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The sustainability of the Italian water sector: An empirical analysis by DEA

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ABSTRACT

The sustainability of the development of water resources is a pressing challenge. Natural forces, economic pressure and increasing population determine a significant growth in water use and pollution not supported by highly inefficient water supply practices. In this framework, the Italian water services with fragmented management, highly deficient collection and treatment of wastewater - and existing and potential problems in water supply in some areas of the country – explains the reasoning of the drastic restructuring introduced by Law 36/1994 (Act n. 36 on Water Resources, 1994). The impossibility of avoiding natural monopoly and the necessity to industrialize the whole sector determined the imposition of a "for the market" competition in order to exploit possible economies of scale and scope. In this work, a group of Italian water utility companies is used to assess the sustainable efficiency of the Italian water sector, using the mathematical/linear programming of Data Envelopment Analysis (DEA) on a set of key variables including, water losses (never considered in the previous studies) to assess technical and environmental efficiency. This well-known technique allows evaluating the systems' efficiency not only by calculating the efficiency of each unit, but also helping policymakers by suggesting corrective policies and measures which could make the inefficient units efficient. This approach can be useful for policymakers to direct decisions towards a more sustainable and efficient water sector.

1. Introduction

The 1992 Rio Earth Summit, in order to enhance sustainable and efficient use of water resources, stated that water systems governance should be built on the "Dublin Principles" taking into account ecological, institutional, and instrumental aspects. According to the World Water Council (2000) in the 20th century, the world population increased three times and the water consumption was multiplied six. It is estimated that the demand for water will grow by 55% in 2050 (OECD, 2012). These factors in combination with an increase in water use will probably result in a water crisis, commonly considered an emerging problem for the 21st century (Gallopin and Rijsberman, 2000), which effects could be further aggravated by highly inefficient water resource use affecting water quality and water quantities. Since water services, like other network services, can be considered a natural monopoly, it has been frequently operated by the public sector. In fact, when a public service is a monopoly, many problems arise such as lower service quality, fewer incentives for the utilities to increase efficiency and cost effectiveness (costs control and reduction). Monopolies tend to seek higher prices than the effective ones jeopardizing water resource and consumer interests. To overcome these negative effects, the regulation systems must be transparent and explicitly addressed to balance the utilities, the environment and the consumer interests. Nevertheless criticism about the inefficiency of public control and the push towards a greater market opening, led to experimenting privatization processes in the late 1980s. At a first stage, the privatization process involved a transformation from a public legal form into private law firms (formal privatization), while

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at a later stage, private capital (substantial privatization) entered into water services capital. According to Nourali et al. (2014), there is no evidence that privatization may lead to improving the water supply chain efficiency and quality. The Italian water supply system mirrors of the above mentioned problems with the high fragmentation, the widespread problems of water losses, the inefficiencies in the collection and treatment of wastewater, the generally low investment levels. The Italian water supply system has a highly differentiated quality level for its provided services, in terms of service coverage (tap water and wastewater services), sustainability (water losses), economic affordability (water prices) and quality of the supplied tap water for household consumption and sewage systems. Water scarcity is still a problem in many Italian regions, in which the water company does not provide tap water to the customers or households suffer water scarcity during summer. Water losses are widespread along the country and the sewage systems are not adequately developed and many disparities exist at a national and regional level. According to the Commission, in 2011 around 143 towns had not suitable sewage systems, with hazard to the environment and the public health, due to this, Italy is under infringement proceedings by the European Community (EU) as the effect of the EU Directive 271/91. Presently, the Italian sewage systems are still experiencing many failures and do not meet the EU requirements: many urban agglomerations over 10.000 inhabitants discharge sewage without any proper treatment. This critical situation asks for a revision of the governance systems to allow the water sector to accomplish the transformations needed to meet the European and national sustainability requirements.

