The Cost Efficiency of Water Utilities: When Does Public Ownership Matter?*

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Abstract

This study explores the impact of different ownership types on the efficiency of the provision of water utilities. Theories and evidence have shown a puzzling relationship between ownership and performance. Moreover, relatively recent contributions (Andrews et al., 2011) have argued that this relationship can be further convoluted by the effect of organisational and environmental variables. The current study aims to contribute to this literature by providing some empirical evidence for Italy, by proposing a methodology that combines nonparametric efficiency estimation and cluster analysis. Our main findings indicate that privately owned utilities indirectly controlled by a public organisation reach the highest level of efficiency but, when size and geographical location enter the analysis, ownership has a stronger significant effect on efficiency, and mixed utilities gain higher cost efficiency. Therefore, we may conclude that administrative reforms about privatisation and the institutional setting should consider a set of variables that characterise each individual organisation.

Keywords: efficiency, geographical location, ownership, size, water utilities.

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1. INTRODUCTION

In recent decades waves of administrative reforms have been implemented to improve local public services performance and cope with increasing constraints on financial resources. In this scenario, devolution and changes in ownership structure have occurred as a solution to public sector inefficiencies (Guy et al., 1996; Pollitt and Bouckaert, 2011; Savas, 2000; Shaw and Munday, 1999). Several scholars have investigated whether and how ownership affects performance, in order to find the most efficient, effective and fair way to deliver public services. The persistence of this issue in the literature can be motivated by different theoretical perspectives, puzzling empirical results and the acknowledgement that the links between ownership and performance is further complicated by the existence of 'moderators' such as organisational and environmental characteristics of the services provided (Andrews et al., 2011).

The extent of the debate about the ownership of public service production has been exacerbated by a wide acceptance of neo-liberal and New Public Management policies (Osborne and Gaebler, 1992; Hood, 1991) rooted in the Public Choice theory (Niskanen, 1971). According to this perspective, competition represents a solution to overcome public over production and inefficiency. Therefore it is assumed that governments, at all levels, should privatise and contract-out services in order to achieve technical and cost efficiency. Ultimately this process would shift the ownership of service from public to private sector.

Along with Public Choice theory, other theoretical perspectives have dealt with issues regarding service delivery choices. First, Williamson (1979, 1999) suggests that transactions cost and monitoring can play an important role in the choice to externalise services. In particular, this approach suggests that when transaction costs are low, privatisation can lead to cost savings. Second, property rights theory (Demsetz, 1967) advocates that private ownership can lead to better performance, due to better defined property rights and incentives to monitor and control the managers' behaviour. Third, the theory of incomplete contracts (Hart and Moore, 1990) suggests that privatisation could reduce costs, but without an adequate incentive system, it can also lower services quality. In recent years several studies, such as Bel and Fageda (2010), Warner and Hefetz (2008), and Bel et al. (2014), among others, have highlighted the popularity of alternative ownership structures that combine public and private capital—such as mixed companies and public-private partnerships. Therefore these new types of organizations can challenge even more the relationship between ownership and performance (Vining and Weimer, 2015).

Empirical evidence on the relationship between ownership and performance has been reviewed by recent studies, such as Andrews et al. (2011), Bel et al. (2010). Andrews et al. (2011) review thirty-two studies examine the link between 'publicness' and performance in a wide range of public services. Bel et al. (2010) conduct meta-analysis of twenty-seven studies comparing the costs of public and private production in solid waste services and water distribution. Both of these extensive reviews reveal that there is no systematic evidence supporting the superiority of either public or private production for delivering public services. These studies suggest that performance and efficiency seems to be affected by other factors apart from ownership, such as transaction costs, economies of scale, regulation, governance, or the environment. Andrews et al. (2011) refer to these factors as 'moderators' of the relationship between ownership and performance.

In light of the literature, this study investigates whether ownership structure has a significant effect on the cost efficiency of water service utilities when 'moderators' such as size and geographical features are simultaneously considered. The empirical evidence is based on a sample of Italian water utilities from 2008 to 2011.

