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Stochastic Frontier Analysis of Selected Nigerian Seaports Container Throughput's Efficiency

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Abstract: This paper measures economic efficiency of container throughputs with the aid of input-output efficiency ratio of selected terminals across Nigerian seaports. Productivity of a terminal does not equal to its efficiency. Different efficiencies like allocative and technical characterized economic efficiency of a port system. Overall economic efficiency means there is no delay at the port in processing container as all ship, labour and machines are optimally utilized. This research determined the overall efficiencies of container throughputs Apapa, Warri, Onne, Calabal and Tin Can Island using secondary data (2012-2022) from Nigerian Bureau of Statistics on container cargo throughputs in Nigeria. Total container outputs in (Tonnes) from different terminals with their corresponding inputs variables from number of ship per annum, cranes used and the dock workers net gang hour (ngh) were aggregated together in form of input-output ratio and arrived at each port's level of overall economic efficiency. The analysis was executed with the aid of R using Stochastic Frontier Analysis (SFA) for each termina/seaport collected data. It was found from the results that; terminals at Onne are most efficient followed by Calabar. Tin can Island terminal efficiency was a slightly higher than that of Apapa as both had a little above average mean efficiency value. Warri terminals are the least while Rivers was not considered for unavailability of data. There may be other unexplained factors causing inefficiencies of mostly Apapa, Tin Can and Warri seaports not explained but can be investigated in future research.

Keywords: Efficiency, Nigerian, stochastic, seaports, terminal, container

1. Introduction

The use of container to majorly import items into Nigeria is increasing on yearly basis because of cargo consolidation, shipping cost and ease of movement in multimodal transport systems [1]. Except with the development of Lekki deep seaport, the Lagos Port Complex which comprises Apapa seaport and Tin Can Island seaports with all terminals surrounding them is not operating efficiently in a manner that can enhance economic development of Nigeria. Ref [2] gave account of capacity challenges at the Nigerian seaports over the years as with increasing number of ships and container traffic. Efficient transport system occurs when there is optimization of all variables in the seaport and is put into use to achieve maximum output of cargo exiting or coming into the port. There is no adequate space for movement and storage at Nigerian various ports and consequently, there used to be disorderliness in freight logistics especially at Apapa and Tin Can Island ports, Lagos. According to [3] the most significant problem causing inefficient port and terminal system in the Eastern part of Nigeria is as a result of inappropriate cargo management. Some of the challenges of inefficient terminals and seaports are enumerated in the following types of congestion militating against African seaport logistics as follows:

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a) The entry for ship and its exit congestion: This happens when is impediment or blockage to the access the port by the vessel/ship. This type of scenario was witnessed in the 1970s in Nigeria “Cement Amanda” where the country had to pay for demurrage for loaded vessel on water for inability to offload.
b) Cargo Stack congestion: when the cargo that are supposed to be in storage area is more than required or the goods or cargo has exceeded the permissible number of days, hours or week of stay.
c) Vehicle work congestion: This is accruable to either lack of capability or efficiency on the dock workers loading/unloading or lack or inadequacy of equipment to facilitate the process.
d) Vehicle gate congestion: This arises from the poor scheduling and gate access management at the port which resultant effects usually culminated in congestion
e) Ship berth congestion: When the ships arriving the ports are notified to queue as there is no available berthing space for them and the resultant effect is congestion.
f) Ship work congestion: This is usually the situation where cargo has to be checked and probably stopped the process mid-way and elongates the total time to be spent at the port.

In the assessment of various African ports’ logistics, Durban in Southern Africa is closer in logistics services to European counterparts, and in all honesty, this port and similarly that of Mombasa in Kenya (which is servicing landlocked countries like Uganda, South Sudan, republic of Congo, Rwanda and Burundi) had been adjudged to be the best in logistical performance and are run by the government authorities through TRANSNET [1]. Drastically these ports have been able to reduce dwell times at the port occasioned by penalties and stringent enforcement with cooperation among the relevant agencies. Two major initiatives have been developed to guarantee Nigerian seaport and terminal efficiency but hitherto have not produced significant results. The first was the development of Inland Container depots across geopolitical zones [4] and the second was the introduction of Electronic Truck Order (ETO). Using Analytical Hierarchical Process (AHP) [5] categorized causes of congestion in Apapa port and terminals into: physical infrastructure, documentation, port operation and organization or management. There are other twenty-four factors derived from the four major categorizations. Ref [6] expressed that, the demand for port facility is above the supply, berth allocation, obsolete equipment and improper supply chain network management.

