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A prospective analysis of the efficiency in the reorganisation process of Italian seaports

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ABSTRACT

The purpose of this paper is to compare the competitiveness of Italian seaports in terms of efficiency scores as a result of significant policy changes adopted in September 2016. An appropriate data set on seaport activities is used that consists of input and output variables obtained by fixing the statistical classification of economic activities (NACE codes) of a sample of 10,763 active firms involved in the new Italian Port Network Authorities (AdSPs). The investigation analyses the major causes of inefficiency and may be viewed as an analysis of the potential of each AdSP, rather than an analysis based on already existing entities. In the authors' opinion, the results of the data envelopment analysis (DEA) are suitable to support policy decisions designed to improve operational performance of inefficient AdSPs. The empirical analysis reveals several findings that can be extended to different territorial districts.

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1 Introduction

Seaports have several economic benefits and some of them are indirect economic effects (Panayides et al., 2015; Cheon et al., 2017). The towns where ports are located can suffer from a negative impact, and the European Commission (2010) and the OECD (2014) underlined the major port-related negative effects. Increasing competition in Europe has affected seaport performance; thus, attention to efficiency has increased significantly in recent years (Panayides et al., 2009; Jugović and Schiozzi, 2013; Aerts et al., 2014; European Commission, 2016; Nguyen et al., 2016; Siqueira et al., 2017). Regulatory interventions specifically aimed at port businesses are often necessary, and several research papers analysed the consequences of new regulations on the performance of this sector (Yörük and Zaim, 2008; Ferrari and Basta, 2009). In addition to efficiency, Coppens et al. (2007) and OECD (2016) highlighted that various factors — such as transport costs, port infrastructures, port centrality, and port congestion — determine maritime performance (Eurostat, 2016).

In Italy, as a consequence of the substantial policy changes adopted in September 2016, the old port administration system has been replaced with new Port Network Authorities (or Port Authority Systems – AdSPs).[1] Fifteen new AdSPs have been created by the law, thus creating new opportunities for economic development.

The purpose of the present paper is to compare the efficiencies of Italian AdSPs. This investigation involves an analysis based on the potential of each AdSP, in terms of viewing everything in perspective, rather than an analysis based on already existing entities. In fact, Italian AdSPs will need several years to strengthen their structure.

In terms of the theoretical models employed, many recent studies deal with seaport efficiency by adopting both non-parametric and parametric techniques. Certain problems and limitations are sometimes faced by researchers, and Ensslin et al. (2017) attempted to provide an overview of the most common techniques. Despite this

[1] The 169/2016 Law updated the previous 84/1994 Law.

effort, a lack of consensus still persists about the most valid approach for measuring seaport efficiency. In the authors' opinion, the performance of the new Italian seaport structure can be properly measured by data envelopment analysis (DEA) considering appropriate NACE (European Statistical Classification of Economic Activities) codes.[2] DEA has been widely adopted for the benchmarking and environmental performance evaluation of different decision-making units (DMUs) involved in transportation (Roll and Hayuth, 1993; Cullinane et al., 2004, 2006; Barros, 2006). This technique appears to be fully justified due to the meaningful implications highlighted in the subject area during the last decades (Chang, 2013; da Cruz and de Matos Ferreira, 2016).

Given these shortcomings, this paper aims to contribute to existing port comparative analyses in several ways. DEA is proposed as a means of supporting policy decisions specifically targeting to new Italian constructs. In addition, a specific set of indicators that might affect efficiency is considered. Due to the relevant issue of selecting indicators that can be involved in the comparative analysis, an additive model is proposed to avoid the exclusion of significant dimensions. The authors refer to (1) the geographical concentration of the maritime firms and (2) an inventory of the NACE classes related to the maritime sector. To the authors' knowledge, such an attempt has not been undertaken so far.

As for the remaining contents of the paper, the next section briefly reviews the relevant theoretical background relating to the Italian AdSPs. Section three presents a literature review on DEA. Section four combines several model specifications and discusses the statistical validation of the model. Finally, the last section summarizes the discussion and conclusion and presents several policy implications.

2 Background: Italian AdSPs

The old Italian port system consisted of approximately 57 ports, which have been reorganized into 15 new AdSPs since September 2016.[3] Each new AdSP construct includes ports that have different characteristics (infrastructures and services), which influence competition and port choices and often constrain the type of maritime traffic that is permitted. Eurostat (2017) showed that three ports located in southern Italy (Naples, Messina and Reggio Calabria) are among the largest thirteen EU ports in terms of passengers. In addition, two ports located in northern Italy (Trieste and Genoa) are among the largest EU ports in terms of goods. Considering the fifteen Italian AdSPs, this research tries to develop a tool that can be used to determine the clusters of ports that have the best performance, even though further analysis is needed to study the consequences of recent administration system reform. Efficiency measurements can differ significantly when considering simulations of port locations, and each scenario can be critically evaluated. Port performance should be studied cautiously because of the wide range of dimensions involved, which need to be considered throughout the process of benchmarking. However, the main weakness of using several dimensions is related to the difficulties of improving port performance when modifications to the dimensions are involved. For urban ports, expansion is constrained due to limited land availability. Excessive or inappropriate investments can induce several inefficiencies and waste resources. Thus, it is crucial to consider the existing infrastructure to achieve the desired results using a model that employs appropriate benchmark measurements.

