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Petroleum Reserves Growth Trend and Pattern: A Case Study of the Niger Delta Basin in Nigeria

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Abstract

For the purpose of this paper, reserves growth is classified into three main categories: new pool discoveries, reserves revision and reserves extension. For each category, there are distinct factors affecting positive and residual reserves growth. The paper shows that fiscal/policy incentives, crude oil price and modern technology are necessary conditions to expand petroleum reserves, thereby prolonging the end of petroleum era in Nigeria. The deepwater remain the most promising area for further significant reserves growth. Therefore, the existing Production Sharing Contract (PSC) deepwater field development projects will undoubtedly impact positively to the country's production and reserves blueprint toward the 40 billion and 4.0 MMBBL per day targets by 2020.

Introduction

Nigeria ranks among the top ten largest producer of crude oil worldwide, perhaps as a result of its continuous efforts in reserves replacement over the last forty years. In order to grow its reserves, several policies formulated by its regulatory bodies facilitated the growth of petroleum recoverable reserves. Understanding Nigerian reserves growth trends and the factors underlying the growth is an important input to national planning. This is more so because the nation's economy depends extensively on energy. Thus, the industry needs to ascertain reserves are replaced accordingly through exploration campaigns and new technologies for reserves additions.

In this paper, a descriptive analysis of reserves growth provides good understanding of the contributions of each reserves category on gross reserves growth in the Niger Delta basin of Nigeria. The paper discusses the causes of reserves growth and shows the importance of government policy incentives, crude oil prices and new technology to reserves growth pattern. The paper also identifies the engineering inputs driving oil discoveries, and the upward revisions of existing reserves through field appraisal drilling, accelerated field development approvals and improved recovery schemes. Reserves discovered, developed and appraised in Niger Delta basin by three major operators were randomly sampled and the reserves growth from this sample space is referenced to describe the reserves growth situation in Nigeria. Over 300 fields-onshore, swamps and offshore terrain from 1954 to 2012 were included in the sample space. The primary source of the key data used in this study of reserves growth in Niger Delta basin of Nigeria is the Department of Petroleum Resources, an Agency of the Ministry of Petroleum Resources.

Niger Delta Basin Reserves Contribution by Categories

Proved reserves are estimated quantities of petroleum, anticipated to be commercially recoverable, from known accumulations, based on interpretation of geologic and engineering data available, by established operating practices, under existing economic conditions, and under current government regulations (JPT, May 1987). Reserves estimates change from year to year as new discoveries are made (discoveries[1]), existing fields are more thoroughly appraised (appraising [2]), existing reserves are produced (production[3]), and prices and technologies change (Improved recovery [4]). Other reserves categories used in this study include temporary shut-in reserves, which are reserves from non-producing fields that awaits development from well interventions/re-entry, surface equipment installations or replacement, etc. Developing reserves category comprises of fields who's Field Development Plans (FDPs) are currently implemented; while awaiting approval are fields waiting to commence development pending approval from the Directorate of Petroleum Resources. Table 1 shows estimated reserves of all

1. Discoveries are new reserves from exploration wells
2 Appraising refers to categories of reserves which are being quantified by appraisal wells
3 Producing refers to categories of reserves which are quantified by development and infill wells
4. Improved recovery refers to categories of reserves quantified by secondary and tertiary recovery methods.

categories mentioned above, while Figure 1 and 2 show their respective contributions to Nigerian reserves growth within each period.

Discoveries include new fields, identification of new reservoirs in previously discovered fields, and extensions; which are additions to reserves that result from additional drilling and exploration in previously discovered reservoirs. Within a given year, extensions are typically the largest percentage of total discoveries. While discoveries of new fields and reservoirs are important indicators of new resources, they generally account for a small portion of overall annual reserves additions. Revisions occur primarily when operators change their estimates of what they will be able to produce from the portfolio they operate in response to changing prices or improvements in technology, or field studies. Higher crude oil prices favour positive revisions as operators consider a broader portion of the resource base economically producible, or proved. Lower prices, on the other hand, reduce reserves estimates as the economically producible base diminishes. The definitions of proved reserves presented above, obviously involve some degree of uncertainty. However, technological developments can clearly change the definition of commercially recoverable, improve interpretation of data, and improve operating practices, resulting in growth in proved reserves over time (Beliveau and Baker, 2003). Changes in economic conditions or government regulations can also impact the definition of commercially recoverable over time.