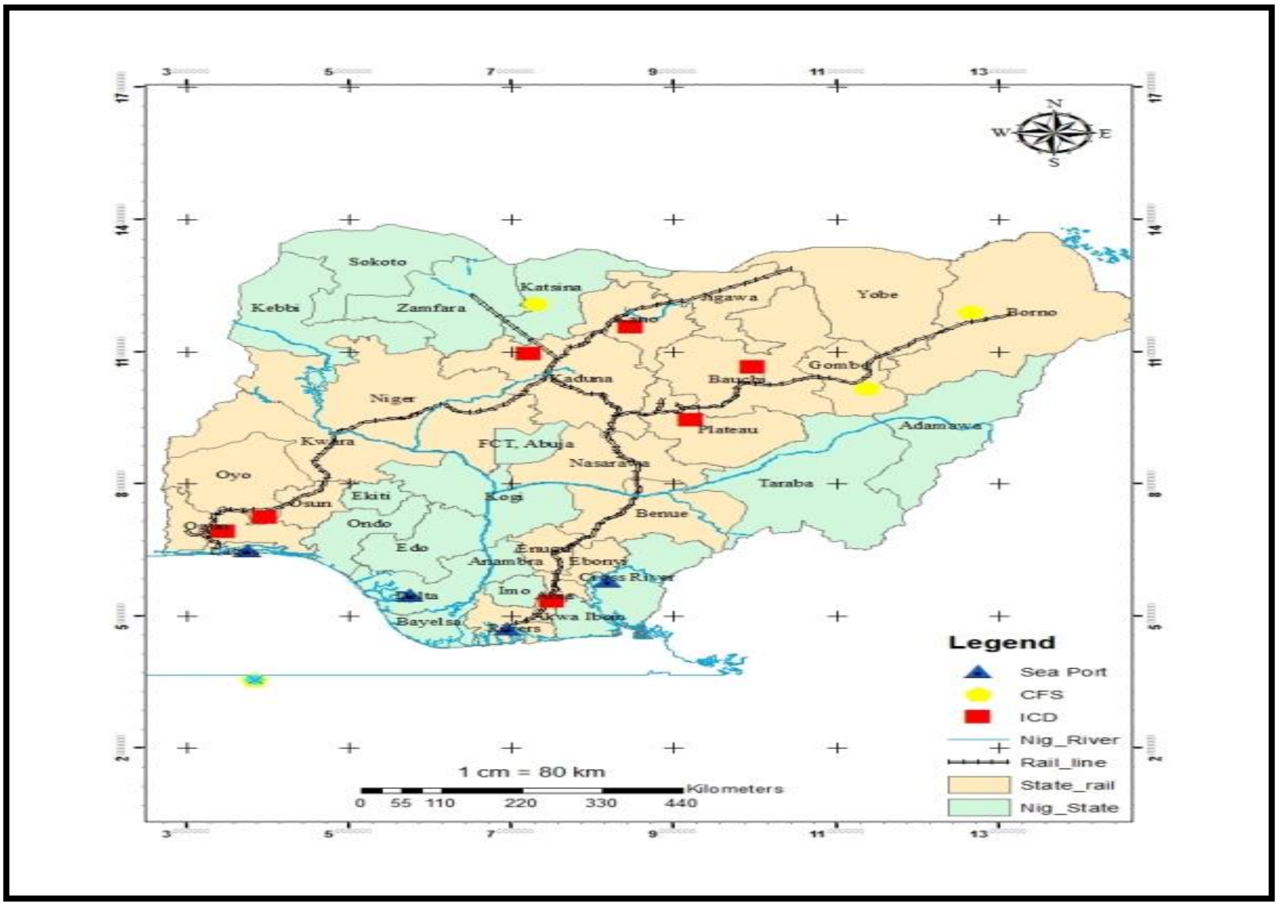

Fig. 1 - Major Seaports in Nigeria, with ICDs (Inland Container Depots) and CFSs (Container Freight Stations)

Ref [4] expressed that, challenges of land availability in port or terminal area and increase in volume of containers used to result in high cost of shipping, congestion and decline of Nigerian ports among others. There is also the issue of political intention going divergent with logistics principles. Logistics principle of intermodal transport is about sharing the volume of carriage according to the strength of modes involved and in a complementing and not competing manner. Violation of logistics network principle of shortest distance carriage to be by truck or shuttle train for liquid, containerized, general cargo movements in densely populated areas like port will always results in congestion. According to [7] a new method or solution has been developed for the purpose of measuring Container Port Performance Index (CPPI). The technical report observed areas of shortcomings and made as a reference point for improvements for all concerned agencies, movement and stakeholders on key areas of focus in port performance metrics. The major seaports of focus because all containers terminals operating in Nigeria are within the cargo throughputs of the five seaports of Onne, Calabar, Warri, Apapa and Tin Can Island as shown in Fig. 1.

Inland Container Depot can be described as a form of port that is located on the dry land (hinterland) to handle containers instead of handling them at the seaport. Often times in intermodal connectivity rail transport are suitable from the seaport of container depots to the hinterland. Container Freight Station is slightly different from ICD because it is located very close to harbor or seaport to facilitate the movement of goods also. It is mostly used as the warehouse to consolidate Less-than-container-load and assist in keeping goods for limited period of time.

Using Stochastic Frontier Analysis (SFA) as a measure of efficiency is to reveal the level of efficiency of each selected seaport with a view to providing interventions and corrective measures for optimal utilization of resources.

2. Concept of Seaport Efficiency and Logistics Theory

Ref [8] defined efficiency as the ratio of input against output in a system. Ref [9] opined that, efficiency can be technical, allocative or economical. Allocative efficiency is concerned with how all the inputs and in this case, the ships, labour and cargo handling equipment can be used optimally to generate an output. Secondly, introduction of technology especially through the input variables of manpower and machines or equipment onboard the vessel to yield outcome of greater output can also be termed as technical efficiency. Economic efficiency is derived from the optimization of both the technical and allocative efficiencies. Technical efficiency is examining the relationships between input and output based on what can be regarded as frontier curve. Cost implication of output is one of the major concerns when technical efficiency is to be achieved. Therefore, the reason for allocative efficiency which measures cost and benefit ratio. Ref [10] opined that, the external traffic situation around the port used to cause internal problem of inefficiency in the face of uncontrolled traffic with all activities in port operations regarding loading and loading of cargoes. Ref [1] expressed that; the issue of parking and concept of parking with attendant trucks around the seaport using same route as entry and exit are to be critically looked into in Nigerian seaport logistics management. The clustering of industrial and commercial activities and tank firms operations For instance, notable industries have been noted to be cited around seaports in Dubai, Yokohama, Antwerp, Hamburg, Huston, Marseilles, e.t.c. However, the activities around the port in the long run if the port is highly progressive will hamper its logistics without proactive intermodal system. Ref [11] noted that, configuration of logistics network determines the efficiency in accessibility and connectivity of a port. Ref [12] maintained that, the concept of-efficiency in maritime can emanate from integration of activities with rail, road, inland waterways, airport and river services.

Ref [2] illustrated with a graph the concept of port efficiency using Labour (L) on the x axis and port throughput. The concept gave an overview of quantity of labour and its effect on the throughput of a port. Port and terminal production function with capital, labour and equipment as a variables determining the port production efficiency f*(k,L,e).*

$$LTC = Pk * k + bPL * L \tag{1}$$

LTC = Longrun Total Cost of a port
Pk=production function for capital
K= capital
b=coefficient of labour production function
PL=production function of Labour
L= Labour

The Equation (1) expressed by [2] to depict the long-run total cost of port throughput using capital and labour are production factors.