As pointed out by the authors, seaport efficiency can be evaluated by using a DEA technique, and the results can be used to promote policy actions suitable for the 'in progress' Italian port reorganization process (and/or a similar context). This paper focuses attention on 2016, and this year was chosen due to data availability.[4]

3 Literature review

3.1 A brief review of DEA

DEA is a non-parametric method widely used to obtain a multivariate frontier estimation and to measure the efficiency of multiple homogeneous DMUs with the same set of inputs and outputs. As above-mentioned, the literature differentiates two fundamental methodologies for measuring the efficiency functions: parametric and non-parametric approaches. Different authors organize the family of frontier estimations using deterministic and stochastic procedures. The original idea behind the DEA model can be traced back to Farrell (1957). The original contribution was significantly advanced by Charnes et al. (1978) and Banker, Charnes and Cooper (1984). The objective of DEA is — quite simply — to highlight the units with the best efficiency. Efficiency scores range between zero and one, and data-oriented DEA identifies the DMUs that are on the efficient frontier (Charnes et al., 1994). DEA involves several approaches: constant returns to scale (CRS or CCR) technology, variable returns to scale (VRS or BCC) technology, and non-increasing returns to scale (NIRS). As originally formulated, DEA models require positive quantitative inputs and outputs, but several contributions have been proposed to deal with negative and qualitative data. Both the input-oriented and output-oriented approaches can be considered; inefficient DMUs can decrease the amount of inputs and/or increase the amount of outputs with the purpose of becoming efficient. In addition to the radial approach, non-radial efficiency models have been

[2] NACE is a four-digit classification providing the framework for the Statistical Classification of the Economic Activities in National Accounts, and it is periodically revised.

[3] Table A4 in the appendix provides the general correspondence table, matching fifty-seven ports belonging to the old Italian port system and the new AdSPs.

[4] The authors collected 2015 data as a proxy when 2016 were missing.

Table 1 DEA Models

Envelopment Model	Input Oriented	Output Oriented
CRC	$\theta^* = \min \theta$ subject to $\sum_{j=1}^{n} \lambda_j x_{ij} \le \theta_0 x_{i0}$ $(i = 1,..., m)$ $\sum_{j=1}^{n} \lambda_j y_{jh} \ge y_{r0}$ $(r = 1,...., s)$	$\phi^* = \max \phi$ subject to $\sum_{j=1}^{n} \lambda_j x_{ij} \le x_{i0}$ $(i = 1,..., m)$ $\sum_{j=1}^{n} \lambda_j y_{jh} \ge \phi_0 y_{r0}$ $(r = 1,...., s)$
VRS	$\sum_{j=1}^{n} \lambda_j = 1$	
NIRS	$\sum_{j=1}^{n} \lambda_j \le 1$	
Two-stage DEA approach		
	$\min \theta_0 - \varepsilon\left(\sum_{i=1}^{m} s_i^- + \sum_{r=1}^{s} s_r^+\right)$ subject to $\sum_{j=1}^{n} \lambda_j x_{ij} + s_i^- = \theta_0 x_{i0}$ $(i = 1,..., m)$ $\sum_{j=1}^{n} \lambda_j y_{jh} - s_r^+ = y_{r0}$ $(r = 1,...., s)$ $\sum_{j=1}^{n} \lambda_j = 1$ $\lambda_j, s_r^+, s_i^- \ge 0$	$\max \phi_0 + \varepsilon\left(\sum_{i=1}^{m} s_i^- + \sum_{r=1}^{s} s_r^+\right)$ subject to $\sum_{j=1}^{n} \lambda_j x_{ij} + s_i^- = x_{i0}$ $(i = 1,..., m)$ $\sum_{j=1}^{n} \lambda_j y_{jh} - s_r^+ = \phi y_{r0}$ $(r = 1,...., s)$ $\sum_{j=1}^{n} \lambda_j = 1$ $\lambda_j, s_r^+, s_i^- \ge 0$

Source: [50]

used in traditional DEA techniques. Certain models refer to constructs based on clustering approaches, multilevel methodologies, etc. More detailed reviews of these methodologies are presented by Emrouznejad et al. (2008) and Cook and Seiford (2009).

3.2 Model specifications

Given the nature of the multidimensionality of Italian AdSPs, this paper utilizes a two-stage DEA process, following the method proposed by Zhu (2015).[5] Table 1 summarizes the well-known DEA models taking into consideration the orientation (input vs. output) and the frontier type (VRS vs. CRC).

