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Recent performance appraisal of six Nigerian seaports using multivariate and data envelopment analysis

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Abstract

Performance appraisal is a regular check which every organization adapts to regulate the performance of its establishment. It shows the relationships between outputs and input variables in organizations. The objective of the study is to review the performance of six Nigerian seaports between the periods of 2012-2017 by applying Data Envelopment Analysis (DEA), General Linear Model (GLM), and Multivariate Analysis (MVA) models. Data collected from Nigerian Ports Authority (NPA) statistics covers the periods (2012-2017) for each port. The empirical result shows that the following Seaports performed efficiently: Lagos Port (LP) in 2014, Tin Can Island Port (TCP) in 2014, Onne Port (OP) in 2014, and Calabar Port (CP) in 2012, 2013, 2014 and 2016. The least efficient performed seaport is Delta Port (DP) in 2012. Hence, the most efficient port over the years under study is Calabar Port (CP) while least performed port is Delta Port (DP). The results of the regression model and the multivariate analysis reject the null hypothesis and accept that at 5% level of significance there is a significant relationship between the input variables and output variables of each port, even that P-value is less than 0.005 ($P<0.05$).

Keywords: Performance Appraisal; Ports; Data Envelopment Analysis (DEA); General Linear Model (GLM); Multivariate Analysis (MVA); Nigerian Seaports.

1. Introduction

Performance appraisal is a fundamental concept to every business organization because all businesses are interested to know their strength and productivity rate which could help to guide against rivals in the business environment, while also measuring her achievements in terms of relationships between output/input variables towards achieving set goals and objectives. Seaports are complex business environment with huge investments as inputs resources with expected results as outputs resources which could be proven through return on investment (ROI) for purposes of sustainable development. To evaluate returns on investment in seaports, operators have employed many techniques of ports performance measurement. However, the recommendations on evaluation of seaports performances have compelled stakeholders and policy makers to take some reform decisions such as privatization and concession of seaports basically to increase productivity or efficiency. This has led to academic interest in seaport performance measures. Hence, this paper will appraise the performance of six Nigerian seaports from 2012 to 2017 using Data Envelopment Analysis (DEA) while applying Multivariate Analysis to evaluate the effect of input variables on the output variables as well as the relationship between inputs and output variables. The results of this research will aid the policy makers, investors and port operators on different ways to invest in seaport operations for greater efficiency.

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1.1. Background Information

Maritime transportation as a major channel of international trade has been subjected to deliberate efforts to improving the efficiency of the sector. The maritime industry is a vital and strategic sector in every country's economy. According to UNCTAD [27], international sea borne trade, from 1980 to 2008 witnessed an increase of over 120%. According to Umang [26], this increase was possible due to the steady growth in world population, rapid industrialization, and the depletion of local resources, road congestion, increase in the need for better living standard and elimination of trade barriers. He also claimed that since the beginning of the decade, dry bulk, liquid bulk and containerized cargo have registered an impressive tonnage increase of 52%, 48% and 154% respectively. In this period of high globalized production and consumption driven by increase in world population with limited available resources, there is a growing need for efficient and productive supply chain management which cannot be without the high efficiency of seaports that serves as the interface between maritime and hinterland transport systems. The fluidity of movement of goods and services within a region aids increase in socio-economic development of such region. This is made possible based on the performance of the seaports. According to Emeghara and Ndikom [9] they reiterated that ship and port relationship is like that of a master/servant relationship. A port is likened to be an enterprise established to provide quality service to her masters/customers to survive economically. This is because shippers as well as ship owners demand efficient service from port operators for continual patronage. Nigeria is endowed with marine domain with estuaries hosting harbors, ports and jetties. However, it is vital to note that the deliberate distribution of vessel traffic in accordance to final consumer's location reduces acute traffic congestions in some ports. Considerably, the importance of ports in the economic life of any nation cannot be over emphasized. According to Managing Director NPA Hadiza Bala Usman in her opening remarks in NPA as reported in [16], she posits that the critical role of ports in national economic and social development is derived from its significance as the cheapest mode of moving large cargoes from one point to another. The demand for port services by vessels is, however, a derived demand earned through conscious and deliberate policy choices made and driven to create the enabling environment for ship operators to make a first call to our ports and make a repeat call thereafter. While the government reforms leading to the concession of cargo operations to private terminal operators (PTOs) represented the foundation for improving efficiency through huge infrastructural investment for smooth and fast service delivery, the ongoing commitment to improve the competitiveness of Nigerian ports and the renewed commitment to pull the country out of the most challenging recession experienced in over two decades represents a key government priority. But the lack of convincing, tangible and concerted effort of the Nigerian government to mitigate the congestion at Lagos Ports and also the incessant sea robbery and militancy challenges in the Nigeria waterways have affected businesses in the Nigerian ports as perceived by port stakeholders which is contrary to the government assertion [19].

1.2. Overview of Nigerian Seaports

The explorations and trade activities of Europeans in Nigeria created the demand for seaports on the wide coastal stretch between Calabar and Lagos. In the 15th century European voyagers discovered the rich natural resources of West and Central Africa – resources they needed for their economic and industrial revolution and this gave birth to Nigerian seaports as we have them today.

In 1906, dredgers were commissioned to work at the Lagos bar and the approval to construct the first section of the East Mole was obtained. This is the first major breakthrough in opening up the Lagos Lagoon. In 1913 the development of Apapa Port was hatched and in 1921 the construction of the first four deepwater berths at Apapa, with a length of 1,800 ft, began. In 1948 an additional 2,500 ft of berths were installed with a reclaimed area of 41ha to accommodate transit sheds, warehouses and marshalling yards. The discovery of coal in Enugu led to the building of the Rivers Port (Port Harcourt wharf) in the first quarter of the century and in 1913 Port Harcourt Port was opened to shipping by the Governor General, Lord Luggard. A berth for colliers was created so that coal could be loaded from rail to ship. Four berths of 1,920 ft were further developed at Port Harcourt Ports in 1927. Prior to 1954, Port operations and management were controlled by Railway Corporation Department in charge of cargo handling, Public Works Department in charge of quay maintenance and Marine Department responsible for maintenance of the harbours, channels, and berthing of vessels.

In 1954, the Nigerian Ports Authority was established by an Act of Parliament (Port Act, CAP155 Laws of the Federation of Nigeria and Lagos 1955, currently NPA Act CAP N126 LFN, 2004) to control and maintain the seaports as well as load and discharge cargo. Its operations started on 1 April 1955. In 1982, Nigerian maritime industry began to feel the impact of the economic recession in spite of government policies to boost product export as against an earlier booming importation business that had kept Nigeria seaports congested and busy since the early 1970s. The decline in government revenue led to public private partnership (PPP) arrangement in port development through port concession. On 17 June 1992 the Authority was incorporated as a public liability company under the provision of the Companies and Allied Matters Act 1990 as a wholly owned government company. However, in 1999 the status of the Nigerian Ports

Authority was reverted to as an Agency of the Federal Republic of Nigeria supervised by the Ministry of Transport. Presently, Nigeria has six seaports namely Lagos Port, Tin Can Island Port, Rivers Port, Onne Port, Calabar Port and Delta Ports. They are along the coastline region of the country covering a stretch of over 853 km, between 4°10' and 6°20' north and between 2°45' and 8°35' east.