In this regard, Italy represents an ideal geographical case to study such a problem given the heterogeneity in the ownership structures, size and environmental features of the water utilities operating in this country. Moreover attention to Italian water utilities can be further motivated by three main reasons. First, in recent years the Italian water industry has been at the centre of a debate about the possibility of liberalisation (Massarutto et al., 2008). Second, in 2011 the legislator modified the multilevel governance of the industry by abolishing the so-called "optimal area authority" ("Autorità d'Ambito Ottimale"), more popularly known by their initials, ATOs, in charge of coordinating the service at territorial level. However the current regulation has not yet determined which existing or new authorities are to take their place. Third, it is claimed that the price of water in Italy is one of the cheapest in Europe, but research results find that this is not sustainable in the long term (Utilitatis, 2011). In this context, efficiency is a necessary condition to guarantee this vital service in a fair and equal manner. The same concern is shared with previous studies carried out for other European countries, such as Spain and Portugal (González-Gómez et al., 2013; Da Cruz et al., 2012). Therefore the current study attempts to provide empirical results that can help policy makers and local governments in countries where the implementation of administrative reforms on ownership structure need to be made in a changing institutional environment and the pressure to fair price of public service is high.

The method applied in this paper combines two well-known nonparametric efficiency estimators—namely, Data Envelopment Analysis (DEA, Charnes et al., 1978) and Free Disposal Hull (FDH, Deprins et al., 1984)—with cluster analysis, following O'Donnell et al. (2008) and Balaguer-Coll et al. (2013). The advantage of using DEA (and its non-convex variant, FDH) is to rank water utilities on the basis of their efficiency score without requiring any assumption on the distribution function of the data (Rao et al., 2005). Moreover, by applying statistical clustering techniques the study controls for the effect of the 'moderators', which has not been carried out in previous studies.

The plan of the paper is as follows. Section 2 provide a brief owerview of the studies regarding the efficiency of water utilities. Section 3 describes the regulatory framework of the Italian water supply service. Section 4 provides an explanation of the method and data. Section 5 reports the results and Section 6 concludes the paper.

2. A BRIEF REVIEW OF THE RELEVANT LITERATURE

Since the early 1970s, several studies have assessed the effect of ownership on water service (WS) efficiency. These studies differ in several respects, including the method used to measure their efficiency levels. In particular, two groups of studies can be identified: those using accounting methods, and those applying econometrics and operational research methods. The current study applies an operational research method, namely DEA (and its non-convex variant, FDH), to estimate WSS utility efficiency. As pointed out by Bogetoft and Otto (2011), the selection of a benchmarking approach should 'reflect and respect the characteristics of the industry'. With particular reference to the WS, Berg and Marques (2011) argue that the lack of knowledge on the production function in this industry can justify the application of DEA. This method is considered more flexible than parametric approaches, since it does not require any assumption on the distribution function of the data. Moreover, Bogetoft (1994) highlighted the incentive-efficient properties of DEA that can be applied by regulators as it can be seen in England and Wales (Thanassoulis, 2000a,b).

The first study to apply the concept of Farrell (1957) efficiency—on which DEA is based—in this particular context was Byrnes et al. (1986), in an analysis focused on the US. The theoretical perspective on which the study was grounded provided arguments that privately-owned firms were more efficient than their publicly-owned counterparts. However, the nonparametric tests reveal no evidence that the latter utilities were 'more wasteful or operated with more slack than privately owned utilities' (Byrnes et al., 1986, p.341). Following and 'adjusting' Byrnes et al.'s (1986) method, several studies have applied DEA to analyse the relationship between ownership and water services' efficiency around the world. In line with the purpose of current study, the following review briefly outlines the research on the effect of ownership on WS utility efficiency, classifying the studies into three groups according to their results: (i) studies that reported no influence of ownership on efficiency; (ii) studies finding that public ownership improves efficiency; and (iii) those finding better efficiency scores for privately owned utilities.

