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Benchmarking technical efficiency of Nigerian seaports

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Abstract: The study adopted *ex post facto* design. Using ship traffic, vehicle traffic, berth efficiency, turnaround time as input explanatory variables and output factors as average throughput to compare the pre concession and post concession. The six Nigerian ports: Tincan Island Ports, Apapa Port, Port of Delta Warri, Calabar Port, Rivers Port and Onne Port were sampled. It is observed that year 2014 is the most efficient year out of the 36 operation years in terms of output maximization with constant levels of inputs under the study period with score 1.0 respectively serving as 32 times benchmark for other years. It is observed from that Tin Can Island Port was technically efficient in the operation years of 1980, 1981, 1985, 1995, 1997, 1998, 2009, 2013, 2014 and 2015 with score 1.0. However, the most efficient operation years are 1998 and 2013 while the most inefficient year is with efficiency score 1.0. The post-concession years that the port was technically inefficient are 2006, 2007, 2008, 2010, 2011 and 2012.

Keywords: Nigerian seaports, sustainable development, ship traffic, benchmarking technical efficiency.

1. Introduction

Efficiency of the use of resources or productivity performance is of key interest thus high productivity in transportation, industry, agriculture and other service sectors are necessary for rapid economic growth of any nation. Productivity can be referred to as a matrix of the technical or engineering efficiency of production. As such quantitative metrics of input and sometime output are emphasized. Productivity is distinct from metrics of allocative efficiency which take into account both the value of what is produce and the cost of input used, and also distinct from metric of profitability, which addresses the difference between the revenues obtained from output and the reference associated with consumption (Courbois & Temple, 2001; Kurosawa, 2000; Pineda, 1999; Saari, 2006). The activity of converting input resources into service(s)/product(s) can be identified with production

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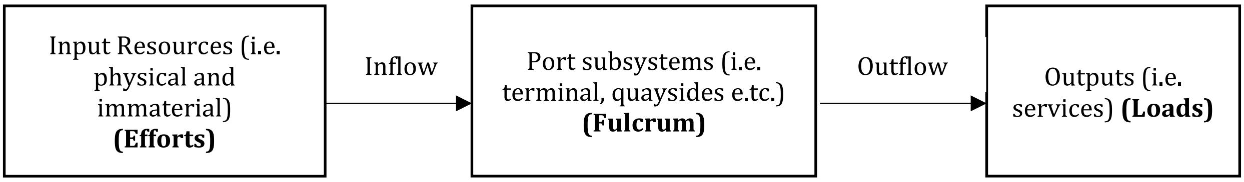
and consumption. Thus, production is a process of combining immaterial and material inputs of production so as to produce tools for consumption. The methods of combining the inputs of production in the process of making outputs are called technology. Technology can be depicted mathematically by the production which describes the function between inputs and outputs. The production function depicts production performance and productivity as the metric for it. Measures may be applied with for example, different technology to improve productivity and to raise production outputs. With the help of production function, it is possible to describe the mechanisms of economic growth.

Port production can be described as the conversion of port capacity i.e. labour capacity, cargo equipment, berth capacity, vehicles e.tc to obtain services i.e. throughput or otherwise may be described as the application of certain physical and immaterial resources to the operational areas of the port system in order to achieve a specific output. From the definition of the latter, it is observed that production highly occur at the place of operation i.e. terminal, quay side, gate side e.tc thus this particular definition simply relates the mechanism of port production to the first class of a simple machine named lever as shown in the below diagram.

Figure 1: Port Production System or Mechanism



Source: The researcher

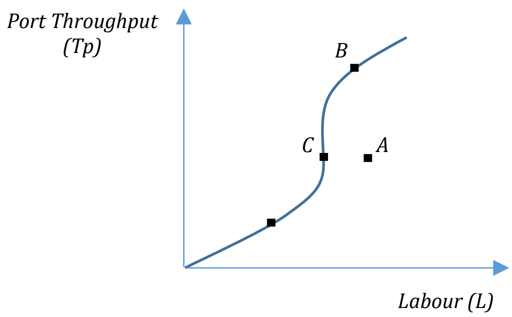
From Figure 1, it is obvious that the resources injected make the port subsystems to function in order to reconcile specific outputs at the other end. Therefore, assessment of productivity of port greatly falls at the central part of a port system i.e. port subsystems.

Furthermore, a port is technically efficient when its output i.e. throughput obtainable given the level of resources i.e. labour, immobile capital e.g. cranes and vehicles are utilized by the port service provider. The technical or functional relationship between the optimal throughput and the level of input resources utilized by the port service provider is the port's economic production function. For instance,

$$Maximum\ port\ throughput = f(port\ resources)$$

If the above expression is fulfilled in a port system then such is technically efficient otherwise it is technical inefficient. Consequently, the port's economic production function with respect to the resources (port labour) is given in the figure below.

Figure 2: Port Cost Minimization for a Single Port Throughput

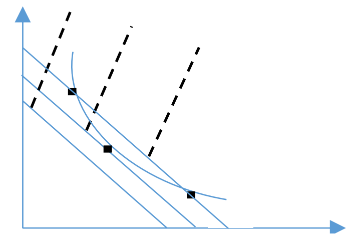


It depicts that the port is technically inefficient below the curve with respect to the corresponding amount of labour. For instance at point A the port is technically inefficient since the labour at that point is providing less throughput whereas such level of throughput can be obtained at lower amount of labour at point C. If a point falls on the curve, it depicts that at that point the port is technically efficient and points above the curve reflect that no such throughput has been obtained by the port service provider with the amount of labour.

The maximum throughput (from an engineering perspective) that a port/terminal can physically handle under certain conditions is the port/terminal capacity which means that the magnitude of the port/terminal capacity to the throughput matters a lot to the productivity of a port which can be represented by the berth efficiency which basically reflect the design, preferred and practical capacity. For a given level of maximum port throughput the port economic production function can be solved for various combinations of capital and labour that can provide this minimum level of port throughput. These combinations of capital (K) and labour (L) for the production of maximum port throughput(T_p) are shown below in the figure as isoquant curve T_p. The long-run cost (LTC) incurred by the port in the use of capital and labour resources may be expressed as

$$LTC = P_k*k + bP_L*L$$

Figure 3: Port Cost minimization for a single port throughput



$where\ P_L\ is\ the\ price\ per\ unit\ of\ capital\ and$
$P_L\ is\ the\ price\ per\ unit\ of\ labour\ measured\ by\ the\ port\ in\ the\ employment\ of\ capital\ and\ labour\ respectively$

For a specific level of cost, the equation plots as an isocost line. A cost expenditure of amount LTC_1 (exhibited by isocost line LTC_1in figure 1.2) is not adequate for the port to run enough resources in order to provide for T_p level of throughput. Similarly, cost expenditure $LTC_3$is also sufficient.

At point X, the port is technically efficient on isocost line LTC_3 in the production of T_p level of throughput as quite large amount of capital to labour is being utilised but cost inefficient since there are other combination of resources on isoquant curve T_p that will incur less cost when employ in obtaining T_p level of throughput. At point B, isocost line LTC_2 is apparently a tangent to isoquant curveT_p. In addition, cost expenditure LTC_2 is the minimum expenditure to be incurred by the port in the provision of T_p. At the resource combination at point O, the port is both technically and cost efficient.