Figure 3 shows the contribution each of the main reserves categories to total reserves. Based on the selected fields reviewed for this paper, the percentage of new reserves in the category of discoveries to the overall reserves increased from 6.7% before 1960 and climaxed at 78.6% in period 1991-1995; while its lowest contribution of 1.24% was realized between 2006 and 2010 (Figures 3 and 4). This declining trend in reserves attributed to new discoveries is perhaps due to low upstream investment in E&P, perhaps, as a result of the uncertainty attributable to the delay in the passage and implementation of the Nigeria Petroleum Industry Bill.

Reserves by revisions (IOR) contributed 64% of the total reserves from 1996-2000 and extensions contributed more than 98% of Niger Delta total reserves from 2006 up till 2010. We can say that reserves growth from these categories can be attributed to new technologies set out to increase finding rate through horizontal well technology, installation of positive displacement pumps, 3D seismic, etc., multidisciplinary study teams that apply computer hard and software to optimize locations and increase the chances of drilling success, improved oil recovery techniques (waterfloods, miscible floods, EOR), and low drilling and operating costs. Around two-thirds of the oil in an average field remains underground because it is too costly to extract; if the oil is especially thick, the quantity left behind can be much higher. Implementing IOR projects adds to the extraction cost of crude oil; therefore, the Nigerian government needs to provide the incentives that will encourage operators to deploy state of the art technology for IOR projects. These projects will target oil recoveries from shallow and viscous crudes, thin bedded oil sands, and commingled production of stratified reservoirs using smart well completions, and implementation of Integrated Field Surveillance (i-field). This drive will convert several reserve resources and contingencies to proved reserves, thereby increase the contribution of reserves revisions. This practice showed high reserves contribution by revision between 1961-1965 and 1996-2000. Further, Iledare, (2000), indicated that the E&P industry needs to encourage the diffusion of technology and its applications to increase the selection of drilling prospects with greater certainty.

Determinants of Petroleum Reserves Growth

There have been many theories proffered to explain the reasons for reserves growth. Additional reserves come not only from discovery of new pools, but also from existing pools. Reserves growth from existing reservoirs has been suggested to be the primary contributor to reserves additions in most mature basins (Baker et al, 2012), contributing approximately 70% of global oil production. Substantial oil production from Niger Delta basin (onshore, shallow, deep/ultra deep waters) began in 1958. Thus, the Niger Delta Basin of Nigeria can be classified as a mature and fully developed petroleum basin. Attanasi et al., (1994) reviewed oil and gas resources in the onshore and offshore areas of the United States and compared observed field reserves growth to prove reserves discovered between 1992 and 1996. According to the authors, the market price during that period undoubtedly influenced the industry's willingness to increase upstream investment to make improvement in recovery. Toole and Grist (2003) examined 55 oil reservoirs and 44 gas reservoirs in the United Kingdom, and found steady reserves growth of 2% per year from the oil fields. The authors attributed the observed steady reserves growth to increased recovery factors. Campbell (1997) examined reserves growth worldwide and discussed the effects of politics on reserves growth; he also stated that 90% of all production comes from fields that have been on production for more than 20 years.

Baker, Jong and Virues (2007) analyzed proved reserves growth in Alberta. The authors concluded that reserves growth occurring at the later life of a field can be attributed to new technologies (horizontal wells, screw pumps, 3D seismic, etc.), multidisciplinary study teams, improved oil recovery techniques (waterfloods, miscible floods, EOR), better local knowledge of the resource as more data is collected (e.g. drive mechanism) and low drilling and operating costs. Iledare (1995) evaluated the effect of economic and policy incentives on natural gas drilling and gross reserves additions using simulation models, he affirmed that a rise in the real wellhead price would lead to a positive change in gross new reserves additions. Further, Iledare opined that higher tax rates (fiscal regime), and market conditions may hinder the natural gas development process.