One of the most relevant contributions among the first group of studies would include Byrnes et al. (1986). More recent research comprise García-Sánchez (2006), who measures the technical and scale efficiency of Spanish municipalities, distinguishing between those which externalised the water services to privately owned utilities and those which provide the service through public business corporations. The study claims that, in the specific context analysed, the creation of a quasi-market does not seem to affect efficiency. The author suggests 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. In this group of studies we also find Peda et al. (2013) who, in an application to Estonian water service utilities, found 'no difference in efficiency between water utilities with different types of ownership'. Their study also found a positive relationship between population size and efficiency, corroborating the hypothesis that efficiency gains are attributable to scale economies.

In the second group of studies, one of the most relevant contributions is the one by Romano and Guerrini (2011) on the efficiency of Italian water utilities. To the best of our knowledge, this is the first study to apply DEA to Italian water utilities, finding that publicly-owned utilities obtain higher efficiencies than mixed-owned. The authors interpret these results as an indication that publicly-owned utilities are better able to acquire and use their inputs. Moreover, the study considers the effect of size and geographical location on the performance of the water utilities. The results show the existence of economies of scale, since larger companies perform better. Regarding the geographical location issue, utilities located in Central and Southern Italy are more efficient than those operating in the north—although the differences were not statistically significant.

Finally, the third group of studies found superior performance in privately-owned utility firms. Specifically, Picazo-Tadeo et al. (2009) found that privately-owned utilities are more efficient than their publicly-owned counterparts. The authors claim that this result is due to efficiency in the use of labour, pointing out that the influence of trade unions makes it difficult to adjust the number of employees.

In sum, the available empirical evidence suggests that the debate on the links between ownership and performance is still unsettled. Moreover, the efficiency of water supply services seems strongly related to their size, as the theoretical approach of economies of scale would predict. Furthermore the efficiency can be affected by environmental variables, such the hydrographical characteristics of the geographical area in which the utilities is located (Martins et al., 2012). The current research therefore attempts to contribute to this literature by investigating the effect of the three variables considered separately in a first stage, and by combining their effect in a subsequent stage. This could shed light on the contribution of different ownership structure to control for exogenous conditions, such as hydrographical characteristics and strategic choices on the size.

3. WATER SERVICE IN ITALY

Water supply services (WSS) are generally considered public services provided through a network, and are regulated by public authorities. Therefore, any speculation on the organisation, the governance and the performance of these services is strongly affected by the regulatory framework of each country. The Italian WSS are regulated by four hierarchical levels of jurisdiction: the European Union, the central government, the regional governments, and the local governments.

European legislation classifies water supply services as a 'service of general economic interest' (European Community Treaty, Article 86(2)). Therefore WSS are economic services that have to be provided to every citizen on a regular basis and at affordable prices, regardless of the ownership of the service provider. Moreover in 2000 the European Commission issued the Water Framework Directive (WFD), addressing most of the challenges facing the management of this crucial resource. Two of the innovations introduced by the WFD were the cost recovery for water services and the polluter-pays principles. These principles aim to create incentives for the sustainable and efficient use of water.

As highlighted in the previous section, the last decades have witnessed changes in the ownership of public service providers. The European Commission lets each Member State to decide how it organises the provision of the service of general economic interest, as long as the rules on both the internal market and competition are observed. As a result, different approaches to the organisation of WSS can be found among EU Member States. For instance, in The Netherlands and Germany, municipal public enterprises provide water services. Conversely, in England and Wales the service was totally privatised and a regulatory authority established (Bauby, 2012).