It is necessary to ensure as soon as possible in Italy a national coherent governance of water resources, able to adopt a regulatory framework with a unified objective of environmental and economic efficiency. It is then of great importance to assess whether and how environmental efficiency (reduction of water losses) and economic efficiency can be reached by the water utilities to address public decisions in order to enhance sector efficiency and sustainability. Good governance of water implies economic and environmental efficiency in order to ensure sustainable use of natural resources, social welfare and economic growth (Act n. 36 on Water Resources, 1994). In this paper a set of Italian water utility companies is used to estimate the technical, environmental and economic efficiency of the Italian water sector. Our study focuses on a three years period from 2011 to 2013. During this period, the sector dealt with a deep transformation due to the 2011 referendum results, rescinding the 7% payments of return on invested capital imposed by the different tariffs and the provisions of the law 135/2009 (Fotino, 2010) in term of public water utility privatization. The referendum favored a tariff reform applied in 2012 with a new single national tariff method. One of the main purposes of the tariff reform was to increase the sector efficiency in term of water losses reduction, investment increases and services modernization (improving water networks and the collection and treatment of wastewater) imposing a specific cost tariff item designed to anticipate the cost of future investments and the full cost recovery through the water pricing. In this context, the observation period allows assessing the impact of the tariff reforms on the sector environmental and economic efficiency by analyzing key factors such as services size, localization or ownership type and for the first time for the Italian water systems, the amount of water losses in the mains systems. The mathematical/linear programming of Data Envelopment Analysis (DEA) was applied to a sample of 68 Italian companies allowing to evaluate the systems' efficiency. This approach allows us to evaluate the technical and economic efficiency of water services and its environmental impact on water resource conservation providing insight for policy/decision makers for a more sustainable and efficient water sector decisions. This paper is organized as follows: after this introduction, an accurate literature review is presented in section 2 followed by the data and model described in section 3. Section 4 and 5 are devoted to the analysis of the obtained results and conclusions.

2. Literature review

In the last decades, several studies have been conducted to evaluate the performance of water companies using both accounting methods and econometric and operational research methods. Among the former ones, researchers have applied performance indicators and financial ratios (e.g. Guerrini et al., 2011; Hassanein and Khalifa, 2007; Reynaud and Thomas, 2013; Shaoul, 1997; Tsagarakis, 2013; Yepes and Dianderas, 1996). Econometric and operational research techniques include the use of regression analysis for the estimation of the cost function or operational research techniques based on frontier models, such as the Stochastic Frontier Analysis (SFA) and DEA. Cubbin and Tzanidakis (1998) highlighted that both techniques are potentially useful tools for comparative efficiency analysis in the regulated water industry. In particular, De Witte and Marques (2010) claim that DEA is flexible because it does not require any assumption regarding the functional relationship between costs and outputs, and that the lack of information on the production function in water industry may justify its use. Additionally, Bogetoft (1994) emphasized the DEA's incentive-efficient properties, which can be advantageous for the regulatory implication of the analysis (Thanassoulis, 2000a, 2000b). Studies applying DEA to examine the performance of companies operating in the water industry can be classified by geographical location, time of analysis, number of involved units, ownership and company size, inputs and output selections.

- Geographical location. Analyses are applied to different countries: USA (Byrnes et al., 1986; Lambert et al., 1993; Shih et al., 2006; Gungor-Demirci et al., 2018), Brazil (Seroa da Motta and Moreira, 2006; Tupper and Resende, 2004; Carvalho et al., 2015), Japan (Aida et al., 1998), Mexico (Anwandter and Ozuna, 2002), Palestine (Alsharif et al., 2008), Australia (Ananda, 2014; Byrnes et al., 2010; Coelli and Walding, 2005; Woodbury and Dollery, 2004), Chile (Molinos-Senante and Sala-Garrido, 2015; Molinos-Senante et al., 2018), China (Deng et al., 2016; Hu et al., 2018; Dong et al., 2018; Song et al., 2018; Zhou et al., 2018), India (Nyathikala and Kulshrestha, 2017; Wu et al., 2016), Southeast Asia (See, 2015), Sub-Saharan Africa (Mande Buafua, 2015), Taiwan (Chen and Chen, 2014) and Iran (Rad et al., 2019). With reference to whole Europe (De Witte and Marques, 2010), and in particular England and Wales (Cubbin and Tzanidakis, 1998; Thanassoulis, 2000a, 2000b; 2002; Pointon and Matthews, 2016) Spain (García-Sánchez, 2006; Garcia-Valiñas and Muñiz, 2007; Picazo-Tadeo et al., 2008, 2009; Suarez-Varela et al., 2017), Italy (Romano and Guerrini, 2011; Romano et al., 2017), Portugal (Martins et al., 2006; Pinto et al., 2017).
- Time of the analysis. In the past, due to the lack of available and reliable data, the authors that used DEA mainly considered data referring to a single year, or at the most a two-year period. Only a few papers used longer periods of time (Byrnes et al., 2010; Corton and Berg, 2009; De Witte and Marques, 2010; Garcia-Valiñas and Muñiz, 2007; Seroa da Motta and Moreira, 2006; Tupper and Resende, 2004). Instead in the last papers it is possible to note a wider reference time interval as in Deng et al. (2016), Molinos-Senante and Sala-Garrido (2015), Wu et al. (2016), Pointon and Matthews(2016)·Nyathikala and Kulshrestha (2017) and Zhou et al. (2018).