Workovers, that use proven and new technology on existing wells that already have casing, tubing, artificial lift systems and surface facilities is also an excellent way to increase reserves and production with a small investment (Lisigurski et al, 2006). Beliveau and Baker (2003) discussed that the influence of regulatory, business and technical progress explained the reserves changes and growth trends observed in Western Canadian Sedimentary Basin (WCSB) between 1950 and 2000. It has also been suggested that Underbalanced Drilling Technology (UDT) affects reserves growth positively and thus enhances ultimate recovery (Babajan and Qutob, 2009). UDT benefits the reservoir (especially the ones that could not be drilled conventionally) by adding reserves through discovery of new zones, reducing formation damage, increasing intra-zone contribution, accessing challenging reservoirs, providing real time reservoir evaluation characterization and increasing well drainage area.

Accordingly, the adoption of *new technologies* has been suggested to be the key factor in adding reserves, enhancing recovery, reducing cost and increasing revenue. However, it is foolhardy for the bulk of replaced produced reserves to be accounted for by adjustment and revised reserves only. The greater the proportion of produced reserves that are accounted for by new discoveries--extension, new field discoveries and/or new pool discoveries--the greater will be the appreciation ratio of recoverable reserves in the future (Iledare, 2000).

Descriptive Analysis of Nigeria's Reserves Growth

Factors underlying reserves growth in Nigeria may be categorized into four main components. These components are innovative legal and fiscal regimes, technology adoption by the operating companies, economics, and policy incentives. Both technology growth and economics are important and their interactions are critical. Reserves discovered, developed and appraised in Niger Delta basin by three major operators were randomly sampled and the reserves growth from this sample space is referenced as representative of the Nigeria's case. The reserves growth is categorized as discussed and pictorially depicted in Figures 1 and 2.

Reserves additions in Nigeria grew by 11% from 1958 to 1969. This is equivalent to 3.9 billion barrels; the growth occurred during this period because of new licenses issued and subsequent competition among the existing IOCs. Between 1970 and 1979, there was another 23% (8.4 billion barrels) additions to the reserves. This reserves growth was triggered by international oil operators whose business models responded favorably to rising crude oil prices in the 1970s. Further, the Nigerian government policy incentives allowing CAPEX for the first exploration well and two subsequent appraisal wells to be expensed before tax computations. Further, the world oil glut of the 1980s inhibited reserves additions by 8.8% in 1986, despite the tax relief and the $2.00/bbl notional margin provided in the 1986 MOU, to ameliorate low exploration activities observed within this period. In 1991, government introduced Reserves Addition Bonus (RAB) initiative, which boosts reserves additions by about 21% (7.6 billion barrels) between 1990 and 1995. The effective reserves additions were 40 MMbbl per well drilled in 1994 (see Figures 5 and 6).

As modern scientific means of exploration continue, government continues to encourage international oil companies with new contractual arrangements such as the Production Sharing Contracts, in addition to the opening up of the frontier areas--the deep and ultra deep sections of the Nigeria offshore waters. The discovery of large oil and gas fields in deep offshore under the 1993 PSC, although now avowed by the government lately as unattractive in terms of government "take", added significantly to reserves additions during the period 1995-2003.

Figure 7 is the contribution of ultimate oil reserves in the onshore, offshore and swamp environments/terrain, with reserves contribution from offshore dominating the gross reserves between 1996 and 2010. This is an empirical evidence suggesting the significance of policy incentives and technology progression in E&P business. Finally, government in its search for more opportunity to grow reserves in 2003, collaborated and engaged in business alliances; conducted licensing rounds and gave out some inland basins leases as well as marginal fields to interested local and foreign oil and gas operators. As expected, this government's initiative ushered in an increase in booked reserves.

During 1970-1975, total drilling efforts (total number of exploratory and development wells drilled within the year) were high; and one dare speculate that drilling responded positively to the sudden price rise in the 1970s. This accounted for 43 percent of the number of wells drilled from 1970 to 1998. Despite drilling the highest number of exploration and development wells in the early 1970's, the industry, however, did not record a correspondingly high reserves addition during the period. Thus, we could infer that the frequency of drilling is not necessarily directly proportional to the rate of reserves additions. By 1990, drilling success rate increased approximately to 95%, we inferred that technology which improves with passage of time has a positive effect on the rate of reserves addition by increasing drilling success rate.

