EFFICIENCY MEASUREMENT OF 6 MAJOR CONTAINER PORTS IN THE WEST AFRICA REGION

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Abstract

Container terminal efficiency is a critical factor in the contemporary global trade. We apply the DEA and SFA methods to evaluate efficiency of 6 major ports in the West Africa region to investigate whether these ports can become the main hubs of container transport to African inland in the future. The DEA and SFA methods were applied to a number of inputs such as total quay length; total terminal area, number of quayside cranes, number of gantry cranes and number of reach stackers and single output, to measure efficiency.

Keywords: Transportation Economics, Ports, Efficiency, Sea Trade
JEL classification: R41, R11

1. Introduction

The efficiency of port operation is an important indicator of economic and, specifically, of regional development. In order to assist port authorities to identify their own strengths, opportunities, weaknesses and potential threats, a set of impartial and objective tools have to be selected and used to investigate transportation efficiency (Lin & Tseng, 2005). In this paper, we investigate Port's efficiency by using the DEA and SFA methods to six (6) major West Africa ports. Since W. Africa is gradually becoming a significant region in global trade, we examine whether these ports can become the main hubs of container transport to the vast African inland in the not too distant future.

2. Literature discussion

Container transport and containerization has led to increased competition between ports worldwide. The result of this intense inter-port competition highlights the importance of efficiency issues by port operators and port users (Cullinane & Wang, 2007). Ports in Western-Europe, North-America and East-Asia have, for many years, utilized efficiency analysis to improve operations by better use of resources. This led to ports infrastructure growth through massive investments in port related activities (Alabanos and Theodoropoulos, 2017). In this context, the port industry in West Africa has seen major growth in recent times. The last 20 years a number of West African ports has undergone serious restructurings by attracting more private sector involvement and increased capacities, efficiency and productivity. Lately, port development in West Africa region has been directed towards attaining hub port status (Kobina G. van Dyck, 2015).

Competition of international ports is at its highest level and private sector investment in port facilities continues to rise in the region. Nowadays, ports that play a regional role in West Africa are generally viewed as the leading potential hub port contenders, including ports in Ghana, Togo, Ivory Coast, Benin and Senegal, providing transit services for landlocked countries in West Africa.

There are several examples of port development projects in West Africa that have regional focus and are directed at attaining regional hub status. For example, in Nigeria, the Lekki Port project pursue to create a multi-purpose deep water port in the Lagos free trade zone area with

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a projected capacity of 2.5 million TEU's (twenty-foot equivalent units) per annum. The port will include container, dry bulk and liquid bulk berths with a 14-metre draught and 670 metres turning cycle to accommodate larger ships[2].

Similarly, the Ghana Ports and Harbours Authority (GPHA) has secured $1.5 billion for the expansion of the Port of Tema. The project involves the construction of four (4) deep water berths and an access channel to accommodate larger vessels with high capacity equipment. The aim of the project is to create the largest cargo port in West Africa with a capacity of 3.5 million TEU per annum once complete in 2018 (Port Finance International, 2014). The Port of Lomé has constructed a $640 million berth in Togo. The new quay has double docking capacity and measures 450 metres able to accommodate vessels of more than 7000 TEU capacity (AFDB, 2010).

Similar port development projects can be found in other West African countries, as there is no exclusivity in the selection of a hub by shipping lines. The selection of a port to act as hub depends on a number of factors. In latest surveys, major shipping lines calling at West African ports were required to rank influential factors to the selection of a hub for the region (Kobina G. van Dyck, 2015). High port efficiency and performance were ranked first amongst a list of 20 factors. West African ports have been noted to be relatively congested and inefficient as compared with ports in Europe and Asia (Cullinane & Wang 2006). Measurement and analysis of port efficiency in West Africa allow port users to make efficiency comparisons and provide regional and national port operators with an important management tool for making informed decisions on port planning and operations (Kobina G. van Dyck, 2015). The improvement for port operating efficiency could include: improvement in efficiency through private sector management skills, enhancement of service quality through improved commercial responsiveness, reduction in the fiscal burden of loss making public enterprises, a reduction in the financial demands on central and local government through access to private sector capital, and additional revenue streams (McDonagh, 1999).

