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Efficiency and Productivity of Nigerian Seaports in the Pre and Post Concessioning Periods

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Abstract

Seaports pose as vital link in the overall trading chain of any nation, therefore operational port efficiency is a critical contributor to a nation's international competitiveness. In order to support trade oriented economic development, port authorities have increasingly been under pressure from stakeholders to improve port operational efficiency by ensuring port services are provided on an internationally competitive basis. The main objective of port concesioning and/or deregulation policies is enhancing greater port operational efficiency by engendering a more competitive market and commercial approach to management. This paper uses Stochastic Frontier Production and inefficiency models to evaluate the port efficiency and productivity of the major Nigerian seaports using panel data from 2000-2013 which covers the pre and post concessioning periods. It further evaluates the effect of port productive resources on port efficiency. The study also uses the Tobit regression model to further examine the effect of port concession policy on port efficiency and productivity. The results of this study highlight the need to improve port operational efficiency and show which characteristics should be given priority.

Keywords: Port efficiency, Concessioning, Stochastic Frontier Model, Port productive resources, Nigerian seaports.

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1. Introduction

Waterborne transport of materials and goods has for centuries been the main prerequisite for trade between nations and regions, and has without doubt played an important role in creating economic development and prosperity. The cost of maritime transport is very competitive compared with land and airborne transport (Tongzon, 1995). Negative aspects of waterborne transport include longer transport time as a result of relatively low ship speed, congestion in harbours resulting in time delays as well as less efficient integration with other forms of transport and distribution (Liu, 2008).

The Nigerian economy accounts for about 70% of all seaborne trade in the West African sub-region due to the huge population of the country, yet her seaports' operational profile ranks low in efficiency among maritime nations of the world (Five Star Logistics, 2008). To curb this development, the federal government of Nigeria embarked on a massive infrastructure concessioning programmes in September 2004 (Leigland & Palsson, 2007) as these port problems were far beyond the financial resources of NPA since they involved capital projects and huge finances. These reforms include ensuring that Nigerian seaports are made efficient in its operation; the cost of port services to port users should be made to decrease, the Federal Government should be freed from the costs it incurred developing or managing port operations since these can be commercialized as in other developed maritime nations of the world, also private sector participation was targeted by the Federal Government as one way to inject new blood into the maritime sector and even take its fortunes to higher levels without committing the lean resources of the public sector which should be channeled to providing basic amenities to the citizenry (Badejo, 2000). The concessioning programme gained global credibility with the involvement of the World Bank, CPCS Transcom of Canada and Royal Haskoning of Holland as project monitors, concession bid managers and consultants respectively. The Haskoning study, as it is referred to, identified some of the bottlenecks to the port operations and recommended the "landlord" model approach. By July 2006, twenty long term port concessions were awarded with some more in progress resulting to six major ports (Leigland & Palsson, 2007).

Since the takeover of ports by private operators in 2006, there have been improvements in some areas (from what it used to be in different aspects) of port operations for instance, cargo throughput increased from 280,000 in 2006 to 545,000 in 2008, vessel turnaround time reduced from 170 hours to 59.4 hours, but generally, the ports cannot be said to be operating at maximum capacity (Ships & Ports, 2010). Whilst, efficiency measurement reveals the best performers from which under-performers can learn, productivity measurement has the additional advantage of identifying which components of productivity lead to progress or retrogress, for example, technical change and/or efficiency change refers to how seaports improve their efficiency from one year to the other while technological catch-up or change refers to how seaports are able to be technologically innovative in order to catch-up with the frontier and hence, be productive from one year to the other. This study will fill that gap by contributing to literature on the productivity and port operational efficiency of Nigerian major ports using the Stochastic Frontier model which is a quantitative method that will be useful for ports of developing countries like Nigeria and in Africa.

2. Review of Literature

Port privatization has expanded significantly over recent decades. Many ports around the world have benefited from private sector intervention. Transfer of property rights which is a unique form of privatization practiced by many countries like Nigeria in the form of concessioning has brought about positive growth in GDP in some countries like China; however, for countries like Russia, they are still counting their woes. Many scholars believe that there are no best practices for private finance of port investment. This remains an area in rapid evolution, not only in the port sector but for all public infrastructures. The increased use of private investment is a necessary complement to privatization. Port privatization, in its broadest sense, addresses the fundamental question of the type of institution that should control the port sector. The arguments for private control of operations and private ownership of assets other than land are well established. The argument for private control of administration is not. The issue to be resolved is which mechanism is most effective for development of the port sector? Should it be a tree market guided by profit and subject to minimal regulation or a public body guided by public interest? Further still, some researchers are of the opinion that states do not need to transfer seaport property rights in order to benefit from private sector expertise as the specific nature of port investment, and the key objective of ports to facilitate trade, may be counter-productive.