1.2.1. The Lagos Port Complex

The Lagos Port Complex is the oldest and largest port in Nigeria termed Premiere Port also referred to as Apapa Quays. It is situated in Lagos State, the commercial capital of Nigeria. The port is concession to the following companies: papa Bulk Terminal Limited Apapa Terminal A and B; Green-view Dev. Nig. Ltd. Apapa Terminal E; and APM Terminals Limited Apapa Container Terminal for 25 years respectively ; while ENL Consortium Apapa Terminal C, ENL Consortium Apapa Terminal D and Lily pond Container Depot Nigeria Ltd Ijora Container Depot for10 years respectively.

1.2.2. Tin Can Island Port

Tin Can Island Port is located within the north-west of Lagos Port Complex built in the mid 1970s in response to an increase in economic activities during the oil boom coupled with post-civil-war reconstruction, rehabilitation and reintegration efforts by the then military government. The port is concession to the following companies: Joseph dam Ports Services Limited TCIP Terminal A, and Ports & Cargo Handling Services Ltd. TCIP Terminal C for 10 years respectively; Tin Can Island Container Limited TCIP Terminal B and Five Star Logistics Limited TCIP RORO Terminal for 15 years respectively; and Port & Terminal Multi services Limited TCIP Terminal E for 25 years.

1.2.3. Rivers Port Complex

Rivers Port Complex, Port Harcourt is the second-oldest port in Nigeria but is the first port to be established in the east of Niger in the country after the Lagos Port Complex, Apapa. The port is concession to Ports & Terminal Operators Nig. Ltd. Port Harcourt Terminal A for 15years; and BUA Ports & Terminals Limited Port Harcourt Terminal B for 25 years

1.2.4. Onne Port Complex

Onne Port Complex is situated on the Bonny River Estuary along Ogu Creek. As a flagship port it is the first of its kind in Nigeria that operates the Landlord Port Model devised to encourage private sector participation in the Port Industry. It is one of the largest Oil and Gas Free Zones in the world supporting exploration and production for Nigerian activities. The Free Zone provides logistics Oil Service centre for the Oil and Gas Industry in Nigeria both Onshore and Offshore operations. The port is strategically located as it provides easy access to the entire West African and Sub-Sahara Oil Onne Port Complex fields. The seaport accounts for over 65% of the export cargo through the Nigerian Seaport. The port is concession to Intels Nigeria Limited Onne FOT A, Brawal Oil Services Ltd. Onne FLT A, Intels Nigeria Ltd. Onne FLT B and Atlas Cement Co. Limited Jetty FOT Onne for 25 years respectively.

1.2.5. Calabar Port

Calabar Port is made up of facilities built and operated previously by various shipping companies which used to serve as an important trading port in the pre-colonial era. The port has supervisory responsibility over crude oil terminals at Antan, Odudu, Yoho and Qua Iboe. Passenger boat services covering Cameroon, Gabon and other West and Central African countries operate from here. The port is concession to Intels Nigeria Limited Calabar New Terminal A, Addax Logistics Nigeria Limited Calabar Terminal C (Old Port) for 25 years respectively and Ecomarine Nig. Limited Calabar New Terminal B for 10 years.

1.2.6. Delta Port

Delta Port is home to the ports of Warri, Sapele, Koko and Burutu at the heart of the Niger Delta. Warri Port is the coordinating point for management and administration of other ports in the delta, operating from natural harbors. By virtue of their geographical location, these ports have land in sufficient quantity for investment purposes more than all the others. The port is concession to Intels Nigeria Limited Warri Old Port Terminal A and B for25 years respectively, Julius Berger Plc Warri New Port Terminal C for 25 years and Associated Maritime Services Limited Warri Old Port Terminal B and Greenling Limited Koko Terminal for 10years respectively.

Table 1 The summary of the Characteristics of the six Nigerian Seaports

S/N	Name of jetty	Year	Quay length	No. of berths	Total port area	Access channel draft	Cargo throughput	Ship traffic	GRT Ocean going	Service boat	GRT service boat	ATT (days)	BOR%	Vehicle traffic
1	LAGOS PORT complex	2012	2537	21	200ha	14	19951807	1445	3207798	191	380444	5.13	55.76	17121
		2013	2537	21	200ha	14	20437369	1510	34189172	NA	NA	5.13	55.76	14397
		2014	2537	21	200ha	14	20645269	1503	37046879	NA	NA	5.13	55.76	9611
		2015	2537	21	200ha	14	20250771	1410	36290502	NA	NA	5.13	55.76	6955
		2016	2537	21	200ha	14	19055385	1194	33612421	NA	NA	5.13	55.76	346
		2017	2537	21	200ha	14	19099690	1154	31932784	1	2876	5.13	55.76	507
2	TinCan port complex	2012	3396	13	158	14	15268897	1508	32636886	NA	NA	4.01	43.92	251322
		2013	3396	13	158	14	16134153	1615	40096754	NA	NA	4.01	43.92	265209
		2014	3396	13	158	14	17500804	1692	47231548	NA	NA	4.01	43.92	237904
		2015	3396	13	158	14	16407133	1656	45864565	NA	NA	4.01	43.92	124841
		2016	3396	13	158	14	15648919	1559	45229402	NA	NA	4.01	43.92	104571
		2017	3396	13	158	14	15464385	1350	41477915	NA	NA	4.01	43.92	180758
3	Rivers port Complex	2012	704	8	58	10	5574653	499	7210520	NA	NA	6.85	37.67	NA
		2013	704	8	58	10	4935944	439	6207092	NA	NA	6.85	37.67	NA
		2014	704	8	58	10	6225008	435	6632480	NA	NA	6.85	37.67	NA
		2015	704	8	58	10	4457785	373	5423002	NA	NA	6.85	37.67	NA
		2016	704	8	58	10	3574235	319	4951913	NA	NA	6.85	37.67	NA
		2017	704	8	58	10	3536873	309	5277722	NA	NA	6.85	37.67	141
4	OnnePort Complex	2012	5172	FLT4/FOT12	2638199	11	27580642	859	42910262	3637	5494535	21.4	11.46	285
		2013		FLT4/FOT12	2638199	11						21.4	11.46	

		2013	5172	FLT4/FOT12	2638199	11	24773387	823	38612995	3534	47	21.4	11.46	260
		2014	5172	FLT4/FOT12	2638199	11	27968861	847	45543000	3455	5678989	21.4	11.46	106
		2015	5172	FLT4/FOT12	2638199	11	26314828	741	44053589	1305	2326922	21.4	11.46	196
		2016	5172	FLT4/FOT12	2638199	11	23434241	659	40091365	1823	3582303	21.4	11.46	272
		2017	5172	FLT4/FOT12	2638199	11	26049226	671	42818946	1916	3671556	21.4	11.46	3
5	Calabar Port	2012	NP86/OP88	7	88	6	6987533	615	2767531	508	333801	5.18	22.93	NA
		2013	NP86/OP88	7	88	6	10361746	609	2834884	198	99669	5.18	22.93	NA
		2014	NP86/OP88	7	88	6	10199169	603	4008361	35	31147	5.18	22.93	NA
		2015	NP86/OP88	7	88	6	7829862	528	3796652	35	31147	5.18	22.93	NA
		2016	NP86/OP88	7	88	6	6836616	438	4207733	53	28522	5.18	22.93	NA
		2017	NP86/OP88	7	88	6	5197773	448	3880058	55	13090	5.18	22.93	NA
6	Delta Port Complex	2012	572	NB7/OB18	353	6	1723195	159	3220686	17390	2480436	3.48	13	658
		2013	572	NB7/OB19	353	6	1732286	373	8667160	15602	2510700	3.48	13	360
		2014	572	NB7/OB20	353	6	2361477	269	7860797	10755	2038242	3.48	13	311
		2015	572	NB7/OB21	353	6	2127259	306	5822393	7276	909390	3.48	13	2
		2016	572	NB7/OB22	353	6	2329984	453	6120242	7542	1582577	3.48	13	NA
		2017	572	NB7/OB23	353	6	2187689	403	6182396	9787	1771834	3.48	13	NA

