Evaluating port efficiency in the Mediterranean

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Abstract: During the last years, there was rapid development in the world port industry which is considered to have resulted from the increase of universal trade. The key to the development of each port is its adaptability to the earliest developments and its resistance to the increasing competition. The influence zones of each port are characterised by instability, while each port authority aims at the creation and exploitation of competitive assets, setting store on specialisation and increase of productivity of each port’s functions. The aims of this study are the comparative efficiency evaluation of ports in the Mediterranean with the use of DEA analysis, the exploitation of the factors that affect ports’ efficiency using a second-stage Tobit analysis and the potential of each port in the era of larger container volumes attraction. The study will focus on the ports which display or are able to display significant achievement in transhipment movement.

Keywords: Mediterranean seaports; DEA analysis; Tobit analysis; two-stage efficiency analysis.


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Spyros Niavis is an Economist. He holds an MSc in Planning and Regional Development. He is a PhD candidate in the Department of Planning and Regional Development, School of Engineering, University of Thessaly. His research interests cover the fields of port economics, combined transport, transport policies and regional development. The subject of his PhD research focuses on port management and especially on container port competition and container port performance measurement. He is a member of the Laboratory of Policy and Developmental Programs Appraisal and has participated in a significant number of projects in the field of regional development and effectiveness of regional policies.
1 Introduction

The port competition in the wide region of the Mediterranean Sea related to the attraction of cargo transport is a phenomenon which is becoming more and more intense. Mostly two facts contribute to this competition: the first one refers to the spread of container transfer and the second one to the continuous increase of the total transferred cargo. The above facts have brought about remarkable changes into the port system of the region and undoubtedly, the way the container transfer is performed both in the interior and exterior of each port has also changed. The high added value which is produced by container transfer has led a lot of ports to be gradually directed to container transfer exclusively, while special terminals for loading and unloading containers have been constructed in mixed use ports (De Lombaerde and Verbeke, 1989). On the other hand, due to the growing volume of every kind of transferred containers, there is an urgent need for the increase of functionality and improvement of productivity of the ports, in order for them to be able to cope with the increasing transfer demands.

The Mediterranean port system has to meet the needs of two kinds of transfer activity: the one which refers to containers loading and unloading from ships which sail all around the world in a single voyage and the other one which meets the needs of the interior area (Gouvernal et al., 2005). Each port tries to develop its competitive asset which relies on factors, such as the geographical position, qualitative service, confidential relationships with the transfer companies, flexible pricing policy, sufficient connections, etc. (Fageda, 2000; Lam and Yap, 2006; Polyzos and Niavis, 2008; Verhoeff, 1981). Moreover, private sector starts gradually playing a dominant role, since the world carriers and the global terminal operators have more and more market share under control. Generally, these global enterprises initiate the development in the Mediterranean region because they are the decision makers for things such as the possible port of calls, the potential buying out of a port’s terminal or the ports and shipping lines that they will cooperate with. There are many examples of such decisions which affected the Mediterranean port system in the past years. We could mention the latest agreement between APM and Cosco in order for the former to gain privileged treatment towards the latter in the Port-Said port, the agreement of MSC for exclusive cooperation with Valencia port, a terminal construction in Piraeus port by Cosco, the exclusive cooperation of HPH with Alexandria port and the large investment of APM in Tanger port (Gouvernal et al., 2005; Institute of Transport and Maritime Management of Antwerp, 2009; Olivier, 2006). Apart from the fact that the global carriers are competent negotiators with port authorities, the entrance of new ports in the market and the claim for biggest market share, the congestion problems and the great investments to a lot of ports, make the market seem much more complicated. The keys to the survival of each port are its adaptability to the new environment as well as its efficiency (Niavis and Polyzos, 2009).
The estimation of port efficiency as a main component of the competitive position of each port and the evaluation of the functional port records are fields that the international bibliography intensely deals with (Cullinane et al., 2006). For this purpose, various techniques of comparative evaluation of ports records have been used and a significant number of suggestions were made for the improvement of the productivity of port systems. The present paper aims at the same target. Particularly, its aim is to contribute to the process of ports efficiency evaluation, proposing a methodological frame, which combines parametric and non-parametric techniques. The study is divided in the following way: in Section 2, a bibliographic review of the methodologies of ports efficiency estimation is provided and in Section 3, the proposed methodology is presented. In Section 4, the application of the proposed methodology is attempted in the Mediterranean port system. Finally, the paper ends with the section of conclusions and the analysis of prospects of the Mediterranean ports growth.