Extant literature has shown that researchers have become increasingly interested in the study of port efficiency and productivity following port reforms and devolution in the world ports. These researches are mainly on western ports of developed countries. Some of these researchers have measured efficiency of the ports using Data Envelopment Analysis and Stochastic Frontier Models. Some of those that applied Stochastic Frontier Analysis to port efficiency include: Liu (1995) in respect of the technical efficiency of twenty eight U.K. ports using a set of panel data from 1983-1990 with a translog functional form of the Stochastic Frontier Production. Banos-Pino, Coto-Millan and Rodrıguez-Alvarez (1999) studied the allocative efficiency of twenty seven Spanish container ports from 1985-1997. Notteboom, Coeck and Van den Broeck (2000) measured the technical efficiency thirty six European and four Asian container terminals by means of Bayesian Stochastic Frontier Models using cross sectional data from 1994. Coto-Millan, Banos-Pino and Rodriguez-Alvarez (2000) in respect of the economic efficiency of twenty seven Spanish ports using panel data between the periods 1985 to 1989.

Estache et al (2002) research was based on the efficiency gains of port reform of eleven Mexican ports from 1996–99. Cullinane, Song and Gray (2002) explored the technical efficiency of fifteen major container ports in Asia using a Cobb-Douglas functional form and an unbalanced panel data from 1989-1998. Cullinane and Song (2003) studied the productive efficiency of two Korean and three UK container terminals using an unbalanced panel data from 1978-1996. Tongzon and Heng (2005) analysed the average efficiency of twenty five selected container terminals around the world with a cross sectional data from 2000. Barros (2005) looked at the economic efficiency of five Portuguese ports using panel data from 1990-2000. Cullinane and Song (2006) used the maximum likelihood estimating model to measure the technical efficiency of seventy four European container ports with cross sectional data of 2003. Gonzalez and Trujillo (2008) in respect of the infrastructure efficiency of nine Spanish container ports using the Distant Function model of panel data from 1990-2000. Yan, Sun and Liu (2009) assessed the efficiency of the world's major container ports using panel data between the period 1997 to 2004 with heterogeneous and time-varying production frontiers.

Early studies on port efficiency primarily focused on partial productivity measures (for example, vessel turnaround time, crane or yard productivity). Later research endorsed more comprehensive methods to examine the overall efficiency of the terminals. An impressive stream of papers use Data Envelopment Analysis (DEA) and Stochastic Frontier Models (SFM) to measure overall terminal efficiency. Notteboom *et al* (2000) introduced a Bayesian approach to SFM with an application to terminals in 36 European container ports.

3. Methodology

For some decades, two methods have been developed to estimate production frontier and measure efficiency in the ports namely, the econometric approach which main example is the Stochastic Frontier and the linear programming technique approach represented by Data Envelopment Analysis (DEA). There are essential differences between these two methodologies from which arises their advantages and dis advantages. The econometric approach which is stochastic can distinguish the noise effects from the inefficiency effects, while the linear programming approach which is not stochastic, deals with the noise and inefficiency together and termed inefficiency. Again, the econometric approach confuses the effects of a bad functional specification of both technology and inefficiency as inefficiency while the linear programming approach is less sensitive to this type of error though it is sensitive to the type of returns to scale applied. The main advantages of linear programming are seen in its inability to impose any functional form *a priori* on the data and handling multiple output processes easily. The disadvantages include that the estimated frontier and the measure of efficiency can be contaminated if there is random noise, therefore since it does not make assumptions on error terms, it does not allow for hypotheses to be contrasted.

3.1. The Stochastic Frontier Model

The Stochastic Frontier Production Function for panel data can be written as

$$Y_{it} = exp(x_{it}\beta + V_{it} - U_{it}) \qquad \text{(i)}$$

where Y_{it} denotes the output for the i-th industry ($i = 1,2,....,N$) in the t-th time period ($t = 1,2,.....,T$); x_{it} denotes the (1×k) vector whose values are functions of inputs for the i-th port in the t-th time period; β is a (1×k) vector of unknown parameters to be estimated; V_{it} s are the error components of random disturbances, distributed i.i.d. $N(0, \sigma^2)$ and independent from U_{it}. U_{it} s are non-negative random variables associated with the technical inefficiency of production. This study uses a Stochastic Frontier production function model of Battese and Coelli (1995) to investigate the relationship between port productive resources and efficiency in which it is formalized technical inefficiency in the production function of Stochastic Frontier for panel data. The equation of the regression of effects of inefficiency on the variables that explain inefficiency is shown in Equation ii as

$$U_{it} = Z_{it}\delta + W_{it} \qquad \text{(ii)}$$

where Z_{it} is a vector of explanatory variables; δ is a vector of unknown scalar parameters; W_{it} is truncation of normal distribution, $N(0, \sigma^2)$, such that the point of truncation is such that point of truncation is - $Z_{it}\delta$.