2. Literature review

In the early 1970s, the total capacity of Nigerian ports was only 6.5m tons of general cargo per annum. Yet, in 1974, the government entered into a contract to import 20m tons of pending sharply. New infrastructure developments were suspended, while existing ones were left unmaintained. Nigerian ports were caught in this web of infrastructural neglect and decline. This was compounded by the reduction in port activities, resulting from a sharp fall in the number of ships arriving in Nigeria. This led to the underutilization of existing port facilities (Nigeria Port Authrority, 2005). Also, between the period of 1970 and 1980, Nigeria Ports witnessed 54.3% increase in dry cargo traffic 7233468 tons and 100% increase in containerized cargo traffic 8871 tons, reflecting the high introduction of containers prior to the containerization era i.e. early 1980s when container services with specialized ships (cellular containerships, first introduced in 1967) became a dominant aspect of international and regional transport systems with the aim to achieve economies of scale by the shippers (Rodrigue, Comtois and Slack, 2006). Subsequent to this, new container terminal and modern cargo handling equipment has been adopted in the ports to speed up the process of loading and discharging vessels in order to reduce turnaround time of ships as the handling of traditional general cargo was usually labour intensive and time-consuming. Pinwa (1999) inferred using container terminal of Lagos that was equipped with gantry cranes and straddle carriers as an epitome of this development in which there was 16830.3% increases in TEUS and 47.2% increases in dry cargo traffic at Lagos Port between 1970 and 1980 while other Nigerian Ports there was increase in dry cargo traffic by 168.6% and containerized cargo traffic 25533.6% thus this analysis reflects the attributes of high dependency on importation during this period. Due to the inability of the port to handcuff the issues bedeviling the investment and port performance, the port was commercialized1992 changing the name of the organization for Nigeria Port Authority to Port Authority.

At the same time, the inability of successive governments to provide the huge amount of capital needed for the smooth and efficient running of Nigeria's seaports, left the NPA unable to perform many of its statutory directives, let alone compete at an international level (Nigeria Port Authrority, 2005). In 1999, the main dock labour management difficulty in Nigeria Ports became the problem of replacing the labour force with capital intensive technology in cargo handling as a consequence of containerization in the absence of adequate financial resources from the stevedoring contractors (Pinwa, 1999). The trend in the size of the vessel also called for the involvement of capital intensive technology in cargo handling thus this and other developments are all designed to improve cargo handling, increase productivity and facilitate ship turnaround time. The changes in cargo handling techniques invariably have contributed to labour reduction particularly in container terminals. Pinwa (1999) affirmed that despite the efforts to improve productivity through the mechanization, there was no noticeable effect on the productivity in the Nigerian ports by depicting it with the below tables.

Table 1: Labour Productivity in Nigerian Ports from 1993-1996

Year	Tonnage Handled	Gross Tons/hour	Net tons/hour	Gross Net Labour Utilization (%)
1993	4669759	12	18	67
1994	3620707	12	18	67
1995	3083107	19	29	66
1996	2412077	14	20	70

Source: Pinwa (1999)

From the table, three attributes is observed which are fluctuation in labour utilization, increase in gross productivity and net productivity overtime, decrease in throughput over the period thereby depicting wrong input mix which caused technical inefficiency and low productivity of the port. The scenario of technical inefficiency after investment in infrastructure is hard to comprehend as Koutsoyiannis (1979) termed trait like that as the irrational behavior of the firm which are not considered by the theory of production, furthermore he affirmed that no rational firm would employ labour or capital beyond marginal points of the inputs, since an increase in the factors beyond these levels would result in the reduction of the total output of the firm. The challenge of cargo handling technology manifests itself in two major ways which are (Pinwa, 1999).

a. The port authority strategies to introducing advanced technology
b. The effect of such technology on the entire range of problems associated with human resources including those related to employment, training, attitudes to changes and social security.

Invariably, this means that Nigerian ports experienced decreasing returns to scale during the period of introduction of technology or mechanization. Furthermore, if the increment can be factored out the production function is termed to be homogeneous whereas if the increment cannot be factored out production function is referred to as homogeneous thus the power raise to the increment is constant return to scale if it's equal to one, decreasing return to scale if it's negative if it's less than one and increasing return to scale if it's greater than one. This also explains the production of Nigeria ports as homogeneous production function.

In this situation, Liu (2010) suggested that checking the infrastructure information during operational years when technical efficiency drops (i.e. efficiency drops after investment in infrastructure is made) will be a milestone to detect the relationship between investment and infrastructure and also solve the low productivity emanating from the problem of input mix.

Beskovnik (2008), acknowledged that difficult labour conditions and more restrictive regulatory have direct impacts on the lower productivity or throughput per terminal space. He suggested the role of productivity quality manager to scrutinize the work and safety rules, workforce motivation, training and handling equipment characteristics in order to achieve balance between labour satisfaction and the productivity as these factors have direct impact on gross labour productivity. Emeghara (2012), accessed the delay factors in Nigeria port operation through an opinion survey conducted with respondents mainly staff of port operators and port users with the aids of questionnaire and it was analyzed with cumulative ranking system and regression model where he concluded that there was deficiency in the ports system in the Nigeria compared to other countries in the industry. He also buttressed the fact with issues of diversion of ships and cargo meant for Nigeria ports to neighboring West-African ports caused by some critical and non-critical delay causative factors which will be mentioned in the preceding topic. Nigerian Ports experienced inefficiencies and inabilities to be user friendly as a result of delays and high cost of using ports in an advantageous or economical positions caused by inadequate cargo handling equipment and other port infrastructure (Emeghara ,2012), which in turn discouraged shipper and ship owner to demand for their services thereby causing diversion of markets to neighboring ports. This was buttressed by the research he carried on delay factors evaluation of Nigerian seaports using Apapa Ports Complex, Lagos as a case study multiple regression analysis model to analyze and evaluate the information obtained from the questionnaires distributed to 50 stakeholders of Apapa Port Complex from which he deduced that there is strong correlation between delay time and some critical and non-critical causative factors which subsequent the consideration of lack of enough functional cargo handling equipment as the most critical factor causing delay at the port in spite of the investment of the private operators on cargo handling equipment because of their dependency on the outdated equipment inherited from the NPA. Another critical factors are administrative bottleneck, extortion of money and shallowness of the entry channel which needed to be addressed as there were low inaccessibility encountered from the advent of larger capacity vessels, this can be solved by constant dredging of the channel to suit uptrend size of vessels which short term may serve as difficulties or challenges for developing nations as cost of dredging influences port cost resulting to disadvantages to the developing countries' economies.

