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FRONTIER STOCHASTIC MODEL: A MAJOR APPLICATION FOR MAGHREB REGION SEAPORT

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Abstract:
This paper aims to estimate a stochastic production frontier to measure the technical efficiency of twenty seaports in the Maghreb region (Tunisia, Algeria and Morocco). The technical efficiency is measured based on the estimation in time-varying. The use of the stochastic frontier model has set notable results. The results showed a minimal improvement in the scores efficiency over the 2008- 2012 period. The average value of the port technical efficiency is 0.766. The results conclude that infrastructure characteristics have a great role in the port efficiency. In addition, the multipurpose port is proven to be more efficient than specialized port.

***Key Words**:*
Technical efficiency, Stochastic Frontier Model, seaports in Maghreb region.

INTRODUCTION

The majority of goods in the world is transported by sea, which provides the important role of ports in the world. For instance, over 90% of the international trades of the world are achieved by the sea. For this reason, some authors argue that the ports constitute one of the main forces that move the economy as [18] [8] Moreover, the events from the Maghreb region aimed at increasing investments in the ports and the transport infrastructure tend to promote the economic cohesion of the different regions.

Several studies focusing on the subject of port efficiency in the literature review. The application of stochastic frontier analysis in the port sector is relatively recent, starting with a study by [13], which measured the efficiency of 28 public and private ports in the UK for the period between 1983 and 1990.

The type of data has a great effect on the estimation results, also both of the cross sectional and panel data are used to analysis technical port efficiency. For example, the studies of ([13]; [9]; [4]; [5]; [10]; [11]; [20]; [7], [17]; [2]) used the panel data. However, the studies of ([15]; [4]; [5]; [6]; [21]; [14]; [16]; [12]) used cross sectional data.

Tab. 1 *Studies Used Technical Efficiency With Stochastic Analysis In Seaport.*

Authors	**Ports region**	**Data years**	**Data Type**
Liu (1995)	28 British ports	1983-1990	Panel
Notteboom et al. (2000)	36 European container terminals + 4 Asian terminals	1994	Cross-sectional
Estache et al. (2002)	11 Mexican port authorities	1996-1999	Panel
Cullinane et al. (2002)	15 Container ports in Asia	1989-1998	Cross-sectional panel
Cullinane and Song (2003)	5 Korean ports and container terminals in Spain	1978-1996	Cross-sectional panel
Cullinane et al. (2006)	57 International terminals	1989-1998	Panel
Tongzon and Heng (2005)	25 container ports/terminals	1999	Cross-sectional
González and Trujillo (2008)	5 Spanish port authorities including 17 ports	1990-2002	Panel
Grace Wanga, Chen Gao (2012)	9 china ports Selected in the Bohai Zone	1995-2010	Panel
Medda and Liu (2013)	165 world container terminals	2006	Cross-sectional
Tovar and Wall (2014)	26 Spanish Terminals	1993-2007	Panel
Chang and Tovar (2014)	14 container terminals	2004-2010	Panel
Serebrisky et al., (2016)	63 container ports in Latin America and the Caribbean	1999-2009	Panel
Barros al., (2016)	33 Chinese seaports	2002-2012	Panel
Nguyen et al. (2017)	43 largest seaports of three regions in Vietnam	2012	Cross-sectional
Hlali (2018)	26 major container ports in the world	2015	Cross-sectional

Source: own elaboration

The table 1 shows the variety of regions that authors analysed as a case of study for seaport efficiency, it is remarkable that no study presents the case of the Maghreb region as an example, for this reason, the main purpose of this paper is to quantify the evolution of technical efficiency in Maghreb ports. The exception of this paper with comparison to other studies appear in the introducing of the Tanger Med as an international hub, with the other 19 ports that seems to be more like feeder ports. The paper will explain why and how an international hub can, meaningfully, be benchmarked against smaller feeder ports.

Methodologically, the paper studies the stochastic function with four inputs and one output used database covering the 2008–2012 period. This paper is structured as follows. Section 2 describes the methodology of analysis, which started by the theoretical aspects of models than the description of the data and the variables. Section 3 deals with the empirical results and discussion. Finally, section 4 conclusions.

1 METHODOLOGY

1.1 Model selection

This research used Battese and Coelli (1995) [3] model, which can be expressed in brief as follows:

$Y_{it} = x_{it}\beta + (V_{it} - U_{it})$ i=1,..., N, t=1,..., T,

With: Y_{it}: is the output obtained by the i-th port at the t-th time period; x_{it}: is the vector of input quantities of the i-th port at the t-th time period; β: is a parameters to estimate; V_{it}: are random variables Y_{it}, and $U_{it}= (U_i \exp(-\eta\ (t-T)))$;

Where: U_{it}: are assumed to be independent and identically distributed (i.i.d) as truncations at zero of N (m_{it}, $\sigma_U{}^2$); $\sigma^2 = \sigma^2 v + \sigma^2 u$ and $\gamma = \sigma^2 u / (\sigma^2 v + \sigma^2 u)$; V_i and U_i are independent; $m_{it} = z_{it}\delta$

With z_{it}: is the vector of exogenous variables which may influence the efficiency of a port; δ: is the vector of parameters.