4. Data

According to Wang, Cullinane & Song (2005), the input and output variables should reflect the actual objectives and process of port production as accurately as possible. A port is more likely to utilise state-of-the art, expensive equipment to improve its productivity if its objective is simply to maximise cargo throughput. On the other hand, a port may be more willing to use cheaper equipment if its objective is simply to maximise profits. It therefore means that the objectives of a port, therefore, are crucial for the definition of variables for efficiency measurement. For instance, if the objective of a port is to maximise its profits, then employment or any information on labour should be counted as an input variable. However, if the objective of a port is to increase employment, employment should be accounted for as an output variable. Hence, the main objective of a port in this research is the minimisation of the use of input(s) such as equipment and labour assuming a given level of cargo throughput that is handled annually.

From orthodox economics, inputs to any form of production process can normally be classified as capital, labour and/or land (Perloff, 2004). This is also the case for the particular circumstances governing productivity of a port which depends crucially on the efficient use of labour, land and equipment. Therefore, this research adopts the number of equipment, quay length, number of employees and turnaround time as suitable variables for the input measure, while cargo throughput serves as the output measure. According to Cullinane (2002) these variables represent the mainstream efficiency physical input variables under capital and labour respectively which are very important in measuring port efficiency and productivity. These port variables are presented in Table 1. It shows the mean values of cargo throughputs (imports and exports) of non-oil commodities handled in the ports under study for the period from years 2000 to 2013 while Table 2 shows the cargo throughput.

Table 1: Distribution of Port Attributes (All ports; years 2000 -2013)

Variable	**Obs**	**Mean**	**Std. Dev.**	**Min**	**Max**
Cargotrupt	84	7,400,811	6,786,728	300,124	2.76E+07
Quay_length	84	1,938.56	791.4157	772	3,990
Equipment	84	93.083	59.796	1	221
Turnrtime	84	6.796	3.985	1.82	22.54
Staff	84	892.726	897.292	129	4,103

Table 3: Efficiency And Turn Round Times In Pre & Post Concession Era.

Ports	Ave. Efficiency (%)		Ave. Turnrd_time (days)	
	Before_Concsn (2000-2005)	**After_Concsn (2006-2013)**	**Before_Concsn (2005)**	**After_Concsn (2013)**
Calabar	26.28	47.43*	3	4
Delta	36.86	46.16*	5	6
LPC	64.27	67.19*	14	8*
Onne	67.4	61.35	6	3*
Rivers	72.56	65.36	13	10*
Tin Can	41.6	59.75*	7	5*

* signifies improvement in value after concession

For all the ports an average of 7.4 million metric tonnes of cargo were handled at the terminals. Other details include; the average quay length (1,938.56 metres), number of cargo handling equipment (93), turn round times in days (7) and number of operational staff (893).

Table 2. Port Cargo Throughput in Metric Tonnes

PORTS	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
LPC	11,008,278	11,461,451	11,754,539	11,875,265	12,294,640	13,432,106	17,921,386	14,814,965	17,427,096	18,914,876	19,052,750	22,808,353	19,957,705	20,344,118
Tin Can	3,937,863	5,116,325	4,754,507	5,293,402	4,693,860	5,461,002	7,399,531	10,303,260	12,807,920	13,541,016	14,461,638	16,242,256	15,268,897	16,134,153
Delta	1,836,660	1,855,200	2,042,959	1,886,085	1,565,588	2,222,758	1,162,404	1,515,592	1,913,148	2,605,101	1,923,258	8,478,359	6,987,533	10,361,746
Rivers	4,683,519	5,690,287	5,301,882	5,531,097	4,963,818	5,660,759	3,001,019	3,112,518	3,488,791	5,141,451	5,808,533	7,501,468	5,574,653	4,935,944
Onne	7,166,436	9,056,487	10,182,079	2,645,719	2,158,548	2,554,328	2,546,759	4,500,291	3,222,663	3,385,455	2,921,727	26,249,274	27,580,642	24,773,387
Calabar	300,124	324,866	399,595	481,062	752,910	857,726	1,600,989	2,210,989	1,914,120	1,721,249	1,594,277	1,875,667	1,723,195	1,732,286