When traffic through the port nearly reaches capacity infrastructure efficiency is also high. When the port invests in infrastructure and facilities, capacity increases, so the utilization of the facility drops until the slack is taken up, thus infrastructure efficiency temporarily declines. The demand placed by traffic passing through the port is ever-growing, so the utilization of port infrastructure and facilities also grew to meet the increased capacity. Therefore, the infrastructure efficiency improves until the port once again invests in infrastructure and facilities (Pinwa, 1999)**.** Nigerian Port activities were hindered by inadequate cargo handling plants and equipment, long turnaround time, cargo pilfering and excessive charges (Jaja, 2011), this he deduced inferentially from the research he carried on the assessment of freight traffic at Nigerian seaports through the analysis of cargo throughput recorded at Nigeria Ports from 1990 – 2005 which divided into general cargo traffic; dry cargo traffic; liquid cargo traffic, turnaround time at Nigerian Port and serviceable cargo handling plant and equipment at the Ports. From his findings he analyzed that there was increase in the general cargo inward between 1990 and 1992 but fell by 39.6% in 1994 which he attributed to the reduction in the nation's revenue from oil incorporated with ineffectiveness of port operations and illegal charges on port users which he stated that large share of Nigeria's external trade were being conducted in neighboring countries and smuggled to Nigeria via road. The issues was also experienced on the outward general cargo traffic which increased by 49.3% but fell till 2004 by 74.0% which he attributed to the significant shift from oil export to non-export. Hence from his analysis, the inward cargo increased by 150% between 1990 and 2005 while outward general cargo decreased by 50% showing the attribute of major dependency on importation. Similarly, the statistics of dry cargo traffic also reflected this trend thus liquid cargo traffic reflect similar trend as the inward traffic decreased by

19.1% in the late 90s but increased by 48.1% in 2005. He stated that the huge investment in port development as null since there are anomalies in the Nigeria maritime freight transport which he attributed to the following issues; absence of intermodal connectivity; inadequate cargo handling plant and equipment which he suggested that they should be improved and place in good condition; increased ship turnaround time as his findings indicated that between 1990 and 2005 turnaround time of ships decreased at Apapa Port by 2.2% from initial 9.84days, Tin Can Island Port by 48% from initial 8.88 days, Warri Port by 16.6% from 7.01days, Port Harcourt Port by 40.7% from 17.22days and high pilfering rate. He concluded that these issues have led to regressed national revenue and competitiveness of the ports in the global port system and that concessioning would be suitable to mitigate these anomalies through promoting competition and increasing port operational capacity**.** Vessel delay period has a significant proportion of ports low productivity in terms total cargo throughput and revenue generated which Ndikom (2006) said has 60%. Incorporation of Dilapidated infrastructure facilities and poor state of terminal operational functionality contributes to congestion at the port. He addressed that Nigerian Ports acutely fell below standard in terms of dock labour productivity using 10-15 days to service medium sized vessel with relative to the smaller African Port of Lome and Cotonu Ports. Furthermore, he stated the consequences of this inefficiency on consumers' behaviours or choices to deny the services of Nigerian Ports as the demurrage that could have been saved if Lome and Cotonu Ports were used is US$4,000. Also the issue of high tariff incorporates to impede port productivity which could be solved on a long-term through the review of price and tariff policy if the government desired to make Nigerian's Ports user and customer friendly and Central African Sub region. The maritime industry is a highly technical, professional, competitive industry being capital and labour intensive as well as subjected to international conventions, rules and regulations. Consequent to this, Nigeria Ports could not meet up with the maritime requirements which as a result of this led to poor managerial skills and techniques resulting to loss of revenue to government, inconsistent policies, low efficiency and effectiveness which he attributed to the wrong mismanagement of ports' sub-systems which include stevedoring, terminal operations, security, port tariff and charges, importing and exporting e.tc by port stakeholders.

The NPA has taken several corrective measures to improve the state of Nigerian ports and to promote their use. To cope with insufficient capacity, the NPA has embarked on a course of integrated infrastructure development in key operational areas. These efforts have involved the expansion and rehabilitation of some of its ports. For instance, the Lagos Port Complex is currently being rebuilt with respect to their construction of quay line, car park deck and a new administrative building, as well as the main gate and berths 7 to13. The total completion rate as of June 2004, was 80%.Similar rebuilding work has taken place at the Federal Ocean Terminal (FOT) and the Federal Lighter Terminal (FLT) at Onne, where the NPA, in conjunction with Integrated Logistics Services – the major terminal operator at FLT and FOT – has embarked on building an integrated infrastructure and superstructure at the FOT and is constructing an additional570m and 376m extension of the FLT. The ports are dedicated to serving ocean going vessels and tankers of oil and gas for the west and central African sub-region. The adoption of a new maintenance system known as the Manufacture-User Maintenance System has also enabled the NPA to deal with the problem of a lack of functional plants at the ports.

The system has proved successful at the Container Terminal port, where it led to a reduction in turnaround time of vessels and to increased plants availability. Container terminal also experienced redevelopment in which required equipment such as automated cranes to handle container operations were acquired thereby encouraging shippers to call at the port which in turn led to more importation. Consequently, Lagos Apapa Port Complex experienced more traffic congestion due to high storage of containers and cumbersome custom formalities undertook by container shippers/carriers who facilitated the introduction of Inland Container Depots (ICDs) in 2009 to every state where containers are cleared under normal custom formalities and accessed by the carriers at the designated areas**.** From the above literature review it is observed that the operational efficiency and low productivity at the Nigeria ports due to poor investment in port infrastructure and operations was disturbing which requested for viable reforms unlike the ones adopted initially during this period. The notion of Public-Private Participation (PPP) was moved to the system in which Royal Haskonning/Dynamar/Challenge International Associate recommended concessioning of the port on landlord basis which identify the roles of the government from the private concessionaires as (Mohammed, 2009).

The Federal Government through the Nigerian Ports Authority has continually made efforts to reposition the Nigerian ports in line with global trends in shipping and ports operation. This led to a comprehensive port industry reform in 2006. The aim was to build a robust, responsive and competitive port economy that will have increased private sector participation and be in tune with global best practices (Usman, 2016).

The impact of concessioning was insignificant due to the inconveniencies on private operators which emanates from high port dues, lack of adequate port infrastructure and also the inconsistency of terminal operators themselves (Oghojafor & Alaneme, 2012). They adopted the ex-post facto study to examine the problems facing the operations of the Nigerian ports before the concession programme of 2006 and evaluated the impact of the concession exercise on the ports efficiency thus assess the efficiency of Nigeria ports through secondary data using annual reports, as well as interview and media reports to deduce their findings which reflected that better ports' efficiencies was realized at the first concession year (2006) with the overall TEU of 54,641,084 tons, turnaround time of 4.70 days and berth occupancy rate of 47.43% which was conversed declining in the following years with throughput 49,173,324 tons, turnaround time of 6.1 and berth efficiency of 46.93%. Conclusively, the researchers attributed the bottleneck to some managerial factors which include negligence on the part of the authority to provide a conducive environment for port operations and poor infrastructures which is not in consonance to the reform policy. Contrary is the case for Onne Port Complex which has been partially concessioned to some terminal operators since 1996 thus Okeudo (2013) testified that increased cargo throughput, low ship turnaround time, low berth occupancy was experienced at the port as a reflection of significant improvement from the reform programme. He viewed that the reforms have brought a significant improvements in cargo throughput so far as compared to the pre-reform era through the use of two sample t-test to analyze and evaluate the distinct between the status of input and output variables i.e. cargo throughput, ship turnaround time and berth occupancy rate at pre-reform era and port-reform era. From his findings, he deduced that there is no statistical difference between the mean cargo throughput for the pre-reform era and port-reform era at Onne Port is invalid.

To buttress this, Somuyiwa and Ogundele (2015), emphasized on the positive impacts of reform programme on the productivity of Tin Can Island Port as the concessionaires scrutinized and invested on cargo handling equipment, storage capacity, and yard occupancy. Using multiple regression analysis and pearson product moment Correlation coefficient model to analyse fifty (50) plant operators as sampled size based on simple random sampling technique, they deduced that the hypothesis test "there is no significant relationship between the mentioned elements and port productivity" is valid during pre-reform and earlier reform era and invalid during post-reform era which means that there is significant relationship between the cargo handling equipment, storage capacity, yard occupancy and port productivity. They concluded that during pre-reform and earlier reform era the cargo handling equipment were in a bad condition thereby caused high dwell time at the port while during the post-reform era the dwell time of cargo and vessels reduced due to the good condition of these elements.