This specification allows us to estimate the stochastic frontier and technical efficiencies of ports as well as explain the variability of estimated efficiencies from one port to another. In other words, this model allows us regression of efficiency (individual risk) U_i on variable data, it estimate the production function frontier and the technical inefficiency in one stage by the (LM) as Fig.1 describes.

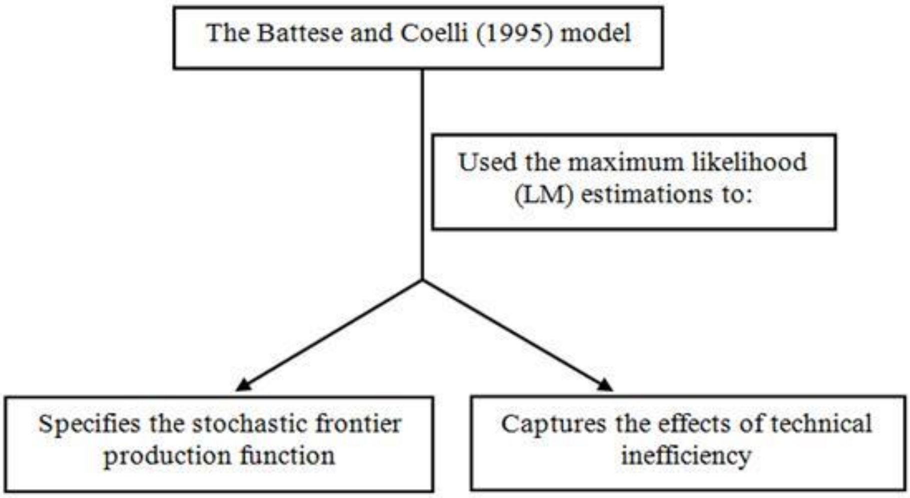

***Fig. 1**. Model Description*
Source: own elaboration

The use of the LM estimate has many advantages: It lower the variance than other methods, it is robust to many violations of assumptions in the evolutionary model, can evaluate different topologies and use all the sequence information, its estimates are among all consistent asymptotically normal estimators and have optimal asymptotic properties. Therefore, the LM is statistically easy to set up as well as to understand.

1.2 Variables and data selection

The Fig. 2 represents the variables used in this study such as: full land surface (hectare), quay length (meter), Draft (length) and the number of Berths as inputs variables. The output variable is the port throughputs in terms of TEU. In addition, one exogenous variable, the type of port, is used, which is a dummy variable differ either it is multipurpose or specialized port (0= Specialized, 1= Multipurpose). Generally, the multipurpose ports may comprise Ro-Ro terminals, timber terminals, dry and wet bulk, container etc. [19]. In addition, container ports are specialized ports, see for example [19] as well as [22]. This classification explained the relationship between efficiency and specialized/multipurpose port. Wherever, to estimate port efficiency with the stochastic frontier for 20 ports located in the Maghreb countries such as Algeria, Morocco and Tunisia the data used are balanced panel data which mean T observations are available for n ports. There are two essential explanations on why exactly these 20 ports are selected. First, is the availability of data and second, these ports are the major ports in the three countries.

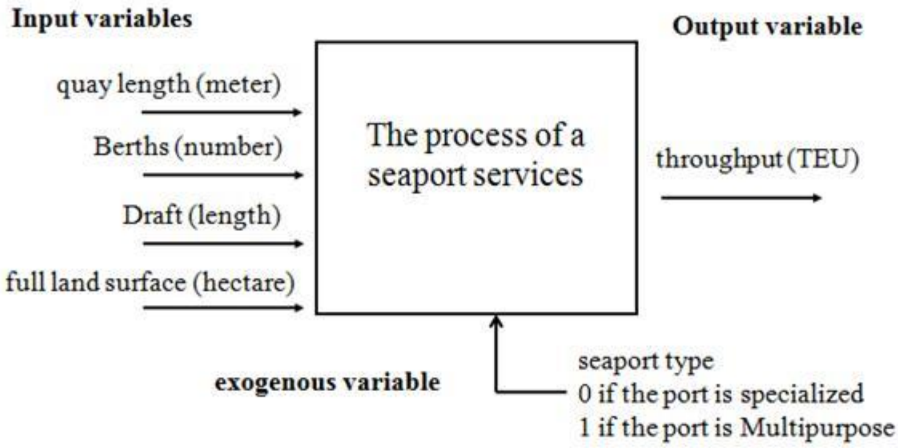

Fig.2. *Variables Presentation*
Source: own elaboration

The data are collected from the annual reports published on the OPNT (National Office of Tunisian ports), OMMP (Office of Merchant Navy and Ports), ANP (National Agency of Moroccan ports), the websites of the Algerian ports companies, statistical yearbooks of Algerian ports and Moroccan port websites.