From the point of view of container terminal productivity, each port player has his own self-interest and his own definition of productivity, proposed by Dowd and Leschine (1990). As most port operations have been privatized, private operators aimed to maximize output, namely, container throughput and operating efficiencies (Heaver et al., 2000).

The operating efficiency of a container port or a container terminal is a mixture of multiple inputs and multiple outputs, which is in conformity with the characteristics of Data Envelopment Analysis (DEA). The DEA with mathematical programming techniques has applied to the measurement of port efficiency for hypothetical port data by Roll and Hayuth (1993). There are numerous papers that have extended and applied alternative models of the Data Envelopment Analysis (DEA) methodology, including BCC, Additive, FDH (Free Disposal Hull), etc, such as an application of BCC model to check global efficiencies of 26 Spain ports using 5 observations for each port from 1993 to 1997 and to examine efficiency evolution of individual port (Martínez et al., 1999). Utilization of CCR and additive models to make an international comparison of technical efficiencies in 4 Australian and 12 other international container ports in 1996 was proposed by Tongzon (2001). The CCR, BCC, and FDH models also used by Wang, Song, and Cullinane (2003) to evaluate production efficiencies of 57 terminals within 28 container ports for year 2001, and find that the FDH model is the best model of port efficiency measurement. Valentine & Gray (2001) further applied CCR model to calculate relative efficiencies of 31 global container ports in 2001, and follow cluster analysis to determine whether there is a particular type of ownership and organizational arrangement that leads to higher efficiency rating. Stochastic frontier analysis (SFA) method has been applied to the measurement of technical efficiency for 28 Britain ports during 1983-1990, by Liu (1995). SFA with Cobb-Douglas and Translog production function for the half-normal and truncated-normal distributions to estimate production efficiencies of 11 Mexico container ports with two inputs labour and capital and one output, volume of merchandise handled from 1996 to 1999, was applied by Estache et al (2002). Also, SFA method with Cobb-Douglas production function for the half-normal, exponential, and truncated-normal distributions to estimate production efficiencies of 15 Asian container

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[2] http://lekkiport.com/theport/key-facilities.html

ports and terminals with unbalanced-panel data between 1989 and 1998) was used by Cullinane, Song, and Gray (2002). DEA and SFA methods also applied both to estimate the relative productive efficiency for 74 railway systems in 1999, and use the two-stage method of DEA with CCR and BCC models and the SFA method with Translog production function for the half-normal and truncated-normal distributions by Lan et al (2003).

DEA and SFA methods are also applied together in transport industry. The slack analysis of DEA supply observation to increase or decrease input resources to improve efficiency scores on the other hand the SFA method focuses on the economic justification and hypothesis testing. A mixture of both DEA and SFA support management helps to have a more comprehensive understanding of the operating efficiency of container ports and terminals and to identify the causes of efficiency and of inefficiency. Furthermore, both methods are frontier function to measure efficiencies of all firms with cross-section and panel data, and many container port and terminal operations may have characteristics of consistency for DEA and SFA. However, we would adopt both DEA and SFA methods to evaluate container port operating efficiency. Previous research on port's and terminals efficiency usually adopts either DEA or SFA method, but not both of them (Lin, L. C. & Tseng, L. A., 2005). We intend to measure the relative operating efficiencies of the 6 West African container ports from 2006 to 2012 by first applying Data Envelopment Analysis (DEA) with DEAP 2.1 and secondly SFA with Cobb-Douglas production function with Frontier 4.1 for the truncated-normal distribution. Previous evaluation to the West African container ports was proposed by Kobin G.van Dyck (2015) using DEA method.

3. Methodology

3.1. DATA ENVELOPMENT ANALYSIS (DEA)

Data envelopment analysis (DEA) is a non-parametric mathematical programming approach to frontier estimation. These models which are presented here is brief, with relatively little technical detail. Detailed methodology presented by Seiford and Thrall (1990), Lovell (1993), Ali and Seiford (1993), Lovell (1994), Charnes et al (1995) and Seiford (1996).

The piecewise-linear convex hull approach to frontier estimation, proposed by Farrell (1957), was considered by only a handful of authors in the two decades following Farrell's paper. Authors such as Boles (1966) and Afriat (1972) suggested mathematical programming methods, which could achieve the task, but the method did not receive wide attention until a paper by Charnes, Cooper and Rhodes (1978), which coined the term data envelopment analysis (DEA). There is large number of papers, which have extended and applied the DEA methodology.