Summary and Conclusions

In this paper reserves data from selected fields for three major oil operators in the Niger Delta basin of Nigeria are used to classify reserves growth into three main categories: new pool discoveries, reserves revision and reserves extension. We observed that discoveries of new fields and reservoirs are important indicators of new resources and, accounted for an average of 32.5% of the overall annual reserves additions. However, reserves additions by extensions accounted for largest percentage

of total discoveries within a given year. Reserves additions as a result of revisions from 1996-2000 contributed about 61 percent of total reserves during this period because operators revised their estimated ultimate recoverable reserves in response to changing prices and improvements in technology. The 125% rise in crude oil prices between 1996 and 2000 also favoured positive revisions as operators consider a broader portion of the resource base to be economically producible.

While analyzing the distinct factors affecting positive and residual reserves growth for each category, we observed that government policy incentives in the form of tax reliefs, reserves additions bonus, MOUs and PSCs influenced new discoveries positively. Appraisal and development of these new discoveries brought about the continuous reserves growth through extensions, although the drive to drill more wells might have been influenced by oil prices as well.

Operational environment/terrain affects the size of new discoveries. We ascertained this fact by estimating reserves additions as function of operational environment/terrain for the oilfields that were studied. Table 2 shows that reserves addition in onshore, offshore and swamp terrains are 50.5MMbbl/field, 142.5MMbbl/field and 181.3MMbbl, respectively. This implies that the start of deep and ultra deep waters E&P activities added value to Nigeria reserves blueprint.

Table 3 is the summary of petroleum reserves growth trend and pattern in Nigeria with the percentage contribution from the three categories and the factors that affected the trend within each period. Government policy incentives has been seen to be effective in increasing reserves through new discoveries, furthermore, incentivizing enhanced oil recovery projects of fields with sizeable reserves addition potential is encouraged to increase recovery factors.

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Nomenclature
MOU = Memorandum of Understanding
CAPEX = Capital Expenditure
MMBBL = Million Barrels
PSC = Production Sharing Contract
FDP = Field Development Plan
IOR = Improved Oil Recovery
EOR = Enhanced Oil Recovery
E&P = Exploration and Production
i-field = Intelligent Field

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Table 1: Classification or Category of Reserves in Nigeria (MMbbl)

DISCOVERIES		AWAITING APPROVAL	APPRAISING	DEVELOPING	PRODUCING	IMPROVED RECOVERY	TEMP SHUT-IN
Year	EUR	EUR	EUR	EUR	EUR	EUR	EUR
1954-1960	173.6	-			1927		507
1961-1965	31.05	-			799	581	98.1
1966-1970	119.3	21.3			943	159	123
1971-1975	148.56	160	2.5		1350	108	179.5
1976-1980	202.5	-			115	19	56.5
1981-1985	469.1	-	1		232		37.4
1986-1990	194.3	-	1.56		185		75.57
1991-1995	362.5	-			9		90.1
1996-2000	240	-	295		20	866	128
2001-2005	114.5	855	939	160.00	51	31	
2006-2010	6	-	425	59			
2010-2015	40		28.1				

Table 2: Reserves Additions Per Field

	ONSHORE		OFFSHORE		SWAMP	
Year	EUR (MMbbl)	Number of Fields	EUR (MMbbl)	Number of Fields	EUR (MMbbl)	Number of Fields
1954-1960	2608	30				
1961-1965						
1966-1970					416	1
1971-1975	1636	54				
1976-1980						
1981-1985						
1986-1990						
1991-1995						
1996-2000			1303	10	128	2
2001-2005			1974	13		
2006-2010						
2010-2012						

Table 3: Summary of Nigerian Historical Reserves Growth Contribution with their Influencing Factors