Table 2: Cargo Throughput during Pre-concession and Post-concession Era

Year	Import (million tons)	Export (million tons)	Throughput (million tons)
1999	15,751,331	6,481,605	22,232,936
2000	19,230,496	9,702,384	28,932,880
2001	24,668,791	11,271,901	35,940,692
2002	25,206,380	11,780,861	36,987,241
2003	27,839,293	11,926,652	39,765,945
2004	26,907,075	13,909,872	40,816,947
2005	29,254,761	15,697,312	44,952,073
2006	31,937,804	17,235,520	49,173,324
2007	33,722,488	20,918,560	54,641,048
2008	41,385,973	23,806,946	65,192,919

Source: (Mohammed, 2009)

Table 3: Vessel Traffic Pre-Post Concession Era

Year	Ship Traffic	Total Gross Tonnage (Tons)
1999	3,123	32,911,941
2000	3,333	44,432,370
2001	3,745	56,106,345
2002	3,500	53,267,921
2003	3,661	60,622,666
2004	3,606	61,384,221
2005	3,692	60,541,810
2006	3,689	63,267,047
2007	4,646	83,197,856
2008	4,477	89, 597,975

Source: (Mohammed, 2009)

Table 4: Overall waiting time, turnaround time and berth occupancy at Nigeria Ports

Year	Waiting time (days)	Turnaround time (days)	Berth occupancy (%)
1995	0.47	6.17	27.76
1996	0.46	6.34	36.68
1997	0.47	6.71	36.73
1998	0.39	7.31	41.39
1999	0.36	6.31	47.09
2000	0.34	7.01	44.76
2001	1.27	7.91	51.78
2002	3.99	11.34	56.58
2003	2.17	7.89	52.75
2004	1.44	6.44	50.93
2005	2.60	7.40	49.70
2006	2.00	6.10	46.93

Source: (Mohammed, 2009)

From the tables above, Mohammed (2009) gave analysis of pre-concession and post –concession era as follows; increased container penetration rate led to annual average growth of 7.8% in the container trade in the 1980s, international container traffic grow by an annual average of 9.5 over the period 1987 – 2006 which in turn result to serious capacity challenges, capacity utilization rate expected to increase from 72% in 2006 to 97.5% in 2012, stagnation was expected in container volumes in 2009, low and declining charter rates, scarcity of funds for infrastructural development, the current recession faced at the period may affect shipping more than ports, need for harbor expansion still topical, growing cargo volumes due to economic growth, rapid expansion of facilities in the late 70s to early 80s, PPP projects through amortization late 1990s to present, landlord model and BOT in mid-year 2000 (24 concessions and 1 BOT), Repeated incidence of congestion in Lagos area. The ports infrastructure keeps compromising the operations at the concessioned terminals hence according to Onwuegbuchunam (2012), low efficiency recorded in Nigerian ports is due to underutilization of port infrastructure. He was of the view that there is low mechanization of cargo handling in the Nigerian ports as there was low contribution of labour inputs to output of these ports. This findings was based on how he used stochastic frontier analysis to evaluate the three (3) input variables such as number of berth; number of equipment; labour size and one (1) output variable such as throughput for 22years (1989-2009) in order to determine the efficient and inefficient ports in which Apapa Port, Tin Can Island (TCIP), RORO Port, Port-Harcourt Port (PHP) and Onne Ports was considered technically efficient (T.E) as their efficiency values was approximately 1.0 while other Ports like Container Terminal, Warri and Calabar Ports were considered inefficient as they could not make the frontier. Ansorena (2018) used methodology based on the exponentially weighted moving average (EWMA) statistic in order to monitor each container vessel that arrives at the Port of Valencia. Research model can be used by terminal managers of Valencia Port to implement better control techniques and thus improve the quality of service.

Serebrisky et al. (2016) tested the efficiencies of 63 LAC ports, which represented 90% of cargo handling in the region. Using panel data (1999-2009), they employed DEA based tests on inputs, which also included exogenous variables. Results revealed an improvement in the average efficiency of ports in the LAC region from 52% to 64% during the 10-year period, with an average of 59% over the same timeframe. Additionally, one key finding of this research has revealed that the ports' efficiency was closely related to port management such as port ownership, than to institutional and countrywide variables. On the other hand, Suarez-Aleman et al, (2016), investigated the regional differences in developing countries' ports. Included in their analysis, 64 ports in LAC were investigated during the period 2000-2010. The region's average technical efficiency stood at 58%, with results of the DEA based Malmquist productivity index revealing an average of 2.4% growth in productivity. This change was primarily the cause of changes in pure efficiency and scale adjustments. Shelly-Ann (2018) concludes that trade volumes play an integral part in affecting efficiency and productivity. Additionally, given port development initiatives, the Caribbean's progresses in efficiency/productivity has been mainly the effects of scale and technical progress respectively. Since these ports are usually smaller scale and yield lesser throughput (compared to their larger counterparts), when they begin to grow, the focus is on enlarging their production scales, however, this is at the expense of adjusting internal practices (Shelly-Ann, 2018).

3. Methodology

Data envelopment analysis (DEA) is a linear programming based technique that provides an objective assessment of the relative efficiency of similar organizational units (Sarica, and Or, 2007). These similar organizational units are considered to be decision making units (DMU), hence the efficiency of these organizational units are calculated. Thus, efficiency is obtained as productivity where it is a ratio of actual output attained to standard input expected (Sumanth, 1984). Mali (1978), generally express the terms productivity as;

Efficiency = Output Obtained/Input Expected =
Performance Achieved/Resources Consumed = Effectiveness/Efficiency.... (1)

Therefore, Sumanth (1984) and Ramanathan (2003) express efficiency:

Efficiency = Output/Input.... (2)

The equation 2 is applicable for evaluation of simple data. The output and input are diverse significantly. Therefore, equation 2 is not suitable for complex relationship between outputs and inputs. The weight cost approach is the solution for complexities of outputs and inputs as follows. The measure of the efficiency of any DMU is obtained as the maximum of a ratio of weighted outputs to weighted inputs subject to the condition that the similar ratios for every DMU be less than or equal to unity. In more precise form,

$$\text{Efficiency} = \sum \text{Weight of Outputs} / \sum \text{Weight of Inputs} \ldots \quad (3)$$

Assuming all weights are uniform, mathematically equation 3 is:

$$\text{Efficiency } (e_o) = \left(\sum_{r=1}^{n} U_r\, Y_{ro}\right) / \left(\sum_{s=1}^{n} V_s\, X_{so}\right) \ldots \quad (4)$$

Subjected to:

$$\text{Efficiency } (e_o) = \left(\sum_{r=1}^{n} U_r\, Y_{rj}\right) / \left(\sum_{s=1}^{n} V_s\, X_{sj}\right) \leq 1;\ j=1\ldots k$$
$$U_r, V_s \geq \varepsilon;\ r = 1\ldots n;\ s = 1\ldots m$$

Y_r = Quantity of Output r
U_r = Weight attached to Output r
X_s = Quantity of Inputs s
V_s = Weight attached to Inputs s

An efficient is denoted = 1, therefore efficiency ranges as 0<Efficiency≤1

*Note***:** The U's and V's are variables of the problem and are constrained to be greater than or equal to some small positive quantity ε in order to avoid any input or output being ignored in computing the efficiency (Bhagavath, 2006).