2 EMPIRICAL RESULTS AND DISCUSSION

2.1 Descriptive statistics

According to the analysis of the container throughput number, it is observable that the 3 Moroccan ports handled more throughput than all the 17 Algerian and Tunisian ports combined during the period 2008-2012. This large difference between the three countries dependent to the Tanger Med the hub ports in Morocco. The table 2 represents the descriptive statistics for the different variables. The test of kurtosis and Jaque-Bera are analyzed under the Table 2.

Tab. 2 *Descriptive Analysis Data.*

	Y	X_1	X_2	X_3	X_4
Mean	237339.0	3681.200	17.40000	11.59500	46.20000
Median	44745.00	1987.500	13.50000	11.00000	30.50000
Maximum	1826000.	23190.00	66.00000	18.20000	152.0000
Minimum	90.00000	420.0000	5.000000	8.200000	7.500000
Std. Dev.	449979.1	5035.459	13.29582	2.371425	39.51096
Skewness	2.533370	3.147413	2.667206	1.378638	1.347665
Kurtosis	8.963834	12.57994	10.19363	4.585072	3.855529
Jarque-Bera	51.03265	109.5000	66.83690	8.429182	6.663950
Probability	0.000000	0.000000	0.000000	0.014778	0.035722

Note: y= throughput (TEU); x_1= quay length (meter); x_2= Berths (number);
x_3= Draft (length); x_4= full land surface (hectare);

The test of Bera-Jarque (1982) is based on the use of the coefficient skewness and kurtosis which should be respectively close to 0 and 3 in the normal case. To evaluate the port efficiency in the Maghreb region, we studied the significance of the impact of inputs variable on the output (container traffic). The Normality was tested by using respectively the calculation of the symmetry (skewness) and the concentration (Kurtosis) coefficients.

The Jarque-Bera tests founded in similar results in all selected variables and are rejected by the normality test. The output variable number of throughput (TEU) has a statistical jarque-Bera (JB) value equal to 51.03 as a result, the normality assumption of throughput number is rejected. The variable quay length has a statistics Jarque-Bera is equal to 66,836, which mean that the normality assumption is rejected. For the berths number the statistics Jarque-Bera is equal to 109.5 therefore, the normality assumption is rejected. The length draft has a Statistics Jarque-Bera equal to 8.429 so the normality assumption of the draft length is accepted at the 10% level. The full land surface has a statistics Jarque-Bera equal to (6.66). Hence, the normality assumption of the full land surface is accepted at the 10% level.

2.2 Estimation efficiency results

The β, γ and σ^2 are the parameters estimated by the maximum likelihood method. These parameters are the coefficients of the production function determined the indices of technical efficiency, $TE_i = \exp(-u_i)$. The maximum likelihood estimates (MLE) of the parameters, production function were obtained from the frontier 4.1. Table 3 describes the different coefficients of parameters and shows that the maximum-likelihood estimate of the parameter equal to -0.591.

The coefficient of the full land surface was found to be insignificant. On the other hand, the other inputs variables are significantly different to zero. Excepted the coefficient of the full land surface (x_4) is negative. Which means that the full land surface have no effect on port production this result is confirmed by the study [16] which indicate that container terminal are more efficient than others ports. In addition, Cullinane et al., [4] found that the statistical variables are significant except the terminal area surface. Thus, it can be concluded that the size of the port or the surface has no effect on technical port efficiency.

Tab. 3 *The Maximum Likelihood Estimators.*

Variables/parameters	ML
Constant	-0.614 (0.152)
X_1	0.107 (0.468)
X_2	0.823 (0.452)
X_3	0.161 (0.120)
X_4	-0.947 (0.387)
Constant (delta0)	-0.297 (0.148)
Z_1 (delta1)	-0.556 (0.231)
sigma-squared (σ2)	0.197 (0.407)
Gamma (γ)	0.500 (0.425)
log likelihood	-0.591

Note: y= throughput (TEU); x_1= quay length (meter);
x_2= Berths (number); x_3= Draft (length); x_4= full land surface (hectare);
S.E = Standard error are in the parentheses.