Year/ Categories	*New Discoveries*	*Extensions*	*Revisions*
1954-1960	8.2%	91.7% (Appraisal and development of previously discovered field)	0%
1960-1965	2.2%	56.6% (Development of existing fields)	41.2% (understanding Niger Delta basin like the drive mechanism, emerging technology)
1966-1970	9.8%	77.2% (Oil price and fiscal incentives)	13%
1971-1975	9.2%	84.1% (Rising crude oil price)	6.7%
1976-1980	60.2% (Fiscal incentives)	34.2%	5.6%
1981-1985	66.8% (MOU tax relief of $2/bbl)	33.2%	0%
1986-1990	51% (Revised MOU and tax relief)	49%	0%
1991-1995	97.5% (RAB onshore and PSC fiscal regime, giant field discoveries, deepwater exploration, technological progression)	2.4%	0%
1996-2000	16.9%	22.2%	60.9% (Increasing crude oil price and technology adoption)
2001-2005	8.8% (Government's intention to restructure regulatory and fiscal framework slows exploratory activities)	88.8% (Development of major offshore projects came on-stream)	2.4%
2006-2010	1.2% (No incentives to drive exploration projects, PIB delay)	98.8% (Continuous development in deepwaters and offshore technology)	0%
2010-2012	58.7% (Passage of Nigeria content act, participation from marginal operators)	41.3%	0%

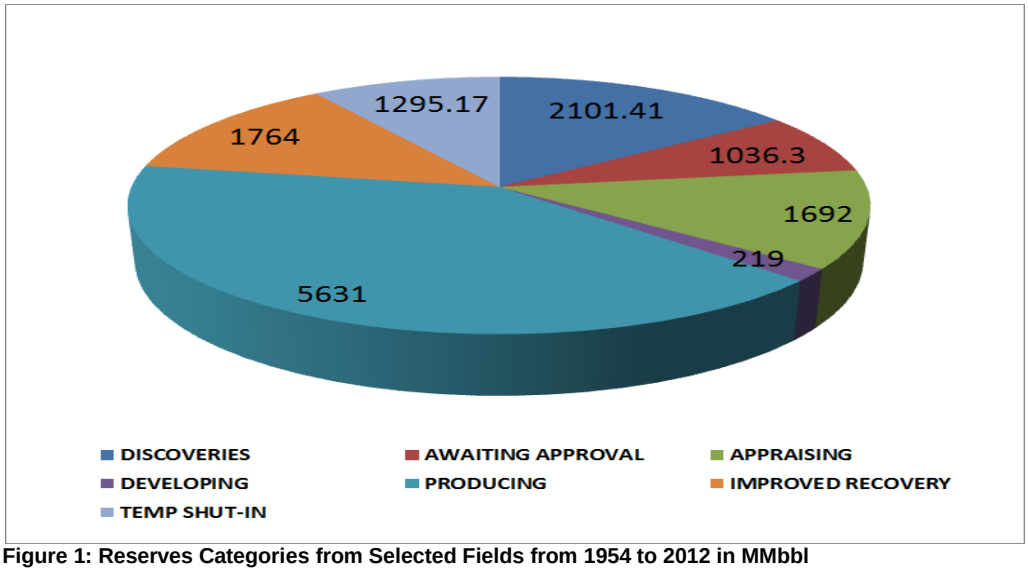

Figure 1: Reserves Categories from Selected Fields from 1954 to 2012 in MMbbl

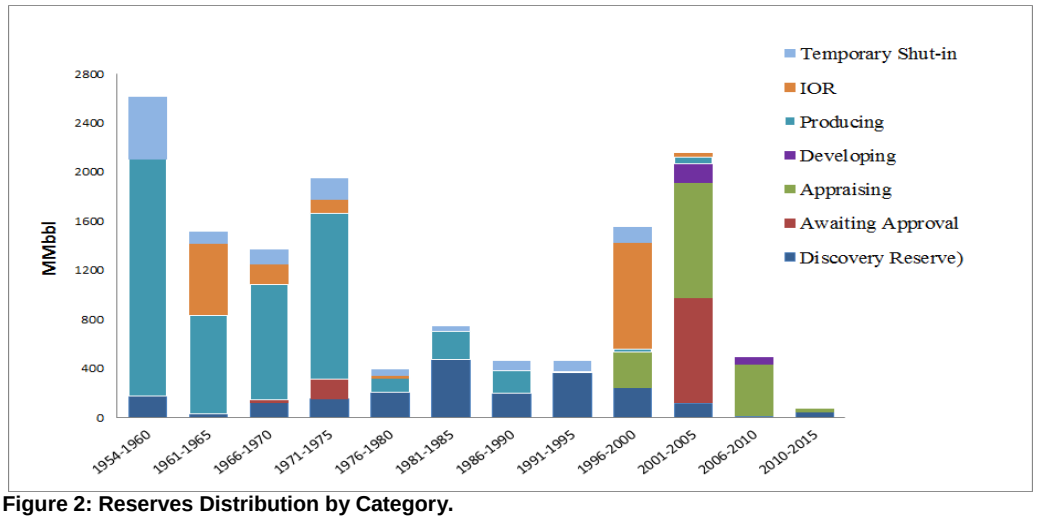

Figure 2: Reserves Distribution by Category.