2 Measures of port efficiency

The basic approaches for evaluating the efficiency of seaports are separated in two categories: the parametric methods and the non-parametric techniques (Tovar et al., 2007). The first category of methods approaches the efficiency through the calculation of a theoretical production function. The deviation from the function line is attributed partly to the lack of efficiency and partly to the existence of measurement error (Cullinane et al., 2006). The most important parametric methodology is stochastic frontier analysis (SFA) which was used for first time in the port industry by Liu (1995). Later, SFA was used by many researchers for the evaluation of efficiency of ports and terminals (Coto-Millan et al., 2000; Cullinane and Song, 2003, 2006; Notteboom et al., 2000; Tongzon and Heng, 2005; Yan et al., 2009).

The non-parametric methods are applied without the adoption of a certain production function while they are based on the use of empirical data. In this case, the deviation from the efficiency frontier is attributed to the inefficiency of each port. The most used non-parametric method is data envelopment analysis (DEA) (Cullinane et al., 2006; Wu and Goh, 2010). DEA constitutes a data analysis method aiming at the comparison of technical efficiency of the so called decision making units (DMU). Generally, DEA is a method of linear programming which uses the inputs and outputs of productive process in order to calculate the relative efficiency of each DMU. The inputs more often used are the elements of the production procedure, such as labour, land and equipment, while the outputs may be elements, such as the size of production, the economic results of the port or other relevant indicators. The methodology was first applied by Farrell (1957), while it was extended by Charnes et al. (1978) and by Banker et al. (1984). The result of these improvements was the creation of the two basic DEA models, which were named CCR and BCC models, from the initials of the writers. The DEA-CCR model assumes constant returns to scale in contrast to the DEA-BCC model, which assumes variable returns to scale.

The first attempt to use DEA in the port sector emanated from Roll and Hayuth (1993) who used a hypothetical sample of 20 ports in which the methodology was
applied using the CCR model. After this attempt, many researchers used DEA for the evaluation of the ports efficiency. Therefore, the bibliography contains studies adopting the CCR model (Tongzon, 2001), the BCC model (Martinez-Budria et al., 1999) and studies with the combination of the two models (Barros, 2003; Barros and Athanasiou, 2004; Koster et al., 2009; Poitras et al., 1996; Wang and Cullinane, 2006). Moreover, there are numerous studies in which the authors developed various theoretical extensions of the two basic models. These studies adopt theoretical extensions of the basic DEA model, such as RDEA, which constitutes a multi-stage DEA model recursively applying CCR and super-efficiency DEA in order to re-rank the ports according to their efficiency scores (Lee et al., 2005), four-stage DEA model which is employed in order to evaluate the productivity, the profitability, the marketability and at last the overall efficiency of each port (Park and De, 2004), DEA window analysis which analyses the efficiency of ports in concrete interval of time (Cullinane et al., 2004; Eraqi Al et al., 2008; Min and Park, 2005), super-efficiency DEA which is used in order to achieve a re-rank of the efficiency ports (Tongzon, 2001), as well as the bootstrapped DEA analysis which is adopted in order to reduce the statistical noise of the basic DEA models (Hung et al., 2010). A particular reference should be made to the study of Panayides et al. (2009) which contains a critical review of a large number of studies that used the DEA as a tool for the evaluation of ports’ efficiency.