As shown in the table, DMU_0 denotes one of the *n* AdSPs (DMUs) that must be evaluated; $\boldsymbol{x}_{i0}$ is the *i*-th input of *m* inputs; and $\boldsymbol{y}_{r0}$ is the *r*-th output of *s* outputs. In the first stage of the DEA process, θ_0 needs to be minimized and represents the input-oriented efficiency score. The output-oriented ϕ score needs to be maximized. In the second step, the non-Archimedean ε enforces strict positivity on the variables. The optimization of the *slack*-based variables $\boldsymbol{s}_r^+$ and $\boldsymbol{s}_i^-$ (which refer to a specific reduction in input or output) is required. λ_j (J=1....n) is a non-negative scalar such that $\sum_{j=1}^{n} \lambda_j = 1$. A DMU is *fully* (100 %) efficient if, and only if, both (1) $\theta^* = 1$ and (2) $s_r^{+*}, s_i^{-*} = 0$. In contrast, a DMU is *weakly* efficient if $\theta^* = 1$, but $s_r^{+*} \ne 0$ and/or $s_i^{-*} \ne 0$[6].

4 Methodology and results

4.1 Model assumptions

This research includes the analysis of economic activities linked to Italian AdSPs, following the approach

[5] It should be noted that the term two-stage computational procedure is also used with a different meaning in DEA.

[6] Several research papers define total economic efficiency by distinguishing between technical efficiency (aimed to maximize outputs), and allocative efficiency (designed for the optimization of the inputs, given their prices).

recommended by Censis (2015). Despite the fact that a substantial body of literature exists on the seaports' activities and on measuring the maritime economy, the subject is still quite controversial. As above-mentioned, this paper employs the NACE classification to identify all firms involved in AdSP activities. A sample of 10,763 active firms is studied in this empirical work (source Bureau Van Dijk AIDA database). The authors consider the companies' attributes (in terms of the number of employees, total sales, and the number of liquidated or dissolved companies) and AdSPs' features (in terms of goods and passengers, including cruise passengers). Thus, the authors fix the spatial dimension (AdSP) and the statistical dimension (NACE codes). An additive model provides an estimation of the extent of all economic activities belonging to the new Italian AdSPs (Quintano et al., 2019). This theoretical assumption is used to define (1) the spatial perimeter of firms selected in the dataset and (2) the port activity boundaries. Oum and Park (2004), De Langen and Haezendonck (2012) and Suris-Regueiro et al. (2013) reported interesting findings on port-related activities. In addition, European Commission and Eurostat (2009) and Rivera et al. (2014) proposed the usage of dimensions connected to both the NACE codes and spatial criterion based on the geographic concentration of firms. This assumption is used to estimate the size of each AdSP using several input and output dimensions. Table A1 in the appendix provides the NACE codes considered in this research. This table also shows the corresponding NAICS (North American Industry Classification System) codes. The DEA literature has suggested using several criteria to select the dimensions, for example the empirical criterion of the availability of inputs and outputs (Barros et al., 2007). A series of largely adopted measurements can be other criteria to take into account. The above-mentioned criteria are used in the present research to select inputs and outputs for the application of DEA. The Italian AdSPs include ports that are different in terms of (1) size, (2) the specific functions they serve (container hub, regional ports, etc.), and (3) infrastructure and services. Taking into consideration these characteristics to compare the ports' performance via DEA can be extremely problematic. Several research papers specifically mentioned these issues (among others, Russo et al., 2016). The indicators chosen for the infrastructure, services (non-material activities), equipment, etc. should be defined according to the objectives of the research. For instance, if the aim of policy makers is to increase employment, then labour can be regarded as an output. In the present paper, a homogeneous and consistent set of indicators is employed. Instead of considering the traditional dimensions (such as input capital), several measurements that can be useful for prospective analysis have been selected. Table 2 shows the descriptive statistics of the inputs and outputs used in this paper.

The authors used two inputs and five outputs as efficiency measurements for Italian AdSP. The first input dimension (*IN_nm_emp*) refers to the number of employees involved in the NACE sectors mentioned above. This economic dimension can measure the numerical consistency of the labour market's features, keeping in mind that this indicator could involve the effects of informal/undeclared workers (Quintano et al., 2018). Informal employment is a feature related to the non-observed economy and depends on a combination of several factors. An extensive analysis of this issue is beyond the aim of the present research.

The second input dimension (*IN_lqt_dis_cpn*) refers to companies that have completely stopped their activities and closed down (liquidated companies and dissolved companies). Renssen (2017) noted that when a company is in financial distress, it has two options: rescue by restructuring or liquidation by dissolution. The authors assume that this (additive) dimension indicates a 'condition of suffering' of firms in the cluster and needs to be minimized (FCA, 2017).