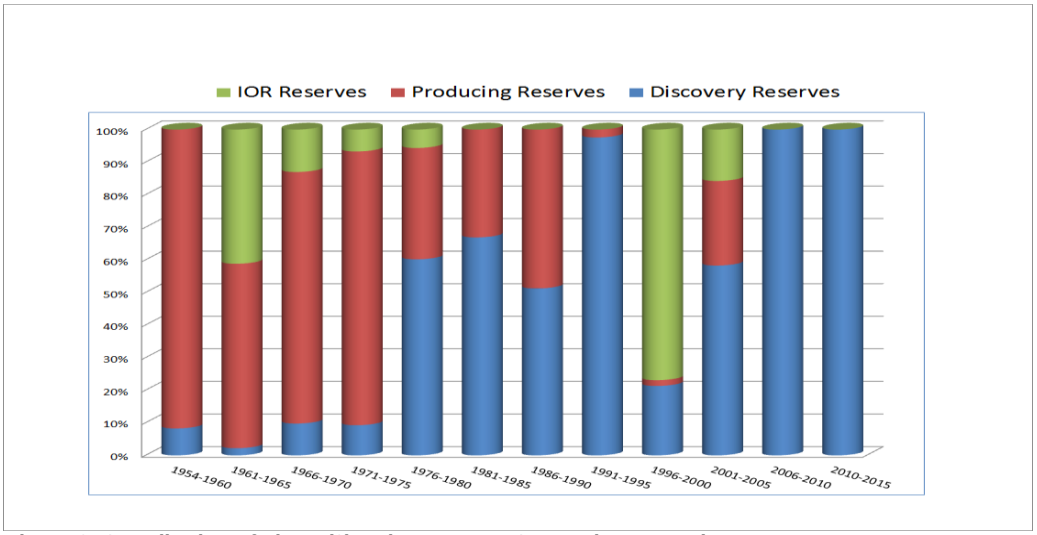

Figure 3: Contribution of Three (3) Main Reserves Categories to Total Reserves.