The above mentioned techniques constitute an important methodological tool for the analysis of differentiations in the functional records of ports. However, beyond their contribution to the analysis of the port efficiency, the two methods also have individual weaknesses. In the parametric techniques the main disadvantage derives from the fact that the functional form that is adopted (e.g. Cobb-Douglas, translog, etc.), is based on a priori assumptions for the production technology. This fact can be considered as a drawback because the production technology that is finally selected may not be appropriate for every port. In the non-parametric methods the main disadvantage derives from the fact that these methods constitute a comparative evaluation of DMUs so, in many cases DMUs are rendered as relatively efficient, while in absolute terms they do not operate efficiently (Cooper et al., 2000; Cullinane et al., 2006; Thanassoulis, 1993). Therefore, SFA provides a strong statistical base in the efficiency evaluation, while DEA provides a great flexibility. Concerning the applicability of the two methods in the port industry, DEA is the most common used methodology.

Apart from the above mentioned, DEA also has one important weakness. More specifically, in a continuously altered environment of operation, as one of the ports, the production process of a port and consequently its effectiveness is also influenced by other factors which cannot be controlled by the port’s authority (Turner et al., 2004). The fact that these factors cannot be included in the DEA process which attributes each deviation from the efficient frontier to inefficiency causes, casts doubt on the explanatory faculty of DEA for the efficiency of each port. In order to overcome this weakness, a different approach for the estimate of port’s efficiency is presented in Section 3, combining the application of DEA with the use of an econometric model. This combination primarily aims at the enlargement of analysis and the interpretation of the effect that various factors, beyond the ports authorities’ control, have on the efficiency and the competitive position of the ports.
3 Port efficiency evaluation methods

The two-stage efficiency evaluation of ports includes initially the use of DEA for the classification of ports on the basis of their relative efficient. The composition of a DEA problem follows the process below.

Suppose that there are \( n \) DMUs to be analysed, each of which uses \( m \) inputs to produce \( s \) outputs. Let \( X_{ij} > 0 \) be the amount of input \( i \) used by DMU \( j \) and let \( Y_{rj} > 0 \) be the amount of output \( r \) produced by DMU \( j \). The input-oriented CCR DEA model is:

\[
\begin{align*}
\theta^* = & \min \theta \\
\text{s.t. } & \sum_{j=1}^{n} x_{ij} \lambda_j \leq \theta x_{io} & i = 1, 2, ..., m \\
& \sum_{j=1}^{n} y_{rj} \lambda_j \geq y_{ro} & r = 1, 2, ..., s \\
& \lambda_j \geq 0 & j = 1, 2, ..., n
\end{align*}
\]

where,

\( y_{ro}, x_{io} \) the \( r \)th output and \( i \)th input for a DMU\( o \) under evaluation

\( \lambda_j \), the decision variables which represent the weights DMU \( j \) would place on DMU\( o \) in constructing its efficient reference set

\( \theta^* \), the decision variable which represents the relative technical efficiency of DMU\( o \).

The variable \( \theta^* \) can take the price (1) rendering one unit relatively efficient and \((< 1)\), rendering one unit relatively not efficient. In the particular study, the super-efficiency methodology will be used in order to extract results that would be used more easily in the parametric analysis that will follow. Super-efficiency constitutes a modification of the basic model and was developed by Andersen and Petersen (1993). The efficiency scores from these models are obtained by eliminating the data of the DMU that is being evaluated from the solution set. This modification can give to the efficient unit an efficient score over the unit. When a DMU presents a score over the unit then this unit is called super-efficient. The efficiency scores of the not efficient units remain the same with the scores that were obtained from the use of the basic DEA model. The basic CCR super-efficiency model is:

\[
\begin{align*}
\min \theta^{super} \\
\text{s.t. } & \sum_{j=1}^{n} x_{ij} \hat{\lambda}_j \leq \theta^{super} x_{io} & i = 1, 2, ..., m \\
& \sum_{j=1}^{n} y_{rj} \hat{\lambda}_j \geq y_{ro} & r = 1, 2, ..., s \\
& \hat{\lambda}_j \geq 0 & j = o
\end{align*}
\]
The application of DEA leads to the classification of ports based on the relative efficiency of each one. However, as it was stressed, DEA is not able to totally explain the differentiations that are presented in the records of ports. For this reason, a further and more precise analysis of DEA results is necessary. Therefore, regression techniques are used, in which the relative efficiency of each port is used as the depended variable and many other factors, equally critical for the seaport operation with the corresponding factors used in DEA analysis, are used as the independent variables of the regression (Turner et al., 2004).