Table 2 Descriptive statistics of the variables involved in the DEA

Description						
Output						
OUT_pass	Number of passengers (thousands of people)	0	13632	3072.87	3784.78	I
OUT_contnrs	Containers: thousands of tonnes	15	25075	6348.80	7246.16	I
OUT_roro	Ro-Ro mobile units, in the total tonnage of goods (thousands of tonnes)	7	13849	5607.73	4196.69	I
OUT_crs_pss	Cruise passengers (included departures + boarding + transits) thousands of people.	0	2339.68	718.30	726.38	I
OUT_totsales	Value of sales (thousands of Euros)	174.86	4699.76	1823.50	1241.31	II
Input						
IN_nm_emp	Number of employees involved in economic activities belonging to the seaport NACE codes	832	14227	6923.07	3797.18	II
IN_lqt_dis_cpn	Number of liquidated companies and dissolved companies	22	158	87.13	40.49	II

Data sources: I – The Italian National Institute of Statistics – http://dati.istat.it ; II – Bureau Van Dijk (AIDA – Italian public and private companies) https://aida.bvdinfo.com

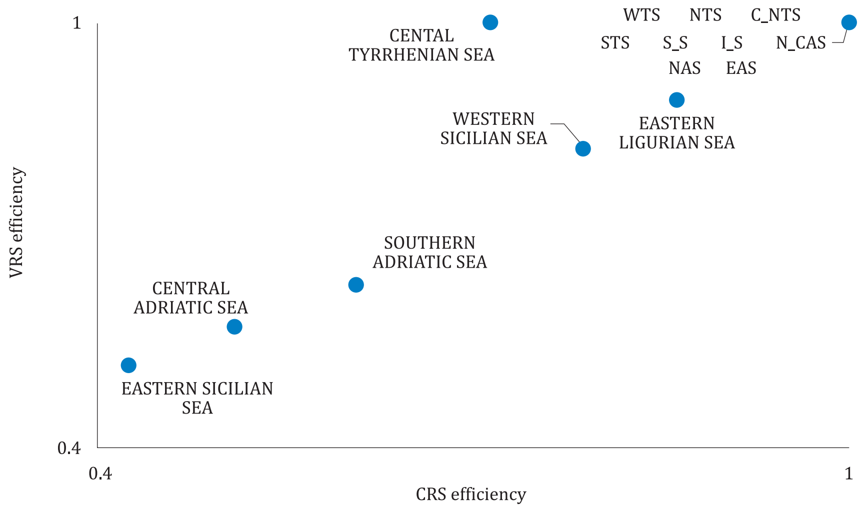

Figure 1 Graphical illustration of the AdSPs' efficiencies.

Source: Authors

Concerning the outputs, the first dimension (*OUT_pass*) refers to the number of passengers, expressed in thousands of people. This dimension includes embarked and disembarked passengers at each Italian AdSP and excludes cruise passengers. The second output measurement (*OUT_contnrs*) indicates the number of containers handled by the AdSP.[7] Barros (2006) noted that this measurement has always been used for the quantitative analysis of seaport efficiency. The third dimension (*OUT_roro*) represents goods transported in Ro-Ro (Roll on – Roll off mobile) units, expressed in tonnage of goods. A Ro-Ro unit refers to wheeled freight-carrying equipment (for instance, a lorry). This indicator represents an important dimension because the share of Ro-Ro units per thousand tonnes of goods assumes very high values in European countries (for instance, Ireland 28 %, Sweden 27 %, Denmark 25 %). A different dimension (*OUT_crs_pss*) considers the number of cruise passengers, including passengers engaged in cruise transit activity. Cruise tourism generates significant economic benefits for each port. The last output measurement (*OUT_totsales*) refers to the value of sales expressed in euros; the authors assume that AdSPs aim to maximize profit, among other things.

Data were collected from the sources listed in Table 2. This table also shows that Italian seaports are relatively heterogeneous. The standard deviation is higher than the mean for several variables, but it is important to consider that the firms involved in the analysis are very different in terms of size. Due to the consequences that these dissimilarities can have on the DEA-based efficiency estimates, Bogetoft and Otto (2011) discussed these effects and noted that DEA efficiencies do not depend on the measurement scale of the different inputs and outputs. The dimensions connected to the liquid bulk (including oil and other liquid products) and solid bulk loaded and unloaded and several different dimensions (*OUT_lqd_bulk, OUT_sld_bulk, OUT_other)* are considered further in the analysis in the Tobit regression section. At this stage, no other dimensions are considered.

