industry, we will use a statistical method known as Vector Autoregression (VAR), which is used to capture the linear interdependencies among multiple time series (Agung, 2009). The most basic form a VAR model treats all variables symmetrically without making reference to the issue of dependence versus independence. Thus, VAR model describes the evolution of a set of *k* variables (called endogenous variables) over the same sample period (t = 1,…, T) as a linear function of only their past evolution. The variables are collected in a k × 1 vector Y_t, which has as the i^{th} element $Y_{i,t}$ the time *t* observation of variable Y_i.

For example, based on two endogenous variables, namely *Y1* and *Y2*, the basic VAR model has the following general equation:

$$Y1_t = \alpha_1 + \sum_{j=1}^{k} \beta_{1j} Y1_{t-j} + \sum_{j=1}^{k} \delta_{1j} Y2_{t-j} + \mu_{1t}$$

(1a)

$$Y2_t = \alpha_2 + \sum_{j=1}^{k} \beta_{2j} Y1_{t-j} + \sum_{j=1}^{k} \delta_{2j} Y2_{t-j} + \mu_{2t}$$

(1b)

where $Y_{t-j} = (Y1, Y2)_{t-j}$ is the j^{th} lagged variable of Y_t, and it is assumed that each of the error terms do not have serial correlations or autocorrelations.

For $j = 2$, the causal association or the path diagram between the endogenous variables in model 1 can be presented as in Figure 3. The correlation between the error terms μ_{1t} and μ_{2t} indicates that the endogenous variables have a type of relationship. Since both regressions represent the first lagged variables $Y1_{t-1}$ and $Y2_{t-1}$ as the cause factors of *Y1* and *Y2*, then it may also be considered that $Y1_{t-2}$ and $Y2_{t-2}$ are the cause factors of $Y1_{t-1}$ and $Y2_{t-1}$. However, the model could not show these causal relationships explicitly. For this reason, dotted lines are used between the four variables $Y1_{t-1}$, $Y1_{t-2}$, $Y2_{t-1}$ and $Y2_{t-2}$.

Model 1 is considered as a bilateral causality model, because of the two exogenous variables *Y1* and *Y2*. Four types of Granger causality can be distinguished, as follows (Gujarati, 2003; p.697):

1. Unidirectional causality from *Y2* to *Y1* is indicated if the estimated coefficients on the lagged *Y2* in Equation 1a are statistically different from zero as a group (that is, $\Sigma\beta_{1j} \neq 0$) and the set of estimated coefficients on lagged *Y1* in Equation 1b is not statistically different from zero (that is, $\Sigma\beta_{2j} \neq 0$).
2. Conversely, unidirectional causality from *Y1* to *Y2* exists if the set of the lagged *Y2* coefficient is Equation 1a is not statistically different from zero as a group (that is, $\Sigma\beta_{1j} = 0$) and the set of estimated coefficients on the lagged *Y1* in Equation 1b is statistically different from zero (that is, $\Sigma\beta_{2j} \neq 0$).

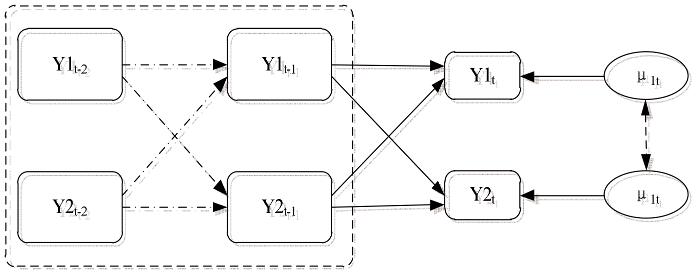

Figure 3. The path diagram of a VAR model in model 1 for k = 2.

Table 3. Data description.

Variable	Output	Well	Price
Mean	1969.503	51.05714	31.10922
Median	2060.795	50.00000	24.44389
Maximum	2499.000	88.00000	97.25597
Minimum	1236.000	4.000000	12.71566
Std. dev.	357.4867	21.81735	20.85596
Skewness	-0.665687	-0.172721	1.646935
Kurtosis	2.342093	2.272957	4.942323
Jarque-Bera	3.216205	0.944886	21.32404
Probability	0.200267	0.623477	0.000023
Sum	68932.60	1787.000	1088.823
Sum Sq. dev.	4345089.	16183.89	14789.02
Observations	35	35	35

3. Feedback or bilateral causality is suggested when the sets of lagged *Y1* and *Y2* coefficients are statistically significantly different from zero in both regressions.
4. Finally, independence is suggested when the sets of lagged *Y1* and *Y2* coefficients are not statistically significant in both regressions.