Using panel data with Data Envelopment Analysis (DEA) [13] observed improvement in the efficiency of ports in some low economic countries' regions from 52% to 64% over a period of ten years. They noted that, port management is the major factor that caused the improvement in the efficiency of the ports.

The variables in terminal port operations are the cargo handling facilities, the quay, labour and ship. According to [14] who noted that, port performance can be improved with the use of cargo handling equipment. Among the most usable equipment at ports today is crane. Crane is used for lifting of containers, at various warehouses and terminals to perform logistics operations. Either the one with in-built inside the ship or the one at the shore, crane is to be used to rapidly transfer loaded cargo at the port or terminal. These cranes can be present at both berth and quay cranes [1]. Ref [15] conducted a study and found out that, there is positive correlation between performance of Tin Can Island seaport and Apapa seaport and the use of cargo handling equipment at the seaports. [16] noted that, industrial action arising from poor remuneration and other factors will lower the output of dockworkers in the industry. Ref [17] opined that, investment in intelligent modern equipment and Information Technology infrastructures are the requirement for port efficiency. The ports all over the world had and are still witnessing series of repositioning or restrictions as the case may be. The change or shift in port operations, management and production is characterized by technological changes and containerization. Ref [18] explained that, digitization and automation will and has been assisting in the port efficiency synchronizations. Ref [19] noted that increase in networking technologies and data analysis will engineer new revolution in efficiency of terminals and seaports. Ref [20] expressed that; port efficiency can be achieved with the integration of services as lack of this was revealed with the use of T-test analysis.

2.1Maritime Logistics Theory

Analysis the port logistics system expressed by [21] observed that, logistics used to undergo certain pressure and the pressure usually lead to change in the system. Fig. 2 highlighted various pressures that logistics can undergo which usually lead to change in the logistics system.

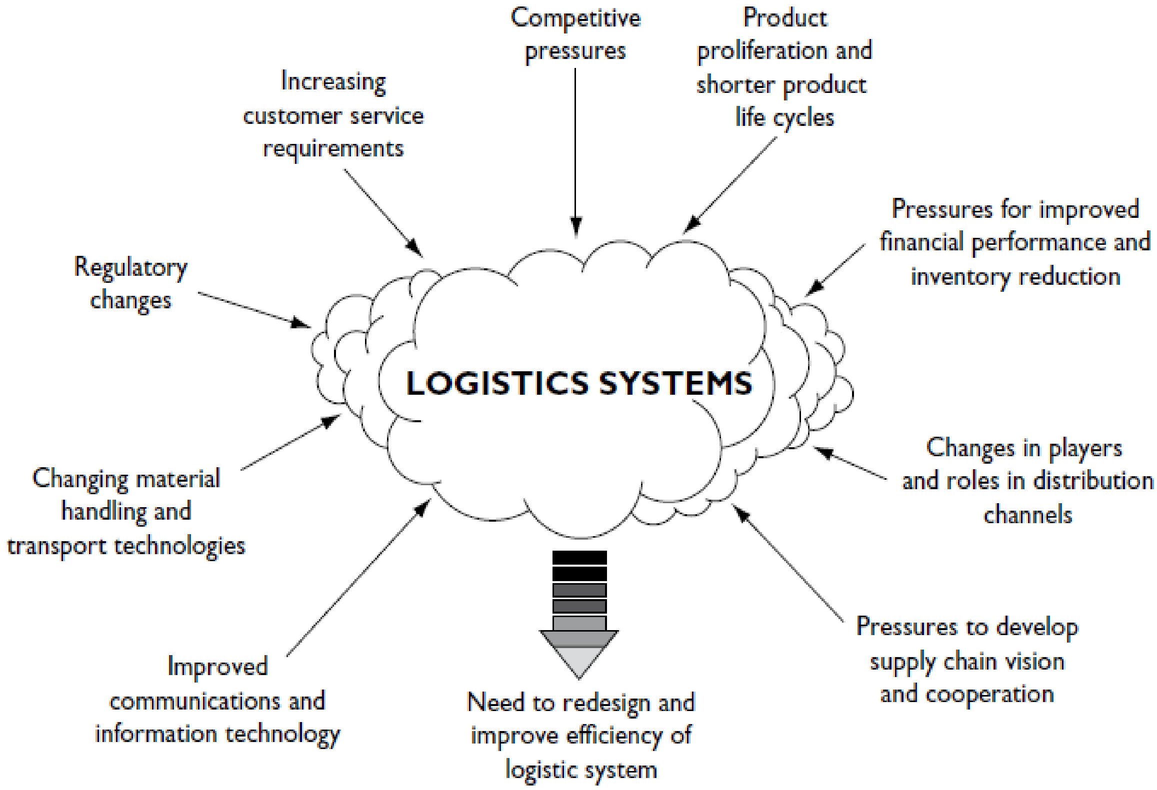

Fig. 2 - Logistics system pressures. Adapted from [22]

One critical issue raised by the postulators of logistics theory is that, if a change is not clearly identified or omitted the necessary change in the logistics system may not be realized. Logistics is the bridge that connect resources for other aspect of life and therefore responsible for economic development. Logistics has four major steps: acquisition, distribution, sustainment and disposition. In the theory of cluster logistics, industries are concentrated around the port. The reason is not far-fetched because, an economy of scale is enjoyed by companies by locating their factories around the seaport and or terminals. However, the adverse effect is that, the increase rate in the number of companies result in reduction of physical logistics of items. In the face of seaport privatization and competition; the more terminal operators seek better ways to compete, the more the battle in logistics space. Therefore, the most crucial issue is to rapidly evacuate goods as faster as possible to allow for effective cargo movement. This is where rail transport seems to be very crucial or intermodal transport in general [21]. The information system and cargo handling equipment are very crucial to reducing the problems of maritime logistics at congested seaports. Table 1 presents various indices for port and terminal performance.