A model proposed by Charnes, Cooper and Rhodes (1978), which had an input orientation and assumed constant returns to scale (CRS)[3] .Papers have considered alternative sets of assumptions, such as Banker, Charnes and Cooper (1984) who proposed a variable returns to scale (VRS) model. The following discussion of DEA begins with a description of the input-orientated CRS model in section 3.1, because this model was the first to be widely applied Data Envelopment Analysis (DEA) made for the purpose of calculating efficiencies in production. In the program that we use methods implemented are based on the work of Fare, Grosskopf & Lovell (1994).

In the program three options are available:

- The first involves the standard CRS and VRS DEA models that involve the calculation of technical and scale efficiencies which are outlined in Fare, Grosskopf and Lovell (1994).

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[3] The constant return to scale assumption allows one to represent the technology using a unit isoquant. Furthermore, Farrell also discussed the extension of his method so as to accommodate more than two inputs, multiple outputs, and non-constant returns to scale.

- The second option considers the extension of these models to account for cost and allocative efficiencies. These methods are also outlined in Fare et al (1994).
- The third option considers the application of Malmquist DEA methods to panel data to calculate indices of total factor productivity (TFP) change, technological change, technical efficiency change and scale efficiency change. These latter methods are discussed in Fare, Grosskopf, Norris and Zhang (1994).

3.2. Stochastic Frontier Analysis (SFA)

3.2.1. SFA and FRONTIER 4.1

The stochastic frontier models can contain panel data and accept firm effects that are distributed as abbreviated normal random variables.

Two primary model specifications considered in the program are:

- Error components specification with time-varying efficiencies permitted (Battese and Coelli, 1992), which was estimated by FRONTIER Version 2.0.
- A model specification in which the firm effects are directly influenced by a number of variables (Battese and Coelli, 1995).

The program also allows the estimation of many other models.

FRONTIER Version 4.1, the program we worked on, is to provide maximum likelihood, estimates of a wide variety of stochastic frontier production and cost functions.

3.2.2. Model specifications

The stochastic frontier production function was independently proposed by Aigner, Lovell and Schmidt (1977) and Meeusen and van den Broeck (1977). The original specification involved a production function specified for cross-sectional data which had an error term which had two components:

- One to account for random effects
- Another to account the technical inefficiency.

This model can be expressed in the following form:

$$(1)\ Y_i = x_{i\beta} + (V_i - U_i) \qquad ,i = 1, \ldots, N,$$

where Y_i is the production (or the logarithm of the production) of the i-th firm,

x_i is a $k \times 1$ vector of (transformations of the) input quantities of the i-th firm is an vector of unknown parameters;

V_i Are random variables which are assumed to be . $N(0, \sigma_{V2})$, and independent of the

U_i which are non-negative random variables which are assumed to account for technical inefficiency in production and are often assumed to be iid.

$|N(0, \sigma_{U2})|$.

This specification has been used in a vast number of empirical applications over the past two decades. It has also been altered and extended in a number of ways and extensions include the specification of more general distributional assumptions for the U_i, such as the abbreviated normal or two-parameter gamma distributions, the consideration of panel data and time-varying technical efficiencies, the extension of the methodology to cost functions and also to the estimation of systems of equations, etc.

A big number of completed reviews of this literature are available, such as Forsund, Lovell and Schmidt (1980), Schmidt (1986), Bauer (1990) and Greene (1993). The FRONTIER Version 4.1 as a computer program can be used to obtain maximum likelihood estimates of a subset of the stochastic frontier production and cost functions which have been proposed in the literature.

The computer program was written to estimate the model specifications detailed in Battese and Coelli (1988, 1992 and 1995) and Battese, Coelli and Colby (1989).

4. Empirical application to 6 Container Port Terminals in West Africa

For this case study, the container port terminals, which were selected in West Africa, are above 100,000 TEUs per year, for the period 2006-2012.

This case study selects six (6) West African container ports in six different countries with total throughput over 100,000 TEUs per year as shown in Table 1.Specifically the ports selected in this paper are:

- Tema Port in Ghana
- Abidjan Port in Cote D'Ivoire
- Dakar Port in Senegal
- Lomé Port in Togo
- Cotonou Port in Benin
- Lagos Complex in Nigeria

These port data are collected mainly from (Kobina G. van Dyck, 2015).

