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 for hydro services. 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). This well-known technique allows evaluating the systems efficiency not only by calculating the efficiency of each unit, but also helping policy makers by suggesting corrective policies and measures which could make the inefficient units efficient. This approach can be useful for policy makers to direct decisions towards a more sustainable and efficient water sector.

Keywords: Water industry, Efficiency, Sustainability.

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 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 of water will grow by 55% in 2050 (OECD, 2012). These factors in combination with an increasing in water use will probably result in a water crisis, commonly considered an emerging problem for the 21st century (Gallopin, 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 (cost control and reduction). Monopolies tend to seek for 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 utility, the environment and the consumer interests. Nevertheless criticism about the inefficiency of public control and the push towards greater market opening led to experiment privatization processes in the late 1980s. At a first stage, the privatization process involved transformation from a public legal form into private law firms (formal privatization), while 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 improve the water supply chain efficiency and quality. The Italian water supply system mirrors of the above mentioned problems with its by 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 wide spread along the country and the sewage systems are not adequately developed and many disparities exist at 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, the social welfare and economic growth. In this paper a set of Italian water utility companies is used to estimate the technical, environmental and economical 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 in term of public water utilities privatization. The referendum favored a tariff reform applied in 2012 with new single national tariff method. One of the main purposes of the tariff reform was to increase the sector efficiency in term of reducing the water losses, increasing the investment 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 to assess 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 loss 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 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.

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 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. The analysis of literature review shows contrasting results and applications, therefore more efforts and researches are needed.

3. Methods

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 pumped and distributed, 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 large or extra large size; and there is only one medium size company (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 ownership companies that are completely under the control of private shareholders (Table 3).

Table 1. Italian geographic areas of the selected companies.

Geographic area	N. of companies	% 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	% Companies
Small (<20 Mio Euro)	24	35.3
Medium (20-50 Mio Euro)	21	30.9
Large (50-100 Mio Euro)	12	17.6
Extra Large (>100 Mio Euro)	11	16.2

Table 3. Companies by ownership type.

Type of ownership	N. of companies	% 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

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 (Bogetof 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, Simar and Wilson, 2007). Bootstrapping simulate a sampling distribution by constructing pseudo-datasets based on a data generation process (DGP) that allows to approximate 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 hypothesis about efficiency measures (Bogetof and Otto, 2010, pp.170-186). In this study, bootstrapped DEA scores was 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: 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 variables and for this reason are excluded from the analysis. Table 6 summarises the input and output variables. In the present study we implement the

CCR-DEA and BCC-DEA model, input and output oriented.

Table 4. Data collected in the current study: variables names, sources and measure unit.

Variables	Measure unit	Source
Water distributed	m^3	• ISTAT[1] 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[2] 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

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

Table 6. Input and output variables of the current study.

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

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

4. Results

Statistical analysis to DEA scores were applied using exogenous and operational variables in order to identify potential effects produced by selected key elements on company's efficiency.
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. The average score value is 0,85 for BCC-DEA output oriented and 0,65 for CCR-DEA output oriented (Table 7); being 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 sample. The small companies have higher scores than the medium, large and extra large firms (Table 8). This result could be explained by the particular condition of the regulation contest in which water companies operate. In fact, 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, policy makers 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.
The BCC-DEA output oriented efficiency is, in average, higher that 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.

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	0.65
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	0.28
% Companies with the highest efficiency	42	28	42	28

Table 8. Mean efficiency scores by 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 Mio Euro)	0.90	0.83	0.87	0.83
Medium (20-50 Mio Euro)	0.81	0.56	0.62	0.56
Large (50-100 Mio Euro)	0.83	0.56	0.70	0.56
Extra Large (> 100 Mio Euro)	0.85	0.50	0.70	0.50

Table 9. Efficiency score in the observation period (2011 to 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	0.64
2012	0.85	0.64	0.73	0.64
2013	0.84	0.65	0.73	0.65

Public owned companies show higher efficiency scores 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 to 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). 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 in reducing operational costs.

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	0.71
Mixed - majority public capital	0.77	0.51	0.64	0.51
Mixed - majority private capital	0.71	0.51	0.51	0.51
Private	0.59	0.34	0.36	0.34

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 (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, excluded score of BCC-DEA output oriented with 0.83 value slightly below the mean of the sample.

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	0.75
Nord East	0.87	0.63	0.73	0.63
Centre	0.77	0.48	0.63	0.48
South	0.83	0.70	0.76	0.70

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

Table 12. Bias corrected mean efficiency score in the observation period (2011 to 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	0.50
2012	0.77	0.50	0.58	0.50
2013	0.74	0.51	0.57	0.51

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	0.58
Nord East	0.77	0.50	0.58	0.50
Centre	0.70	0.39	0.51	0.39
South	0.73	0.53	0.59	0.53

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	0.54
Mixed - majority public capital	0.69	0.42	0.51	0.42
Mixed - majority private capital	0.65	0.40	0.42	0.40
Private	0.54	0.27	0.30	0.27

5. Conclusion

DEA was applied to the Italian water companies to comparatively assess their efficiency under regulatory framework (Thanassoulis 2002).
The present research confirm the results presented section 4 regarding the superiority of the public owned companies compared with mixed and private enterprises in terms of efficiency. In accordance to 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".
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 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.
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 confirms the natural monopoly character of the water service and the need for an improved regulatory framework taking into account sustainability factors and implementing tariff method based on national standard.
In fact the first application period of the new tariff method has not 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 ask 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.

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