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An Inter-temporal Analysis of Operational Efficiency of Oil Firms: Further Evidence from Nigeria

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ABSTRACT: There have been growing needs to investigate oil and gas firms more closely due to their corporate scandals. Globally, oil firm managements have become more risk intolerant. They are sometimes under pressure to deliver results within a short time, which often negatively affect their ability to undertake risky ventures that are rewarding.Applying the Data Envelopment Analysis, this paper shows a high level of technical operational inefficiency of 0.51 in Nigerian oil industry over the period 2006-2009. The fall in technical efficiency of the oil firms in 2009 might be attributed to the banking crisis in Nigeria in 2009 that affected financial operations of some oil firms that relied on banking credits for running their business, and the fall in global oil prices relative to mid 2008.

Keywords: Operational efficiency; oil firms; data envelopment analysis
JEL Classifications: C14; H21; Q49

1. Introduction

All over the world, oil and gas operations are facing blurred business landscape- one shaped by progressively more complex and often difficult forces such as geopolitical turmoil, financial upheavals, shifting regulatory environments and constantly evolving trends in global energy consumption (SAA and Company, 2011). Oil markets in Nigeria seemed to suffer more from these predicaments. The geopolitical turmoil in the Niger Delta area of Nigeria in the early 21st century was momentous until June 29, 2009 when the Federal Government of Nigeria granted amnesty to the militant youths in the region who were vandalizing oil infrastructures, kidnapping oil expatriates and workers and collecting ransom before releasing them.As regulatory environment in Nigeria was unstable, it has remained tough for oil firms too to harness funds to finance gigantic projects. The mono-economic nature of the country has continued to make the country susceptible to adverse effects of global oil crises.

As oil prices peaked at $147 in mid-2008, operational efficiency became a postscript for energy companies reaping windfall profits. The rapid price collapse in the subsequent months, however, exposed poor processes and an often distended and untenable operational cost structure. Energy companies would have to be focused on their operations in the face of even the most lush commodity prices, given this era of financial volatility and environmental risk. A precipitous rise in the price of oil in 2011, a return to 2007-8 levels, underlines the importance of avoiding profit-driven complacency.Besides, energy companies would have to squeeze what they can from their existing projects and then utilize resources efficiently if they are to be successful.

Several factors have accounted for operational inefficiency of oil firms. Example of these factors include lack of transparency and visibility in operations; a reactive rather than preemptive maintenance and management philosophy; an implemented technology solution that provides real-time manageable data, that is, give inaccurate pictures of operations; and poor cultural buy-in and task accountability among management and the workforce alike (see SAA and Company, 2011). Another source of inertia in oil firms has to do with approach-based: energy companies often fail to directly engage the sources of their operational complexity, or do so in a piecemeal way. This results in the poor integration of interdependent focus areas. The risk profiles of such operational complexities or deficiencies are unforgiving: a maximum potential exposure is a front-page environmental disaster. Average-to-low exposures, though clearly less detrimental, can be equally noxious for the income statement; frequent maintenance failures, for example, eat away at top and bottom lines and tie up resources, costing companies untold revenues and opportunities.

Operational efficiency is vital in any industry. It is pertinent not because it is a desirable end in itself, but because it enables us to achieve all our other goals to the fullest possible extent.It holds special significance in energy, where maintenance failures and flow disruptions due to complexity or inefficiency can quickly translate into millions of dollars in revenue losses and incalculable liability. This has huge implication for sustainable development in oil-dependent economies like Nigeria whose GDP is largely financed by royalties and taxes levied on oil companies. This paper, therefore, investigated operational efficiency of a number of oil firms in Nigeria. Following the introduction is a brief theoretic explanation of efficiency and x-inefficiency of oil firms in section 2. The methodological issues and results are discussed in sections 3 and 4, respectively. Concluding remarks are drawn in the last section.