It is observed that Delta and Calabar ports recorded low volumes of cargo throughput less than the other ports yet the ports are seen to be efficient. This is because in reality these ports are quite underutilized due to inaccessibility to these ports as few vessels call at the ports and shippers prefer to ship cargoes through LPC and Tin Can ports then truck the cargoes by road down to the eastern part of the country – a cumbersome and expensive venture. Calabar port as an example does not have good rail and road connection though it is equipped with the extra facility of an export processing zone (EPZ) located within port grounds, with additional provision of 34 hectares of land for expansion purposes. Its cargo handling capacity has been put at 1.5 million tonnes while the infrastructures were designed to accommodate vessels of 8,000 GRT to 15,000 GRT. However, apart from inaccessibility problem, Calabar port has the problem of shallow draught which hampers the entrance of big ships. Thus, year-round navigability of the port's channel is not assured and, at 96 nautical kilometres from the fairway buoy, it is a considerable dredging challenge to surmount. This problem has militated against the growth of cargo throughput for the port, which ordinarily, should be an investor's haven due to its strategic location as a feasible gateway for the south-south, south-east and north-east markets of Nigeria. The draught limitations mean that ships drawing heavier draughts of 7 metres and above, for example, are restricted from calling at the port. Delta port faces the same challenges coupled with security concerns and piracy prevalent in the Niger Delta region.

In estimating the effect of turnaround times on port operational efficiency, Table 3 shows the distribution of the average turnaround times of these ports. Calabar and Delta ports which were seen to be efficient after concessioning seem to have longer turnround times after concessioning. Though the increase is marginal, this effect can be associated to the fact that these ports are underutilized arising from heavy siltation of the channels which causes difficulty in navigation of vessels. Secondly these delay causative factors inherent in Calabar port explain the high ship turnaround

Table 3. Efficiency And Turn Round Times In Pre & Post Concession Era.

Ports	**Ave. Efficiency (%)**		**Ave. Turnrd_time (days)**	
	Before_Concsn (2000-2005)	**After_Concsn (2006-2013)**	**Before_Concsn (2005)**	**After_Concsn (2013)**
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time, scarcity of skilled manpower, lack of storage facilities, inadequacies of berths, deliberate attempt by port workers to extort money from port users and the issue of government agencies' functions like Customs in issuing clearance to vessels when they call at berth. Oftentimes, there are cases where vessels are berthed for three days without clearance from the appropriate government agency thereby incurring demurrage.

5. Results

In line with the cardinal objectives of this study, Stochastic Frontier Analysis regression presented in Table 4 shows the relationship between port productive resources and its subsequent efficiency indices. The productivity model is based on Cobb –Douglas specification which links output (i.e. volume of cargo throughput) of a port to its input resources or the number of port equipment, its terminal area (proxied by quay length) and quantity of labour resource (proxied by number of operational staff).

In ideal productive environment, the productivity or a port should be 100%. But this is hardly achieved owing to inefficiency in resource use, measurement error and other random variations. In examining the effect of port productive resources on efficiency, a null hypothesis which states that there is no significant effect of port productive resources on efficiency is tested using the regression analysis of the Stochastic Frontier model. Thus from Table 4, the explanatory variables are observed to be statistically significant as their p –values are all less than 0.05 (our alpha level of significance). The result is consistent with Cobb –Douglas productivity model.

Table 4. Regression Output Stochastic Frontier Productivity model

Variable	**Coef.**	**Std. Err.**	***t*-stat**	**p-value**
Equip	0.0074134	0.002	3.080	**0.002**
quay_length	0.0004961	0.000	3.390	**0.001**
Staff	0.0002692	0.000	-2.320	**0.020**
_cons	14.65435	0.521	28.140	0.000
Model Fitting Information				
$\ln(\sigma_{2v})$	-1.016	0.699	-1.450	0.146
$\ln(\sigma_{2u})$	-0.213	0.949	-0.220	0.823
σ_v	0.602	0.210		
σ_u	0.899	0.426		
σ^2	1.171	0.542		

λ	1.494	0.626
No of Obs. =	84	
Wald Chi2(3) =	36.530	
Prob. > Chi2 =	0.000	
Log-likelihood =	-100.884	

Dependent variable: ln(Cargo throughput). Significant p –values in bold.