In Italy, water supply services were traditionally provided by municipalities. In this context, the service was financed via public budget, and the tariff was usually insufficient to cover the costs (Massarutto et al., 2008). In order to improve the efficiency of the industry, the Law 196/94 was enacted in 1994 to reform the industry. First, the reform recognised the network features of the WSS and introduced the concept of 'integrated water service', considering the whole water supply and sewage system. Second, the reform reorganised the WSS by introducing territorial authorities, ATOs, with the aim of exploiting economies of scale in the management of the service. Regions were in charge of identifying these ATOs and municipalities could own ATOs' equity shares. About 90 ATOs were identified according to the political-administrative and hydrographical features of each area (Utilitatis, 2011). The main function assigned to the ATOs was to draw up a management plan for the WSS and to designate the WSS provider.

In the mid-2000s, Law 196/94 was replaced by the Environmental Code (Decree 152/2006), which retained the two main innovations of the previous law introduced the European principle of cost recovery for the WS. Among other norms, article 154 of the Environmental Code stated that the WSS price had to guarantee remuneration for the capital invested.

Meanwhile, changes had occurred in the institutional organisation of service providers. Since 1990, a series of reforms, inspired by New Public Management, have been introduced to promote local public services externalisation. The result is that the WSS provider could be a municipality, a municipal corporation, a mixed enterprise or a private entity. Moreover some municipalities have create municipal holdings that invested in private entity providing public service (Grossi and Mussari, 2009), therefore private entities can have a municipality as indirect shareholder.

Finally, water supply services were also affected by a series of relatively recent events. First, the financial crisis of 2010 forced governments to cut their budgets. In this context, the Italian legislator suggested eliminating the ATOs by the end of 2011. However, this regulation did not determine which authority should replace the ATOs, a question that still remains unanswered. Second, in 2011 a referendum repealed article 23-bis of Law 113/2008 and article 154 of the Environmental Code. Subsequently, the appointment of the WSS is based only on European legislation, with the result that the service can be provided directly by the municipalities, in house, by mixed enterprises without any specification of the percentage that must be owned by private partners, or by privately owned enterprises. A further consequence of the referendum was that the tariff should not be set according to the return on the capital invested.

In conclusion, it can be argued that the main consequences of reforms and counter-reforms of the water supply services are: (i) a multilevel governance structure of the industry, although the levels of this structure are still uncertain regarding the replacement of the ATOs and the role of the regions; and (ii) in the absence of an intermediate authority such as the ATOs, it seems that municipalities could once again be free to choose the delivery mode and appoint the service provider as they did in the past; (iii) changes in the tariff computation, with particular regard to the return on the capital invested.

4. METHODS AND DATA

Our study investigates the effect of ownership and the 'moderators' size and geographical location on the cost efficiency of Italian water utilities. To this end a three-stage methodology is applied: (i) we measure cost efficiency using two nonparametric estimators, namely, Data Envelopment Analysis (DEA) and its non-convex variant (Free Disposal Hull, FDH); (ii) cluster analysis, building groups based on ownership, size and geographical allocation of the organisations; and (iii) testing for differences in the efficiencies in each group and each cluster—i.e., nonparametric test is applied to verify whether type of ownership, size, geographical location, or their combination in clusters result in *significant* efficiency differences.

This methodological approach is similar to the one considered by Balaguer-Coll et al. (2013) in studying the efficiency of Spanish municipalities. However it differs from previous relevant work on water utilities, such as (Peda et al., 2013; Romano and Guerrini, 2011), who considered an *a priori* classification of organizations, without considering the combined effect of different classification on performance. Therefore, the procedure carried out in this study allows to define the clusters *ex post* instead of *ex ante* identifying a combination of factors that can influence cost efficiency and controlling for heterogeneity.

An explanation of the models applied to estimate the cost efficiency and the non-parametric test used are provided in the following two subsections, respectively. Then a description of the sample and the data used is provided.

4.1. Data Envelopment Analysis and Free Disposal Hull

The origin of Data Envelopment Analysis (DEA) dates back to Farrell's (1957) approach to frontier estimation, although it was not until 1978 that the term was first used (Charnes et al., 1978). Since then, this method has become one of the most popular techniques for benchmarking, with applications from financial firms to public service utilities—including water utilities (Fethi and Pasiouras, 2010).