2. Explaining Efficiency and X-inefficiency of Oil Firms

An oil firm is operationally efficient when it is operating at equilibrium. At this point, it is maximizing economic surplus (producers' and consumers' surplus)[1]. Permitting firms (for example, oil firm) to reach equilibrium is important because when economic surplus is maximized, it is possible to pursue every goal more fully. Whenever a market is out of equilibrium, there is waste and this is bad for the firm and the economy at large (Frank and Bernanke, 2004).[2] A firm's efficiency is based on its predetermined attributes and that of its customers such as profits, dividends, tastes, abilities and knowledge.

Farrell (1957) drew upon the work of Debreu (1951) and Koopmans (1951) to define a simple measure of firm efficiency that could account for multiple inputs. Farrell (1957) proposed that the efficiency of a firm consists of two components: technical efficiency, which reflects the ability of a firm to obtain maximal output from a given set of inputs, and allocative efficiency, which reflects the ability of a firm to use the inputs in optimal proportions, given their respective prices and the production technology. These two measures are then combined to provide a measure of total economic efficiency or cost efficiency.[3] Cost efficiency is ascertainable if input price information is available. Theoretically, an oil firm is fully efficient if it produces the output level and mix that maximize profits and minimize possible costs.

It is possible that an oil firm is both technically and allocatively efficient but the scale of operation may not be optimal. Suppose the firm is using a variable-returns-to-scale (VRS) technology, then, the firm involved may be too small in its scale of operation, which might fall within the increasing returns to scale part of the production function. Similarly, an oil firm may be too large and it may operate within the decreasing returns to scale part of the production function. In both of these cases, efficiency of the firms might be improved by changing their scales of operation, that is, to keep the same input mix but change the size of operations. If the underlying production technology is a globally constant returns-to-scale (CRS) technology then the firm is automatically scale efficient.

X-inefficiency which is sometimes called technical inefficiency reflects bad management by the firm's managers and directors. Since it is one of the causes of increasing costs, several authors have regarded it as cost inefficiency. Without competitive pressure on profit margins, cost controls may become lax. The result may be overstaffing, spending on prestige buildings and equipments, managers having goals, such as corporate growth, an easier work life, avoidance of business risk or no

[1] Private efficiency in the market is obtained where the marginal utility equates marginal cost for all producers and all consumers. On the other hand, social efficiency takes place in the market when marginal social benefit equals marginal social cost (See Sloman, 2006).

[2] Pareto optimality is required for equilibrium to lead to efficiency. A Pareto-optimal allocation of resources is achieved when it is not possible to make anyone better off without someone else worse off.

[3] Farrell (1957) original proposition of efficiency used the term price efficiency instead of allocative efficiency and the term overall efficiency instead of economic or cost efficiency.

risk management and giving jobs to incompetent relatives, that conflict with cost minimization. X-inefficiency may also arise because a firm's workers are poorly motivated or supervised or less effort are made to update technology adopted, scrap old plant or branch, research and develop new products, or develop new domestic and export markets. Also, firms may simply become lethargic and inert, relying on rules of thumb in decision making as opposed to relevant calculations of costs and revenues (Sloman, 2006; McConnell and Brue, 2005). X-inefficiency increases as competition decreases, thus it will be more if the oil firm is a monopoly, followed by oligopoly, monopolistic competition and least in pure competition. It makes average cost and marginal cost higher than what should be the minimum.

3. Methodological Discussion

The simple neoclassical production function adapted for oil firms specifies a relationship between the input and output, where q_i is producible output and x_i is input factor in equation (1) below

$$q_i = f(x_i) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$ [4]

The theoretical model developed by HartleyandMedlock (2008) and thework of Eller et al. (2007) provided some background information for the choice of our variables. In order to cover a wide range of inputs, the sum of capital and reserves are used as input. This is always equal to total assets employed based on the principle of accounting. The output used is revenue.The input is a sum of fixed assets, intangible assets, long-term investments, deferred tax assets and long-term receivables, net current liabilities, borrowings and other non-current liabilities, deferred taxation, provision for other liabilities and charges. These data were obtained from the audited financial reports and accounts of five selected oil firms in Nigeria, which are Total Plc, Oando Plc, Mobil Plc, Niger Delta Exploration and Production Plc, and Forte Oil Plc- formerly African Petroleum Plc over the period 2006-2009. This purposive sample is a combination of oil firms that engaged in production and marketing operations.