3.1 Technical efficiency

Data envelopment analysis (DEA) was first introduced by Charnes, Cooper and Rhodes (CCR) in 1978 (Charnes, Cooper, Rhodes, 1978), extended Farrell (1957) idea of estimating technical efficiency with respect to production frontier. The definition of efficiency is referred from the "Extended Pareto-Koopmans and "Relative Efficiency". The CCR is able to calculate the relative technical efficiency of similar decision making units (DMUs) through the analysis with the constant returns to scale basic (CRS).

This is achieved by constructing the ratio of a weighted sum of outputs to a weighted sum of inputs where the weights for both the inputs and outputs are selected so that the relative efficiencies of the DMUs are maximized with the constraint that no DMU can have a relative efficiency score greater than one i.e. DMU > 1.

On the other hand, the DEA-BCC model by Banker, Charnes, and Cooper, 1984) extend from DEA-CCR by assuming variable returns to scale where performance is bounded by a piecewise linear frontier. There are other DEA models but DEA-CCR and DEA-BCC are the most commonly used models.

3.2 Scale efficiency

Since the CCR (1978), the development has introduced the BCC model that is Banker, Charnes and Cooper in 1984. The BCC model relaxes the convexity constraint imposed in the CCR model which allows for the efficiency measurement of DMUs on a variable returns to scale basis. The BCC model results in an aggregate measure of technical and scale efficiency, the CCR model is only capable of measuring technical efficiency. This allows for the separation of the two efficiency measures. The BCC model is an extension of the CCR model, which investigates variable returns to scale.

The development of the Additive model, which involves reduction of inputs with a simultaneous increase in outputs, and Multiplicative models noteworthy advances which, along with further explanations of the DEA technique and its extensions, are outlined in Ali, and Seiford (1993)**,** Charnes, Cooper, Lewin and Seiford, 1994a)**,** Charnes, Cooper and Seiford (1994b) and Lovell (1993). Since the first application of DEA for measuring the efficiency of business student to schools by Charnes, Cooper, Rhodes (1978) the technique has been applied in over 50 industries i.e., healthcare, transportation, hotel, education, computer industry etc.

3.3 Model development

The model is developed from the extension of the ratio technique used in traditional efficiency approaches. The measurement is obtained from DMU as the maximum of a ratio weighted output to weighted input. The numbers of DMUs are not determined outputs and inputs, however, larger DMUs are able to capture higher performance. This would determine the efficiency frontier (Golany, and Roll, 1989). In addition, they opined that the number of DMUs should be at least twice the number of inputs and outputs for the sake of statistical accuracy. The parameters and variables are needed in developing the model.

N = number of DMU {j=1, 2...n}
y= number of outputs {y=1, 2...R}
x= number of inputs {x=1, 2...S}
y_i = Quantity of output rth of output jth DMU
x_i = Quantity of input sth of input of jth DMU
U_r = Weight attached to Output r
V_s = Weight attached to Inputs s

Therefore, the model is based on the following parameters and variables. Golany, and Roll (1989) describe that homogenous unit is important in choosing DMUs to be compared and identifying the factors affecting DMUs. Therefore, homogenous group of units need to perform similar task and objectives, under same set of market conditions and the factors (inputs and outputs).This concept is using linear programming (LP) formulation to compare the relative efficiency of a set of decision making units (DMUs). Farrell (1957), develops similar approach to compare the relative efficiency of a cross-section sample of agricultural farms. The efficiency measures under constant returns to scale (CRS) are obtained by *N* linear programming problems under (Charnes, Cooper, and Rhodes, 1978) as below:

$$\text{Min}\psi,\ \lambda\psi j$$

$$\sum_{i=0}^{n} \lambda\ iYri\ \geq Y_j;\ r=1,\ldots,R$$

$$\sum_{i=0}^{n} \lambda\ iYsi\ \geq \psi x_j;\ s=1,\ldots,S$$

$$\lambda i \geq 0; \forall_i$$

Where $y_i = y_{1i}, y_{2i}, \cdots y_{Ri}$is the output vector, $x_i = x_{1i}, x_{2i}, \cdots x_{Si}$is the input vector. Solving above equation for each one of the *N* container terminals of the sample, *N* weights and *N* optimum solution found. Each optimum solution ψ_j is the efficiency indicator of container terminal *j* and, by construction satisfies$\psi_j \leq 1$.Those container terminals with $\psi_j < 1$are considered inefficient and $\psi_j = 1$ are efficient. (Charnes, , Cooper, and Rhodes, 1978), model constant returns to scale (CRS) was modified by Banker *et al* (1984) by adding the restriction $\sum_{i=1}^{N} \lambda_i = 1$, this has generalizing model to variable returns to scale (VRS) as below;

$$\text{Min}_{\partial,}\ \lambda\partial_j$$

$$\sum_{i=0}^{n} \lambda\ iYri\ \geq Y_j;\ r=1,\ldots,R$$

$$\sum_{i=0}^{n} \lambda\ iYsi\ \geq \partial x_j;\ s=1,\ldots,S$$

$$\sum_{i=0}^{n} \lambda i \geq 0; \forall_i$$

Charnes et al. (1978) from DEA-CCR discover the objective evaluation of overall efficiency and identify the resources and estimates the amounts of the identified inefficiencies. Thus it is called constant return to scale (CRS). Albeit, Banker et al, (1984), DEA-BCC remove the constraint from the CCR model by adding $\sum_{i=0}^{n} \lambda_i = 1$thus, BCC is able to distinguish between technical and scale inefficiencies by (i) estimating pure technical efficiency at the given scale of operation and (ii) identifying whether increasing, decreasing or constant return to scale possibilities are present for further exploitation. It is called as variable return to scale. Therefore, for CCR efficient is required both scale and technical efficient, BCC efficient is only required technically efficient.

3.4 Model specification and measurement of variables used

The variables had already been measured, aggregated and categorized by Nigeria Port Authority and their respective values were collated separately from each terminal operator from different port: six (6) major geo-political ports. The input variables are ship traffic, vessel traffic, berth efficiency and turnaround time while outputs are throughput obtained and revenue generated.

Outputs Variable

a. *Ship traffic:* This deals with the number of vessels that called at Nigerian ports at a specified period of time. The ship traffic are usually expressed on a weekly, monthly or annual basis. But for the sake of this study we use the annual compilation of ship traffic.

b. *Cargo throughput:* It measures the total tonnage of cargo handled at a terminals of the ports under study in a stated period. Cargo throughput is usually expressed on a weekly, monthly or annual basis and the unit for it is tons for general and bulk cargo while TEU for containerized cargo. It does not, however, provide an indication of how efficiently the facilities have been managed. Therefore it has to be evaluated against some inputs in order to acquire meaningful result.

Input Variables

a. Number of berth: This is an input variable that signify the number of berth at the individual Port. This proxy the capital factor of production.

b. *Turnaround time:* This is the operational indicator of productivity which measure the time at which a vessel leaves the port completely i.e. the difference between the arrival time of vessel at the port and the departure time of vessel from the port. Apparently, this indicator measures how time efficient a port/terminal is when rendering services to vessels i.e. loading and discharging. (De Monie, 1987), disintegrates total turnaround time into;

1. Total turn-round time in port as a function of cargo tonnage to be handled during that call.
2. Total turn-round time in port of a given vessel on a given call (generally expressed in hours)
3. Total turn-round time in port in the light of cargo composition (traditionally presented by main classes, e.g. bulk liquids, bulk solids, conventional general cargo, containerized cargo

Thus the individual records of the components mentioned above are difficult to acquire at the ports under study because they are not always available at most ports. In addition, the ports handle different types of cargo i.e. River Port handles dry bulk cargo while Tin Can Island Port handles mainly containerized cargo. Consequently, this productivity indicator is not also adequate to conclude productivity as there are variation in cargo compositions. This proxy both the capital and labour factor of production.