DEA is a mathematical programming technique for the estimation of the best production frontier (or envelopment) and the measurement of the relative efficiency of different organisations (Bogetoft and Otto, 2011). This approach assigns a score between 0 and 1 to each decision making unit (in the case that an input orientation and Farrell distance functions are considered), allowing the organisations to be ranked on the basis of an increasing efficiency order. The term 'frontier' identifies the most efficient organisation that satisfies either the input or output-based Farrell efficiency condition.

In this study, efficiency measures are computed on the basis of two assumptions. Firstly efficiency score are input-based and thus measure the level of input to obtain a given amount of output [1]. Secondly inputs are expressed in monetary terms allowing to measure cost efficiency.

Formally, the input-oriented DEA is based on the solution of the following linear programming problem (Rao et al., 2005; Coelli and Walding, 2006):

$$\begin{aligned} &\min_{\theta,\lambda} \theta \\ &\text{s.t.} \\ &y_i + Y\lambda \geq 0, \\ &\theta x_i - X\lambda \geq 0, \\ &N1'\lambda = 1, \\ &\lambda \geq 0. \end{aligned} \tag{1}$$

where:

- y_i is an $M \times 1$ vector of outputs produced by the i^{th} firm,
- Y is the $M \times N$ matrix of outputs of the N firms in the sample,
- X is the $K \times N$ matrix of inputs of the N firms,
- λ is an $N \times 1$ vector of weights (which relate to the peer firms) and θ is a scalar measure of efficiency, which takes a value between 0 and 1 (inclusive).

[1] As indicated by Rao et al. (2005), the input-oriented efficiency addresses the question: 'By how much can input quantities be proportionally reduced without changing the output quantities produced?' (Rao et al., 2005, p.137). This approach seems particularly suitable for the context of water industry, where utilities are more more able to control their inputs rather than their outputs—such as water delivery and population served (Abbott and Cohen, 2009; Coelli and Walding, 2006; Romano and Guerrini, 2011).

When considering FDH (Deprins et al., 1984) instead of DEA, the last assumption is dropped and it is therefore a more general version of the DEA estimator, since it is not restricted to convex technologies. This, in practical terms, implies that each utility is compared only to other existing ones, and that it cannot be evaluated against any convex combinations of efficient utilities. As a result, the FDH frontier can be considered even more flexible than DEA, since the required assumptions are fewer.

The FDH estimator might be a reasonable choice in those cases where it is difficult to find a theoretical (or empirical) justification for postulating convexity. Indivisibilities of inputs and outputs might exist as well as economies of scale and specialisation, which thwart the convexity assumption. In addition to this, if the true production set is convex, then the DEA and FDH are both consistent estimators; in contrast, if the true production set is not convex, FDH is a consistent estimator of the production set, whereas DEA is not. Some of the characteristics of FDH have recently been reviewed by Diewert and Fox (2014).

4.2. Testing for the equality of distributions of efficiency scores

A variety of instruments can considered to test whether the differences between some of the moments that characterise two given distributions differ statistically. Some of these instruments are tests, such as the Wilcoxon test, which have the advantage of being relatively robust to the violation of the normality assumption, but have the limitation of restraining the analysis to one moment of the distribution only (in our case, the distribution of efficiency scores), namely the median. However, some recent applications (Balaguer-Coll et al., 2010) have considered some tools developed in the field of nonparametric statistics such as the Li (1996) test, which tests whether two distributions, and not just two summary statistics such as the mean or the median, differ statistically.

To apply this test, the univariate density functions of the indicators of interest—in our case efficiency scores—must be first estimated nonparametrically considering kernel smoothing methods (Li and Racine, 2007). Specifically, the kernel estimator $\hat{f}$ of a univariate density function f based on a sample of N efficiency scores, corresponding to the N firms, can be expressed as:

$$\hat{f}(z) = \frac{1}{Nh} \sum_{i=1}^{N} K\Big(\frac{z - \hat{\theta}_i}{h}\Big) \tag{2}$$

where i is the utility firm index, $\hat{\theta}_i$ is the efficiency score of the firm under analysis, z the evaluation point, h is the smoothing parameter,[2] and K is a Gaussian kernel satisfying certain properties (Li and Racine, 2007).