The general form of the applied regression is presented below:

\[ y_i = \sum_{k=1}^{K} \beta_k x_{ki} + \epsilon_i \]  

where,

- \( y_i \) the relative efficiency of \( i \) port as a result of the DEA application at the \( N \) ports \( (i = 1, \ldots, N) \)
- \( k \) the defining factor being under review \((k = 1, \ldots, k)\)
- \( \beta_k \) the coefficient which corresponds to the \( k \) factor
- \( x_{ki} \) the variable which reflects the effect of \( k \) factor to the port \( i \)
- \( \epsilon_i \) a continuous independent and equally distributed, random variable.

The query that emerges from what we noted earlier concerns the type of regression that should be used in order to reach the most reliable conclusions. The utilisation of the ordinary least squares method (OLS) may result in a truncated bias, because the indicators of efficiency have predetermined prices. The use of super-efficiency suppresses the restriction of the high prices at the unit, but it is not possible to do the same with the restriction of the minimum prices which can be equal to zero. For this reason, the Tobit analysis is preferred for the estimation of the proposed model (Tobin, 1958).

Tobit model represents the expected price of the dependent variable \( y \), as a latent variable \( \hat{y} \), which only partially can be observed, inside the breadth of acceptable prices \((\geq 0)\) the efficiency indicator. The Tobit model for the \( i \) port is represented as follows:

\[ \hat{y}_i = \sum_{k=1}^{K} \beta_k x_{ki} + \epsilon_i \]

\[ y_i = \begin{cases} 0, & \text{av} \hat{y}_i < 0 \\ \hat{y}_i, & \text{av} \hat{y}_i \geq 0 \end{cases} \]  

Combinations of DEA and Tobit analysis have been used adequately in a wide spectrum of scientific fields (Afonso and Gaspar, 2007; Kerstens, 1996; Tipi et al., 2009; Waldo, 2007), while according to Maddala (1983) and Hoff (2007), the Tobit methodology constitutes a satisfactory solution for the further analysis of the DEA results. Nevertheless, the particular combination was seldom used in the efficiency analysis port industry. The main effort emanated from Turner et al. (2004) in their study for the
analysis of port’s efficiency in North America for the period 1984–1997. In this study, DEA was used for the diachronic comparison of ports efficiency. DEA results were further analysed in order to examine the relationship between the efficiency of each port with factors that influence a port’s function. These factors represented elements of the ports’ function focusing especially on the structure of the certain port industry, the behaviour of port authorities and carriers and the possibility of the ports to provide transit services. The research led to the conclusion that there might be a lot of factors influencing the port’s effectiveness.

4 Two-stage efficiency analysis of the Mediterranean ports

The present work will rely on the work above mentioned with certain, however, differentiations that concern the methodology that will be used and the factors that will be included in the model. More analytically, as far as methodology is concerned, in the present paper the bootstrapped Tobit model and not the simple Tobit analysis will be used. The use of techniques of parametric simulation (bootstrap) is adopted, so that statistically reliable and more sufficient estimators could be produced.

The process for the application of technical parametric simulation is as follows. In the first stage the \( \varepsilon = Y - X^\prime \beta \) equation is formed, where \( \varepsilon \) represents the residuals, \( Y \) is the depended variable, \( X^\prime \) the independent variables and \( \beta \) a constant. Based on the above equation a random sample \( \varepsilon^* \) with \( n \) observations is selected with the method of replacement. The new bootstrap sample is produced by the equation \( Y^* = X^\prime \beta + \varepsilon^* \). Then, this equation is calculated through the Tobit model. The procedure is repeated for \( N \) times, where \( N \) is a number set by the researcher, while there is not a certain model for the times that a bootstrap procedure must be repeated (Chernik, 2008). Concerning the differentiations of the factors that will be entered in the model, these will be analysed at the application of Tobit model in the sample.