Source: Researcher compiled from [16]

2. Literature review

The globalization of the world economy has tremendously increased the importance of the maritime transportation role vis-à-vis seaports internationally. This has lent great credence to all nodes or echelons of the economic global supply chain. However, the seaports as an important node in the supply chain process of international trade have been under the searchlight of investors, governments and academia over the years and especially in the recent time of technological era. This is as a result of its performance importance in the survival of most countries of the world, hence the huge technological input or investment in the sector. Therefore, for the sake of such huge investment in the maritime sector world over, these seaports are subjected to competition which in turn leads to the monitoring of their productivity and efficiency. Studies on port efficiency, productivity or performance are done regularly within the port organization or externally by academic researchers in many parts of the world. A number of such studies have done by many researchers. Considerably, Hlali ([11] who estimated and compared the technical efficiency of the container ports using both data envelopment analysis (DEA) and stochastic frontier analysis (SFA) models to check the role of the characteristics of infrastructure on container port efficiency based on cross-sectional data for 26 world's major container ports in 2015.

Evangelos, [7] in their paper, measured US Ports efficiency by analyzing port productivity using Data Envelopment Analysis technique on containerization and traditional port operations. They obtained two main results. First, a set of the best practice ports was identified. Second, the sources and extent of inefficiency on which an inefficient port should focus in order to improve their operations were determined.

Evangelos [8] also evaluated the efficiency of major North American container ports and terminals using Data Envelopment Analysis (DEA) and the Free Disposal Hull (FDH) Model. However, the results show that the above two techniques lead to different conclusions. Furthermore, they concluded that the availability of panel data, rather than cross sectional data, would improve the validity of the efficiency estimates derived from all applied mathematical programming techniques. Tongzon [23] study applied data envelopment analysis (DEA) to provide an efficiency measurement for four Australian and twelve other international container ports. The ports of Melbourne, Rotterdam, Yokohama and Osaka are found to be the most inefficient ports in the sample, based on constant and variable returns to scale assumptions, mainly due to the enormous slack in their container berths, terminal area and labor inputs. The study also drew some policy implications for ports and recommends certain areas for future research.

DEA application in port efficiency is growing over the years, Turner, [24] applied Data Envelopment Analysis (DEA) technique in the productivity study of North America ports using a panel data from 1984 – 1997. Jara-Diaz, [13] researched on 26 Spanish seaports, estimating a multi output cost function using a flexible form from a sample of over an 11-year period. Talley [22] also compared the actual performance of seaport with optimum throughput over a specific time period. Karen, [14] analyzed the efficiency of available elements used at public port terminals located in the state of Espírito Santo, Brazil. In Northeast Asia, SoonHoo, [21] applied DEA models, to measure the operational efficiency of the 19 major container ports in the Northeast Asia. This analysis of operational efficiency revealed the causes of inefficient operation and also suggests how to overcome the drawbacks. An additional analysis for ranking the container ports was conducted using the super-efficiency model. According to the results of this study, eight container ports are operated efficiently among which Hongkong is ranked top as the most efficient port in the Northeast Asia. Two Korean container ports, both Busan and Gwangyang show relatively low operational efficiency compared to their rival ports and suggested to either cut labour and capital (inputs) or increase TEU (output) of the two ports to improve efficiency.

Hong-Oanh, [12] applied bootstrapped DEA to a sample of 43 largest Vietnamese ports and compared the results with those from stochastic frontier analysis (SFA) and standard DEA. The results showed that while the efficiency scores obtained from the three methods provide useful and consistent measures of the ports' efficiency, they differed significantly. Furthermore, while the efficiency scores produced by bootstrapped DEA are consistent, unbiased, and not sensitive to the sample size, standard DEA and SFA yielded efficiency scores that were much larger than bootstrapped DEA. In addition, bootstrapped DEA provided the confidence intervals for efficiency scores and allowed for hypothesis tests of port performance.

Medal-Bartual, [15] assessed the impact of the economic crisis on the productivity growth of the Spanish Port System (SPS). The Malmquist Productivity Index (MPI) was estimated for the 28 Port Authorities of the SPS, for a 'non-crisis period' (2005–2008) and a 'crisis period' (2008–2011). From a policy perspective, the MPI is a very useful approach for assessing the productivity change because it can be decomposed into the catching-up index and the frontier productivity index. The results showed that the economic crisis did not impact all of the Spanish Port Authorities equally. Some Port Authorities presented higher productivity growth during the crisis period than in the non-crisis period. Further analysis

by the Mann–Whitney test revealed that Port Authority investments and productivity growth were statistically related. The findings illustrate that the economic crisis should not be seen as an international tragedy, but as an opportunity to adapt port traffics and installations to new needs and market demands.

However, in a developing country like Nigeria, Peter [19] focused on assessing the efficiency of six major Nigerian ports from 2007 to 2013 by applying a two-stage fuzzy-based methodology adequate to handle imprecise data. More precisely, fuzzy data envelopment analysis models for traditional assumptions with respect to scale returns were employed to assess the productivity of Nigerian ports over the course of time. In the second stage, fuzzy regressions based on different rule-based systems were used to predict the relationship of a set of contextual variables on port efficiency. These contextual variables are related to different aspects of port service level, berth utilization, accessibility, cargo type, and operator type. The results revealed the impact of operator and cargo type on efficiency levels. Policy implications for Nigerian ports are derived. Nwanosike, [10] applied a Malmquist Productivity Index (MPI) technique to benchmark pre-and post-reform total factor productivity growth of the six major Nigeria seaports namely Tin Can Island, Apapa, Calabar, Onne, Port Harcourt, and Warri for the periods (2000–2011) which represents six years before (2000–2005) and six years after (2006–2011) the reform. The results indicated progress in technical efficiency of the ports after reform but deterioration in technological progress. Overall productivity growth was higher in the pre-concession period compared to the post-concession period. Okeudo, [18] focused on the impact of reforms on port performance using Onne and Rivers ports in Nigeria as a reference point and she applied DEA to analyze the pre and post reform eras of the ports in terms of their performance for the period 2001 to 2010. Madueke, [25] applied DEA and OEE in analyzing the performance of Atlas Cove liquid bulk terminal and depot facility in Nigeria by benchmarking efficiency and productivity levels of the facility. Onwuegbuchunam, [17] applied Stochastic Frontier Analysis model in assessing the productivity and efficiency of Nigeria's seaports, the study revealed that total factor productivity of the port averages greater than 2.5 million tons per annum. In addition, capital input is statistically significant while labour input is insignificant in the port productivity. However, he suggested that DEA should be applied to incorporate multiple output variables. He also suggested the development of a hybrid model that can incorporate the advantages of SFA and DEA in seaport efficiency analysis.