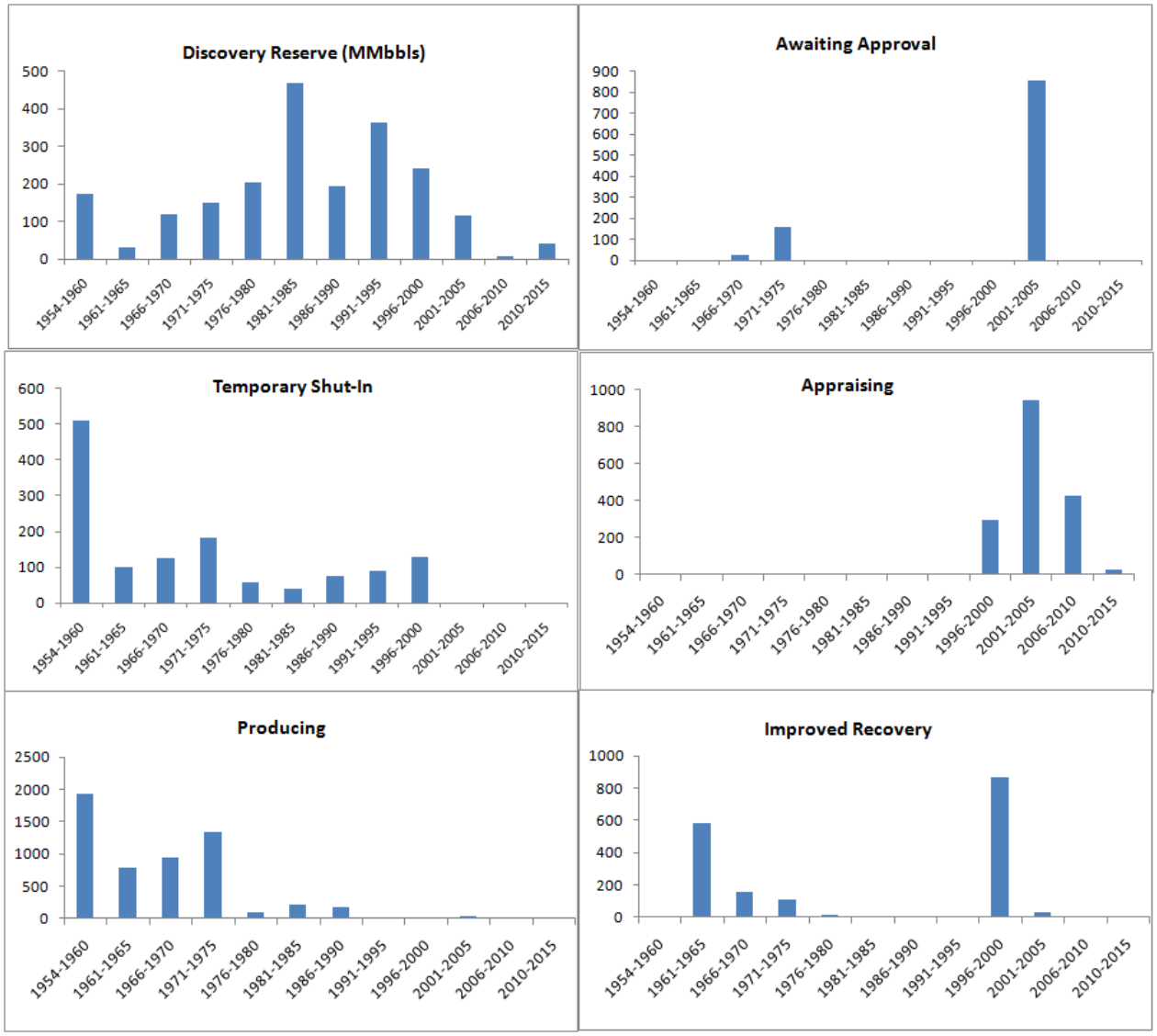

Figure 4: Reserve categories from three (3) major operating companies in Nigeria

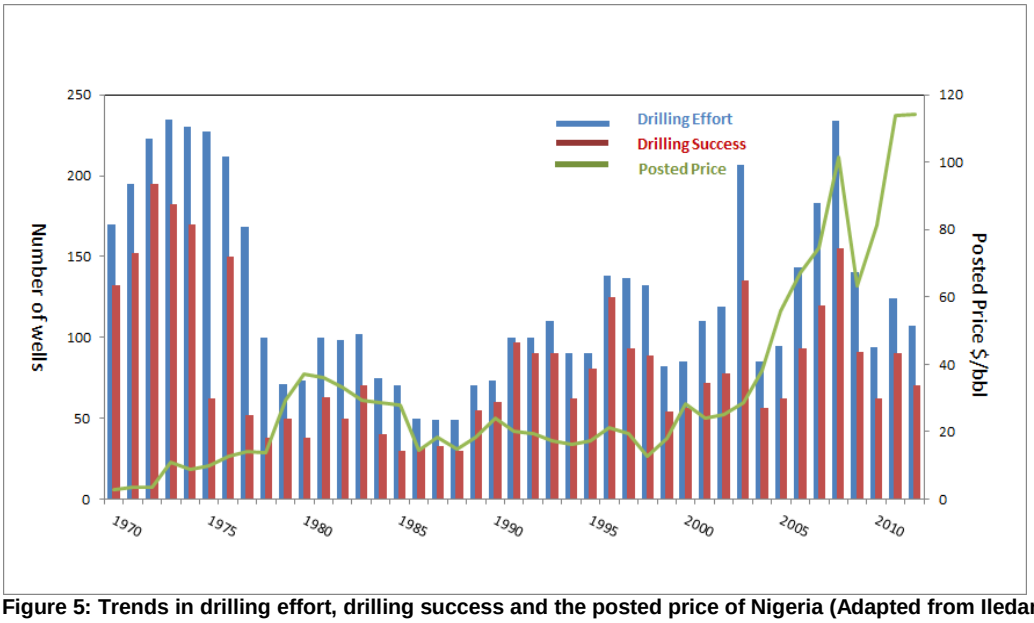

Figure 5: Trends in drilling effort, drilling success and the posted price of Nigeria (Adapted from Iledare, 2000)