It considers all the indicators with their respective descriptions which are the major issues in maritime logistics. The observation and consideration to minimize or maximize these metrics as may be required are crucial to the level of service in maritime logistics

Table 1 - Indices for port and terminal performance

S/N	Port and terminal performance index	Explanation
1	Ship day per tonnage	This is the use of total number of vessels present at the port to divide the total number of cargo or goods handled per time.
2.	Waiting Rate Average time of ship	This is regarded as the total hours of vessels waiting at berth over total time spent at the berth
3	Turnaround time for ship (average time)	This is expressed by the total hours a ship stays in the port for carriage divided by the number of available ship at the time.
4.	Occupancy rate at the berth	The berth hours available is used to divide the total time that vessel stays at the berth
5	Productivity for Gross berth	The vessel total time is used to divide the number of container or tonnage of goods moved from the first one to last using break-bulk and other cargoes
6.	Over time working at the berth	The total hours spent or being at the berth is used to divide the total time the vessels are serviced at the berth. Rainfall, failure of some of the equipment, union unrest, strike action and holidays can cause some of the reasons for overtime work
7	Productivity index for ship	The total hours spent in port is used in this case to divide numbers of containers or tonnes of goods carried.
8	Dwell time of cargo	The time used in days by tonnage of cargo is used to divide the total time in days cargo present at seaport or terminal from loading time to the time that the cargo will leave the port.
9	TEU's Per Crane Hour Twenty Equivalent Unit of container per/ crane	The hours of using crane is used to divide the total number of containers that was handled in Twenty Equivalent unit
10	Goods in tonnage per gang	Workers are to work for the carriage or goods handled and this is divided by gang hours handled by the workers.

Source: Ref [15]

3. Methodology

The major six seaports in Nigeria includes Calaba in Cross River State, Apapa in Lagos State, Warri in Delta State, Tin Can Island in Lagos State and Onne in Rivers State apart from Burutu, Koko,Bonny, Sapele, Eket, Ikang among others [1]. Five terminal operators like AP Moller, ENL, Apapa Bulk Termina, Greenview Development Ltd and Lilypond Inland Terminal with eight jetties for petroleum products and four fishing warves are operating across all segments. It has 55 hectares with container handling capacity of I million Teus with mobile and tire grane facilities. Tin Can Island seaports has about 79 hectares, handles Roll on/Roll off cargoes including other cargoes with lighter terminals at Kirikiri. The port is designed to accommodate about 650,000TEUs containers per annum. Josepdam Ports Servcies, Tin Can Container Ltd, Ports and Cargo handling Services, Five Stars logistics Ltd and Port & Terminal Multi-servcices Ltd have different areas in the port terminals. Ballore and other Chinese firms are also operators at this port. It also has cranes, forklift and provide reefer services. With cement plant and provision of four crude oil terminals, Calabar seaport is managed by intels Nigeria Ltd and Shoreline Logistics Nigeria Ltd at New Calabar port. Calabar seaport has about 90,000 stacking area with 28,000sqm for containerization. Onne seaport has a port to serve oil and gas segment of West Africa has two sections of Federal Ocean Terminal and Federal lighter Terminal with four wharves and eleven berths respectively. Intels and Brawals ltd are the major operators at the port. Associated Maritime Services Ltd and Intels are also part of the operators at Warri seaport. It has new and old like Calabar port with facilities like forklifts and cranes with processing units and offices. Port Harcourt seaport has facilities for storage of petroleum products and has been strategically positioned for crude oil production and transhipment. Though, it handles containerized cargo, but because the data were not completed across the year; it is not included in the analysis. National Bureau of Statistics is a data repository agency in Nigeria. It has branches with headquarters situated at Abuja, the Federal Capital Territory. Therefore, secondary data used for the purpose of this research was collected from their database. The collected data in the Table 2 to Table 6 commenced from year 2009 to 2022 and the use of R-software was adopted to measure the efficiencies of each selected seaport/terminal based on the number of ships and volume of containers, labour or dock workers, quay and crane for cargo handling available recorded at each of these terminals.

Stochastic Frontier Analysis (SFA) is mostly used as one of the measures of efficiencies especially in relation to economic efficiency as it is been considered here. It is majorly based on input- output concept from production function using input variables like in this case, ship, labour and cargo handling to generate the efficiency of a port from the cargo throughputs as the output of port operations. Quay length was not factored by SFA because it has the same unit for all the considered seaports. SFA is used for parametric data with Cobb Douglas production to produce the frontier efficiency. Technically, the output of SFA lies between 1 and 0, i.e . The effect of inefficiencies is revealed through SFA. The loglikehood effect is about taking optimization which turned first order derivatives to zeros to obtain maximum output. SFA estimates noise level to determine external effect not captured by data.

3.1Model Specification

The use of Stochastic Frontier Analysis with Cobb-Douglas production function method in this paper is to determine the efficiencies of each selected port based on the total volume of data across terminals at each selected seaports in Nigeria. According to [7] Stochastic Frontier Analysis (SFA) is measured by ensuring that we compare and also observe input coefficient points for a firm (port) with the frontier efficiency of input coefficients for the same factor's measurements. This is invariably used to express maximum likelihood econometric estimation and separates noise from efficiency scores. The correct procedure (flowchart) with the Cobb-Douglas production function in the R-statistics is as shown Fig.3.