- Number of involved units. The number of units varied considerably, from 3 units (Garcia-Valiñas and Muñiz, 2007) to more than 200 (Lambert et al., 1993; Wu et al., 2016). The majority of the studies used less than 40 units. Only a few papers used more than 100 units for a single country and none of these regarded European countries; they referred to the USA (Byrnes et al., 1986; Lambert et al., 1993; Shih et al., 2006), Japan (Aida et al., 1998), Brazil (Seroa da Motta and Moreira, 2006), India (Wu et al., 2016) and Mexico (Anwandter and Ozuna, 2002).
- Ownership and company size. In order to analyse the relationship between ownership and water companies efficiency it is possible to classify the studies in three groups with reference to their results: 1) studies that reported no influence of ownership on efficiency; 2) researches that argue that public ownership improve the efficiency and finally 3) analysis claiming to find better efficiency score for private owned utilities. In the first group of studies Byrnes et al. (1986) beside other more recent research can be included. Firstly, Garcia-Sanchez (2006) estimates the technical and the scale efficiency of the Spanish municipalities and distinguishes between those which externalized the water service to private owned utilities and those who provide the service through public business corporations. The paper does not reject the hypothesis that the type of ownership discriminates efficiency level. Therefore, it claims that in the specific context analysed the creation of quasi-market does not seem to affect efficiency. The author suggested that this result can be justified by the fact that the creation of public business corporations relieves the management of the business from the traditional public sector bureaucratic procedures. Secondly, in 2013 a study about Estonian water companies did not reject the hypothesis of no difference in efficiency between water utilities with different types of ownership grounded on transaction cost and industrial organization theory (Peda et al., 2013). Moreover, the research studies the influence of size on efficiency. In this case, the paper found a positive relationship between the size of the population served and the efficiency levels corroborating the assumption of scale economy gains. However, the study did not combine the influence of both size and ownership on efficiency score. Finally, in the same year another study focused on Spain rural area has been published (Gonzalez-Gomez et al., 2013). It found that both private owned utilities and public-private partnerships are significantly more efficient than public ownership. However, the differences in the association between the type of ownership and external variables such as economies of density, water source and seasonality of demand, are found not significant. The authors argue that these results indicate that whether environmental factors are taken into account the differences in the efficiency scores disappears. Among others, in the second group of studies, it can be found research published in 2011 about comparing the efficiency of 43 Italian water utilities in 2007 (Romano and Guerrini, 2011). The paper founds that publicly owned utilities obtain a higher efficiency score compared with mixed enterprises. The authors interpret these results suggesting that public owned utilities are better able to acquire and use their inputs. Also Le Lannier and Porcher (2014) found that private management is on average slightly less efficient than public management in France. In the third group of studies, the superiority of privately owned utilities is found. In Gonzalez-Gomez et al. (2013) is reported that this group is constituted by a smaller number of researches compared with the other two groups. In particular, Picazo-Tadeo et al. (2009) found that privately owned utilities have better efficiency score than publicly owned utilities. The authors claim that this result is due to efficiency in the employment of labour.