A. S. Ogunsiji & O. O. Ogunsiji [1] explored the problems bedeviling the various efficiency measurement techniques of ports performance. They identified the Matching Framework Analysis (MFA) as the appropriate method for measuring performance and efficiency at the Nigeria ports, cognizant of disproportionate problems attendant to the simple operations there. The application of MFA, matched the identifiable problems to the three major configurations of environment, structure and strategy over a period six years (2001-2006) therefore making ground breaking recommendations that could plummet the driving capability of the port for economic growth and development.

The above references and more shows that DEA has been applied internationally but there is a gap on the Nigerian ports efficiency studies. There is a lack of assessment on Nigerian ports from multiple inputs and super multiple outputs standpoint which exists in the port complexes. This is the interest of the researcher. This study adopts Data Envelopment Analysis Model for this purpose, covering a period from 2012 to 2017. For further studies the application of different models in analyzing port efficiency for developing countries like Nigeria should be encouraged.

3. Methodology

In this study both deterministic and behavioral approaches were adopted. The approaches authenticate the data from the studied seaports as published by Nigerian Ports Authority. The data used for the study were secondary data gotten from the websites of Nigerian Ports Authority (NPA), NPA Bulletin and Handbook. Some of the data were reconfirmed by direct observation and random questions to cargo surveyors and vessel pilots. The secondary data comprises the following input variables; Quay Length, Number of Berth, Total Port Area, and Access Channel Draft, while the output variables used were Ship Traffic, Cargo Throughput, and GRT Ocean going. These data were collected for a seven-year period from 2012 to 2017.

3.1.1. Model specification

For the analysis of data the following statistical models were applied to assess and answer the research questions namely; Data Envelopment Analysis Model, Generalized Linear Model, and Multivariate Analysis Techniques.

3.1.2. Data Envelopment Analysis (DEA)

Data Envelopment Analysis is a non-parametric model for measuring the efficiency of Decision Making Units (DMU) with multiple inputs and or multiple outputs. Charnes, [4] first introduced the DEA as a multi-factor productivity analysis module for measuring the relative efficiencies of DMUs. The DEA analysis shows how inputs and output have

to be changed in order to maximize the efficiency levels of the target DMU. DEA is used in this study because of its suitability in analyzing efficiency of transit services such as seaports.

DEA as developed by Charnes, [4] explain that suppose we have a set of n peers DMUs which produces multiple output vector Y by using observed multiple input vector X respectively.

Where,

X= input vector used in the DMUs.

Y= output vector produced by DMUs.

Є is a constant non Archimedean (infinitesimal of the order of 10-6) that insures no input or output is given a zero weight s+ and s- is the slack vectors for output and input respectively

θ=represents the proportional reduction of the input in relation to the amount of the projected input. The optimal value of λ forms a composite unit outperforming the DMU under analysis and providing targets for this DMU to identify sources of its inefficiency. This model is known as input-oriented BCC, the initial being in recognition of its formulators and users [2, 3, 5, and 6]

Then the production possibility set will be defined as follows in relation to this study:

Thus:

F= {(Y, X)/X can produce Y}

As cited by [20]

Where in this study n=Lagos Port Complex(LPC), Tin Can Island Port(TCP), Rivers Port Complex(RPC),Onne Port Complex(OPC),Calabar Port(CP), Delta Port complex(DPC)

Y= Quay Length (QL), Number of Berth (Berths), Total Port Area (TPA), and Access Channel Draft (ACD)

X= Ship Traffic (ST), Cargo Throughput (CTP), GRT Ocean Going (GOG),

According to Cooper [5], the performance of a DMU is efficient if and only if it is not possible to improve any input or output without worsening any other input or output, while the performance of a DMU is inefficient if and only if it is possible to improve some input or output without worsening some other input and output. (Pareto-Koopmans Definition of Efficiency)

Hence, DEA model is a linear programming model applied on the input-output variables to empirically or quantitatively estimate the technical and scale efficiency of all the 6 Nigerian seaports for a 6 years period, using 36 industrial-years as the decision making units (DMUs). These will determine the level of inefficiency plus the input/output slack that would have been needed to make them efficient. The efficiency scores were computed using an Open Access R-Statistical Software version 3.4 designed by The R Foundation for Statistical Computing (2018). The analysis were done both under constant return to scale (CRS) and variable return to scale (VRS) so as to determine first the Technical Efficiency (TE) as well as the extent to which scale of operation affected port performance (i.e. scale efficiency). Efficiency of DMUs range between 0 and 1, and any unit that has a score of unity (1) is considered efficient, while those DMUs with less than 1 (unity) are considered inefficient.

Further focus was on how to highlight associated input/output slack among the DMUs or various industrial-years. This will enable managements to determine necessary adjustment for input/output mix to achieve efficient performance.

3.1.3. Generalized Linear Model

The generalized linear model (GLM) is a flexible generalization of ordinary linear regression that allows for response variables that have error distribution models other than a normal distribution. The GLM generalizes linear regression by allowing the linear model to be related to the response variable via a *link function* and by allowing the magnitude of the variance of each measurement to be a function of its predicted value. Generalized linear models were formulated

by John Nelder and Robert Wedderburn as a way of unifying various other statistical models, including linear regression, logistic regression and Poisson regression. They proposed an iteratively reweighted least squares method for maximum likelihood estimation of the model parameters. Maximum-likelihood estimation remains popular and is the default method on many statistical computing packages. Other approaches, including Bayesian approaches and least squares fits to variance stabilized responses, have been developed.

The Generalized Linear model is a family of linear model that is applied when the dependent variable of a regression model is not normally distributed. It uses appropriate link functions depending on the nature of the dependent variable. Here we will adopt normal regression model (Linear regression model), Gamma Regression Model and Inverse Gaussian regression model with identity link.

A general linear model is given by:

$$\phi(i) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_n X_n + \varepsilon_i$$

Where,

$\phi(i)$ - is the link function of the dependent variable, here the output variables.

X_i^s - ith independent variables (here the input variables)

β_i^s - regression coefficients

ε_i - error component.

3.1.4. Multivariate Analysis Techniques

Multivariate analysis (MVA) techniques allow more than two variables to be analyzed at once. Two general types of MVA technique are Analysis of dependence and Analysis of interdependence. Many statistical techniques focus on just one or two variables. Multivariate analysis (MVA) techniques allow more than two variables to be analyzed at once. The ultimate goal of these analyses is either explanation or prediction, i.e., more than just establishing an association.

The four common test statistics for multivariate test are given thus:

$$\text{Pillai (V)} = \sum_{i=1}^{s} \frac{\lambda_i}{1 + \lambda_i} \tag{1}$$

$$\text{LawLey-Hotellings (U)} = \sum_{i=1}^{s} \lambda_i \tag{2}$$

$$\text{Wilks's Lambda } \Lambda = \prod_{i=1}^{s} \frac{1}{1 + \lambda_i} \tag{3}$$

$$\text{Roy's Largest Root } \theta = \frac{\lambda_1}{1 + \lambda_1} \tag{4}$$

Where, λ is the Eigen values from the product of covariance matrices of the sum of squares of error and due to fit of the model.