The input-oriented measure of technical efficiency (TE) of an oil firm is expressed in terms of input-distance function $x_i d_i(x_i, q_i)$ as:

$$TE = 1/\, d_i(x_i, q_i) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

The oil firm is technically efficient if it is on the frontier, in which case TE= 1 and $d_i(x_i, q_i)$ is also equal to 1. For instance, a TE of 0.6 implies that the firm is 40% operationally inefficient or x-inefficient. That is, it is only 60% of the output it has the "technical" capability of producing.

The DEA is a non-parametric method which is non-stochastic but is used profitably in a broad variety of circumstances when parametric methods which are stochastic are impracticable or impossible to use. Parametric methods are not likely to be successful if few data points are available due to limited degrees of freedom (Jerome, 2004, Coelli et al., 2005). The Linear Programming(Duality) DEA model as specified by Coelli et al., (2005) is given as:[5]

$$\begin{aligned} &\text{Min}_{\varnothing,\lambda}\ \varnothing, \\ &\text{Subject to } -q_i + Q\lambda \geq 0\,, \\ &\qquad \varnothing x_i - X\lambda \geq 0\,, \ldots\ldots\ldots^{6}\ldots\ldots\ldots\ldots\ldots\ldots (3) \\ &\qquad \lambda \geq 0\,, \end{aligned}$$

Where Ø is a scalar and λ is a I × 1 vector of constants. The value of Ø obtained is the efficiency score for the i-th oil firm. It satisfies; Ø ≤ 1, with a value of 1 indicating a point on the frontier and hence a technically efficient firm (Farrel, 1957, Coelli et al., 2005)

The production technology associated with our Linear Programming specification in equation (3) can be defined as $H = \{ (x, q) : q \leq Q\lambda,\ x \geq X\lambda \}$. Fare et al.(1994) show that this kind of technology defines a production set that is closed and convex, and exhibits constant returns to scale

[4] Imposition of an explicit functional form for the technology and inefficiency terms is not required for using non-parametric approach which this study adopted (See Seinford and Thrall, 1990) .

[5] Ratio and multiplier formulation can also be used but the envelopment form is preferable because it has infinite number of solutions whereas the former involves more constraints than the latter.

[6] For the i-th firm, the measured output slacks are equal to zero if $Q\lambda - q_i = 0$ and the measured input slacks are equal to zero if $\varnothing x_i - X\lambda = 0$ (for the given optimal values of Ø and λ).

and strong disposability.[7] Therefore, we consider DEA models that correspond to production technologies that have less restrictive properties. That is, the Constant Returns to Scale (CRS) Linear Programming problem is modified to account for Variable Returns to Scale (VRS) by adding the convexity constraint: $I1'\lambda = 1$ to equation (3) to form :

$$\begin{aligned} &\text{Min}_{\varnothing,\lambda}\ \varnothing, \\ &\text{Subject to } -q_i + Q\lambda \geq 0, \\ &\qquad \varnothing x_i - X\lambda \geq 0, \quad \ldots\ldots (4) \\ &\qquad I1'\lambda = 1, \text{ (where I1 is an } I \times 1 \text{ vector of ones)} \\ &\qquad \lambda \geq 0, \end{aligned}$$

This approach, according to Coelli et al., (2005) forms a convex hull of intersecting facet that envelope the data points more tightly than the CRS conical hull and thus provides technical efficiency scores that are greater than or equal to those obtainable using the CRS model. The convexity constraint ($I1'\lambda = 1$) essentially ensures that an inefficient oil firm is only "benchmarked" against oil firms of similar size. This convexity restriction is not imposed in CRS case. Hence, our interpretation of technical efficiency/ inefficiency is done within the scope of CRS case. In CRS DEA, an oil firm may be benchmarked against oil firms that are substantially larger (smaller) than it. In this instance, the λ-weights sum to a value less than (greater than) one.