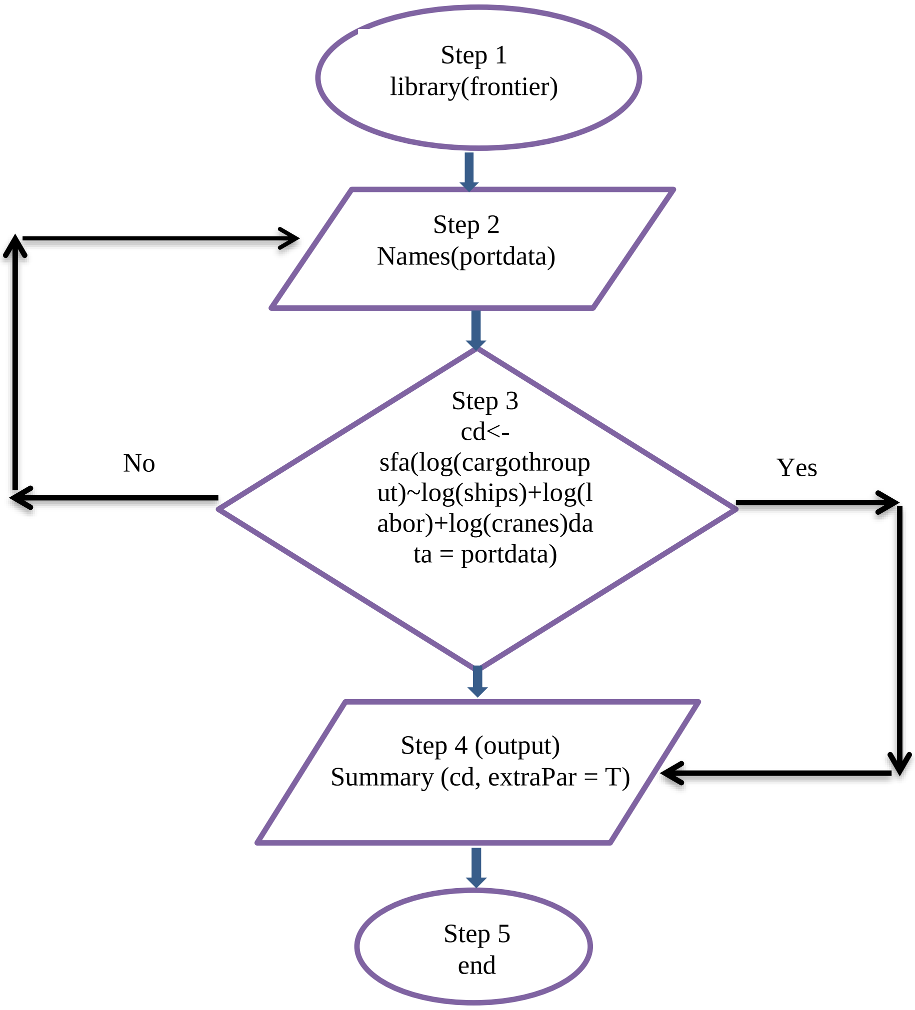

Fig. 3 - Flowchart of stochastic frontier analysis. Source: Author's design (2023)

Fig. 3 shows the flowchart procedure for the analysis of port data collected. It starts with the input of library with a command for frontier analysis to be executed. Then, the data stored for each of the selected seaport was imported with the stored name in the directory as port data. Thereafter, the Cobb Douglas function of cd equating to stochastic function of logarithm for cargo throughput as a function of data for ships, labour and cranes at the ports to give the output. The output is gotten with summary *(cd, extraPar = T).*

The interpretations of some of the terms in the analysis are:

Sigmasqv can be described as the variance parameter used for the error term
Sigmasq can be considered to mean the total sum of Sigmasqv and Sigmasqu
Gammar is therefore the ratio Sigmasqu to Sigmasq is the proportion of variation due to inefficiency

Hence, *gammar* is zero it then means that the inefficiency term u is irrelevant and the resultant result will now be equal to Ordinary Least Square. However, if the *gammar is 1*, then the noise term not relevant or simply means it is irrelevant. Again, if gamma is 0.58, it means that both noise and inefficiency are very important nonetheless inefficiency can be seen to be more important than noise. Note that, noise is not contributing to the efficiency on overall input-output ratio.

This means that cargo throughputs in tonnes are a function of:

$$lnyit = \beta_0 + \beta_1 lnx\ _1it + \beta_2 lnx\ _2it + \beta_3 lnx\ _3it + Vit - Uit \qquad (2)$$

yit: is the number of ships that berthed at the port i during period t;
β_0=this is termed the intercept in equation 2
$x\ _1it$ *: in the equation means this is the number of port labour in port i during consideration for the time t;*
$x\ _2it$ *: means this is the number of crane equipment used by port i in time t as shown in the equation 2;*
$x\ _3it$ *: connotes that this is the quay length in port i in time t;*
β $_{1\text{-}k}$: means from β $_{1\ to}$ β $_k$ of which unknown parameters to be considered as k = 0, 1,2, 3;
Vit: in equation 2 are depicted as random variables which are assumed to be N (0, σV^2), and lonely of the Uit;
Uit: are representing non-negative random variables of the technical inefficiency and d to be as half-normal with N (0, σU^2);
η : is what we considered to be calculated with respect to$x\ _{1.n}$;
σV: is regarded as noise term parameter
σU: is regarded as the inefficiency parameter of the variance

The number total container vessels, the container throughputs in tonnes, dock workers measured in (net gang hour ngh) at each selected seaport, TEUs per crane hour (mobile cranes, rubber tyred gantries, reach stackers, empty handlers and forklift combined), measured in (Teus Per Crane Hour) are all used as indicated in the Table 2 to Table 6 as follows:

Table 2 - Apapa port and terminal data

YR APAPA	No Of Ships	labour measured in ngh	Crane hr in TEU	Quay length (m)	Throughput (measured in tons)
2009	1359	512	30	2,537	**248348**
2010	1452	545	42	2,537	**184180**
2011	1545	543	48	2,537	**266522**
2012	1588	551	51	2,537	**277288**
2013	1594	566	53	2,537	**336864**
2014	1445	597	55	2,537	**327626**
2015	1510	633	60	2,537	**369052**
2016	1503	693	60	2,537	**408002**
2017	1410	628	64	2,537	**344074**
2018	1194	651	68	2,537	**328244**
2019	1154	638	68	2,537	**361247**
2021	1232	638	71	2,537	371,238
2022	1248	712	73	2,537	412,187