3.2. Data presentation and interpretation

Table 2 Input and Output Data Used For the Study of 6 Nigerian Ports

SN	JETTIES	YEAR	QL	BERTHS	TPA	ACD	CTP	ST	GOG
1	LP	2012	2537	21	200	13.5	19951807	1445	32072798
		2013	2537	21	200	13.5	20437369	1510	34189172
		2014	2537	21	200	13.5	20645269	1503	37046879
		2015	2537	21	200	13.5	20250771	1410	36290502
		2016	2537	21	200	13.5	19055385	1194	33612421
		2017	2537	21	200	13.5	19099690	1154	31932784
2	TCP	2012	3396	13	157.808	14	15268897	1508	32636886
		2013	3396	13	157.808	14	16134153	1615	40096754
		2014	3396	13	157.808	14	17500804	1692	47231548
		2015	3396	13	157.808	14	16407133	1656	45864565
		2016	3396	13	157.808	14	15648919	1559	45229402
		2017	3396	13	157.808	14	15464385	1350	41477915
3	RP	2012	704	8	58	9.5	5574653	499	7210520
		2013	704	8	58	9.5	4935944	439	6207092
		2014	704	8	58	9.5	6225008	435	6632480
		2015	704	8	58	9.5	4457785	373	5423002
		2016	704	8	58	9.5	3574235	319	4951913
		2017	704	8	58	9.5	3536873	309	5277722
4	OP	2012	5172	16	2638.199	11	27580642	859	42910262
		2013	5172	16	2638.199	11	24773387	823	38612995
		2014	5172	16	2638.199	11	27968861	847	45543000
		2015	5172	16	2638.199	11	26314828	741	44053589
		2016	5172	16	2638.199	11	23434241	659	40091365
		2017	5172	16	2638.199	11	26049226	671	42818946
5	CP	2012	174	7	88	6.4	6987533	615	2767531
		2013	174	7	88	6.4	10361746	609	2834884
		2014	174	7	88	6.4	10199169	603	4008361
		2015	174	7	88	6.4	7829862	528	3796652
		2016	174	7	88	6.4	6836616	438	4207733
		2017	174	7	88	6.4	5197773	448	3880058
6	DP	2012	572	25	352.67	5.9	1723195	159	3220686
		2013	572	25	352.67	5.9	1732286	373	8667160
		2014	572	25	352.67	5.9	2361477	269	7860797
		2015	572	25	352.67	5.9	2127259	306	5822393
		2016	572	25	352.67	5.9	2329984	453	6120242
		2017	572	25	352.67	5.9	2187689	403	6182396

Source: Researcher's summary from [16].

4. Results

Table 3 Input and output Slack for DEA under Variable Return to Scale Model

DMU Name	TEvrs	RTS	Actual Input Variables				Input Target				Input Slack			
			QL	Berths	TPA	ACD	QL	Berths	TPA	ACD	QL	Berths	TPA	ACD
LP2012	0.96	IRS	2537	21	200	14	2436	20	192	13	101	1	8	1
LP2013	0.99	IRS	2537	21	200	14	2512	21	198	14	25	0	2	0
LP2014	1.00	CRS	2537	21	200	14	2537	21	200	14	0	0	0	0
LP2015	0.98	DRS	2537	21	200	14	2486	21	196	14	51	0	4	0
LP2016	0.92	DRS	2537	21	200	14	2334	19	184	13	203	2	16	1
LP2017	0.91	IRS	2537	21	200	14	2309	19	182	13	228	2	18	1
TCP2012	0.89	DRS	3396	13	158	14	3022	12	141	12	374	1	17	2
TCP2013	0.95	DRS	3396	13	158	14	3226	12	150	13	170	1	8	1
TCP2014	1.00	CRS	3396	13	158	14	3396	13	158	14	0	0	0	0
TCP2015	0.98	DRS	3396	13	158	14	3328	13	155	14	68	0	3	0
TCP2016	0.96	DRS	3396	13	158	14	3260	12	152	13	136	1	6	1
TCP2017	0.88	DRS	3396	13	158	14	2988	11	139	12	408	2	19	2
RP2012	0.96	DRS	704	8	58	10	676	8	56	10	28	0	2	0
RP2013	0.85	DRS	704	8	58	10	598	7	49	9	106	1	9	2
RP2014	0.93	DRS	704	8	58	10	655	7	54	9	49	1	4	1
RP2015	0.72	DRS	704	8	58	10	507	6	42	7	197	2	16	3
RP2016	0.62	DRS	704	8	58	10	436	5	36	6	268	3	22	4
RP2017	0.60	DRS	704	8	58	10	422	5	35	6	282	3	23	4
OP2012	0.99	DRS	5172	16	2638199	11	5120	16	2611817	11	52	0	26382	0
OP2013	0.93	DRS	5172	16	2638199	11	4810	15	2453525	10	362	1	184674	1
OP2014	1.00	CRS	5172	16	2638199	11	5172	16	2638199	11	0	0	0	0
OP2015	0.97	DRS	5172	16	2638199	11	5017	16	2559053	11	155	0	79146	0
OP2016	0.88	DRS	5172	16	2638199	11	4551	14	2321615	10	621	2	316584	1
OP2017	0.94	DRS	5172	16	2638199	11	4862	15	2479907	10	310	1	158292	1
CP2012	1.00	CRS	174	7	88	6	174	7	88	6	0	0	0	0
CP2013	1.00	CRS	174	7	88	6	174	7	88	6	0	0	0	0
CP2014	1.00	CRS	174	7	88	6	174	7	88	6	0	0	0	0
CP2015	0.94	DRS	174	7	88	6	164	7	83	6	10	0	5	0
CP2016	1.00	CRS	174	7	88	6	174	7	88	6	0	0	0	0
CP2017	0.93	DRS	174	7	88	6	162	7	82	6	12	0	6	0
DP2012	0.35	DRS	572	25	353	6	200	9	124	2	372	16	229	4
DP2013	0.93	DRS	572	26	353	6	532	24	328	6	40	2	25	0
DP2014	0.85	DRS	572	27	353	6	486	23	300	5	86	4	53	1
DP2015	0.63	DRS	572	28	353	6	360	18	222	4	212	10	131	2
DP2016	0.703	DRS	572	29	353	6	402	20	248	4	170	9	105	2
DP2017	0.67	DRS	572	30	353	6	383	20	237	4	189	10	116	2