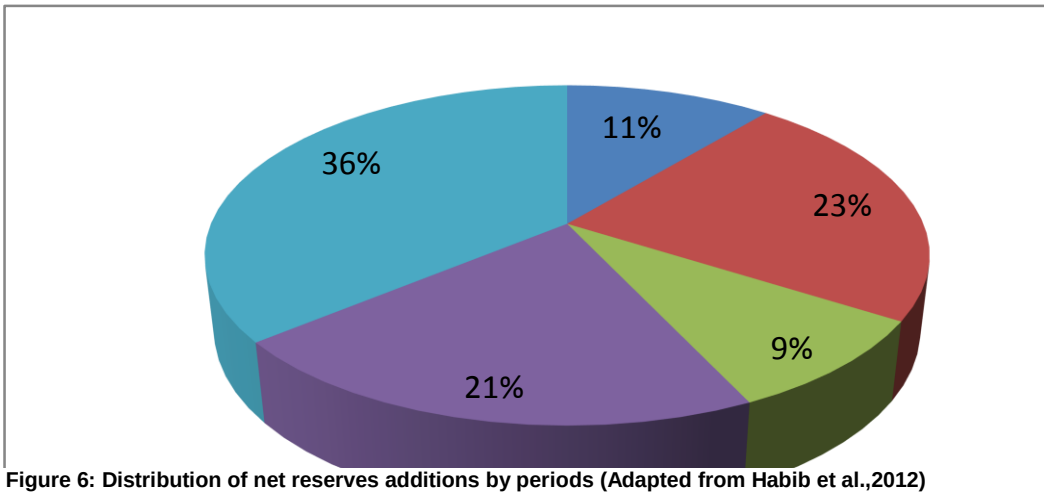

Figure 6: Distribution of net reserves additions by periods (Adapted from Habib et al.,2012)

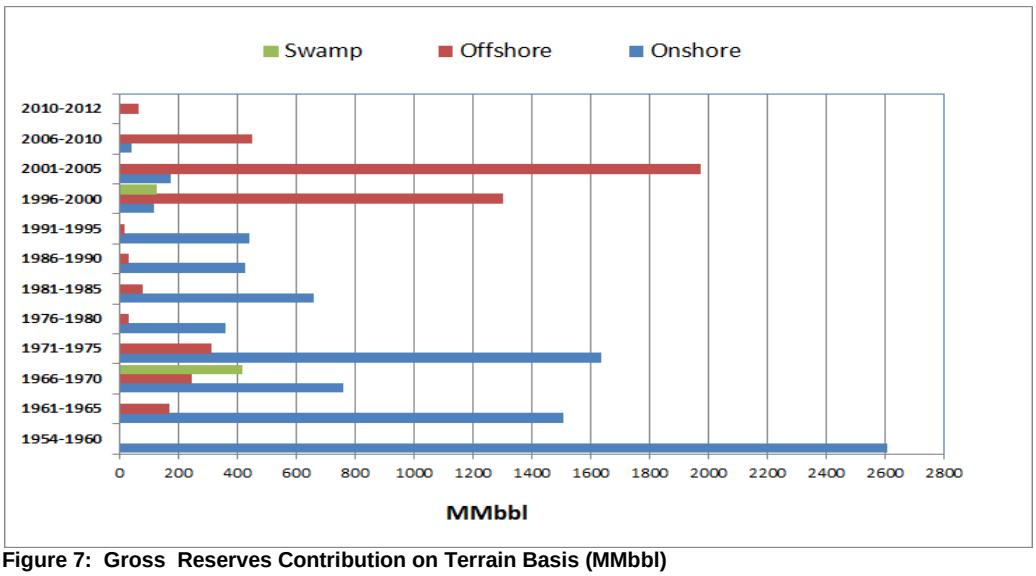

Figure 7: Gross Reserves Contribution on Terrain Basis (MMbbl)