The majority of West African ports have both dedicated container berths/terminals and multi-purpose berths. The container terminals were used for the analysis in order to have equality in comparison and analysis of the data. Furthermore, the container terminals were the main terminals for the handling of containerized cargo at the ports. The ports analysed can be found in Table 1.

Table 1. Container throughput 2006-2012

Port	Terminal	Container Throughput (TEUs)						
Years		2006	2007	2008	2009	2010	2011	2012
Tema	MPS Terminal	425,408	489,147	555,009	525,694	590,147	756,899	824,238
Abidjan	SETV Terminal	507,100	531,809	652,358	610,185	561,535	546,417	633,917
Dakar	DP World Terminal	375,876	424,457	347,483	331,076	349,231	369,137	383,903
Lomé	Bollore Africa Logistics	215,892	237,891	296,109	354,480	339,853	352,695	288,481
Cotonou	Bollore Africa Logistics	140,500	167,791	193,745	272,820	316,744	334,798	348,190
Lagos Complex	APM Terminals-Apapa	587,600	711,100	947,400	710,800	1,128,171	1,413,27	1,623,141

(Source: Kobina G. van Dyck (2015)

This case study initially selected five inputs of container port infrastructures, including:

- Total Quay Length
- Terminal Area
- Number of Quayside Cranes
- Number of Container Gantry Cranes
- Number of Reach Stackers and single output,
- Container Throughput as shown in Table 1.

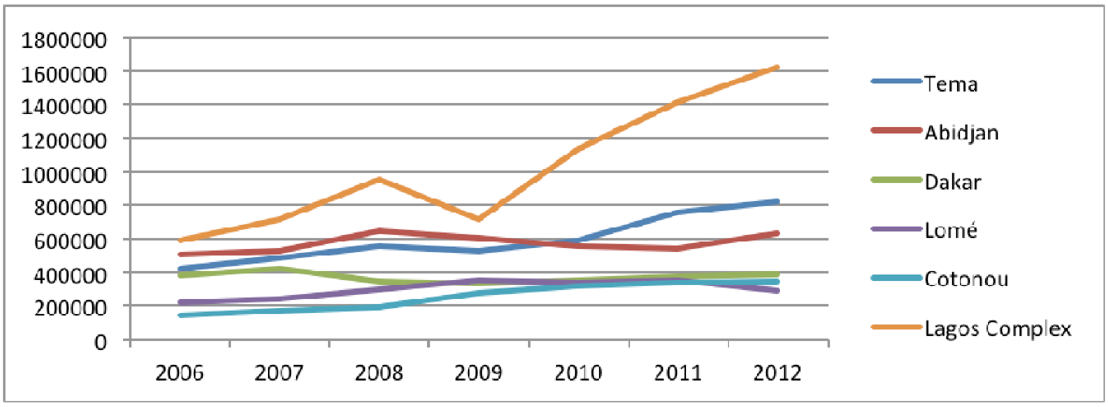
These indicators were selected to be in compliance with characteristic of consistency for both DEA and SFA.

Figure 1. Data and analysis indicators

DATA	
INPUTS	OUTPUTS
Total Quay Length (m)	Container throughput (TEUs)
Terminal area (ha)	
Number of Quayside Cranes	
Number of Yard Gantry Cranes	
Number of Reach Stackers	

Container throughput trend for the period 2006-2012 is shown on Figure 1. The difference between Lagos Complex Port and the other ports is clear. However we can see that it suffers from throughput fluctuations over time. Insignificant fluctuations on throughput noticed in all the other ports with exception of the port of Cotonou, which increased its throughput levels since 2006.

Figure 2. Container throughput trend 2006-2012



The selection of input and output variables is very important to the analysis of efficiency of ports and container terminals. Unclear variables can lead to false conclusions about port efficiency (Cullinane and Wang, 2006). Input and output variables should explain container port production as much as possible (Cullinane K.P.B. et al., 2004). Container throughput (output data) used in the efficiency analysis as primary basis upon which container ports are compared. As a container terminals and ports depends on the efficient use of land, labour and capital (equipment), the input data includes the quay length (m), the terminal area (ha), the number of quayside cranes, the number of yard gantry cranes, and the number of reach stackers used in each port over the period 2006-2012.