Table 3 cont Input and Output Slack for DEA under Constant Return to Scale Model

DMU Name	TEvrs	Actual Output Variables			Output Target			Output Slack			Benchmark
		CTP	ST	GOG	CTP	ST	GOG	CTP	ST	GOG	
LP2012	0.96	19951807	1445	32072798	19153735	1387	30789886	798072	58	1282912	LP2014
LP2013	0.99	20437369	1510	34189172	20232995	1495	33847280	204374	15	341892	LP2014
LP2014	1.00	20645269	1503	37046879	20645269	1503	37046879	0	0	0	LP2014
LP2015	0.98	20250771	1410	36290502	19845756	1382	35564692	405015	28	725810	LP2014
LP2016	0.92	19055385	1194	33612421	17530954	1098	30923427	1524431	96	2688994	LP2014
LP2017	0.91	19099690	1154	31932784	17380718	1050	29058833	1718972	104	2873951	LP2014
TCP2012	0.89	15268897	1508	32636886	13589318	1342	29046829	1679579	166	3590057	TCP2014
TCP2013	0.95	16134153	1615	40096754	15327445	1534	38091916	806708	81	2004838	TCP2014
TCP2014	1.00	17500804	1692	47231548	17500804	1692	47231548	0	0	0	TCP2014
TCP2015	0.98	16407133	1656	45864565	16078990	1623	44947274	328143	33	917291	TCP2014
TCP2016	0.96	15648919	1559	45229402	15022962	1497	43420226	625957	62	1809176	TCP2014
TCP2017	0.88	15464385	1350	41477915	13608659	1188	36500565	1855726	162	4977350	TCP2014
RP2012	0.96	5574653	499	7210520	5351667	479	6922099	222986	20	288421	TCP2014
RP2013	0.85	4935944	439	6207092	4195552	373	5276028	740392	66	931064	TCP2014
RP2014	0.93	6225008	435	6632480	5789257	405	6168206	435751	30	464274	TCP2014
RP2015	0.72	4457785	373	5423002	3209605	269	3904561	1248180	104	1518441	TCP2014
RP2016	0.62	3574235	319	4951913	2216026	198	3070186	1358209	121	1881727	TCP2014
RP2017	0.60	3536873	309	5277722	2122124	185	3166633	1414749	124	2111089	TCP2014
OP2012	0.99	27580642	859	42910262	27304836	850	42481159	275806	9	429103	OP2014
OP2013	0.93	24773387	823	38612995	23039250	765	35910085	1734137	58	2702910	OP2014
OP2014	1.00	27968861	847	45543000	27968861	847	45543000	0	0	0	OP2014
OP2015	0.97	26314828	741	44053589	25525383	719	42731981	789445	22	1321608	OP2014
OP2016	0.88	23434241	659	40091365	20622132	580	35280401	2812109	79	4810964	OP2014
OP2017	0.94	26049226	671	42818946	24486272	631	40249809	1562954	40	2569137	OP2014
CP2012	1.00	6987533	615	2767531	6987533	615	2767531	0	0	0	CP2012
CP2013	1.00	10361746	609	2834884	10361746	609	2834884	0	0	0	CP2013
CP2014	1.00	10199169	603	4008361	10199169	603	4008361	0	0	0	CP2014
CP2015	0.94	7829862	528	3796652	7360070	496	3568853	469792	32	227799	CP2012
CP2016	1.00	6836616	438	4207733	6836616	438	4207733	0	0	0	CP2016
CP2017	0.93	5197773	448	3880058	4833929	417	3608454	363844	31	271604	CP2012
DP2012	0.35	1723195	159	3220686	603118	56	1127240	1120077	103	2093446	CP2012
DP2013	0.93	1732286	373	8667160	1611026	347	8060459	121260	26	606701	CP2012
DP2014	0.85	2361477	269	7860797	2007255	229	6681677	354222	40	1179120	CP2012
DP2015	0.63	2127259	306	5822393	1340173	193	3668108	787086	113	2154285	CP2012
DP2016	0.70	2329984	453	6120242	1637979	318	4302530	692005	135	1817712	CP2012
DP2017	0.67	2187689	403	6182396	1465752	270	4142205	721937	133	2040191	CP2012

Source: Results on efficiency using Open Access R-statistical Software Version 3.4

Table 4 Input and Output Slack for DEA under Variable Return to Scale Model

DMU Name	TEvrs	RTS	Actual Input Variables				Input Target				Input Slack			
			QL	Berths	TPA	ACD	QL	Berths	TPA	ACD	QL	Berths	TPA	ACD
LP2012	0.96	IRS	2537	21	200	14	2436	20	192	13	101	1	8	1
LP2013	1.00	CRS	2537	21	200	14	2537	21	200	14	0	0	0	0
LP2014	1.00	CRS	2537	21	200	14	2537	21	200	14	0	0	0	0
LP2015	0.98	DRS	2537	21	200	14	2486	21	196	14	51	0	4	0
LP2016	0.93	DRS	2537	21	200	14	2359	20	186	13	178	1	14	1
LP2017	0.92	IRS	2537	21	200	14	2334	19	184	13	203	2	16	1
TCP2012	0.92	DRS	3396	13	158	14	3124	12	145	13	272	1	13	1
TCP2013	0.97	DRS	3396	13	158	14	3294	13	153	14	102	0	5	0
TCP2014	1.00	CRS	3396	13	158	14	3396	13	158	14	0	0	0	0
TCP2015	0.99	DRS	3396	13	158	14	3362	13	156	14	34	0	2	0
TCP2016	0.98	DRS	3396	13	158	14	3328	13	155	14	68	0	3	0
TCP2017	1.00	CRS	3396	13	158	14	3396	13	158	14	0	0	0	0
RP2012	1.00	CRS	704	8	58	10	704	8	58	10	0	0	0	0
RP2013	1.00	CRS	704	8	58	10	704	8	58	10	0	0	0	0
RP2014	1.00	CRS	704	8	58	10	704	8	58	10	0	0	0	0
RP2015	1.00	CRS	704	8	58	10	704	8	58	10	0	0	0	0
RP2016	1.00	CRS	704	8	58	10	704	8	58	10	0	0	0	0
RP2017	0.99	DRS	704	8	58	10	697	8	57	10	7	0	1	0
OP2012	0.93	DRS	5172	16	2638199	11	4810	15	2453525	10	362	1	184674	1
OP2013	1.00	CRS	5172	16	2638199	11	5172	16	2638199	11	0	0	0	0
OP2014	0.98	CRS	5172	16	2638199	11	5069	16	2585435	11	103	0	52764	0
OP2015	0.94	DRS	5172	16	2638199	11	4862	15	2479907	10	310	1	158292	1
OP2016	0.97	DRS	5172	16	2638199	11	5017	16	2559053	11	155	0	79146	0
OP2017	1.00	CRS	5172	16	2638199	11	5172	16	2638199	11	0	0	0	0
CP2012	1.00	CRS	174	7	88	6	174	7	88	6	0	0	0	0
CP2013	1.00	CRS	174	7	88	6	174	7	88	6	0	0	0	0
CP2014	1.00	CRS	174	7	88	6	174	7	88	6	0	0	0	0
CP2015	1.00	CRS	174	7	88	6	174	7	88	6	0	0	0	0
CP2016	1.00	CRS	174	7	88	6	174	7	88	6	0	0	0	0
CP2017	1.00	CRS	174	7	88	6	174	7	88	6	0	0	0	0
DP2012	1.00	CRS	572	25	353	6	572	25	353	6	0	0	0	0
DP2013	1.00	CRS	572	26	353	6	572	26	353	6	0	0	0	0
DP2014	1.00	CRS	572	27	353	6	572	27	353	6	0	0	0	0
DP2015	1.00	CRS	572	28	353	6	572	28	353	6	0	0	0	0
DP2016	1.00	CRS	572	29	353	6	572	29	353	6	0	0	0	0
DP2017	1.00	CRS	572	30	353	6	572	30	353	6	0	0	0	0

Source: Result on efficiency using Open Access R-statistical Software version 3.4