We proceed to estimate the scale efficiency of the oil firms. A difference in CRS and VRS technical efficiency scores indicates the presence of scale inefficiency. In order to determine whether the oil firm is operating at constant returns to scale (scale efficient point) , increasing returns to scale (economies of scale) or decreasing returns to scale (diseconomies of scale), an additional DEA problem with non-increasing returns to scale (NIRS) is given by Coelli et al. (2005), as in equation (5)[8]:

$$\begin{aligned} &\text{Min}_{\varnothing,\lambda}\ \varnothing, \\ &\text{Subject to } -q_i + Q\lambda \geq 0, \\ &\qquad \varnothing x_i - X\lambda \geq 0, \quad \ldots\ldots (5) \\ &\qquad I1'\lambda \leq 1 \\ &\qquad \lambda \geq 0, \end{aligned}$$

The difference between equations (4) and (5) is that $I1'\lambda = 1$ restriction in equation (4) is substituted with $I1'\lambda \leq 1$, which ensures that the i-th oil firm is not "benchmarked" against oil firms that are substantially larger than it, but may be compared with oil firms smaller than it.

4. Discussion of Results

Table 1 shows that among the five sampled oil firms in 2006, the most technically efficient firm was the Forte Oil Plc, which TE score was 1.000. The firm was also scale efficient as it operated its oil marketing businesses (including production chemicals, lubricants and grease) at constant returns to scale. The least efficient firm was Niger Delta Exploration and Production (NDEP) Plc, which principally invested in oil field properties. Total Plc and Oando Plc experienced diseconomies of scale (operated at decreasing returns to scale) while Mobil and NDEP benefited from scale economies (operated at increasing returns to scale). The overall average efficiency of the firms in the period was 0.479, meaning that there was technical inefficiency of 0.52.

The technical efficiency scores of the firms, except that of NDEP, were enhanced in 2007 relative to 2006 as shown in Table 2. On average, the TE score rose from 0.479 in 2006 to 0.518 in 2007. However, while Total, Oando and Forte Oil had diseconomies of scale, NDEP still enjoyed economies of scale without improving its gross relative inefficiency. This was possible because the firm was small relative to other firms. It was also the youngest firm in the sample, established in 1992. Mobil, the oldest firm in the group, incorporated as a Private Limited Liability Company in 1951 and became a Public Limited Company in 1958, was the most technically efficient in 2007. This majorly

[7] The assumption of strong disposability means that a firm can always costlessly dispose off unwanted inputs (and outputs).

[8] If NIRS TE equals VRS TE, the oil firm is operating under DRS and if the two are not equal, the firm's economies of scale is IRS. However, if CRS TE = VRS TE, the firm's operation is CRS (See Coelli et al., 2005 for more explanations). The DEA generates the notation automatically without indicating the NIRS TE score(s).

petroleum marketing firm, largely owned by Exxon Mobil Oil Corporation, was also the only firm in the group that was scale efficient in 2007.

Table 1. Firm-Level Technical and Scale Efficiencies in 2006

FIRM	CRSTE	VRSTE	SCALE	NOTATION
Total Plc	0.658	1.000	0.658	DRS
Oando Plc	0.179	1.000	0.179	DRS
Mobil Plc	0.537	0.866	0.620	1RS
NDEP Plc	0.023	0.777	0.029	1RS
Forte Oil Plc	1.000	1.000	1.000	CRS
Average	0.479	0.929	0.497	

Source: Authors' Computation

Note: CRSTE=Technical Efficiency from CRS DEA, VRSTE=Technical Efficiency from VRS DEA
SCALE=Scale Efficiency = CRSTE/VRSTE, DRS= Decreasing Returns to Scale
IRS=Increasing Returns to Scale, CRS= Constant Returns to Scale
DEAP=Data Envelopment Analysis (Computer) Program

Table 2. Firm-Level Technical and Scale Efficiencies in 2007

FIRM	CRSTE	VRSTE	SCALE	NOTATION
Total Plc	0.893	1.000	0.893	DRS
Oando Plc	0.121	0.135	0.896	DRS
Mobil Plc	1.000	1.000	1.000	CRS
NDEP Plc	0.006	0.653	0.009	IRS
Forte Oil Plc	0.571	0.624	0.915	DRS
Average	0.518	0.682	0.743	