The model described can only be used when the series involved are stationary and without a linear cointegrating term between them; otherwise, Granger causality tests with cointegrated variables may utilize the integrated data in their first difference, *I(1)* data, including an error-correction mechanism term (Oxley and Greasley, 1998; Enebeli, 2010), that is,

$$\Delta Y1_t = \alpha_1 + \sum_{j=1}^{k} \beta_{1j} \Delta Y1_{t-j} + \sum_{j=1}^{k} \delta_{1j} \Delta Y2_{t-j} + \phi_1 ECM_{t-1} + \mu_{1t} \tag{2a}$$

$$\Delta Y2_t = \alpha_2 + \sum_{j=1}^{k} \beta_{2j} \Delta Y1_{t-j} + \sum_{j=1}^{k} \delta_{2j} \Delta Y2_{t-j} + \phi_2 ECM_{t-1} + \mu_{2t} \tag{2b}$$

where the error-correction mechanism term is denoted ECM.

Lastly if the data are *I(1)* but not cointegrated valid Granger-type tests require transformations to induce stationarity. In this case, the tests deploy formulations like Equations 2, but without the ECM term, that is, Equations 3.

$$\Delta Y1_t = \alpha_1 + \sum_{j=1}^{k} \beta_{1j} \Delta Y1_{t-j} + \sum_{j=1}^{k} \delta_{1j} \Delta Y2_{t-j} + \mu_{1t} \tag{3a}$$

$$\Delta Y2_t = \alpha_2 + \sum_{j=1}^{k} \beta_{2j} \Delta Y1_{t-j} + \sum_{j=1}^{k} \delta_{2j} \Delta Y2_{t-j} + \mu_{2t} \tag{3b}$$

With optimal lag lengths determined by AIC (Akaike's information criterion) and BIC (Bayesian information criterion) in the estimated unrestricted VAR models, Granger causality tests conducted upon Equations 2 and 3 as explained using Equations 1a and b.

For an empirical analysis of the relationship between oil price and petroleum exploration activities, we used "*output*" and "*price*" to denote Nigeria's average annual crude oil daily production in barrels and Brent crude spot price in dollar per barrel respectively as obtained from BP (2011). While "*Well*" denotes annual data on the number of new well drill and appraisal in Nigeria obtained from Wood Mackenzie. Brent crude oil spot price is usually regarded as benchmark price for West African crudes in the international oil market (Horsnell and Mabro, 1993). The range of years used is from 1976 to 2010, comprising of 35 time series data in each observed variable. We believe that crude oil production figure is a good proxy to measure the exploration activity level as oil price fluctuates; while the number of new well drilling and appraisal proxies increase in exploitation of the available resource base. Table 3 represents the summary of descriptive statistics for the data used in the empirical analysis. All the data were further transformed

Table 4. Unit root test of ADF and PP.

Variable	ADF	ADF (-1)	PP	PP (-1)
LOutput	-2.33	-4.68*	-2.21	-4.06*
LWell	0.33	-5.07*	0.33	-5.04*
LPrice	-1.53	-5.84*	-1.57	-5.84*

*Rejection of the null hypothesis of a unit root at the 5% significant level. Model with intercept and trend for LPrice and without trend for LWell.

Table 5. Cointegration tests.

Series	Null hypothesis	Trace stat	P-value
LOutput – LPrice	No relation	10.21**	0.27
LWell – LPrice	No relation	12.31**	0.14

*Reject the null hypothesis at 5% significance level. **Accept the null hypothesis at 5% significance level. Model with intercept and without trend.

to their natural logarithm forms henceforth represented by LOutput, LWell, and LPrice for output, well and price, respectively.

RESULTS AND DISCUSSION

To evaluate the linear interrelationship between the variables using VAR model demands that we first perform tests of their individual stationarity. We employ Augmented Dickey-Fuller (ADF) (Dickey and Fuller, 1979) and Phillips-Perron (Phillips and Perron, 1988) (PP) unit root tests. The test results are in Table 4. The results confirm that all the series are integrated in Order 1, that is, *I(1)*.