Table 4 cont Input and Output Slack for DEA under Variable Return to Scale Model

DMU Name	TEvrs	Actual Output Variables			Output Target			Output Slack			Benchmark
		CTP	ST	GOG	CTP	ST	GOG	CTP	ST	GOG	
LP2012	0.96	19951807	1445	32072798	19153735	1387	30789886	798072	58	1282912	LP2013
LP2013	1.00	20437369	1510	34189172	20437369	1510	34189172	0	0	0	LP2013
LP2014	1.00	20645269	1503	37046879	20645269	1503	37046879	0	0	0	LP2014
LP2015	0.98	20250771	1410	36290502	19845756	1382	35564692	405015	28	725810	LP2013
LP2016	0.93	19055385	1194	33612421	17721508	1110	31259552	1333877	84	2352869	LP2013
LP2017	0.92	19099690	1154	31932784	17571715	1062	29378161	1527975	92	2554623	LP2013
TCP2012	0.92	15268897	1508	32636886	14047385	1387	30025935	1221512	121	2610951	TCP2014
TCP2013	0.97	16134153	1615	40096754	15650128	1567	38893851	484025	48	1202903	TCP2014
TCP2014	1.00	17500804	1692	47231548	17500804	1692	47231548	0	0	0	TCP2014
TCP2015	0.99	16407133	1656	45864565	16243062	1639	45405919	164071	17	458646	TCP2014
TCP2016	0.98	15648919	1559	45229402	15335941	1528	44324814	312978	31	904588	TCP2014
TCP2017	1.00	15464385	1350	41477915	15464385	1350	41477915	0	0	0	TCP2014
RP2012	1.00	5574653	499	7210520	5574653	499	7210520	0	0	0	TCP2017
RP2013	1.00	4935944	439	6207092	4935944	439	6207092	0	0	0	TCP2012
RP2014	1.00	6225008	435	6632480	6225008	435	6632480	0	0	0	TCP2013
RP2015	1.00	4457785	373	5423002	4457785	373	5423002	0	0	0	TCP2014
RP2016	1.00	3574235	319	4951913	3574235	319	4951913	0	0	0	TCP2016
RP2017	0.99	3536873	309	5277722	3501504	306	5224945	35369	3	52777	TCP2012
OP2012	0.93	27580642	859	42910262	25649997	799	39906544	1930645	60	3003718	OP2014
OP2013	1.00	24773387	823	38612995	24773387	823	38612995	0	0	0	OP2014
OP2014	0.98	27968861	847	45543000	27409484	830	44632140	559377	17	910860	OP2014
OP2015	0.94	26314828	741	44053589	24735938	697	41410374	1578890	44	2643215	OP2014
OP2016	0.97	23434241	659	40091365	22731214	639	38888624	703027	20	1202741	OP2014
OP2017	1.00	26049226	671	42818946	26049226	671	42818946	0	0	0	OP2014
CP2012	1.00	6987533	615	2767531	6987533	615	2767531	0	0	0	CPC2012
CP2013	1.00	10361746	609	2834884	10361746	609	2834884	0	0	0	CPC2013
CP2014	1.00	10199169	603	4008361	10199169	603	4008361	0	0	0	CPC2014
CP2015	1.00	7829862	528	3796652	7829862	528	3796652	0	0	0	CPC2012
CP2016	1.00	6836616	438	4207733	6836616	438	4207733	0	0	0	CPC2016
CP2017	1.00	5197773	448	3880058	5197773	448	3880058	0	0	0	CPC2012
DP2012	1.00	1723195	159	3220686	1723195	159	3220686	0	0	0	CPC2012
DP2013	1.00	1732286	373	8667160	1732286	373	8667160	0	0	0	CPC2012
DP2014	1.00	2361477	269	7860797	2361477	269	7860797	0	0	0	CPC2012
DP2015	1.00	2127259	306	5822393	2127259	306	5822393	0	0	0	CPC2012
DP2016	1.00	2329984	453	6120242	2329984	453	6120242	0	0	0	CPC2012
DP2017	1.00	2187689	403	6182396	2187689	403	6182396	0	0	0	CPC2012

Source: Result on efficiency using Open Access R-statistical Software version 3.4

Table 5 Generalized Linear Model of the Cargo Throughput (CTP) on Input Variables

Model Coefficient	Families of Generalized Linear Model		
	Normal	Gamma	Inverse Gaussian
Constant	-1476596.050 (0.678)	14901819.910 (0.000)	17034296.836 (0.000)
QL	2281.982 (0.085)	9778.846 (0.000)	11075.353 (0.000)
Berths	-39058.687 (0.634)	-368306.103 (0.000)	-390745.074 (0.000)
TPA	2.500 (0.159)	-7.330 (0.030)	-9.060 (0.046)
ACD	883898.757 (0.056)	-1293427.917 (0.018)	-1649666.133 (0.002)

Source: Analytical result from the application of SPSS Version 20

Table 6 Generalized Linear Model of the Ship Traffic (ST) on Input Variables

Model Coefficient	Families of Generalized Linear Model		
	Normal	Gamma	Inverse Gaussian
Constant	428.349 (0.013)	1096.260 (0.000)	1245.414 (0.000)
QL	0.437 (0.000)	0.729 (0.000)	0.814 (0.000)
Berths	-6.901 (0.083)	-19.493 (0.000)	-21.787 (0.000)
TPA	-0.001 (0.000)	-0.001 (0.000)	-0.001 (0.000)
ACD	-12.942 (0.564)	-101.520 (0.000)	-123.232 (0.000)

Source: Analytical result from the application of SPSS Version 20

Table 7 Generalized Linear Model of the GRT Ocean Going (GOG) on Input Variables

Model Coefficient	Families of Generalized Linear Model		
	Normal	Gamma	Inverse Gaussian
Constant	-230516.531 (0.943)	11948686.515 (0.000)	
QL	13194.771 (0.000)	18119.141 (0.000)	
Berths	29412.871 (0.693)	-205224.740 (0.000)	Could not Fit the Data
TPA	-9.378 (0.000)	-15.702 (0.000)	
ACD	-127617.884 (0.761)	-1692182.290 (0.000)	

Source: Analytical result from the application of SPSS Version 20

Table 8 Multivariate Analysis of the Effect of Input Variables on output Variables

Model Coefficient	Pillai's Trace	Wilks' Lambda	Hotelling's Trace	Roy's Largest Root	F	p-value
Constant	0.46	0.54	0.851	0.851	8.22	0.000
QL	0.862	0.138	6.269	6.269	60.60	0.000
Berths	0.195	0.805	0.242	0.242	2.34	0.094
TPA	0.894	0.106	8.392	8.392	81.11	0.000
ACD	0.389	0.611	0.638	0.638	6.16	0.002

Source: Analytical result from the application of SPSS Version 20

5. Discussion

Table3 is the DEA results of the ports under study when Constant Return to Scale is considered. The result is on the year, technical efficiency of each port, the return to scale status, the input target, output target, input slack and output slack. The efficiency value 1 shows that the port performed very efficiently with best input mix. The further the value of efficiency is from 1, the poorer the performance of that port in that particular year.

The result in table3 shows that the least efficient year/port was Delta Port (DP) in 2012 with efficiency value 0.35. On the average, Calabar Port (CP) was the most efficient port within the years under review.

For the Return to Scales, we have three classes:

Constant Return to Scale (CRS) which are those with efficiency 1 and input variables equals input targets, i.e. zero slack variables.

Increase Return to Scale (IRS) which deals with port that requires some changes in input mix. Here decrease is required on the input variables for the output to be optimum. This return to scale depicts excess or waste of input resources.

Decrease Return to Scale (DRS), this is the direct opposite of IRS. More input variables are needed to achieve optimum output.

On the slack variables, the slack values greater than zero signifies the input variables either to be added/remove depending return to scale.

Table3 is equivalent of the Table4 except that it is on Variable Return to Scale. Every other information remains the same but with consideration to variable return to scale.

However, a test for fitness of both indicated that the constant return to scale is more appropriate for the study data. We recommend that inference be based on that.

Table5i is on the generalized linear model of an output variable Cargo Throughput (CTP) on the input variables. This linear model enabled the researcher to evaluate the effect of each input variables on CTP. The families of the Generalized Linear model adopted because of the nature of the study data are Normal (Linear Regression model), Gamma regression model and Inverse Gaussian regression model. The result showed that the Gamma and Inverse regression model best fitted the data set with each coefficient significant ($p < 0.05$). The coefficients are interpreted thus using Gamma regression model:

The value of the coefficient of Quay Length (QL) equals 9778.846 which imply an increase in QL will lead to increase in Cargo Throughput (CTP) by about 9779 when other input variables are held constant.