1. *Berth occcupancy rate:* This is an input variable which deals with the utilization rate of the berth facilities. This proxy the capital and labour factor of production. This is selected based on the nature of DEA model i.e. minimization of input objective.

4. Results and discussion

Table 5: Input-Oriented Technical Efficiency Benchmarking for Lagos Port Complex

NO	DMU	IO-CRS TE Score	OO-CRS TE Score	Times as Benchmark	Benchmark (Lambda)
1	2015	1.0	1.0	6	2015(1.000000)
2	2014	1.0	1.0	14	2014(1.000000)
3	2013	1.0	1.0	15	2011(0.430697); 2014(0.543627)
4	2012	1.0	1.0	1	2012(1.000000)
5	2011	1.0	1.0	5	2011(1.000000)
6	2010	1.0	1.0	22	2012(0.046823); 2014(0.905238)
7	2009	0.9	0.9	1	2014(0.879433)
8	2008	0.9	0.9	1	2014(0.585795); 2015(0.226953)
9	2007	0.8	0.8	1	2014(0.681287); 2015(0.019483)
10	2006	0.6	0.6	1	2011(0.307586); 2014(0.237736)
11	2005	0.4	0.4	1	2014(0.396572)
12	2004	0.5	0.5	1	2014(0.411348)
13	2003	0.5	0.5	0	2014(0.475177)
14	2002	0.4	0.4	0	2011(0.024906); 2014(0.350150)
15	2001	0.9	0.9	0	2014(0.794135)
16	2000	0.7	0.7	0	2014(0.629016)
17	1999	0.5	0.5	0	2014(0.473198)
18	1998	0.5	0.5	0	2014(0.447529)
19	1997	0.4	0.4	0	2014(0.387116)
20	1996	0.5	0.5	0	2014(0.454492)
21	1995	0.4	0.4	0	2014(0.348700)
22	1994	0.5	0.5	0	2014(0.397754)
23	1993	0.4	0.4	0	2014(0.294326)
24	1992	0.4	0.4	0	2014(0.299054)
25	1991	0.5	0.5	0	2014(0.361111)
26	1990	0.4	0.4	0	2014(0.342790)
27	1989	0.4	0.4	0	2014(0.306147)

28	1988	0.4	0.4	0	2014(0.308511)
29	1987	0.4	0.4	0	2014(0.300827)
30	1986	0.4	0.4	0	2014(0.320331)
31	1985	0.4	0.4	0	2014(0.328014)
32	1984	0.4	0.4	0	2014(0.324468)
33	1983	0.4	0.4	0	2014(0.309102)
34	1982	0.3	0.3	0	2014(0.267139)
35	1981	0.4	0.4	0	2014(0.285461)
36	1980	0.4	0.4	0	2014(0.281915)

Source: Author's Computation

It is observed that year 2014 is the most efficient year out of the 36 operation years in terms of output maximization with constant levels of inputs under the study period with score 1.0 respectively serving as 32 times benchmark for other years.

Table 6: Input-Oriented Technical Efficiency Benchmarking for Tin Can Island Port Complex

NO	DMU	IO-CRS TE Score	OO-CRS TE Score	TAB	Benchmark (Lambda)
1	1985	1	1	0	1985(1.000000)
2	1995	1	1	0	1995(1.000000)
3	1998	1	1	0	1998(1.000000)
4	2009	1	1	0	2009(1.000000)
5	2013	1	1	0	2013(1.000000)
6	2014	1	1	0	2014(1.000000)
7	1997	1	1	0	1995(0.597122); 1998(0.398082)
8	1980	1	1	0	1998(0.097475); 2014(0.751002)
9	2015	1	1	0	2013(0.866995)
10	1981	1	1	0	1998(0.538428); 2014(0.273409)
11	1996	0.9	0.9	0	1998(0.906816); 2013(0.002749)
12	2010	0.9	0.9	17	2013(0.882284)
13	1993	0.9	0.9	0	1985(0.019394); 1995(0.520622); 1998(0.308713); 2013(0.024580)
14	1982	0.9	0.9	0	1998(0.689436); 2013(0.155805)
15	1994	0.9	0.9	0	1998(0.681028); 2013(0.153905)
16	1992	0.8	0.8	0	1985(0.058243); 1995(0.068991); 1998(0.689466)
17	1984	0.8	0.8	0	1985(0.144669); 1995(0.245484); 1998(0.356600); 2013(0.036060)
18	2011	0.8	0.8	7	2013(0.817140)
19	1986	0.8	0.8	0	1998(0.671055); 2014(0.070435)
20	1983	0.8	0.8	0	1998(0.556132); 2014(0.133778)
21	1987	0.8	0.8	0	1998(0.432905); 2013(0.028129); 2014(0.241320)
22	1991	0.7	0.7	0	1998(0.359684); 2013(0.333041)
23	2001	0.7	0.7	3	1998(0.650024); 2013(0.065002)
24	2012	0.7	0.7	0	2009(0.088755); 2013(0.594203)
25	1988	0.7	0.7	0	1998(0.367580); 2013(0.103169); 2014(0.203058)
26	1989	0.7	0.7	0	1998(0.480576); 2013(0.042916); 2014(0.151000)
27	1999	0.7	0.7	0	1998(0.557714); 2013(0.126037)
28	1990	0.7	0.7	0	1998(0.564613); 2013(0.051841); 2014(0.055078)
29	2002	0.7	0.7	0	1998(0.588193); 2013(0.077506)
30	2005	0.6	0.6	0	1998(0.509496); 2013(0.110887)
31	2000	0.6	0.6	0	1998(0.493320); 2013(0.076926)
32	2003	0.6	0.6	0	1998(0.478102); 2013(0.084751)
33	2004	0.5	0.5	4	1998(0.455558); 2013(0.058454)
34	2008	0.5	0.5	0	1998(0.145511); 2013(0.356382); 2014(0.000248)
35	2007	0.5	0.5	0	2014(0.451078)
36	2006	0.4	0.4	0	1998(0.304084); 2014(0.135734)

Source: Author's Computation

It is observed from the table above that Tin Can Island Port was technically efficient in the operation years of 1980, 1981, 1985, 1995, 1997, 1998, 2009, 2013, 2014 and 2015 with score 1.0. However, the most efficient operation years are 1998 and 2013 while the most inefficient year is with efficiency score 1.0. The post-concession years that the port was technically inefficient are 2006, 2007, 2008, 2010, 2011 and 2012.