The Li (1996) test is based on measuring the distance between two density functions, $f(x)$ y $g(x)$, via the mean integrated square error (MISE):

$$I = I\big(f(z), g(z)\big) = \int_z \big(f(z) - g(z)\big)^2 dz = \int_z \big(f^2(z) + g^2(z) - 2f(z)g(z)\big) dz$$
$$= \int_z \big(f(z)dF(z) + g(z)dG(z) - 2g(z)dF(z)\big) \quad (3)$$

where F and G are two candidates for the distribution of Z, with density functions $f(z)$ and $g(z)$, which are estimated by considering the kernel smoothing methods referred to above. Therefore, $\hat{f}$ is the nonparametric kernel smoothing estimator for f, and $\hat{g}$ the nonparametric kernel smoothing estimator for g, whose expression is analogous to (2):

$$\hat{g}(z) = \frac{1}{Nh} \sum_{i=1}^{N} K\Big(\frac{z - \hat{\delta}_i}{h}\Big) \quad (4)$$

where $\hat{\delta}_i$ would be the efficiencies corresponding to another distribution—in sum, to another group of firms.

Given expressions (2) and (4), a possible estimator for I is:

$$\tilde{I} = \int_x \big(\hat{f}(z) - \hat{g}(z)\big)^2 dx$$
$$= \frac{1}{N^2 h} \sum_{j=1}^{N} \sum_{i=1}^{N} \Big[K\Big(\frac{\hat{\theta}_j - \hat{\theta}_i}{h}\Big) + K\Big(\frac{\hat{\delta}_j - \hat{\delta}_i}{h}\Big) - 2K\Big(\frac{\hat{\delta}_j - \hat{\theta}_i}{h}\Big) - K\Big(\frac{\hat{\theta}_j - \hat{\delta}_j}{h}\Big)\Big]$$
$$+ \frac{1}{N^2 h} \sum_{i=1}^{N} \Big[2K(0) - 2K\Big(\frac{\hat{\theta}_j - \hat{\delta}_i}{h}\Big)\Big] \quad (5)$$

The statistic on which the test is based, which could be constructed from the MISE, is therefore (see Fan, 1994; Li, 1996; Pagan and Ullah, 1999):

$$T = \frac{N h^{1/2} \tilde{I}}{\hat{\sigma}} \quad (6)$$

where

$$\hat{\sigma} = \frac{1}{N^2 h} \sum_{j=1}^{N} \sum_{i=1}^{N} \Big[K\Big(\frac{\hat{\theta}_j - \hat{\theta}_i}{h}\Big) + K\Big(\frac{\hat{\delta}_j - \hat{\delta}_i}{h}\Big) + 2K\Big(\frac{\hat{\theta}_j - \hat{\delta}_i}{h}\Big)\Big] \quad (7)$$

[2]We chose the plug-in methods proposed by Sheather and Jones (1991) because of their reasonable balance between bias and variance.

4.3. The sample

As stated above, the empirical evidence presented in this paper focuses on a sample of water utilities operating in Italy from 2008 to 2011. A complete list of Italian water utilities is obtained from *Federutilities*, an Italian association of public services provider.[3] However, the sample is restricted to mono-service utilities with available data and stable ownership structure. Therefore, only utilities for which the percentage of ownership has not changed from 2008 to 2011 are included in the analysis. The final sample is comprised of 68 utilities in each of four years analysed, leading to 272 observations across the four years (Table 1). The 68 utilities represent 70% of the ones listed by Federutilities and they served about 45% of the Italian population 2011. Furthermore utilities are classified according to three variables: ownership structure, size and geographical location.