Specifically the quay length indicator is important in evaluating the efficiency of ports and container terminals. The quay length is also one important indicator as to the turn and around time that can be achieved by ports, since it shows the size of a ship that can be allocated a berth at a particular point in time.

Berth availability as a function of quay length can influence the efficiency of shipping lines. Furthermore, the number of quay-side cranes is an important measure of productivity. This input directly changes the speed with which container ships may be served for example if a container terminal has more cranes, this may increase the number of containers handled per hour, and effects the turn-around time as well.

The number of quayside cranes increases the agility of the port by handling more vessels at the same time (Pjevčević, 2012). The berth length and number of quay-side cranes accordingly influence the berth-side productivity. Likewise, the terminal area, the number of yard gantry cranes, and the number of reach-stackers reflect yard-side productivity. In this case study, the number of yard gantry cranes and reach stackers is used in the evaluation because of their common use within terminals and ports in particular. The input and output data have been collected from (World Bank, 2014 & MLTC/CATRAM, 2013).

In Table 2 are shown the summary statistics of the data used.

Table 2. Sum statistics for sample of 6 West African ports

	Container throughput (TEUs)	**Total Quay Length (m)**	**Terminal area (ha)**	**Number of Quayside Cranes**	**Number of Yard Gantry Cranes**	**Number of Reach Stackers**
Mean	683645.00	701.50	27.67	5.17	8.67	20.33
Standard deviation	502677.21	244.54	17.07	2.40	5.75	6.02
Minimum	288481.00	430.00	10.00	4.00	0.00	15.00
Maximum	1623141.00	1005.00	55.00	10.00	16.00	31.00

In Tables 3, 4, 5, 6, 7 and 8 are shown the inputs and the output data for the period 2006-2012 more precisely.

Table 3. Input and output variables for port of Tema

Port	Variables	2006	2007	2008	2009	2010	2011	2012
Port of Tema	Container throughput	425,408	489,147	555,009	525,694	590,147	756,899	824,238
	Total quay length (m)	574	574	574	574	574	574	574
	Terminal area (ha)	10	10	10	10	10	10	10
	Number of quayside cranes	6	6	6	6	6	6	8
	Number of yard gantry cranes	4	4	4	4	4	4	13
	Number of reach stackers	0	4	4	10	10	10	23

Table 4. Input and output variables for port of Abidjan

Port	Variables	2006	2007	2008	2009	2010	2011	2012
Port of Abidjan	Container throughput	507,100	531,809	652,358	610,185	561,535	546,417	633,917
	Total quay length (m)	1000	1000	1000	1000	1000	1000	1000
	Terminal area (ha)	34	34	34	34	34	34	34
	number of quayside cranes	3	3	3	3	3	3	4
	number of yard gantry cranes	16	16	16	16	16	16	16
	number of Reach stackers	19	19	19	19	19	19	19

Table 5. Input and output variables for port of Dakar

Port	Variables	2006	2007	2008	2009	2010	2011	2012
Port of Dakar	Container throughput	375,876	424,457	347,483	331,076	349,231	369,137	383,903
	Total quay length (m)	660	660	660	660	660	660	660
	Terminal area (ha)	35	35	35	35	35	35	35
	number of quayside cranes	4	4	4	4	4	4	4
	number of yard gantry cranes	8	8	8	8	10	10	10
	number of reach stackers	15	15	15	15	15	15	15

Table 6. Input and output variables for port of Lomé

Port	Variables	2006	2007	2008	2009	2010	2011	2012
Port of Lomé	Container throughput	215,892	237,891	296,109	354,480	339,853	352,695	288,481
	Total quay length (m)	430	430	430	430	430	430	430
	Terminal area (ha)	12	12	12	12	12	12	12
	number of quayside cranes	4	4	4	4	4	4	6
	number of yard gantry cranes	0	0	0	0	0	0	0
	number of reach stackers	19	19	19	19	19	19	19

Table 1. Input and output variables for port of Cotonou

Port	Variables	2006	2007	2008	2009	2010	2011	2012
Port of Cotonou	Container throughput	140,500	167,791	193,745	272,820	316,744	334,798	348,190
	Total quay length (m)	540	540	540	540	540	540	540
	Terminal area (ha)	20	20	20	20	20	20	20
	number of quayside cranes	4	4	4	4	4	4	8
	number of yard gantry cranes	10	10	10	10	10	10	10
	number of reach stackers	15	15	15	15	15	15	15