The σ^2 parameter indicates the variance of the error terms. This parameter is in the order of 19.7 %. The γ estimators are significantly different to zero, which indicates the presence of inefficiencies production. These estimates indicate the proportion of the errors controlled in the total variance of the error terms in the model which is 50%. This means that 50% of the variability of the production ports is caused by the technical inefficiency for the Maghreb ports case. The negative sign of the estimated coefficient Z_1 (port type) implies that there is a positive relationship between the technical efficiency and the port type (multipurpose or specialization), the coefficient related to the exogenous variable equal to (-0.556). The effect of port type on efficiency is important for economic reasons.

The Table 4 represents the technical efficiency estimates for the Maghreb port over the 2008-2012 period.

Tab. 4 *Scores Efficiency.*

		2008	**2009**	**2010**	**2011**	**2012**	**Mean efficiency**
1	Alger	0.780	0.831	0.842	0.871	0.878	0.840
2	Bejaia	0.762	0.777	0.789	0.732	0.804	0.772
3	Annaba	0.750	0.804	0.809	0.813	0.865	0.802
4	Arzew	0.411	0.649	0.739	0.739	0.795	0.666
5	Djen-djen	0.878	0.889	0.899	0.906	0.765	0.867
6	Ghazaout	0.714	0.724	0.786	0.821	0.909	0.790
7	Mostaganem	0.496	0.557	0.705	0.716	0.818	0.658
8	Oran	0.837	0.771	0.817	0.818	0.784	0.805
9	Skikda	0.775	0.776	0.781	0.787	0.825	0.788
10	Tenes	0.739	0.798	0.831	0.831	0.834	0.806
11	Tanger Med	0.907	0.918	0.927	0.927	0.933	0.922
12	Casablanca	0.895	0.909	0.916	0.919	0.922	0.912
13	Agadir	0.827	0.853	0.884	0.885	0.897	0.869
14	Goulette	0.446	0.449	0.449	0.646	0.662	0.530
15	Rades	0.635	0.652	0.749	0.749	0.801	0.717
16	Bizerte	0.210	0.586	0.705	0.775	0.776	0.610
17	Sousse	0.606	0.725	0.725	0.734	0.791	0.716
18	Sfax	0.667	0.802	0.765	0.812	0.821	0.773

19	Gabes	0.619	0.733	0.742	0.798	0.798	0.738
20	Zarzis	0.668	0.681	0.755	0.804	0.804	0.742
	Average efficiency						**0.766**

The analysis of the score efficiency presented in Table 4 shows that all the ports are efficient. The minimal average efficiency is 0.530 reporters to Goulette port (Tunisian port). The maximum average efficiency is 0.922 reporters to the Tanger Med (Moroccan port). Therefore, the evolution of the scores efficiency between the years is minimal. The minimal variation is a result of the less progression of the infrastructure port (input variables has a small progression) over time, it has a small increasing variation. The analysis of the average efficiency at the national level for each country shows that Djen-Djen ,Tanger Med and Sfax are the best efficient port in Algeria, Morocco and Tunisia, respectively. The regional analysis shows that Tanger Med is the most efficient port in the Maghreb region.

The Moroccan ports full the best score efficiency. This indicates the importance of multipurpose port to improve efficiency. The most Tunisian ports are in the last order. This is caused by many reasons. First, the majority of Tunisian ports is specialized in some activities. Second, they are characterized by poor infrastructure. Third, there is no investment in port infrastructure in Tunisia during the studied period. Finally, the improvement of port infrastructure can improve economic activities and then improve port efficiency. The model shows the effect of exogenous variable on the estimation efficiency result. The infrastructure characteristics of port are insufficient for the technical efficiency study. In addition, is to differentiate between the types of port operations, according to their activities. A port is inefficient, according to the some infrastructure criteria, but efficient in its activities.

3 CONCLUSIONS

This paper studies the technical efficiency of twenty ports located in the Maghreb region using a panel data. The use of panel data shows that the evolution of the level efficiency is minimal between the years.

The results noted that the efficiency of the three countries has improved over the analysis period. In adition, the Morocco ports were more efficient than Algerian and Tunisian ports. Since, the Moroccain ports are multipurpose ports, however the majority of Tunisian and Algerian ports specialized in various activities. The results show the infrastructure variables selected as input variables are significant. However, the full land surface has a negative sign. Furthermore, shows the influence of port type on the efficiency estimated either port is multipurpose or specialized is efficient in its activities.

Finally, it can conclude that the most efficient port are those handled more containers and have the greatest infrastructure as quay length, Berths (number), Draft (length) and full land surface. This proved the importance of infrastructure in port efficiency and encourages these three countries to invest more in the infrastructure seaport. Therefore, these ports are multipurpose ports or the specialized ports are less efficient.

Furthermore, the including of Tanger Med as hub port with the feeder ports showed that it is the highest efficient port in Maghreb region still now according to this study. Tanger Med is an international container port, for this reason it is more efficient. It can be synthesized according to this paper that the container ports are more efficient than feeder ports such as their activities.

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