Figure 1 The Mediterranean ports (see online version for colours)

The ports that are going to be evaluated in this survey are presented on Figure 1 and their annual transfer exceeds 100,000 TEUs. TEU is an acronym which stands for ‘twenty-foot equivalent unit’. TEU is a generally accepted measure, used to describe the capacity of container ships and container terminals. This size is likely to indicate either a strong past
in this sector or a glorious future in the sector of container transfer. These ports either
display strong transfer movement or they could do so, because of their geographical
position or some benefits which derive from infrastructure and superstructure of the
ports. In Figure 1, five port geographical zones can be seen, while in Figure 2 the overall
performance of transfer container in each zone is presented (Containerisation
International Yearbook, 2010). From Figure 2, it can be inferred that there is a superiority
of the ports in West Zone which consists of the ports of Spain and the recently
constructed Tanger port. The North Zone of the ports displays the lowest performance
which is partially explained by the fact that the Marseille port confronted a big decline in
the past five years (Containerisation International Yearbook, 2010).

Figure 2  Container volumes (TEUs) of five activity zones

The segmentation of the ports in five zones facilitates mainly the better understanding of
market structure. The competitive forces that evolve inside the zones are clearly bigger
than the ones among ports of different zones. However, the big transhipment movement
of the Mediterranean port system and the fact that the procedures among the maritime
companies are going ahead rapidly, can make ports of different geographical zones act as
competitors.

The methodology will be applied on the 30 ports of Figure 1. The length of quays and
the number of ship to shore cranes will be used as inputs, while the number of TEUs that
were moved by each port for the year 2008 will be used as output. The utilisation of these
inputs and outputs was preferred because of the existence of data for all ports. The entire
data sample can be considered as valid, as it was cross-checked by various
sources (Containerisation International Yearbook, 2010; Port Authorities). The DEA
CCR super-efficiency model focused on the inputs will be adopted. It should be
mentioned that the CCR super-efficiency scores are used because of the fact that this
indicator expresses the total efficiency (pure technical and scale efficiency) of each port.
Additionally the BCC super-efficiency is not preferred because it often leads to
unfeasible solutions, because it is very sensitive to input or output outliers (Lovell and
Rouse, 2003).

The results of application are distinguished in Table 1.

From the results of Table 1, it is evident that the port of Valencia can be characterised
as the most efficient. Also, Port Said is relatively efficient with its record exceeding the
unit. In order to draw more conclusions concerning the functional records of ports, a stem
and leaf and a box-plot diagram have been constructed via the results of Table 1 and are
presented in Figure 3. Through the stem and leaf analysis, it is obvious that precisely the 50% of ports present efficiency scores between 0.2 and 0.4, while only seven ports present efficiency scores over 0.5. This fact leads to the conclusion that for most ports, the land and cranes are not combined in the most efficient way. By the analysis of box-plot, it is evident that the distribution of effectiveness of ports is positively asymmetrical, while the relatively small length of the frame confirms the low efficiency scores that ports present.

Based on the CCR super-efficiency level of each port, four categories of ports could be shaped which are presented in Table 2. The majority of ports are included in the third category which presents quite low records. Excluding the ports of second category which could be upgraded to the first category, after adopting careful functional changes, the majority of ports should proceed in serious functional upgrades so that they can be efficient. In Table A1 in the Appendix, the results of the DEA model are mentioned analytically, laying great stress on the functional changes that every port should adopt.