  The papers that analysed the dimension issue using a DEA approach found contradictory results. For example, Aida et al. (1998), with reference to Japan, observed that smaller-sized firms were more efficient. On the contrary, Shih et al. (2006), studying the US water industry, found that smaller companies tended to face higher unit production costs and Byrnes et al. (2010) observed that larger water utilities were characterized by a higher degree of managerial efficiency. Finally, a recent paper investigates the adequacy of DEA as a regulatory tool in the water sector and its affection by data quality (Cabrera et al., 2018).
- Inputs and outputs selection. The specific model applied in almost all the DEA studies was the input-oriented and multi-output model using both constant returns to scale and variable return to scale. Only Picazo-Tadeo et al. (2008) applied an output-oriented model. With reference to inputs, all the studies used operating expenses, considered as a whole or divided into its main components (labour expenses, material costs, energy costs, etc), the number of employees and/or the length of the water main. As regards outputs, the majority of researchers used, sometimes together with other variables, the volume of delivered, billed or produced water (e.g., Byrnes et al., 1986; Coelli and Walding, 2005; Cubbin and Tzanidakis, 1998; Lambert et al., 1993; Picazo-Tadeo et al., 2008). Only in a few cases these data were not used, substituted by other variables that were usually correlated to delivered/billed/produced water, such as the resident population or its density and the number of water connections (Thanassoulis, 2002; García-Sánchez, 2006; Alsharif et al., 2008; Romano and Guerrini, 2011; See, 2015).

In conclusion, from the literature review emerges contrasting results and applications, therefore more evidence is needed. This paper applies DEA to the Italian water companies confirming the results presented above regarding the superiority of the public owned companies compared with mixed and private enterprises in terms of efficiency. The main novelty of this paper is firstly to rely on a larger sample of companies and so it is more representative of different Italian territories; secondly, in order to evaluate the performance of water companies, it considers also as relevant output variable of the analysis, the water losses, completely absent in the previous studies applied to the Italian market. Water losses play a key role in the evaluation of the performance of water-based companies and the need to keep a low leakage level is a priority for most water utilities hardly influencing their efficiency in a sustainable world. In fact, there are many reasons for attaining and subsequently maintaining a low leakage level in water networks, chief amongst which is the environmental and social damage that the overexploitation of such a valuable natural resource can cause.

3. Methods

In this section the characteristics of the set of companies utilized in this paper are presented (3.1). Moreover, a brief description of the DEA technique is outlined (3.2) and the selection of collected input and output variables with their sources is shown (3.3).

3.1. Data collection and description

The study focuses on a selected sample of 68 Italian water utility companies in the period from 2011 to 2013. The dataset was compiled using financial data provided by the Bureau Van Dijk AIDA database providing financial statements information such as revenues, production value, capital cost, staff cost, amortization and interest value, operational costs; technical data was collected (network length, water losses given by the difference between the amount of water pumped and delivered, etc.) along with demographic data by companies websites. The sample does not include multi-utilities companies since their financial statement includes a wide range of activities together with water services, such as energy provision and/or waste collection, producing a jointly effect on specific water service efficiency. The selected companies are evenly distributed in the Italian territory: Table 1 shows the distribution of the selected companies among the different Italian geographic areas. Companies were classified according to their size based on total revenue. Most of them have a small or medium size (66.2% of the total, Table 2). The considered companies differ by the type of ownership: public ownership companies that are fully controlled by one or more local public entities, mixed ownership companies that have both public and private shareholders, and private owned companies that are completely under the control of private shareholders (Table 3).

3.2. DEA model

Water companies were compared using the efficiency indicator obtained from the data envelopment analysis (Charnes et al., 1978). Generally speaking, efficiency may be thought of as a measure of the distance between the optimal production level, which lays on the production possibility frontier, and the actual level adopted by the Decision-Making Units (DMU).

DEA is a well know technique able to evaluate the efficiency of a set of units with multiple inputs and outputs. In its input-oriented version, efficiency calculation is obtained by minimizing inputs in order to reach predetermined levels of outputs. DEA with constant returns to scale (CRS) has been formulated by Charnes, Cooper and Rhodes (Charnes et al., 1978).