Table 2. Input and output variables for port of Lagos Port Complex

Port	Variables	2006	2007	2008	2009	2010	2011	2012
Lagos Port Complex	Container throughput	587,600	711,100	947,400	710,800	1,128,17	1,413,27	1,623,14
	Total quay length (m)	1005	1005	1005	1005	1005	1005	1005
	Terminal area (ha)	55	55	55	55	55	55	55
	number of quayside cranes	10	10	10	10	10	10	10
	number of yard gantry cranes	12	12	12	12	12	12	12
	number of reach stackers	31	31	31	31	31	31	31

4.1. CRS Technical Efficiency results input oriented with DEAP 2.1

The most efficient West African ports are found to be the Port of Tema in Ghana and the Port of Lomé in Togo which both exhibit an average relative efficiency score of 100% for the period of analysis. The Port of Tema and the Port of Lomé achieves 100% efficiency in all 7 years while the port of Abidjan achieves 99.66% efficiency. Due to the world financial crisis on trade in 2008 as it shown in Table 9 we notice a shortfall in years 2008 and 2009 but after 2009 efficiency scores start to rise again. Amongst the ports in this case study, the Port of Tema is one of the smallest ports in terms size (terminal area and berth length) but one of the largest in terms of throughput in West Africa. On the other hand, the Port of Cotonou is relatively the least efficient port amongst the sample taken with an efficiency score of 52%, which indicates the port could have achieved efficiency with 52% of its inputs. The port has excessive capacity in relation to its inputs and therefore there exists a lot of waste in production.

Table 3. CRS Technical Efficiency scores for the period 2006-2012 and Means

PERIOD 2006-2012

PORTS	2006	2007	2008	2009	2010	2011	2012	Mean
TEMA	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
ABIDJAN	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	97.60%	99.66%
DAKAR	95.00%	97.50%	67.80%	68.30%	66.60%	61.50%	59.10%	73.69%
LOME	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
COTONOU	40.30%	43.10%	42.80%	63.90%	66.50%	58.90%	49.50%	52.14%
LAGOS	80.60%	85.20%	99.70%	79.00%	100.00%	100.00%	100.00%	92.07%
Mean	85.98%	87.63%	85.05%	85.20%	88.85%	86.73%	84.37%	

Cotonou never achieves efficiency levels higher than 67% in the period 2006-2012.

In size, Cotonou is similar to Tema Port but achieves significantly lower output than Tema.

As a solution to increase its efficiency, there are two ways

- Put in measures to attract more containerized cargo
- Reduce its use of inputs.

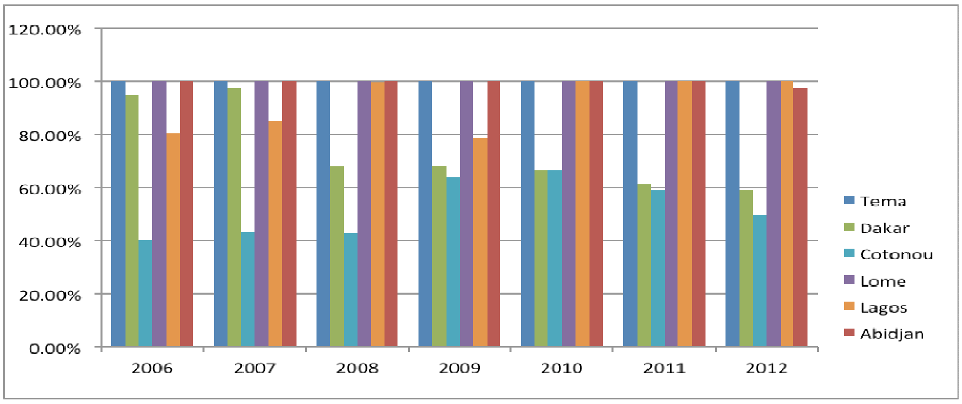
Lagos Port Complex is the largest port in terms of size and throughput amongst the ports under this case study. The port is located in Nigeria, Africa's largest economy and most populous nation.