Table 3 - Tin can port and terminal data

YR TINCAN	No Of Ships	labour measured in ngh	Crane hr in TEU	Quay length (m)	Throughput (measured in tons)
2009	1133	159	8	3,396	121851
2010	1318	168	12	3,396	260943
2011	1389	167	24	3,396	329373
2012	1504	181	24	3,396	344002
2013	1628	170	24	3,396	420869
2014	1508	183	27	3,396	452215
2015	1615	190	29	3,396	507345
2016	1692	201	31	3,396	515898
2017	1656	205	31	3,396	474712
2018	1559	261	33	3,396	383212
2019	1307	251	41	3,396	441830
2020	1002	209	43	3,396	325,623
2021	1623	219	48	3,396	321,987
2022	1831	300	56	3,396	298,716

Table 4 - Onne port and terminal data

YR ONNE	No Of Ships	labour measured in ngh	Crane hr in TEU	Quay length (m)	Throughput (measured in tons)
2009	733	231	6	5,172	42803
2010	712	234	6	5,172	42803
2011	686	261	8	5,172	51831
2012	769	261	8	5,172	59454
2013	885	281	8	5,172	79429
2014	859	281	8	5,172	98144
2015	823	251	11	5,172	111553
2016	847	271	11	5,172	131663
2017	741	230	11	5,172	119832
2018	659	283	11	5,172	94830
2019	671	242	14	5,172	15316
2020	231	225	14	5,172	35,684
2021	361	240	23	5,172	37,092
2022	684	245	23	5,172	36,901

Table 5 - Calabar port and terminal data

YR Calabar	No Of Ships	labour measured in ngh	Crane hr in TEU	Quay length (m)	Throughput (measured in tons)
2009	897	41	5	86	946523
2010	351	50	6	86	1245599
2011	321	50	6	86	1721269
2012	197	50	6	86	1584277
2013	179	52	6	86	1878753
2014	159	58	6	86	1722195
2015	373	58	8	86	1722286
2016	269	58	8	86	2341477
2017	306	61	8	86	2127209
2018	453	63	8	86	2329084
2019	403	63	8	86	2104689
2020	309	63	8	86	1843801
2021	439	71	8	86	1976542
2022	451	79	8	86	2047822

Table 6 - Warri port and terminal data

YR WARRI	No Of Ships	labour measured in ngh	Crane hr in TEU	Quay length (m)	Throughput (measured in tons)
2009	272	37	7	572	**1604**
2010	309	37	7	572	**2512**
2011	321	41	8	572	**4099**
2012	341	51	10	572	**3940**
2013	362	56	10	572	**1962**
2014	615	56	10	572	**2066**
2015	609	56	10	572	**2891**
2016	603	58	13	572	**2671**
2017	528	59	13	572	**374**
2018	438	60	13	572	**316**
2019	448	59	15	572	**115**
2020	453	61	15	572	**212**
2021	462	66	15	572	**229**
2022	471	74	15	572	**319**

4. Result and Discussion

In order to achieve the objectives of this study, one of the measures of efficiency which is Stochastic Frontier Analysis (SFA) with parametric condition has been used to estimate the economic efficiency using some input factors as ships, cargo handling equipment available and labour to produce outputs in form of cargo throughput. Quay length was not considered as it does not vary per time across the selected seaport/terminals. SFA makes use of hypothesized function to calculate the efficiencies of what is called Decision Making Units (MDUs). The DMUs here are the selected seaports (terminals) which their respective Cobb Douglas functions of logarithms were used to calculate their efficiencies as indicated in Table 7 to Table 11. It has been previously mentioned that economic efficiency deals with the combination of allocative and technical efficiencies. The DMUs are observed through the mean of efficiencies for each of the selected seaports analyzed.

The mean efficiency level of Apapa seaport was approximately 0.68425. Using metrics of available gang hours of dockworker per annum, number of ships and cranes with 0.68425 from 1.0 value shows that the port is just above average in efficiency value. From this analysis (Table 7), it can be observed that; 1% increase in the number of ship increases the cargo throughput by 0.4% if 4.0231e *log(ships)* converted from logarithm at Apapa terminals. Similarly, 1% increase in the number of labour will result into *2.1758e log(labour) 3.7008e-02* converted to logarithm increase in cargo throughput at Apapa (terminals). Likewise, it can be observed that, 1% increase in the number of cranes will also increase the output of containers by 0.02%. However, *SigmaSq* means all the errors due to other things are irrelevant and gamma is calculated from other loglikehood test is for validity of the inefficiency. The value of gamma shows that, error due to inefficiency is very high compare to noise with 99.9% having converted 0.999 into percentage; this means that error term u for noise is irrelevant. Noise can be referred to as the external effect affecting the efficiency not captured by the data.

Using the same metrics as in Table 4.1, the output of mean efficiency level for Tin Can Island terminal was 6960482 which shows that the efficiency level is also above average. (see Table 8). However, it is slightly better in efficiency when compare with that of Apapa.1% increase in ship will give rise to about 0.9% in cargo throughputs at the terminals. Similarly, a percentage increase in gang hour of dockworkers will increase cargo throughputs by 0.1% at the terminals also. Conversely, an increase by 1% of crane which was expected to increase the cargo throughputs will have it declined by 0.2%. Considering Sigmasq and gamma, the error due to noise is pronounced in the case of terminals around the Tin Can Island seaport. Noise can be referred to as the external effect affecting the efficiency not captured by the data. And in this case, it is not also relevant because gammar is greater than sigmasq.

In related manner to the previous analysis, Table 9 presents the efficiency of Onne terminals with the confine of the seaport. 1% increase in number of ship berthing at the port will lead to 0.2.13 increase in the container throughput of the terminals. Observe that the level of efficiency at this terminal is very high with mean efficiency value of 0.9877238. Also, of importance is that in labour gives rise to container throughput by 0.2%. 1% increase in crane will also lead to 0.02% in container throughputs at the terminals. *Sigmasq and gamma,* here also connotes that error due to noise was irrelevant. The value of gamma 2.3307e-02 is above the *sigmaSq* 1.0356e-02.