The advantage of the DEA is to produce an aggregate measure of efficiency for each DMU using multiple inputs and outputs, which measurement units may also vary (Charnes et al., 1994). In addition, DEA is a non-parametric approach to estimate a production frontier and does not impose particular specifications on the technology. The disadvantage is that the efficiency value attributed to each DMU is relative, i.e. depends on the efficiency of the other units that are in the sample. If the best performing firms are left out of the sample the DEA efficiency measures may overestimate efficiency since it relies on an internal production frontier. Indeed, DEA is often viewed as a deterministic approach that is not easily conducive to statistical analysis, in particular to hypothesis testing (Bogetoft and Otto, 2010). One way to address this shortcoming is to introduce a substitute for sampling variability in DEA estimates through bootstrapping methods that rely on smoothing the empirical distribution (Simar and Wilson, 2000, 2007).

Table 1
Italian geographic areas of the selected companies.

Geographic area	N. of companies	% of Companies
North East	16	23.5
North West	16	23.5
Centre	16	23.5
South	20	29.4

Table 2
Companies by size.

Size	N. of companies	% of Companies
Small (<20 Million€)	24	35.3
Medium (20–50 Million€)	21	30.9
Large (50–100 Million€)	12	17.6
Extra Large (>100 Million€)	11	16.2

Table 3
Companies by ownership type.

Type of ownership	N. of companies	% of Companies
Public	49	72.1
Mixed - majority public capital	16	23.5
Mixed - majority private capital	1	1.5
Private	2	2.9
Mixed and Private	19	27.9

Bootstrapping simulates a sampling distribution by constructing pseudo-datasets based on a data generation process (DGP) that allows approximating the true sampling distribution. DEA efficiency scores are then re-computed for each pseudo dataset, and a sample of DEA scores is obtained for each DMU. As far as the number of repetitions is sufficiently large, a good approximation of the true distribution can be obtained and statistical inference can be used to test the hypothesis about efficiency measures (Bogetoft and Otto, 2010, pp.170–186). In this study, bootstrapped DEA scores were used to provide confidence intervals for the score of each DMU, and to stipulate scores corrected for the bias induced by the sample frontier.

3.3. Input and output selection

Several variables of interest were identified from 2011 to 2013. Table 4 summarizes these variables and shows their sources. The collected data for each company are:

- Water Distributed (m^3): the volume of drinking water delivered to a user for civil use and effectively consumed (for internal uses or outside watering). It includes also public uses, such as road cleaning, water in schools and hospitals, public green watering, and fountains.
- Water Pumped (m^3): the total volume of drinking water entering the distribution system.
- Network length (km): the length of the drinking water distribution system, from the supply tanks to users.
- Residents (unit): the resident population, nationals or foreigners, representing the number of inhabitants of a given area served by a company.
- Materials Cost (€): the expenditure for material resources necessary to the water service operation.
- Cost of services (€): includes all costs relative to the purchase of services (e.g. electricity).
- Cost of leases (€): cost for the use of tangible and intangible assets of third parties (e.g. rents and royalties).
- Labour cost (€): the sum of all wages, as well as the cost of employee benefits and payroll taxes.
- Capital cost (€): the cost of a company's funds (both debt and equity).

By combining some of these data, we also get the following variable:

- Percentage delivery of water (%): the ratio between the volume of water distributed and the volume of water pumped.

Table 5 shows the correlation matrix for the eleven variables collected to explain the choices of inputs and outputs in the DEA model adopted in the current analysis. We use five inputs: the cost of material, labour, services leases and capital. The output choice is based on the analysis of the correlation coefficients between the five potential output variables: the residents' number and the volume of water pumped show a strong correlation with other

Table 4
Data collected: variables names, sources and measure unit.