The value of the coefficient of Berths equals -368306.103 which implies an increase in the number of Berths by one will lead to a decrease in Cargo Throughput (CTP) by about 368306 when other input variables remain unchanged.

The value of the coefficient of Total Port Area (TPA) equals -7.330, indicates that when every other input variables in the model are held constant, that an increase in TPA by one unit will lead to a decrease in Cargo Throughput (CTP) by about 7.

The value of the coefficient of Access Channel Depth (ACD) equals -1293427.9 indicate that when every other input variables in the model are held constant, an increase in ACD by one unit will lead to a decrease in Cargo Throughput (CTP) by about 1293428.

Table5ii is on the generalized linear model of an output variable Ship Traffic (ST) on the input variables. This linear model enabled the researcher to evaluate the effect of each input variables on Ship Traffic (ST). The families of the Generalized Linear model adopted because of the nature of the study data are Normal (Linear Regression model), Gamma Regression Model and Inverse Gaussian Regression Model. The result showed that the Gamma and Inverse regression model best fitted the data set with each coefficient significant ($p < 0.05$). The coefficients are interpreted thus using Gamma regression model:

The value of the coefficient of Quay Length (QL) equals 0.729 which implies that an increase in QL will lead to increase in Ship Traffic (ST) by about .729 when other input variables are held constant.

The value of the coefficient of Berths equals -19.493 which implies an increase in the number of Berths by one will lead to a decrease in Ship Traffic (ST) by about 19.493 when other input variables remain unchanged.

The value of the coefficient of Total Port Area (TPA) equals -0.001, which indicates that when every other input variable in the model are held constant that an increase in TPA by one unit will lead to a decrease in Ship Traffic (ST) by about 0.001.

The value of the coefficient of Access Channel Depth (ACD) equals -101.520 which indicates that when every other input variables in the model are held constant, an increase in ACD by one unit will lead to a decrease in Ship Traffic (ST) by about 101.520.

Table5iii is on the generalized linear model of an output variable Gross Registered Tonnage Ocean Going (GOG) on the input variables. This linear model enabled the researcher to evaluate the effect of each input variables on Gross Registered Tonnage Ocean Going (GOG). The families of the Generalized Linear model adopted because of the nature of the study data are Normal (Linear Regression model), Gamma regression model and Inverse Gaussian regression model. The result showed that the Gamma and Inverse regression model best fitted the data set with each coefficient significant ($p < 0.05$). The coefficients are interpreted thus using Gamma regression model:

The value of the coefficient of Quay Length (QL) equals 18119.141 which imply that an increase in QL will lead to increase in Gross Registered Tonnage Ocean Going (GOG) by about 18119 when other input variables are held constant.

The value of the coefficient of Berths equals -205224.740 which implies an increase in the number of Berths by one will lead to a decrease in Gross Registered Tonnage Ocean Going (GOG) by about 205224 when other input variables remain unchanged.

The value of the coefficient of Total Port Area (TPA) equals -15.702, indicates that when every other input variables in the model are held constant, that an increase in TPA by one unit will lead to a decrease in Gross Registered Tonnage Ocean Going (GOG) by about 15.

The value of the coefficient of Access Channel Depth(ACD) equals -1692182.290 indicate that when every other input variables in the model are held constant, an increase in ACD by one unit will lead to a decrease in Gross Registered Tonnage Ocean Going(GOG) by about 1692182.

Table 6 is the multivariate analysis of the relationship between the input variables and output variables. The result is unlike the univariate test in tables 5i to 5iii above. Multivariate analysis is when the effect of the input variables is measured on all the output variables simultaneously. The test statistics for the multivariate relationship measure are as listed in Table 6 above.

From the result of the analysis, it could be seen that the coefficient of QL, TPA and ACD are significant ($p < 0.05$) while Berths are not. This suggests that when all the output variables are considered simultaneously with all the input variables, under consideration there is a significant relationship on them except the Berths.

6. Conclusion

This study has assessed the performance of six Nigeria's seaports using four input variables namely Quay Length (QL), Number of Berths (Berths), Total Port Area (TPA),Access Channel Depth (ACD), and three output variables namely Cargo Throughput (CTP), Ship Traffic (ST), and Gross Registered Tonnage Ocean Going (GOG). The Open Access R-statistical Software Version 3.4was employed to solve the relative efficiencies and benchmarking of the 6 Nigeria's seaports. The SPSS version 20 was also employed to analyze the significance and effect of the input variables and the output variables simultaneously. In answering the following research questions;

How significant is the relationship between the input and output variables used in this study?

Based on the result of the regression models in tables 5i to 5iii and multivariate analysis in table 6, the input variables has a significant relationship with output variables.

How has the seaports performed in Nigeria over the study period?

Based on the result of the DEA in tables 3 and 4, using constant return to scale, the following Seaports performed most efficiently: Lagos Port (LP) in 2014, Tin Can Island Port (TCP) in 2014, Onne Port (OP) in 2014, and Calabar Port (CP) from 2012 to 2014 and 2016. The least performed seaport is Delta Port (DP) in 2012. It is clear that the most efficient port over the year under study is Calabar Port (CP) while least performed port is Delta Port (DP).

How best can the individual seaports operate optimally based on their respective input mix?

The individual port can operate optimally by putting into consideration the values of the input and output slacks on table 3 and 4.

Which seaport could serve as a benchmark to other ports in Nigeria?

Calabar Port (CP) port can serve as Benchmark seaport within the year under review because Calabar Port (CP) from 2012 to 2014 and 2016 showed the highest number of efficiencies.

Test of Hypothesis

Ho: There is no significant relationship between the input variables and the output variables.

Based on the result of the regression model as well as the multivariate analysis in tables 5i, to 6, we reject the null hypothesis and state that at 5% level of significance that there is a significant ($p<0.05$) relationship between the input variables and output variables.

Recommendations

The study has shown that the performance of Calabar port is most efficient than other ports. This could be as a result of the ease of cargo movement into and out of the port. For Calabar seaport to be this efficient, the hinterland road networks are devoid of chronic vehicular congestions which would have hindered the smooth evacuation of goods in and out of the state. Though, Calabar seaport has smaller size of input variables when compared to some other ports in this study which could be the reason for its efficiency, therefore more cargo should be routed to other ports to enhance their optimality also.

The Nigeria's seaports enjoyed a boom in 2014 as shown in the study, which could connote that the volume of trade between Nigeria and other counties was high. This also means that there was growth in the revenue base of Nigerian Ports Authority and by extension the Nigeria economy.

The statistical prove of the significance and importance of quay length variable in seaports over other input variables such as (Number of Berths, Access Channel Depth, Total Port Area) as applied in this study, have also shown that in the course of prioritizing investment in the ports, the quay length should be considered as paramount in the development of any new port and expansion of old ports because of its positive impacts on the output variables (Ship Traffic, Cargo Throughput, and Gross Registered Tonnage Ocean Going) as used in this study. Though further empirical tests in this research shows that Quay length, Total Port Area, and Access Channel Depth have effect on the output variable while number of berths has little or no effect statistically.

Compliance with ethical standards

Disclosure of conflict of interest

There is no conflict of interest.

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