Table 7 - APAPA terminals efficiency

Maximum like hood calculations				
	Estimate Std.Error	**z value**	**Pr(>|z|)**	
(Intercept)	1.71E+00	7.22E-01	14.2165	< 2.2e-16 ***
log(Ships)	4.02E-01	3.88E-02	7.2671	3.674e-13 ***
Log(labour)	2.18E-01	3.30E-01	0.64	0.5093404
log(Cranes)	2.70E-02	2.11E-02	1.7559	0.07911 *
sigmaSq	5.02E-03	1.03E-03	4.6605	3.268e-06 ***
gamma	1.00E+00	4.46E-04	2310.6816	< 1.2e-16 ***
sigmaSqU	0.259002	0.127968	2.024	0.0429740 *
sigmaSqV	0.157408	0.031782	2.8761	0.0046408 **
sigma	0.614571	0.059587	7.9105	1.274e-14 ***
sigmaU	0.508122	0.568724	4.0479	5.164e-05 ***
sigmaV	0.342744	0.011896	5.3483	1.358e-08 ***
lambdaSq	2.204866	1.780996	1.238	0.2154686
lambda	1.560879	0.527711	2.428	0.0145867 *
varU	0.092326	NAP	NAP	NAP
sdU	0.343383	NAP	NAP	NAP
gammaVar	0.467815	NAP	NAP	NAP
Signif. codes:	0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1			
log likelihood value:	-77.5174			
cross-sectional data				
total number of observations = 14				
mean efficiency:	0.68425			

Table 8 - Efficiency for tin can island

Maximum like hood calculations				
	Estimate Std.Error	**z value**	**Pr(>|z|)**	
(Intercept)	11.035962	0.432657	25.5074	< 2.2e-16 ***
log(Ships)	0.910532	0.065902	13.8165	< 2.2e-16 ***
Log(labour)	0.157363	0.029735	5.2922	1.208e-07 ***
log(Cranes)	-0.209442	0.102404	-2.0453	0.0408302 *
sigmaSq	0.376470	0.097652	3.8552	0.0001156 ***
gamma	0.687975	0.173398	3.9676	7.260e-05 ***
sigmaSqU	0.342736	0.060895	5.6283	1.820e-08 ***
sigmaSqV	0.117468	0.041742	2.8141	0.0048908 **
sigma	0.613571	0.079577	7.7105	1.254e-14 ***
sigmaU	0.508922	0.127968	2.0240	0.0429740 *
sigmaV	0.342736	0.041742	2.8141	0.0048908 **
lambdaSq	2.204866	1.780996	1.2380	0.2157176
lambda	1.484879	0.59971	2.4760	0.0132867 *
varU	0.094116	NAP	NAP	NAP
sdU	0.306783	NAP	NAP	NAP
gammaVar	0.444816	NAP	NAP	NAP
Signif. codes:	0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1			
log likelihood value:	-77.51736			
cross-sectional data				
total number of observations = 14				
mean efficiency:	0.6960482			

Table 9 - Onne terminals efficiency

Maximum like hood calculations				
	Estimate Std.Error	**z value**	**Pr(>|z|)**	
(Intercept)	1.2762e+01	1.5477e+00	8.2456	< 2.2e-16 ***
log(Ships)	2.1310e-01	6.4006e-02	3.3293	0.0013539 **
Log(labour)	2.1758e-01	3.2967e-01	0.6600	0.5092604
log(Cranes)	1.0287e+00	3.2105e-01	3.2043	0.0013539 **
sigmaSq	1.0356e-02	2.6980e-02	0.3838	0.7011005
gamma	2.3307e-02	3.9844e+00	0.0058	0.9953327
sigmaSqU	2.4137e-04	4.1884e-02	0.0115	0.9954020
sigmaSqV	1.0114e-02	1.5691e-02	0.6446	0.5191708
sigma	1.0176e-01	1.3256e-01	0.7677	0.4426829
sigmaU	1.5536e-02	1.3480e+00	0.0115	0.9908042
sigmaV	1.0057e-01	7.8007e-02	1.2892	0.1973118
lambdaSq	2.3863e-02	4.1768e+00	0.0057	0.9954415
lambda	1.5448e-01	1.3519e+01	0.0114	0.9908831
varU	8.7708e-05	NAP	NAP	NAP
sdU	9.3652e-03	NAP	NAP	NAP
gammaVar	8.5969e-03	NAP	NAP	NAP
Signif. codes:	0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1			
log likelihood value:	12.23095			
cross-sectional data				
total number of observations = 14				
mean efficiency:	0.9877238			

Table 10 - Warri seaport’s efficiency

Maximum like hood calculations				
	Estimate Std.Error	**z value**	**Pr(>|z|)**	
(Intercept)	5.12689232	0.78124500	3.1754	< 2.2e-14 ***
log(Ships)	0.22353125	0.15672782	3.1062	3.051e-04 ***
Log(labour)	0.11987688	0.35021268	0.2918	0.34091
log(Cranes)	0.08359872	0.38168281	0.1443	0.28957
sigmaSq	0.12083316	0.19521254	1.3198	0.06522
gamma	0.99178233	0.00676389	9097.5719	< 2.2e-14 ***
sigmaSqU	1.4456e-04	3.1267e-02	0.0085	0.9390202
sigmaSqV	1.4804e-02	3.1267e-02	0.0085	0.9390202
sigma	1.0382e-01	1.3267e-01	0.7633	0.3796829
sigmaU	1.8631e-02	1.3471e+00	0.5389	0.9834042
sigmaV	1.0051e-01	7.87379-02	1.6721	0.1876544
lambdaSq	1.9622e-02	3.8201e+00	0.0072	0.8522281
lambda	1.2213e-01	1.6721e+01	0.7621	0.8999212
varU	7.8992e-05	NAP	NAP	NAP
sdU	6.8732e-03	NAP	NAP	NAP
gammaVar	6.8971e-03	NAP	NAP	NAP
Signif. codes:	0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1			
log likelihood value:	-6.76819			
cross-sectional data				
total number of observations = 14				
mean efficiency:	0.51921			

The next is Warri terminals combining both old and new terminals came up with output of 0.51921 as the mean efficiency value of the terminals. This suggests that these terminals are not optimally utilized as expected. However, 1% increase in ship at the terminals will result in 0.22 container throughputs. Similarly, 1% increase in gang hour of dockworkers will lead to 0.11 increases in the container throughputs at the terminals. Again, 1% increase in cargo handling equipment (cranes) will lead to 0.08% increase in the container throughput of the terminals. Examining the noise level, it can also be confirmed that the noise is irrelevant with the value of *gamma* equal 0.991 above the *sigmasq* with value of 0.1208.