Due to the analysis, the port achieves an average efficiency rating of 92.07%. Lagos Port Complex achieves its lowest rating during 2009, as a result of the effects of the world financial crisis on trade. The Port of Dakar exhibits quite an average performance throughout the period 2006-2012. The lowest efficiency score throughout the period was 49%, also in 2009 as with other ports in the sample. The port however only manages to achieve a high efficiency score of 82%, averaging 62% efficiency over the seven-year period under study. Table 10 and figure 3 show the ranking of West African ports according to their relative efficiency.

Table 10. DEAP Port Ranking 2006-2012

PORTS	TECHNICAL EFFICIENCY	RANK
TEMA	100.00%	1st
LOME	100.00%	2nd
ABIDJAN	99.66%	3rd
LAGOS	92.07%	4th
DAKAR	73.69%	5th
COTONOU	52.14%	6th

Figure 3.Technical Efficiencies for each port for the period 2006-2012



4.2. SFA application results. Technical Efficiency results with Frontier 4.1

Below are the SFA application results. Table 11 presents the technical efficiency scores – and figure 4 the relative percentages-, while table 12 presents the port rankings.

Table 11. Technical Efficiency scores for the period 2006-2012 and Means

PERIOD 2006-2012

PORTS	2006	2007	2008	2009	2010	2011	2012	Mean
TEMA	79.50%	73.40%	83.30%	68.20%	76.60%	98.20%	91.10%	81.47%
ABIDJAN	73.90%	77.50%	95.10%	88.90%	81.90%	79.60%	73.50%	81.49%
DAKAR	88.40%	99.80%	81.70%	77.90%	85.30%	90.20%	93.80%	88.16%
LOME	50.80%	56.00%	69.70%	83.50%	80.00%	83.70%	49.00%	67.53%
COTONOU	40.30%	48.10%	55.60%	78.30%	90.90%	96.10%	57.50%	66.69%
LAGOS	34.40%	41.60%	55.50%	41.60%	66.10%	82.80%	95.10%	59.59%
Mean	61.22%	66.07%	73.48%	73.07%	80.13%	88.43%	76.67%	

Figure 4. Technical Efficiencies for each port for the period 2006-2012

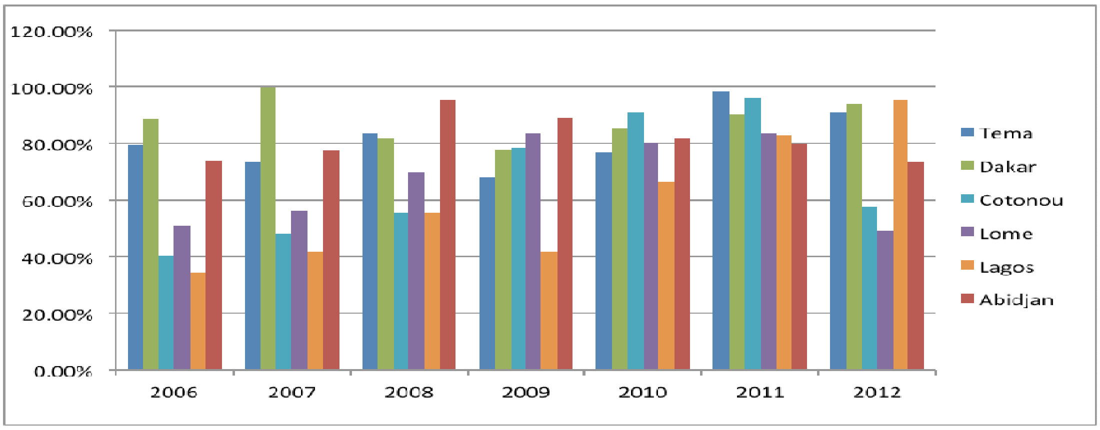


Table 12. SFAcd Port Ranking 2006-2012

PORTS	TECHNICAL EFFICIENCY	RANK
DAKAR	88.16%	1st
ABIDJAN	81.49%	2nd
TEMA	81.47%	3rd
LOME	67.53%	4th
COTONOU	66.69%	5th
LAGOS	59.59%	6th