Source: Authors' Computation

The mean TE value of the firms rose further from 0.518 in 2007 to 0.583 in 2008 but fell to 0.359 in 2009 as shown in Tables 3 and 4. The fall in TE in 2009 could be attributed to the banking crisis in 2009 that affected financial operations of some oil firms that relied on banking credits for running their business and the fall in global oil prices relative to mid 2008. It was Total, one of the oldest firms in the sample, established in 1956 and completed merger with Elf Oil Nigeria Limited in 2002 that had the highest TE of 1.000 in 2008 and 2009. It was also scale efficient in both periods, while other firms only benefited from scale economies.

Table 3. Firm-Level Technical and Scale Efficiencies in 2008

FIRM	CRSTE	VRSTE	SCALE	NOTATION
Total Plc	1.000	1.000	1.000	CRS
Oando Plc	0.008	0.085	0.099	1RS
Mobil Plc	0.964	1.000	0.964	1RS
NDEP Plc	0.037	0.350	0.107	1RS
Forte Oil Plc	0.904	0.908	0.996	1RS
Average	0.583	0.669	0.633	

Source: Authors' Computation

Table 4. Firm-Level Technical and Scale Efficiencies in 2009

FIRM	CRSTE	VRSTE	SCALE	NOTATION
Total Plc	1.000	1.000	1.000	CRS
Oando Plc	0.005	0.119	0.039	IRS
Mobil Plc	0.581	1.000	0.581	IRS
NDEP Plc	0.023	0.366	0.061	IRS
Forte Oil Plc	0.187	0.197	0.948	IRS
Average	0.359	0.537	0.526	

Source: Authors' Computation

Table 5 shows that the firm with the highest technical efficiency over the 2006-2009 period was Total (0.888), followed by Mobil (0.771), then Forte Oil (0.666) followed by Oando (0.078) and the least was NDEP with (0.022). Oando, the biggest oil firm in the sample in terms of total assets size, which was formerly Unipetrol Nigeria Plc and which merged with Agip Nigeria Plc in 2002 did not technically operate efficiently relative to Total and Mobil. On average, the TE of the firms over the four years was about 0.49, implying x-inefficiency of 0.51. This finding is consistent with that of Eller et al. (2007) that found average technical efficiency measure of 0.40 for a sample of 76 oil firms across the globe over the period 2002-2004 using DEA.

Table 5. 4- Year Average Technical Efficiency (2006-2009)

FIRM	TE	RANKING
Total Plc	0.888	1st
Oando Plc	0.078	4th
Mobil Plc	0.771	2nd
NDEP Plc	0.022	5th
Forte Oil Plc	0.666	3rd
Average	0.485	

Source: Authors' Computation

5. Conclusion

We have examined efficiency measures of a sampled five oil firms in Nigeria. In particular, the technical and scale efficiencies as well as economies of scale and diseconomies of scale of the firms have been critically analyzed. Niger Delta Exploration and Production (NDEP) Plc and Total Plc performed badly in terms of technical efficiency in the group. These two firms were only able to conduct their activities at 2.2 and 7.8 per cent efficiency levels, respectively. Their management must realize that without them adopting international best practices, they might remain in the dungeon of inefficiency. Application of best practices to field operations have been said to reduce field downtime, increases field cash flow and reduces cost, and is a more effective, long-lived approach than merely lowering costs without best practices. This paradigm shift was from a "reactive operation" like immediate cost reduction targets to a "proactive operation" focusing on core causes of operating problems to put in solutions that would naturally increase field cash flow. This paradigm shift should be the basis for the firm's pursuit of operational excellence, thereby improving their operational and production efficiency. There are much to be done by the management of Oando in the area of monitoring and control. One quick inference from the results is that this firm had grown big such that there are administrative laxities and compromises. The management of these firms should be fully committed and should pursue people efficiency. They must translate analysis into action and be willing to save costs through efficient logistical operations and collaborations. Aging staff should be replaced with competent and young professionals and training should not be under-emphasized.The NDEP management board should comprehensively re-engineer their operations, not just benefitting from scale economies and remaining grossly inefficient.

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