Variables	Measure unit	Source
Water distributed	m^3	• ISTAT[a] for 2012; • Corporate annual reports for 2011 and 2013.
Water pumped	m^3	• ISTAT for 2012; • Corporate annual reports for 2011 and 2013.
Network length	km	• Firms websites • ATO websites
Percentage delivery of water	%	Water distributed*100/Water pumped
Residents	unit	• Firms websites • ISTAT • ATO websites
Costs of material	€	Bureau Van Dijk's AIDA[b] database
Costs of services	€	Bureau Van Dijk's AIDA database
Costs of leases	€	Bureau Van Dijk's AIDA database
Labour costs	€	Bureau Van Dijk's AIDA database
Capital costs	€	Bureau Van Dijk's AIDA database

[a] ISTAT is the Italian National Institute of Statistics.
[b] Bureau Van Dijk's AIDA database provides data from the annual reports of many Italian companies.

Table 5
The correlation matrix of inputs and outputs.

	A	B	C	D	E	F	G	H	I	J
A Network Length	1.00									
B Residents	0.79	1.00								
C Water Pumped	0.74	0.97	1.00							
D Water Distributed	0.70	0.95	0.96	1.00						
E % Delivery	0.03	0.08	0.02	0.22	1.00					
F Materials Cost	0.48	0.51	0.48	0.44	−0.03	1.00				
G Services Cost	0.71	0.92	0.94	0.91	0.08	0.42	1.00			
H Leases Cost	0.49	0.57	0.59	0.58	0.08	0.31	0.49	1.00		
I Labour Cost	0.75	0.91	0.94	0.90	0.05	0.61	0.92	0.63	1.00	
J Capital Cost	0.67	0.83	0.86	0.81	0.03	0.41	0.80	0.63	0.86	1.00

variables and for this reason are excluded from the analysis. Table 6 shows the input and output variables. In the present study we implement the CCR-DEA model (Charnes, Cooper and Rhodes, with Constant Return of scale; Charnes et al., 1978) and BCC-DEA model (Banker, Charnes and Cooper, with Variable Return of Scale; Banker et al., 1984), both input and output oriented.

4. Results

Statistical analysis to DEA scores was applied using exogenous and operational variables in order to identify potential effects produced by selected key elements values on the company's efficiency.

Table 6
Input and output variables.

Inputs	Outputs
Cost of materials	Water distributed
Cost of labour	Percentage delivery of water
Cost of services	Network length
Cost of leases	
Capital costs	

The descriptive statistics show that, during the observation period, an average of 42% of the companies reach the efficiency in BCC-DEA output oriented while in the CCR-DEA output oriented just an average of 28% of the companies are ranked efficient. Only a small number of firms reach the efficiency in the output oriented models. Considering the CCR-DEA model the number is lower, showing that the companies in the sample have difficulties in reaching technical efficiency. The CCR-DEA output oriented scores are bounded by the regulation systems, allowing the water companies to charge in tariff all the water pumped whether it is water delivered or water loss in the distribution infrastructures. In fact the tariff accounts the water loss as revenue water, and, as a consequence, the companies have not incentives to invest money in the water losses reductions to maximize the input/output ratio. BCC model assesses the pure/technical efficiency not influenced by scale effect and its value is lower than the BCC-DEA assessing scale efficiency. The average score value is 0,85 for BCC-DEA output oriented and 0,65 for CCR-DEA output oriented (Table 7); the BCC-DEA output oriented value is coherent with the previous research on the Italian sector (Romano and Guerrini, 2011; Romano et al., 2013) using different variables and a different firms sample. The small companies have higher scores than the medium, large and extra large firms

Table 7
Descriptive statistics of DEA scores.

	DEA Output Oriented		DEA Input Oriented	
	BCC-DEA	CCR-DEA	BCC-DEA	CCR-DEA
Average efficiency	0.85	0.65	0.74	0.63
Maximum efficiency	1.00	1.00	1.00	1.00
Minimum efficiency	0.42	0.17	0.17	0.17
Standard deviation	0.16	0.28	0.27	0.26
% Companies with the highest efficiency	42	28	40	27

Table 8
Mean efficiency scores by the size of the company type.