As specified in the literature review section, DEA entails comparing homogeneous DMUs. In addition to considering homogeneity, several conditions need to be preserved to validate the DEA model. First, the model requires the isotonicity condition, which means that the outputs must not decrease while the inputs increase. Table A2 in the appendix presents the correlation matrix of the input and output variables that had positive relationships with the indicators. Second, it is important to fix many input and output dimensions to capture the complexity of the phenomenon. At the same time, the sample size must be adequate for the model to avoid biased results. Boussofiane and Dyson (1991) suggested that there should be a minimum threshold for the DMUs evaluated through DEA. The product of the number of outputs and number of inputs identified are used for this threshold. These authors also noted that by increasing the number of dimensions included in the model, the number of efficient DMUs increased as well. Golany and Roll (1989) proposed a different minimum threshold that is equal to 2 times the number of inputs and outputs considered in DEA. Current research involves fifteen AdSPs; therefore, the validity of the DEA model is verified. The authors estimate the output and input-oriented measurements by using the VRS and CRC approaches, although the input orientation appears to be more appropriate than the output-oriented approach. In fact, controlling for the outputs implies that several restrictions may be necessary. For instance, the use of VRS requires the strong availability of inputs and outputs.The

[7] As for the containers, the Istat database presents figures expressed in TEUs (twenty-foot equivalent units) and in thousands of tonnes as well. In the present work, the choice of the latter measurement unit ensures the analysis is consistent.

VRS approach also assumes that technical efficiency consists of both 'pure' technical efficiency and 'scale' efficiency, while the CRS approach is used to identify the 'global' inefficiency. The estimation of scale efficiency is based on the calculation of the ratio of CRS and VRS values. Thus, the DEA findings provide various measures of scale efficiency and reflect the different positions of the AdSPs on the frontier. The efficiency of Italian AdSPs is shown in Table 3. The AdSPs are listed according to input (or output)-oriented efficiency and according to variable (or constant or not-increasing) returns to scale.

Based on the DEA results, a number of themes emerge. First, there are several AdSPs on the efficient frontier, and all AdSPs present almost the same efficiency scores for

Table 3 DEA technical efficiency scores for the Italian AdSPs in 2016 using input- and output-oriented approaches

Code	AdSP	**Input oriented (I)**				**I/O**	**Output oriented (O)**			
		Technically efficient – variable returns to scale (VRS) model	**Technically efficient, not -increasing returns to scale (NIRS) model**	**Scale efficiency**	**Variable returns to scale – IRS versus DRS**	**Technically efficient, constant returns to scale CRS model**	**Technically efficient, variable returns to scale VRS model**	**Technically efficient, not – increasing returns to scale (NIRS) model**	**Scale efficiencies**	**Variable returns to scale – IRS versus DRS**
		θ	θ			$\theta\&\phi$	ϕ	ϕ		
WLS	Western Ligurian Sea	1	1	1	-	1	1	1	-	
ELS	Eastern Ligurian Sea	0.890	0.862	0.968	Irs	0.862	0.877	0.862	0.983	IRS
NTS	Northern Tyrrhenian Sea	1	1	1	-	1	1	1	-	-
C_ NTS	Central/Northern Tyrrhenian Sea	1	1	1	-	1	1	1	-	-
CTS	Central Tyrrhenian Sea	1	1	0.714	Drs	0.714	1	1	0.714	DRS
STS	South Tyrrhenian Sea	1	1	1	-	1	1	1	1	-
S_S	Sardinian Sea	1	1	1	-	1	1	1	1	-
WSS	Western Sicilian Sea	0.823	0.788	0.956	Irs	0.788	0.801	0.788	0.983	IRS
ESS	Eastern Sicilian Sea	0.515	0.424	0.822	Irs	0.424	0.425	0.425	0.996	DRS
SAS	Southern Adriatic Sea	0.631	0.606	0.960	Irs	0.606	0.614	0.614	0.987	DRS
I_S	Ionian Sea	1	1	1	-	1	1	1	1	-
CAS	Central Adriatic Sea	0.568	0.509	0.896	Irs	0.509	0.527	0.509	0.966	IRS
N_CAS	Central/Northern Adriatic Sea	1	1	1	-	1	1	1	1	-
NAS	Northern Adriatic Sea	1	1	1	-	1	1	1	1	-
EAS	Eastern Adriatic Sea	1	1	1	-	1	1	1	1	-

Notes: IRS – increasing returns to scale (*curve trend* – or *portion* – of the VRS frontier); DRS – decreasing returns to scale (*curve trend* – or *portion* – of the VRS frontier)

Source: Authors

both the CRC and VRS approaches. The calculations indicate that in 2016, ten Italian AdSPs (nine for the CRS model) showed high levels of efficiency. The size feature differs among the Italian AdSPs. Figure 1 shows the efficiencies for both the CRS model and VRS model (columns 3 and 7 of Table 3). The graphical illustration shows (1) the role of pure technical inefficiency (VRS) and (2) the scale effects of the total technical efficiency of the AdSPs. The graph can be divided into four sections. The AdSPs positioned in the upper part of the right side of the graph present higher pure technical and scale efficiency values. The AdSPs positioned in the lower-left section of the figure have rather low pure technical value and low CRS efficiency; thus, they have relatively high scale efficiency. The *Central Tyrrhenian Sea* AdSP is positioned in the upper-left part of the diagram. This AdSP has high pure technical efficiency, moderately low scale efficiency, and decreasing returns to scale (DRS) for both the input and output approaches. The AdSPs with DRS are too large in dimension for their production results, and the dimension should decrease if the current level of DRS prevails. In contrast, the dimension should increase if IRS prevails. The *Eastern Ligurian Sea,* the *Western Sicilian Sea,* and the *Central Adriatic Sea* AdSPs present IRS for both the output and input orientations. The *Southern Adriatic Sea* and the *Eastern Sicilian Sea* AdSPs exhibit DRS for technology in the output-oriented model instead of IRS as in the input model.