### Table 1  Efficiency scores of the 30 Mediterranean ports

<table>
<thead>
<tr>
<th>Port</th>
<th>Efficiency</th>
<th>Port</th>
<th>Efficiency</th>
<th>Port</th>
<th>Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Valencia</td>
<td>1.59372</td>
<td>Salónica</td>
<td>0.40853</td>
<td>Leghorns</td>
<td>0.25555</td>
</tr>
<tr>
<td>Port Said</td>
<td>1.41054</td>
<td>Izmir</td>
<td>0.39330</td>
<td>Limassol</td>
<td>0.25081</td>
</tr>
<tr>
<td>Marsakloxx</td>
<td>0.74904</td>
<td>Haifa</td>
<td>0.34774</td>
<td>Marseilles</td>
<td>0.21294</td>
</tr>
<tr>
<td>Algeciras</td>
<td>0.63140</td>
<td>Pireaus</td>
<td>0.33039</td>
<td>Salerno</td>
<td>0.20640</td>
</tr>
<tr>
<td>Barcelona</td>
<td>0.58770</td>
<td>Alicante</td>
<td>0.31170</td>
<td>Beirut</td>
<td>0.20084</td>
</tr>
<tr>
<td>Ambarli</td>
<td>0.54243</td>
<td>Rades</td>
<td>0.30316</td>
<td>Gemlik</td>
<td>0.19805</td>
</tr>
<tr>
<td>Gioia Tauro</td>
<td>0.50051</td>
<td>Taranto</td>
<td>0.28391</td>
<td>Napoli</td>
<td>0.17379</td>
</tr>
<tr>
<td>Damietta</td>
<td>0.49789</td>
<td>Alexandria</td>
<td>0.26844</td>
<td>Haydarpasa</td>
<td>0.14973</td>
</tr>
<tr>
<td>Mersin</td>
<td>0.46055</td>
<td>La Spezia</td>
<td>0.26209</td>
<td>Savona</td>
<td>0.11985</td>
</tr>
<tr>
<td>Genoa</td>
<td>0.42506</td>
<td>Tanger</td>
<td>0.26018</td>
<td>Cagliari</td>
<td>0.09260</td>
</tr>
</tbody>
</table>

### Figure 3  Stem and leaf and box-plot figures of efficiency scores (see online version for colours)
Table 2  
Classification of Ports based on their efficiency scores

<table>
<thead>
<tr>
<th>Category</th>
<th>Efficiency score</th>
<th>Ports</th>
</tr>
</thead>
<tbody>
<tr>
<td>Super-efficient</td>
<td>&gt;1</td>
<td>Valencia, Port Said</td>
</tr>
<tr>
<td>Semi-efficient</td>
<td>0.5–0.99</td>
<td>Marsakloxx, Algericas, Barcelona, Ambarli, Gioia Tauro</td>
</tr>
<tr>
<td>Inefficient</td>
<td>0.2–0.49</td>
<td>Damietta, Mersin, Genoa, Salonica, Izmir, Haifa, Piraeus, Alicante, Rades, Taranto, Alexandria, La Spezia, Tanger, Leghorn, Limassol, Marseiles, Salerno, Beirut</td>
</tr>
<tr>
<td>Problematic</td>
<td>0–0.19</td>
<td>Gemlik, Napoli, Haydarpasa, Savona, Cagliari</td>
</tr>
</tbody>
</table>

4.1  A further analysis

The results of DEA demonstrated functional weaknesses of the Mediterranean ports. However, some factors which influence the port operation and are lying beneath the control of the port enterprise are excluded from DEA application. The specialisation of bootstrapped Tobit regression in the subject’s data is attempted afterwards, so that the differentiations in efficiency scores of ports could be further explained. As far as the study of Turner et al. (2004) is concerned, apart from the utilisation of bootstrap at the estimation of Tobit model, certain more changes are proposed in the set of explanatory factors that will be used in the model. Concerning the independent variables, only a variable of this previous study will be used in the present model and it is the one that represents the size of port. The remainder variables are not used in the present analysis, due to lack of reliable data, or due to the fact that some of these variables are part of the ports’ function and that is why they should be included as inputs of DEA model. Additionally, the variables that will be used in the present model represent the distance of each port from the main sea-route Suez-Gibraltar and the population of the direct hinterland of each port.

The Tobit model for the Mediterranean ports is specified below.

\[ Y_i = \beta_1 + \beta_2 \text{DIS}_i + \beta_3 \ln\text{AREA}_i + \beta_4 \text{POP}_i + \epsilon_i \]  

(5)

where,

\[ Y_i \]  
the relevant efficiency of \( i \) port

\[ \beta_i \]  
the coefficients to be estimated \((i = 1, \ldots, 4)\)

\[ \text{DIS}_i \]  
the distance of port \( i \) from the main route Suez-Gibraltar

\[ \ln\text{AREA}_i \]  
the natural logarithm of the total area of port \( i \)

\[ \text{POP}_i \]  
the population of the direct hinterland (city or metropolitan area) of port \( i \)

\[ \epsilon_i \]  
the disturbance term.