Efficiency by company size	DEA Output Oriented		DEA Input Oriented	
	BCC-DEA	CCR-DEA	BCC-DEA	CCR-DEA
Small (<20 Million€)	0.90	0.83	0.87	0.81
Medium (20–50 Million€)	0.81	0.56	0.62	0.54
Large (50–100 Million €)	0.83	0.56	0.70	0.54
Extra Large (>100 Million€)	0.85	0.50	0.70	0.48

Table 10
Mean efficiency scores by property type.

Efficiency by type of ownership	DEA Output Oriented		DEA Input Oriented	
	BCC-DEA	CCR-DEA	BCC-DEA	CCR-DEA
Public	0.89	0.71	0.79	0.67
Mixed - majority public capital	0.77	0.51	0.64	0.49
Mixed - majority private capital	0.71	0.51	0.51	0.49
Private	0.59	0.34	0.36	0.32

(Table 8). As Table 5 shows there are high correlations between network length and service cost, labor cost and water pumped and distributed, that imply that the small is the water utility size the small are the impacts of those costs. This result could, also, be explained by the particular condition of the regulation contest in which water companies operate. In accordance to Thanassoulis (2000a) the size of the water utility is not a variable under control of the companies' management but depend on contextual variables, (demography, population density, policymakers decisions). The utilities' size cannot vary in the short run and is defined by variables such as the served population. In the short run and under regulatory framework the companies cannot improve efficiency via size adjustments, while they can act in optimizing operational cost and technical standard.

The BCC-DEA output oriented efficiency is, in average, higher than the BCC-DEA input oriented, possibly due to the tariffs methods based on the Full Cost Recovery (FCR) rule without any standard reference cost, needed in order to boost companies' cost saving efforts. This hypothesis seems confirmed by the efficiency scores during the observation period (Table 9). The average efficiency values decline from 2011 to 2013. In 2012, the new tariff methods were established with the FCR rules, affecting costs functions and saving strategies of the water utilities.

Public owned companies show higher efficiency scores both for technical efficiency and scale efficiency, than the private ones (0.89 and 0.59; Table 10), mixed reach an intermediate efficiency value with the mixed with a majority of public shareholder being more efficient than the mixed with a majority of private shareholder. In accordance with Guerrini and Romano (2014), this result could rely on the set of variable considered for the present analysis. In fact, the set includes the difference between the amount of water pumped and delivered, accounting for water loss in the mains and for sustainability of issues (water and energy waste). Sustainability concerns are probably more addressed by public companies, that pay more attention to extra-economic objectives (environment, low tariffs and service qualities, public opinion) and to public opinion requests in term of costs and water resource savings. The other factor influencing this company's efficiency is connected to the objective of guaranteeing the population with low tariffs pushing public companies to put more effort into reducing operational costs.

Table 9
Efficiency score in the observation period (2011–2013).

Efficiency by year	DEA Output Oriented		DEA Input Oriented	
	BCC-DEA	CCR-DEA	BCC-DEA	CCR-DEA
2011	0.86	0.64	0.74	0.60
2012	0.85	0.64	0.73	0.61
2013	0.84	0.65	0.73	0.61

The geographical localization seems to be a key element in ranking efficiency scores of the companies. Central Italy is the area with less efficient water utilities; the cluster shows scores below the sample mean (Table 11) in all the types of measures of technical and scale efficiency (variable or constant, input or output oriented). The companies located in the north of the country show higher efficiency scores while the south remains in an intermediate level with all the values above the mean of the entire sample, with the exception of BCC-DEA output oriented score (0.83) slightly below the mean of the sample. The technical efficiency CCR-DEA score of the South region companies is very close to the Nord West region companies, showing a high technical efficiency level because of water scarcity affecting the area. Water scarcity acts as a limiting factor of the water service revenue.