Next, we study the cointegration between the oil production and oil price and also between the number of well drill and oil price, employing the trace test proposed by Johansen and Juselius (1992). According to the trace test results in Table 5, we accept the null hypothesis of cointegration between the variables under consideration at the 5% significance level. Therefore, the data do not reveal any long-term relationship between the variables judging from their estimated P-values implying that a better model for the empirical analysis should utilize the VAR model in Equations 3.

The results of the VAR models are presented next. In Models 1 and 2, *t*-statistics are in parentheses below the coefficient. The lag order (k = 2) of the models have been determined by using the information criteria proposed by AIC and BIC in the estimated unrestricted VAR models. The t-statistics were used to determine whether or not a lagged variable has a significant adjusted effect on the corresponding dependent, by using a critical point of t_0 = 2 or 1.96. if $/t_0/ > 2$, or 1.96, then it can be concluded that in the two models, the corresponding independent variable has less significant adjusted effect except for the coefficient of price with lag = 2 in model 1. Note that the "*b*" parts (that is, Equation *3b*) of both models were omitted as they are not needed in the analysis.

Model specifications

Model 1

$$\Delta LOutput_t = 0.01 + \underset{[1.91]}{0.33\Delta LOutput_{(-1)}} - \underset{[-1.50]}{0.26\Delta LOutput_{(-2)}} - \underset{[-1.20]}{0.07\Delta LPrice_{(-1)}} - \underset{[-2.34]}{0.15\Delta LPrice_{(-2)}}$$

$\bar{R}^2 = 0.23$; AIC = -3.47

Model 2

$$\Delta LWell_t = -0.05 - \underset{[-0.48]}{0.11\Delta LWell_{(-1)}} - \underset{[-0.78]}{0.17\Delta LWell_{(-2)}} + \underset{[1.99]}{0.50\Delta LPrice_{(-1)}} - \underset{[-0.45]}{0.12\Delta LPrice_{(-2)}}$$

$\bar{R}^2 = 0.04$; AIC = -0.54.

The VAR Granger causality tests results showed in Table 6 indicates that in model 1, the null hypothesis that oil price is not a Granger-cause of production rate is rejected based on the chi-square test of 6.93, with 2 degree of freedom and a p-value of 0.03, while the null hypothesis that production rate is not a Granger-cause of oil price is accepted based on the chi-square test of 0.06 with 2 degree of freedom and a p-value of 0.97. Therefore, there is a unidirectional causality running from oil price to production rate of Nigerian petroleum industry. Model 2 analyzed in the same way as Model 1, contrarily,
no Granger causality exist between well drill and appraisal with oil price.

The results obtained in the empirical analysis conducted using data from Nigerian petroleum industry are in accordance with our discussion from earlier part of this paper. Hence, while oil price affects production rate and in turn determines the return and viability of exploration and production ventures it is not a key strategic factor in deciding when appropriate to drill more wells or exploit more resource.

Table 6. Results of causal endogeneity tests (P-value).

Model	Variables	$\chi^2_{(2)}$	P-value
Model 1	∆LPrice does not Granger cause ∆LOutput	6.93	0.03
	∆LOutput does not Granger cause ∆LPrice	0.06	0.97
Model 2	∆LPrice does not Granger cause ∆LWell	4.20	0.12
	∆LWell does not Granger cause ∆LPrice	1.40	0.50

Conclusion

In this paper, we have described changes expected to occur in upstream petroleum exploration industry's activities in response to oil price dynamics. We observed that an increase in oil price accelerates production activities and expand profit margins but because of subsequent increase in rent-taking by host governments, service suppliers, technological developments and so on, it does not imply increase in new exploration activities. We empirically ascertained that oil price increase could lead to higher crude production but does not simultaneously translate to more well-drilling and appraisal using statistical Vector Autoregressive Model on annual data obtained from Nigerian petroleum industry.

Therefore, in developing a petroleum exploration strategy that will attract foreign investment, less emphasis should be place on oil price increase scenarios; rather governments should focus on reserves development, access to capital, technology and facilities development. The interdependence of these key strategic factors must be established. For instance, the access to capital may be derived from funds generated through taxation of an existing large petroleum resource. Similarly, level of technology may be dependent on the existence of a substantial resource base or an adequate access to capital. As many of the oil fields manure, a better alternative to concession agreement is the production sharing agreement as it will increase governments' participation through their national oil companies and provide needed investment capital as entrenched in the agreements.

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