The choice of these particular variables was made with the scope to investigate the effect that human and geographic factors have on the effectiveness and, consequently, on attractiveness of each port. Through the variable of distance, the degree of positive effect
on a preferential placement of port, concerning the main marine street of the Mediterranean, is investigated. The variable of port size measures the effect that a congestion problem may have on the port’s operation. In the present analysis, the natural logarithm of port’s total area is used, because up to a point the further increase of port’s extent is not considered to influence considerably its functionalism, because it remains unused. Finally, the variable of population incorporates the effect of the economies of scale which are able to be developed in the large urban centres. It should be noticed that it is impossible for any port authority to put these factors under its control and so, it is considered that these factors influence the port operation exogenously. Even the size of port is considered constant in the medium-term interval, because the extension is considered difficult, due to the large investments that an extension needs, or due to the lack of adjacent extents of ground that is observed in the urban ports. Table 3 depicts descriptive statistics of efficiency and control variables. The estimation of model parameters after its application to the data of the Mediterranean ports is presented in Table 4.

### Table 3
Descriptive statistics of efficiency and control variables

<table>
<thead>
<tr>
<th>N Valid</th>
<th>Efficiency Mean</th>
<th>Efficiency Median</th>
<th>Population Mean</th>
<th>Population Median</th>
<th>Distance Mean</th>
<th>Distance Median</th>
<th>Port area Mean</th>
<th>Port area Median</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>0.414295</td>
<td>0.30743</td>
<td>1,914,018</td>
<td>951,419</td>
<td>215.53</td>
<td>179.5</td>
<td>664,129.6</td>
<td>485,000</td>
</tr>
<tr>
<td>30</td>
<td>0.335896</td>
<td>2,823,734</td>
<td>2,823,734</td>
<td>2,823,734</td>
<td>178.34</td>
<td>178.34</td>
<td>773,513</td>
<td>773,513</td>
</tr>
</tbody>
</table>

The variable ‘DIS’ is statistically important ($P > |z| = 0.029$) and negatively related with the effectiveness of each port ($\beta_2 = –0.0006324$). This result is presumable, because the ports with preferential placement near the international marine routes are rendered more attractive for the world carriers in their main effort for saving time. The importance of the port’s distance increases, particularly when containers are transported, because their value is high and so time cost does burden increasingly their transport (Fleming and Hauyth, 1994; Malchow and Kanafani, 2004). So the effect of the certain variable might be a result of specialisation of the ports close to main marine routes in container handling.

### Table 4
Estimation of Tobit analysis parameters

<table>
<thead>
<tr>
<th>Tobit regression’s results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Log likelihood $= –6.464902$</td>
</tr>
<tr>
<td>Wald chi²(3) $= 10.23$</td>
</tr>
</tbody>
</table>

| Efficiency | Coefficient | Std Error | z | $P>|z|$ | 95% Confidence Interval |
|------------|-------------|-----------|---|---------|-------------------------|
| DIS        | $–0.0006324$ | 0.0002893 | –2.19 | 0.029 | $–0.0011993$ to $–0.0000655$ |
| ln Area    | 0.1015787   | 0.0428873 | 2.37 | 0.018 | 0.0175212 to 0.1856363 |
| POP        | 2.29e-08    | 0.338     | 0.96 | 0.338 | –2.39e-08 to 6.97e-08 |
| Constant   | $–0.8164867$ | 0.5462544 | $–1.49$ | 0.135 | $–1,887,126$ to 0.2541523 |

The size of port represented by the variable ‘ln Area’ is also found as statistically important ($P > |z| = 0.018$) with a positive connection with the effectiveness of ports ($\beta_2 = 0.1015787$). This is reasonable because a large port particularly provides bigger
certainty to the world carriers and the container transport is conducted in a faster rate. This conclusion is also confirmed by a recent study of Wang and Jiang (2007), who analysed the importance of time and pricing concerning port competition. Via an empiric example they showed that in order for a port to achieve high demand and profits, the low pricing is not enough if it is not combined with a large area in which the port’s functions could be carried out. It should be marked that the international bibliography lays emphasis on what is called ‘cost of congestion’ and its negative impact on the efficiency of ports (Organisation for Economic Cooperation and Development, 2008). It is therefore explicit, that the lack of congestion in a seaport renders it more efficient and attractive.