The productive resources are therefore as follows number of equipment (0.0074134), total length of quay (0.0004961) and number of operational staff (0.0002692). The estimated model has a large Chi-square value of 36.530 with significant p –value (0.000). Therefore the estimated productivity model has reasonable explanatory powers which has been adopted for testing the null hypotheses which states that there is no significant effect of port productive resources on port efficiency. Subsequently, the null hypothesis is rejected as the port productive resources are statistically significant with $p \leqslant 0.05$.

The frontier productivity model, apart from producing estimates of productive inputs captures the value of efficiency or inefficiency as part of its output. The efficiency values for all ports are then regressed as dependent variable against the determinants of port productivity. To assess the determinants of efficiency and hence the relative operational efficiencies of the ports, a Tobit model is used in estimating the efficiency values obtained from the productivity model in Table 4. The Tobit analysis is ideal in cases where the dependent variable has values that range between 0 and 1. The efficiency values range from 0 to 1. Thus, in the Tobit regression analysis, various input variables were tested namely: number of equipment, number of operational staff, 'concession effect' (a dummy variable capturing regimes of pre and post concession introduction) and ship turnaround times (proxy for overall level of service at the port). The results of the Tobit model is presented in Table 5.

Table 5. Tobit Regression: Efficiency Model

Variable	**Coef.**	**Std. Err.**	***t*-stat**	**p-value**
Equip	-0.001	0.000	-1.220	0.224
Staff	0.000	0.000	0.800	0.425
concessn_effect.	0.140	0.048	2.910	**0.005**
turnrd_time	0.018	0.004	4.000	**0.000**
_cons	0.382	0.038	9.930	0.000
σ	0.135	0.010		
Model Fitting Information				
No of Obs. =	84			
Prob. > Chi2 =	0.000			
Log-likelihood =	49.126			
Pseudo R^2 =	0.654			

Dependent variable: efficiency. Significant p –values in bold.

It shows the results of the efficiency model, it is noted that only two variables significantly affect efficiency levels of Nigeria's seaports: Concession policy introduction (0.140) and ships' turnaround times (0.018). The other variables: equipment and staff are not significant. Although these variables do not directly impact on efficiency in the present model, probably because they lack skilled manpower to operate these sophisticated equipment but the concession policy brought about investments in more facilities by private operators and these improved efficiency levels. The improvement in port's level of service as a result improved the turn round time of vessels visiting the ports. This may explain the global effect of concession policy and turn round time variables in the Tobit model perhaps masking the direct effect of equipment and staff.

Therefore, in addressing the null hypothesis, which states that there is no effect of port concession policy on port efficiency and productivity, we therefore reject the null hypothesis as concession policy and ships turn round time were found to have statistically significant relationship with port efficiency with $p \leqslant 0.05$. These significant variables are policy pivots which needs to be focused on. However, the implication is that concession policy is favorable to attaining port efficiency and measures which reduce turnaround time should be maintained in order to sustain efficiency levels at the ports.

6. Conclusion

The aim of this paper was to evaluate the port operational efficiencies of the major Nigerian seaports using panel data from 2000-2013 which covers the pre and post concessioning periods. The research was conducted using the Stochastic Frontier Production and inefficiency models. To achieve this aim, it was necessary first to hypothesize this relationship and then to empirically examine the relationship, and this was done using an empirical study intended to evaluate the determinants of efficiency and productivity of the seaports under consideration. It further evaluated the effect of port productive resources on port efficiency and utilized the Tobit regression model to further examine the effect of port concession policy on port efficiency and productivity. The results show that the average operational efficiency levels of the ports varied in the pre and post concession periods. There were more efficient ports in the post concession period than in the pre concession. One of the reasons of inefficiency is hinged on low utilization of operational port infrastructure, another is the insignificant contribution of staff input to the output of the ports suggests inadequate skilled manpower and/or low mechanization of cargo handling equipment. These results provide valuable implications to port authorities, port operators and stakeholders. The results go further to show that infrastructure, cargo handling equipment and skilled manpower are important determinants of port efficiency.

Further studies can extend this study by covering years 2014 to 2017 with a causal outlook on the effect of port financing on efficiency and productivity. Although Data Envelopment Analysis is a non-parametric technique which can measure multiple output measures of seaports bearing in mind its limitations and Stochastic Production Frontier model which assumes that a port's output is a single measure, further research can consider improving on the methodology of this research by developing a hybrid model that integrates the advantages of Stochastic Frontier Analysis and Data Envelopment Analysis.

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