Table 7: Input-Oriented Technical Efficiency Benchmarking for Rivers Port Complex

NO	DMU	Score	Times as benchmark	Benchmark (Lambda)
1	2004	1.0	3	2004(1.000000)
2	2005	1.0	21	2005(1.000000)
3	2007	1.0	2	2007(1.000000)
4	2008	1.0	1	2008(1.000000)
5	2009	1.0	21	2009(1.000000)
6	2010	1.0	1	2010(1.000000)
7	2011	1.0	3	2011(1.000000)
8	2012	1.0	9	2012(1.000000)
9	2013	1.0	0	2010(0.500000); 2012(0.500000)
10	2014	1.0	5	2014(1.000000)
11	2006	1.0	0	2004(0.170087); 2007(0.375328); 2011(0.146621); 2012(0.058653)
12	2015	1.0	0	2014(0.945146)
13	2003	0.8	0	2004(0.475560); 2007(0.179719); 2014(0.057599)
14	2002	0.7	0	2004(0.187042); 2005(0.502885); 2014(0.024221)
15	2001	0.7	0	2005(0.187616); 2009(0.355808); 2012(0.034673)
16	2000	0.5	0	2005(0.497653); 2009(0.028169)
17	1980	0.5	0	2005(0.460814); 2009(0.055856)
18	1999	0.5	0	2005(0.092397); 2009(0.279594); 2011(0.059458)
19	1990	0.5	0	2005(0.249737); 2009(0.210305)
20	1981	0.5	0	2005(0.368133); 2009(0.103943)
21	1983	0.5	0	2005(0.143550); 2009(0.158212); 2012(0.094101)
22	1995	0.5	0	2009(0.104098); 2011(0.208197)
23	1982	0.5	0	2005(0.175613); 2009(0.173248); 2012(0.052486)
24	1991	0.4	0	2005(0.171066); 2009(0.238696)
25	1998	0.4	0	2005(0.233919); 2009(0.183817)
26	1986	0.4	0	2005(0.031271); 2009(0.351801)
27	1984	0.4	0	2005(0.190280); 2009(0.205502)
28	1985	0.4	0	2005(0.003682); 2009(0.353501)
29	1988	0.4	0	2005(0.186553); 2009(0.108470); 2012(0.058294)
30	1989	0.4	0	2005(0.110521); 2009(0.092386); 2012(0.109694)
31	1996	0.4	0	2005(0.274121); 2009(0.105431)
32	1992	0.4	0	2005(0.197527); 2009(0.166338)
33	1997	0.4	0	2005(0.027314); 2009(0.183983); 2014(0.083533)
34	1987	0.4	0	2005(0.131471); 2009(0.089066); 2012(0.074815)
35	1993	0.3	0	2005(0.005237); 2009(0.167406); 2012(0.085685)
36	1994	0.3	0	2008(0.029971); 2014(0.170370)

Source: Author's Computation

It is observed that the preceding year 2005 and year 2009 are the most efficient years out of the 36 operation years for both input and output orientation under the study period with score 1.0 respectively serving as 21 times benchmark for other years while year 1993 and 1994 are the least inefficient years with score 0.3.

Table 8: Input-Oriented Technical Efficiency Benchmarking for Delta Port Complex

NO	DMU	IO-CRS TE Score	OO-CRS TE Score	Times as benchmark	Benchmark (Lambda)
1	1996	1.0	1.0	1	1996(1.000000)
2	2001	1.0	1.0	20	2001(1.000000)
3	2002	1.0	1.0	4	2002(1.000000)
4	2003	1.0	1.0	0	2003(1.000000)
5	2009	1.0	1.0	1	2009(1.000000)
6	2011	1.0	1.0	17	2011(1.000000)
7	2013	1.0	1.0	2	2013(1.000000)
8	2014	1.0	1.0	0	2014(1.000000)
9	1995	1.0	1.0	0	2001(0.061078); 2011(0.677764)
10	2010	1.0	1.0	0	2001(0.119014); 2002(0.090646); 2011(0.678218)
11	1998	1.0	1.0	0	2001(0.990741)
12	1989	1.0	1.0	0	2001(0.983779)
13	1988	1.0	1.0	0	2001(0.981481)
14	1997	1.0	1.0	0	1996(0.717020); 2011(0.176251)
15	1985	1.0	1.0	0	2001(0.960648)
16	2000	1.0	1.0	0	2001(0.749647); 2011(0.152213)
17	2015	1.0	1.0	0	2011(0.240105); 2013(0.540092)
18	1994	1.0	1.0	0	2011(0.653805)
19	1987	0.9	0.9	0	2001(0.547783); 2011(0.292151)
20	1999	0.9	0.9	0	2001(0.324073); 2011(0.446997)
21	2006	0.9	0.9	0	2002(0.535552); 2011(0.367163)
22	2012	0.9	0.9	0	2011(0.697652); 2013(0.150635)
23	1984	0.9	0.9	0	2001(0.912037)
24	2007	0.9	0.9	0	2002(0.359774); 2011(0.398108)
25	1986	0.9	0.9	0	2001(0.907407)
26	1992	0.9	0.9	0	2001(0.900463)
27	1983	0.9	0.9	0	2001(0.863584); 2011(0.014014)
28	1990	0.9	0.9	0	2001(0.683825); 2011(0.138848)
29	2005	0.9	0.9	0	2002(0.594306); 2011(0.294211)
30	1982	0.9	0.9	0	2001(0.863426)
31	1993	0.9	0.9	0	2001(0.486101); 2011(0.273860)
32	1991	0.8	0.8	0	2001(0.287790); 2011(0.396952)
33	2008	0.8	0.8	0	2009(0.141396); 2011(0.611751)
34	1980	0.8	0.8	0	2001(0.805556)
35	1981	0.8	0.8	0	2001(0.752315)
36	2004	0.6	0.6	0	2001(0.872408)

Source: Author's Computation

From the table above, it is observed that the DMUs that fall on the frontier are DMU 1985, 1988, 1989, 1994, 1995, 1996, 1997, 1998, 2000, 2001, 2002, 2003, 2009, 2010, 2011, 2013, 2014, 2015which means that Delta Port was efficient with respect to input minimization and output maximization in the aforementioned years while the inefficient DMUs are DMUs 1980, 1981, 1982, 1983, 1984, 1986, 1987, 1990, 1991, 1992, 1993, 1999, 2004, 2005, 2006, 2007, 2008, 2012. It is observed that DMU/operation year 2001 is the most efficient DMU/operation year serving as benchmark for other twenty-one (21) DMUs/years and the least efficient years are DMU/operation year 2004 with efficiency score of 0.6.