5. Conclusion

DEA was applied to the Italian water companies to comparatively assess their efficiency under the regulatory framework (Thanassoulis, 2002) with the aim of contributing to the ongoing debate on the strategic and organizational choices of both policymakers and utility managers (Marques, 2010). Our main findings point out that public owned firms have the highest efficiency scores, implying that public owned companies purchase and employ inputs in a much better way, when compared with mixed or private owned firms. This result confirms and extends the outcomes of prior studies on Italian water utilities based on a smaller dataset of firms (Guerrini et al., 2011; Romano and Guerrini, 2011). In accordance with Thanassoulis (2002), "barriers to effective competition regulation of privatized utilities are seen as the main defense of the public interest against potential abuse of monopoly power". In a natural monopoly and under regulation framework public opinion could play an important role in bolstering efficient and sustainable water resource management. The public companies better efficiency scores confirm the natural monopoly character of the water service and the need for an improved

Table 11
Mean efficiency scores by geographical localization.

Efficiency by geographical localization	DEA Output Oriented		DEA Input Oriented	
	BCC-DEA	CCR-DEA	BCC-DEA	CCR-DEA
Nord West	0.94	0.75	0.81	0.73
Nord East	0.87	0.63	0.73	0.62
Centre	0.77	0.48	0.63	0.46
South	0.83	0.70	0.76	0.66

All the results are confirmed by DEA scores bias-corrected (Tables 12–14) providing robustness of the findings.

Table 12
Bias-corrected mean efficiency score in the observation period (2011–2013).

Bias corrected Efficiency by year	DEA Output Oriented		DEA Input Oriented	
	BCC-DEA	CCR-DEA	BCC-DEA	CCR-DEA
2011	0.77	0.50	0.58	0.47
2012	0.77	0.50	0.58	0.47
2013	0.74	0.51	0.57	0.48

Table 13
Bias-corrected mean efficiency scores by geographical localization.

Bias corrected Efficiency by geographical localization	DEA Output Oriented		DEA Input Oriented	
	BCC-DEA	CCR-DEA	BCC-DEA	CCR-DEA
Nord West	0.83	0.58	0.63	0.56
Nord East	0.77	0.50	0.58	0.48
Centre	0.70	0.39	0.51	0.37
South	0.73	0.53	0.59	0.52

Table 14
Bias-corrected mean efficiency scores by property type.

Bias corrected Efficiency by type of ownership	DEA Output Oriented		DEA Input Oriented	
	BCC-DEA	CCR-DEA	BCC-DEA	CCR-DEA
Public	0.79	0.55	0.62	0.53
Mixed - majority public capital	0.69	0.42	0.51	0.40
Mixed - majority private capital	0.65	0.40	0.42	0.38
Private	0.54	0.27	0.30	0.26

regulatory framework taking into account sustainability factors and implementing tariff method based on a national standard. In fact the first application period of the new tariff method has no effect in improving sector efficiency. The efficiency shows a declining trend of the scores with negative implication both in term of economic and environmental issues. This asks for implementation of specific adjustments to address the water sector toward the safeguard the public interest overcoming the lack of effective competition regulation and reducing/avoiding potential abuse of monopoly power affecting natural monopoly like water services.

The main novelty of this paper is firstly to rely on a larger sample of companies and so it is more representative of different Italian territories; secondly, in order to evaluate the performance of water companies, it considers also as relevant output variable of the analysis, the water losses, completely absent in the previous studies applied to the Italian market. Water losses play a key role in the evaluation of the performance of water-based companies and the need to keep a low leakage level is a priority for most water utilities hardly influencing their efficiency in a sustainable world. In fact there are many reasons for attaining and subsequently maintaining a low leakage level in water networks, chief amongst which is the environmental and social damage that the overexploitation of such a valuable natural resource can cause. Considering water losses in our dataset our research shows that companies located in northern Italy are more efficient than those operating in the centre and in the south. This new result, unlike those obtained in the previous papers, is due to the structural features of water mains (companies operating in central and southern Italy had the lowest performance in terms of water losses). Moreover, small companies showed the highest scores of pure efficiency, followed by large and extra large firms. In order to improve assessment of the performance of water utilities and to overcome the limitations of this paper further works could be useful. It would be interesting to add data on the quality of water in order to extend results to water service characteristics. Moreover this study used only Italian data, so would be valuable to compare efficiency results considering a wider set of countries where the water industry has features similar to Italy in order to identify and study the specificity of each country and the relative strengths and weaknesses. Unfortunately, it is not possible actually to extend this analysis since authors do not have access to similar databases.

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