Table 4 lists the peers and the corresponding peer weights (benchmarks) according to the 'principle of dominance' that an inefficient AdSP is dominated by another unit (peer) that presents a best practice.

The top three efficient AdSPs most frequently indicated as peers (by using the input and output approaches and CRS and VRS technologies) are, in sequence, the *Northern*

Table 4 DEA results: peers and peer weights (benchmarks, λ): VRS vs. CRS and input vs. output approaches

Inefficient AdSPs \ Efficient AdSPs	Western Ligurian Sea	Northern Tyrrhenian Sea	Central/Northern Tyrrhenian Sea	South Tyrrhenian Sea	Sardinian Sea	Ionian Sea	Central/Northern Adriatic Sea	Eastern Adriatic Sea
Eastern Ligurian Sea	0.173* 0.310** 0.180*** 0.360****	0.041* 0.085***		0.351* 0.291** 0.403*** 0.338****		0.272* 0.150***		0.162* 0.011** 0.182*** 0.012****
Central Tyrrhenian Sea	0.525** 0.735****	0.084** 0.117****	0.093** 0.131****	0.313** 0.439****				
Western Sicilian Sea		0.126* 0.184** 0.193*** 0.233****	0.162* 0.103** 0.168*** 0.131****	0.065* 0.005***	0.103** 0.166*** 0.305****	0.647* 0.469***		
Eastern Sicilian Sea		0.070* 0.114** 0.268*** 0.268****	0.018*	0.038***	0.009** 0.022****	0.912* 0.337** 0.694*** 0.794****		
Southern Adriatic Sea	0.030* 0.135***	0.347* 0.444** 0.640*** 0.733****				0.375*	0.019** 0.032****	0.221* 0.203** 0.225*** 0.335****
Central Adriatic Sea		0.257* 0.569***				0.726* 0.431***	0.017*	
Approaches	**Frequencies**							
*	2	5	2	2		5	1	2
**	2	4	2	2	2	1	1	2
***	3	4	1	3	1	4		2
****	1	5	2	2	2	1	1	2

Note: *Input oriented – VRS variable returns to scale; **Input oriented – CRS constant returns to scale; ***Output oriented – VRS variable returns to scale; ****Output oriented – CRS constant returns to scale

Source: Authors

Tyrrhenian Sea, *Ionian Sea*, and *South Tyrrhenian Sea* AdSPs. The *Northern Tyrrhenian Sea* AdSP has the highest frequency when considering the four approaches separately. The efficient *Northern Adriatic Sea* AdSP is not included in the matrix shown in Table 4 because it never appears as a peer. In the same way, the *Central Tyrrhenian Sea* AdSP does not appear as a peer, but this is due to the efficiency score obtained only with the CRC approach. The *Eastern Adriatic Sea* AdSP is the only peer with the same frequencies for all four approaches considered. At this stage, these most frequently cited efficient AdSPs can be considered as peers with best practices that could help inefficient AdSPs, and seaport policies could focus on these findings to improve the operational performance. Nevertheless, it is important to emphasize that efficient AdSPs need to be treated with caution, especially when they have zero weights for some variables.

To calculate the slacks in the DEA framework, a two-stage computational procedure is performed. The mathematical derivation of these slacks shows that none of the efficient AdSPs had slack different from zero (the results revealed non-zero slacks only for inefficient AdSPs).

4.2 Model validation: Tobit regression

Over the last twenty years, the use of statistical tests in DEA has increased and thus validated the model. In addition, DEA has been employed to explore the possible causes of variations in efficiency, for example by using hypothesis tests for CRC technology versus VRS technology. A different example is the use of bootstrapping, a computer-based method that replicates sampling of the original dataset; this method has become particularly popular in the recent literature. In this work, a second-stage Tobit regression is conducted, as proposed by Tobin (1958). Overall, the aim is to explain (and/or to validate) the variations in the model using the post-efficiency analysis, and Tobit regression is fairly often used to perform this type of DEA with continuous variables. The DEA scores range from zero to one, and the Tobit approach requires data to be restricted at both the lower and upper bounds. In contrast, ordinary regression suffers from theoretical problems when using the benchmarking setting. Although this methodology is widely applied for truncated linear regression, it has been widely debated in the recent literature (Simar and Wilson, 2007).