Finally, the existence or not of large urban concentration in the direct hinterland of port does not appear to influence its efficiency. Even if the variable ‘POP’ is connected positively with the efficiency ($\beta_4 = 2.29e-08$), the statistical importance of variable ($P > |z| = 0.338$) does not allow us to reach any definite conclusions. This conclusion appears to be explained partially from two factors. The first concerns the big rate of transhipment that the market of the Mediterranean presents, taking into account that for such type of transport the economies of scale are not required in a port. The second factor that explains this conclusion arises from the extension of land transport networks particularly in Europe. This extension decreases considerably time-distance and renders the hinterlands of ports mixed up and extremely competitive. The low statistical importance of population variable is in contrast with the remarks of Peters (1990) and Clark et al. (2002), who in their studies stressed the importance of population for attracting cargo movement. On the contrary, it coincides with the conclusions of Hayuth’s (1988) and Slack and Wang’s (2002) studies, in which the authors attribute the reduction of importance of the factor ‘population’ to a process of decentralisation in cargo transport, which they call ‘challenge of peripheral ports’.

5 Conclusions

Undoubtedly, the developments in the Mediterranean port industry are significant. In this perpetually changing environment, the key to the survival of each port is the development of its competitive assets. The results of DEA analysis indicate functional inefficiencies of the ports, since what matters is not only the attraction of large volume of containers but mainly the qualitative, valid and safe transportation of containers. All in all, ports have to be prepared to meet any increase in transfer burden. This presupposes perfect premises, flexible pricing policy, sufficient connection with the hinterland and specialised staff. Then, in order for a port to become efficient, instant structural changes in its function are required.

It is therefore true that the significance of the Mediterranean ports is increasing, as they are included in a regular basis in the itineraries of global carriers. The recent picture that the Mediterranean port system presented, led to the conclusion that there was a tendency for two kinds of ports to be created in regard to what type of transport manages each one. The ports which functioned exclusively or at a big percentage as nodes of transhipment were included in the first category (Gioia Tauro, Algeciras Bay) and in the second one, there were the ports which constituted the gate for the transport of merchandises from the sea to the land and reversely (Barcelona, Genoa). In the first category the main competitive advantage was the vicinity with the main sea route
Suez-Gibraltar and the existence of quite large port areas in order to meet the figurative and stocking needs, while in the second category the competitive advantage emanated from the geographical position of the port which was near big urban areas. Such areas allow the rise of economies of scale from the increased needs of hinterland’s big population.

Over the past years, this situation seems to change under the pressure of the strong competition in the area. This is evident according to the results of the second stage of the survey. The distance and extent of the port influence its attractiveness. On the contrary, the existence of an urban city nearby does not affect its efficiency. Therefore, it is obvious that the factors which were supposed to be crucial for the development of a port may lose their significance. At the same time, this change might elevate aspects of port function where competition may focus. The absolute specialisation in one kind of transfer may be unsafe for a port, as any decision of a global carrier not to serve the route to this port, may lead to a sharp decrease in movement, as occurred in Cagliari port for a short period of time. On the other hand, the diversification of factors of production in the administration of various kinds of cargo transport is fraught with danger, which flows mainly from functional inefficiencies. Therefore, the attraction of larger container volumes is a complicated issue which should make the port managers alert.

This survey cannot deal with all aspects of port competition. We presume that through its exploitation from the managers of the ports, the survey contributes to the improvement of the performance of ports rendering them more and more effective. In conclusion, it has to be mentioned that the research may be enriched with new variables-factors of port function in order to be more complete.

References


Evaluating port efficiency in the Mediterranean


Appendix

Table A1  Slack-based model efficient targets

<table>
<thead>
<tr>
<th>Port</th>
<th>Efficient input target</th>
<th>Efficient output target</th>
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</thead>
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<tr>
<td></td>
<td>Length</td>
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<tr>
<td>Algeciras(Juan Carlos)</td>
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</tr>
<tr>
<td>limassol</td>
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