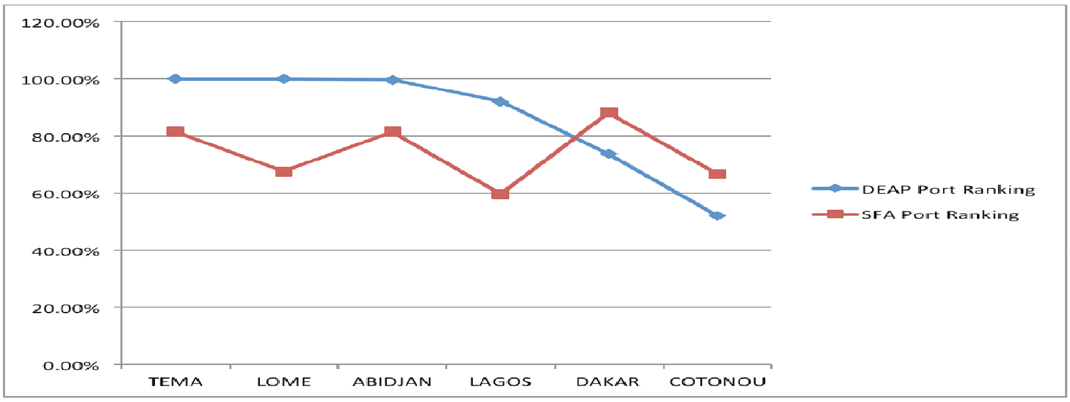
4.3. DEAP vs SFAcd

Below (table 13 and figure 5), one can find a comparison between the two methods. The results are different as efficiency via SFA method scores includes luck and random error which often leads to more accurate results and conclusions. Random effects and other factors like weather, political stability and economic crisis in each port country, when taken under consideration they usually offer more accurate results.

Table 13.DEAP and SFAcd Port Rankings

DEAP Port Ranking			SFAcd Port Ranking	
PORTS	TECHNICAL EFFICIENCY	RANK	TECHNICAL EFFICIENCY	RANK
TEMA	100.00%	1st	81.47%	3rd
LOME	100.00%	2nd	67.53%	4th
ABIDJAN	99.66%	3rd	81.49%	2nd
LAGOS	92.07%	4th	59.59%	6th
DAKAR	73.69%	5th	88.16%	1st
COTONOU	52.14%	6th	66.69%	5th

Figure 5. DEAP and SFAcd Port Rankings



5. Conclusions

The aim of this paper was to apply the DEA and SFA methods to evaluate efficiency in 6 major ports in the region of West Africa. The selection of 6 West African ports was based on their container throughput levels (up to 100,000 TEU's). The DEA and SFA methods were used to determine their relative efficiencies over time for the period 2006-2012.

Both DEA and SFA constitute efficiency frontier analysis methods and they provide a suitable way of treating the measurement of port operating efficiency. According to the results of the DEA model, the Port of Tema in Ghana with the Port of Lomé are the most efficient ports amongst the sample with the port of Abidjan closely following the first two. On the other hand, the Port of Cotonou is the least efficient and exhibited substantial waste in production throughout the period under study. The performance of the Lagos Port Complex adds to literature a doubt on the notion that larger ports are more efficient. The Lagos Port Complex, which is the largest amongst the sample in terms of size and throughput, achieves an average efficiency score of 92%, which is a result of some inefficiency in its operations. Lagos Port Complex achieves its lowest rating during 2009, as a result of the effects of the world financial crisis on trade. The Port of Dakar exhibits quite an average performance throughout the period 2006-2012. The lowest efficiency score throughout the period was 49%, also in 2009 as with other ports in the sample. The port however only manages to achieve a high efficiency score of 82%, averaging 62% efficiency over the seven-year period under study. The analysis also shows that three neighbouring ports, Tema, Abidjan and Lomé, who are the three largest providers of transit services to landlocked West Africa region, have the highest efficiency ratings. For most of the ports, major inefficiencies in production occurred in 2009, can be explained by the world financial crisis and a consequent reduction in output. The results of SFA model are quite different and this is because of the parametrical way it estimates the efficiency. SFA absorbs some effect of heterogeneity in inputs and outputs and also enable statistical testing of hypotheses, calculating confidence intervals. The main difficulty with the parametric approaches is the necessity of correct functional form and error term distributions to obtain unbiased parameter estimates. The efficiency via SFA method scores includes luck and random error which often leads to more accurate results and conclusions. Random effects and other factors like weather, political stability and economic crisis in each port country, when taken under consideration they usually offer more accurate results.

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