The variables that are not been included in the first-stage DEA model are considered in the Tobit technique, with the purpose of detecting the factors that affect efficiency: *OUT_lqd_bulk, OUT_sld_bulk* and *OUT_other*. The Tobit regression is designed to examine the relationship shown in equation (1).

$$y_1 = \alpha + \beta_1\, OUT\_lqd\_bulk + \beta_2\, OUT\_sld\_bulk + \beta_3\, OUT\_other \qquad (1)$$

In equation (1) the VRS output efficiency scores are considered as the dependent variable, but the results do not change considerably by using a different technology (and/or orientation). Table A3 in the appendix shows the descriptive statistics of the variables involved in the Tobit regression, and Tobit regression findings. The selected explanatory variables do not have any significant effects on efficiency. The coefficients are positive, but they are not statistically significant. The results of this analysis corroborate the main model's results, which do not include the three variables above-mentioned.

Table 5 Super-efficiency results

	CRS input oriented	CRS output oriented
Eastern Adriatic Sea	3.587	0.28
South Tyrrhenian Sea	3.36	0.29
Northern Adriatic Sea	1.85	0.54
Central/Northern Tyrrhenian Sea	1.62	0.62
Northern Tyrrhenian Sea	1.30	0.77
Ionian Sea	1.19	0.84
Sardinian Sea	1.18	0.85
Western Ligurian Sea	1.15	0.87
Central/Northern Adriatic Sea	1	1
Eastern Ligurian Sea	0.86	1.16
Western Sicilian Sea	0.79	1.27
Central Tyrrhenian Sea	0.71	1.40
Southern Adriatic Sea	0.61	1.65
Central Adriatic Sea	0.51	1.97
Eastern Sicilian Sea	0.42	2.36

Source: Authors

4.3 Super-efficiency analysis

The issue of the robustness of DEA efficiency models has been largely covered in research papers on sensitivity and stability analysis. Several studies consider a context in which the set of DMUs under observation requires modification. Some authors deal with the modification of the number of inputs (or outputs) included in the model (Cooper et al., 2011). In the current paper, sensitivity analysis refers to the super-efficiency DEA procedure used to rank the efficiency of DMUs. The research in this area was first developed by Andersen and Petersen (1993). They proposed using CRS efficiency for ranking DMUs (radial CRS super efficiency) by deleting the DMU under evaluation from the original dataset. Different authors extended this idea by adding new assumptions. These themes include the description of infeasibility (and unboundness) problems, which are caused by (1) weight restrictions, (2) the VRS (or CRS) assumption, and (3) the input (or output) orientation. See Zhu (2015) and Podinovski and Bouzdine-Chameeva (2013) for an extensive discussion on these subjects.

Table 5 ranks the Italian AdSPs according to their super-efficiency scores calculated using the CRS approach and both the input and output orientations. Table 5 shows that the *Eastern Adriatic Sea*, the *South Tyrrhenian Sea*, the *Northern Adriatic Sea*, the *Central/Northern Tyrrhenian Sea* and the *Northern Tyrrhenian Sea* AdSPs appear on the top of the list.[8]

5 Discussion and conclusion

This paper presents the results of a prospective analysis of Italian AdSPs from an efficiency point of view as a consequence of the new port administration system adopted in Italy in September 2016. Fifteen AdSPs are evaluated by using output and input orientations and by considering VRS and CRC technologies. This study provides useful information regarding the investigation of the statistical validation of the model using a second-stage DEA approach. The impact of the economic activities of the firms involved in the AdSPs is measured considering the European NACE classification. A data set of 10,763 active firms is used for the empirical work. As stressed by the authors, the DEA framework can be properly used to analyse the efficiency scores in this scenario, although this analysis is based on prospective performance rather than an already consolidated arrangement. In fact, the new AdSP entities will need several years to strengthen their structure.

Several conclusions are drawn from the results of the proposed models, and this approach can be extended to different territorial districts. According to the results, nine Italian AdSPs (ten using the CRS approach) operate at a high level of efficiency. The *Eastern Ligurian Sea*, *Western Sicilian Sea*, *Eastern Sicilian Sea, Southern Adriatic Sea* and *Central Adriatic Sea* AdSPs appear to be inefficient when employing both the input and output approaches. The scores indicating inefficiency are almost the same for both the CRC and VRS models using 2016 data. A signifi

[8] The *Eastern Adriatic Sea* and the *Ionian Sea* AdSPs are on the top of the list when considering the VRS perspective, although several 'infeasibility' problems appear when using this kind of orientation.

The present research can be extended by an investigation of both the involved dimensions and other dimensions. The firms were selected by fixing four-digit NACE codes (*classes*), and the main data source is the Bureau van Dijk database. This database contains key establishment information based on the activity declared by the establishment upon creation. Therefore, the assigned code may not exactly reflect the economic activity, and/or there could be changes in the NACE classification over several years. Furthermore, the number of firms could be underestimated since some firms involved in maritime activities could have a main (primary or secondary) activity that is different from the classifications considered in the present research. As a consequence, Surìs-Regueiro et al. (2013) suggested analysing the NACE codes that are fully and/or partially involved in the maritime economy. The dimension directly connected to undeclared workers involved in seaport activity should also be considered. The DEA model should be improved by using various inputs and outputs with different weights to explore various potential reasons behind the inefficiencies of the Italian AdSPs. Nevertheless, the selection of variables depends on (1) data availability, (2) the correlations among the variables, (3) the selected group of units, etc. In future research, it would be interesting to add new data over several years, with the aim of monitoring the annual variations of the AdSPs' efficiency.