The efficiency level of Calabar terminal (old and new) is also high with the value of 0.837017. In the logarithm function of the ship, 1 % increase in the number of ships berthing at the port will increase the container throughput with 21%. Similarly, increase in labour by 1% will lead to increase in throughput by 0.3%. The container throughput will rise by 0.6% if there is 1% increase in the usage and availability of cargo handling equipment at the terminals. The error term due to noise is also irrelevant when comparing gamma and *sigmasq*. *Gamma* value is 1 and the *sigmasq* is 0.05.

From the analysis of all the selected terminals across the major seaports in Nigeria excluding Rivers port and terminals; it was observed that, the least efficient terminals among them are Warri with the least efficiency value of 0.51921. This is followed by Apapa terminals with the mean efficiency value of 0.68425. The third on the next least efficient terminals are that of Tin can Isand in Lagos with mean efficiency value of 0.6960482. Calabar terminals came second in order of ranking with the mean efficiency value of 0.837017 while the most efficient terminal goes to Onne terminals with high value of 0.9877238 mean efficiency value. Considering all variables considered, it was realized that, Eastern Nigerian terminals are more efficient than the Western terminals. However, with the introduction of new deep Lekki seaport, the inefficiency may reduce and there will be share of cargo among the seaports in the region. Determining the efficiencies with the input variables like the ship, labour and cargo handling have been seen to produce different efficiencies for each of these selected seaports according to what they have as data. Economically therefore, Warri is not efficient has shown with the efficiency value and also Apapa with their respective values as shown above with 0.51921 and 0.68425 respectively. Onne is the most efficient with the highest value of mean efficiency of 0.9877238 and followed by Calaba that has 0.837017. The third among the Ports is Tin Can Island with the value of 0.6960482. It must be noted that efficiency here deals with economic efficiency as it means that all processes to evacuate, load and discharge cargo by ship is faster at Onne in Nigeria among the selected seaports. This paper has shown that significant difference in the operations at various selected Nigerian seaports. It therefore means that, labout, cargo handling equipment and ships are to be carefully examined to operate optimally in order to achieve higher level of economic efficiency.

Table 11 - Calabar terminals efficiency

Maximum like hood calculations				
	Estimate Std.Error	**z value**	**Pr(>|z|)**	
(Intercept)	1.1974e+01	1.8417e+00	6.5016	7.948e-11 ***
log(Ships)	2.18777+02	1.8344e+01	3.5662	7-897e-11
Log(labour)	3.2042e-01	7.3913e-01	0.4335	0.6646489
log(Cranes)	6.7306e-01	6.0814e-01	1.1067	0.2684022
sigmaSq	5.3755e-02	1.6011e-02	3.3574	0.0007869 ***
gamma	1.0001e+00	2.1457e-05	46605.7588	< 2.3e-16 ***
sigmaSqU	5.3755e-02	1.6011e-02	3.3575	0.0007865 ***
sigmaSqV	5.3759e-10	1.1535e-06	0.0005	0.9996281
sigma	2.3185e-01	3.4529e-02	6.7147	1.885e-11 ***
sigmaU	2.3185e-01	3.4528e-02	6.7150	1.881e-11 ***
sigmaV	2.3186e-05	2.4875e-02	0.0009	0.9992563
lambdaSq	9.9994e+07	2.1454e+11	0.0005	0.9996281
lambda	9.9997e+03	1.0727e+07	0.0009	0.9992562
varU	1.9534e-02	NAP	NAP	NAP
sdU	1.3976e-01	NAP	NAP	NAP
gammaVar	1.0000e+00	NAP	NAP	NAP
Signif. codes:	0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1			
log likelihood value:	10.14392			
cross-sectional data				
total number of observations = 14				
mean efficiency:	0.837017			

5. Summary, Conclusion and Recommendations

All measures to improve port and container throughputs' performance mostly focused on improving variables line cargo handling equipment, cranes, labour and hours of work and ship turnaround time. In spite of this, efficiency of the seaport or terminal is about harnessing all the functions of internal logistics with the aim of maximizing all input variables' output for economic efficiency. While it can be observed that, there is progressive increase in number of vessels at Tin Can and Apapa seaports and also increase in container throughputs per annum, there is no corresponding capacity increase to accommodate the rise in traffic. With this analysis, there are other factors responsible for inefficiencies of mostly the western terminals at Apapa, Tin Can and the Eastern one at Warri. Since technical efficiency focuses on technology, cargo handling equipment and other apparatus, all seaports must invest in this to realize optimum performance. Similarly, allocative efficiency should utilize workforce and the ships to gain maximum turnaround so as to achieve desired optimal performance. As port and terminal increases, other factors must also increase; otherwise there will be a setback in the entire port operations and logistics system. Size of the seaport or terminal does not determine how efficient it will be. The crucial determination can be observed by how rapid the input is processed and in this regard, handling of cargo, delivery by ships and proficiency of personnel. In terms of external logistics and movement to the hinterland, the identified factors may not determine the efficiency but within the system of port or terminal operations, these can be found to be very critical arising from the results. The overall general efficiency performance of each of the selected seaport has been provided and there is need for the seaports that are having bigger traffic to fathom out modalities for their efficiencies so as not to be losing customers patronizing them. Some other factors causing port expansion and congestion can be examined in future research.

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