Table 9: Input-Oriented Technical Efficiency Benchmarking for Onne Port Complex

NO	DMU	Score	Score	Times as benchmark	Benchmark (Lambda)
1	2004	1.0	1.0	3	2004(1.000000)
2	2005	1.0	1.0	21	2005(1.000000)
3	2007	1.0	1.0	2	2007(1.000000)
4	2008	1.0	1.0	1	2008(1.000000)
5	2009	1.0	1.0	21	2009(1.000000)
6	2010	1.0	1.0	1	2010(1.000000)
7	2011	1.0	1.0	3	2011(1.000000)
8	2012	1.0	1.0	9	2012(1.000000)
9	2013	1.0	1.0	0	2010(0.500000); 2012(0.500000)
10	2014	1.0	1.0	5	2014(1.000000)
11	2006	1.0	1.0	0	2004(0.170087); 2007(0.375328); 2011(0.146621); 2012(0.058653)
12	2015	1.0	1.0	0	2014(0.945146)
13	2003	0.8	0.8	0	2004(0.475560); 2007(0.179719); 2014(0.057599)
14	2002	0.7	0.7	0	2004(0.187042); 2005(0.502885); 2014(0.024221)
15	2001	0.7	0.7	0	2005(0.187616); 2009(0.355808); 2012(0.034673)
16	2000	0.5	0.5	0	2005(0.497653); 2009(0.028169)
17	1980	0.5	0.5	0	2005(0.460814); 2009(0.055856)
18	1999	0.5	0.5	0	2005(0.092397); 2009(0.279594); 2011(0.059458)
19	1990	0.5	0.5	0	2005(0.249737); 2009(0.210305)
20	1981	0.5	0.5	0	2005(0.368133); 2009(0.103943)
21	1983	0.5	0.5	0	2005(0.143550); 2009(0.158212); 2012(0.094101)
22	1995	0.5	0.5	0	2009(0.104098); 2011(0.208197)
23	1982	0.5	0.5	0	2005(0.175613); 2009(0.173248); 2012(0.052486)
24	1991	0.4	0.4	0	2005(0.171066); 2009(0.238696)
25	1998	0.4	0.4	0	2005(0.233919); 2009(0.183817)
26	1986	0.4	0.4	0	2005(0.031271); 2009(0.351801)
27	1984	0.4	0.4	0	2005(0.190280); 2009(0.205502)
28	1985	0.4	0.4	0	2005(0.003682); 2009(0.353501)
29	1988	0.4	0.4	0	2005(0.186553); 2009(0.108470); 2012(0.058294)
30	1989	0.4	0.4	0	2005(0.110521); 2009(0.092386); 2012(0.109694)
31	1996	0.4	0.4	0	2005(0.274121); 2009(0.105431)
32	1992	0.4	0.4	0	2005(0.197527); 2009(0.166338)
33	1997	0.4	0.4	0	2005(0.027314); 2009(0.183983); 2014(0.083533)
34	1987	0.4	0.4	0	2005(0.131471); 2009(0.089066); 2012(0.074815)
35	1993	0.3	0.3	0	2005(0.005237); 2009(0.167406); 2012(0.085685)
36	1994	0.3	0.3	0	2008(0.029971); 2014(0.170370)

Source: Author's Computation

It is observed that the preceding year 2005 and year 2009 are the most efficient years out of the 36 operation years for both input and output orientation under the study period with score 1.0 respectively serving as 21 times benchmark for other years while year 1993 and 1994 are the least inefficient years with score 0.3.

Table 10: Input-Oriented Technical Efficiency Benchmarking for Calabar Port Complex

NO	DMU	IO-TE Score	OO-TE Score	Times as benchmark	Benchmark (Lambda)
1	1985	1.0	1.0	16	1985(1.000000)
2	2007	1.0	1.0	28	2007(1.000000)
3	2008	1.0	1.0	1	2008(1.000000)
4	2013	1.0	1.0	0	2008(0.359033); 2014(0.556437)
5	2014	1.0	1.0	4	2014(1.000000)
6	2015	1.0	1.0	7	2015(1.000000)
7	1986	0.9	0.9	0	1985(0.434381); 2007(0.404845); 2015(0.021097)
8	1987	0.9	0.9	0	1985(0.737189); 2007(0.118927); 2015(0.069518)
9	2005	0.9	0.9	0	2007(0.864322)
10	2006	0.9	0.9	0	2007(0.895894)
11	2009	0.9	0.9	0	2007(0.384778); 2014(0.549682)
12	2011	0.9	0.9	0	2015(0.883699)
13	2012	0.9	0.9	0	2015(0.817161)
14	2010	0.8	0.8	0	2007(0.182177); 2014(0.592075)
15	1989	0.7	0.7	0	1985(0.384105); 2007(0.127195); 2015(0.061860)
16	1998	0.7	0.7	0	1985(0.551613); 2007(0.108977)
17	2001	0.7	0.7	0	1985(0.501203); 2007(0.214801)
18	2003	0.7	0.7	0	2007(0.703812)
19	2004	0.7	0.7	0	2007(0.724328); 2014(0.018619)
20	1999	0.6	0.6	0	1985(0.375435); 2007(0.257064)
21	1984	0.5	0.5	0	1985(0.238003); 2007(0.178943)
22	1992	0.5	0.5	0	1985(0.207207); 2007(0.310811)
23	1997	0.5	0.5	0	1985(0.378781); 2007(0.043859)
24	2000	0.5	0.5	0	1985(0.135958); 2007(0.394278)
25	2002	0.5	0.5	0	2007(0.546921)
26	1981	0.4	0.4	0	1985(0.041348); 2007(0.347718); 2015(0.008139)
27	1982	0.4	0.4	0	2007(0.444282)
28	1983	0.4	0.4	0	1985(0.136784); 2007(0.214884)
29	1988	0.4	0.4	0	1985(0.050244); 2007(0.285815); 2015(0.055461)
30	1994	0.4	0.4	0	2007(0.357771)
31	1995	0.4	0.4	0	1985(0.210822); 2007(0.201546)
32	1980	0.3	0.3	0	1985(0.167750); 2007(0.175286)
33	1993	0.3	0.3	0	2007(0.259531)
34	1996	0.3	0.3	0	1985(0.139986); 2007(0.209979)
35	1990	0.2	0.2	0	2007(0.209677)
36	1991	0.2	0.2	0	2007(0.241935)

Source: Author's Computation

From the table above, it is observed that the DMUs that fall on the frontier are DMU 1985, 2007, 2008, 2013, 2014 and 2015 which implies that Calabar Port was efficient with respect to input minimization and output maximization in the aforementioned years while the inefficient DMUs are DMU 1986 to DMU 2006, DMU 2009, DMU 2010, DMU 2011 and DMU 2012. However, the most efficient DMU/year is DMU/year 2008 serving as benchmark for other twenty-eight (28) DMUs/years and the least efficient years are 1990 and 1991.

5. Conclusion

Hence, the impacts of concessioning was really felt at Onne Port and Tin Can Island Port because the level of technical and scale efficiencies were very unacceptable in the pre-concession period as it was recorded that the only highest level of efficiency (0.8) the Port achieved in the pre-concession was in year 2003 while Tin Can Island Port achieved technical and scale efficiency of 0.9 only in pre-concession year 2001. However, they were able to utilize their input resources consistently to the optimal level to produce adequate or required outputs' quantities for more than five (5) consecutive post concession years with technical, scale and managerial efficiency score of 1.0 respectively. They were able to use their scale size optimally in the post concession years with scale efficiency score of 1.0 respectively.

Rivers, Delta, Calabar and Lagos Port experienced unstable efficiencies in the post concession era. However, Delta Port experienced the least efficiency score in the pre-concession era in year 2006, 2007 and 2008 with score 0.4, 0.5 and 0.5 respectively in terms of input minimization and output maximization. The most efficient operation year in Lagos Port Complex is year 2011 and the least inefficient operation years are year 1992, 1993, 1994 and 1999 with efficiency score of year 0.8. The most efficient operation year in Tin Can Island Port is year 2014 and the least inefficient year is 1982 with efficiency score of 0.3. The most efficient operation year in River Port is year 2001 while the least inefficient year is 2004 with efficiency score of 0.6. The most efficient operation year in Delta Port is year 2013 and the least inefficient operation year in Delta Port is 2006 with efficiency score 0.4. The most efficient operation year in Calabar Port is year 2007 and the least inefficient year is year 1991 with score 0.2. The most efficient years in Onne Port are year 2005 and 2009 while the least inefficient year are 1993 and 1994. Hence, all Nigerian Ports achieved the highest level of efficiency in the post concession year except River Port that had the highest level of efficiency in year 2001.

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