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Appendices

Table A1 NACE (Rev 2) codes and descriptions of the economic activities considered for each AdSP and the corresponding NAICS categories

NACE code (ATECO 2007; UK SIC 2007)	NACE description	NAICS 2012 code	NAICS category
3012	Building of pleasure and sporting boats	336612	Boat building
3011	Building of ships and floating structures	336611	Ship building and repairing
5224	Cargo handling	488320	Marine cargo handling
3831	Dismantling of wrecks	562910	Remediation services
5040	Inland freight water transport	483211	Inland water freight transportation
5030	Inland passenger water transport	483212	Inland water passenger transportation
0321	Marine aquaculture	112519	Other aquaculture
0311	Marine fishing	114119	Other marine fishing
5229	Other transportation support activities	488999	All other support activities for transportation
1020	Processing and preserving of fish, crustaceans and molluscs	311710	Seafood product preparation and packaging
7734	Renting and leasing of water transport equipment	532411	Commercial air, rail, and water transportation equipment rental and leasing
3315	Repair and maintenance of ships and boats	336611	Ship building and repairing
5020	Sea and coastal freight water transport	483111	Deep sea freight transportation
5010	Sea and coastal passenger water transport	483112	Deep sea passenger transportation
5222	Service activities incidental to water transportation	488390	Other support activities for water transportation
4638	Wholesale of other food, including fish, crustaceans and molluscs	424460	Fish and seafood merchant wholesalers

Source: [8]

Table A2 Correlation matrix of input and output variables

	IN_nm_emp	IN_lqt_dis_cpn	OUT_pass	OUT_contnrs	OUT_roro	OUT_crs_pss
IN_nm_emp	1					
IN_lqt_dis_cpn	0.609*	1				
OUT_pass	0.090	0.319	1			
OUT_contnrs	0.249	0.037	0.656**	1		
OUT_roro	0.154	0.299	0.890**	0.576*	1	
OUT_crs_pss	0.671**	0.668**	0.178	0.197	0.137	1
OUT_totsales	0.922**	0.505	0.035	0.273	0.189	0.570*

Notes: *Correlation is significant at the 0.05 level (2-tailed); **Correlation is significant at the 0.01 level (2-tailed).

Source: Authors

Table A3 Descriptive statistics of the variables involved in the Tobit regression and Tobit regression results

Variables	Description	Minimum	Maximum	Mean	Standard deviation	Coefficient	Prob.
OUT_lqd_bulk	Tonnes of liquid bulk loaded and unloaded (thousands of tonnes)	632	34527	11343.60	10014.26	6.57e-01	0.11
OUT_sld_bulk	Tonnes of solid bulk loaded and unloaded (thousands of tonnes)	42	11343	3854.87	3680.41	1.90e-05	0.23
OUT_other	Other – thousands of tonnes	17	4304	1092.73	1261.70	1.36e-05	0.77

Source: Authors

Table A4 Correspondence table matching fifty-seven ports belonging to the old Italian port system and the new fifteen AdSPs

Port	AdSP
Genoa – Savona – Vado Ligure	Western Ligurian Sea
La Spezia – Marina di Carrara	Eastern Ligurian Sea
leghorn – Capraia – Piombino – Portoferraio – Rio Marina – Cavo	Northern Tyrrhenian Sea
Civitavecchia – Fiumicino – Gaeta	Central/Northern Tyrrhenian Sea
Naples-Salerno-Castellammare di Stabia	Central Tyrrhenian Sea
Gioia Tauro – Crotone – Corigliano Calabro – Taureana di Palmi – Villa San Giovanni – Messina – Milazzo – Tremestieri – Vibo Valentia – Reggio Calabria	South Tyrrhenian Sea (and Ionian Sea/Strait of Messina)
Cagliari – Foxi Sarroch – Olbia – Torres port – Golfo Aranci – Oristano – Portoscuso Portovesme – Santa Teresa di Gallura	Sardinian Sea
Palermo – Termini Imerese – Empedocle – Trapani	Western Sicilian Sea
Augusta – Catania	Eastern Sicilian Sea
Bari – Brindisi – Manfredonia – Barletta – Monopoli	Southern Adriatic Sea
Taranto	Ionian Sea
Ancona – Falconara – Pescara – Pesaro – San Benedetto del Tronto – Ortona	Central Adriatic Sea
Ravenna	Central/Northern Adriatic Sea
Venice – Chioggia	Northern Adriatic Sea
Trieste	Eastern Adriatic Sea

Source: Italian Law 169/2016