As highlighted in the previous section, a water supply services' provider could be a municipality, a municipal corporation, a municipal holding, a mixed enterprise or a private entity. In this scenario, our study focuses on water services which are externalised by the local government through a separate entity, namely an utility, with a different type of ownership structure. In our particular sample, five types of ownership are identified (Table 1). Therefore, as demonstrated above, the conventional classification of private, public and mixed ownership used by previous research (Guerrini et al., 2011) does not seem to fully reflect the complexity of the Italian context or any other national setting where many alternative modes to delivery public services coexist (Tavares and Camöes, 2007; Bel and Fageda, 2010). Along with publicly owned (type 1) and privately owned (type 2) utilities, this research distinguishes mixed utilities in two groups: in one group, utilities in which the controlling shareholder is a public organisation (type 3) and, in the other, utilities in which the controlling shareholder is a private organization (type 4). Finally, we define a separate category of private utilities in which the indirect main shareholder is a public are identified (type 5). As reported in 1 32 utilities (128 observation over four years), corresponding to 47% of the sample, are publicly owned. The remaining utilities are mainly spread in type 2 and type 3. Only three and six utilities are classified as type 4 and type 5, respectively.

The size of water utilities is usually measured considering the population served. However, due to a lack of data over the time span analysed, a proxy is used. A possible proxy is total revenue, obtained from the financial statements. This variable shows to be strongly linear correlated with the population served (92%), suggesting revenue can be used as proxy of the

[3] In 2015 *Federutilities* was merged in *Utilitalia*.

population served with confidence. Table 1 shows that the sample is mainly characterised in small and medium size utilities, only three are considered to be large.

Finally, the third variable considered is geographical location. Most of the utilities in the sample are situated in the Northern of Italy, while 15% and 19% are in the Centre and Southern regions, respectively (Table 1). Italy is characterised by heterogeneous hydrographical features that can affect efficiency levels. Northern and Southern regions, except for few exceptions, are characterized by surface waters that required more sophisticated purification process leading to high operational and capital costs (Istat, 2008, 2014).

Utilities are further classified using cluster analysis, with the attempt to maximise the homogeneity of units within the clusters while maximising the heterogeneity among clusters. In the current analysis, five clusters are identified, whose characteristics are reported in Table 2. All the variables are significant with regard to the clusters, except for the fourth type of ownership (mixed owned utilities with a private organisation that owns 50% or more). The cluster analysis discriminates between medium size publicly owned utilities in central and Southern Italy (Cluster 1) and those that are located in the north of the country (Cluster 3). Cluster 2 contains both mixed and privately owned utilities but in both cases the main direct or indirect shareholder is a public organisation and do not discriminate between size and geographical location. Cluster 4 is characterised by mainly small sized privately owned utilities located in Southern Italy. Finally, Cluster 5 aggregates mainly small sized publicly owned and mixed owned utilities in Northern Italy.

4.4. Inputs and outputs

One of the biggest challenges in the application of DEA and FDH is the selection of the input-output variables suitable and available for water utilities. Consistently with the aim to estimate cost efficiency scores, operational costs are used. In details, four operational costs are considered as input, namely, cost of materials, cost of services, cost of using third party resources (such as rented plant and equipment), and wages.

The most popular measures of outputs are the amount of water delivered, the population served and the length of water mains (Coelli and Walding, 2006). However, the above data are not accessible for all the utilities in the sample and the population served is available only for 2011. Therefore, as for the variable size, revenue is used as a proxy.

Finally, since the analysis is longitudinal and both inputs and outputs are expressed in monetary terms, the data are deflated by the Italian consumer price index in order to correct them for the inflation (Coelli and Walding, 2006). This adjustment is particular relevant, since the time frame analysed is characterised by a considerable increase in prices (5.5%).

5. RESULTS

5.1. DEA and FDH efficiencies

Efficiency scores for the utilities in the sample over the 4 years computed via DEA and FDH are reported in Tables 5–8. The first two tables (5 and 6) report DEA efficiencies, considering the three classification criteria both separately (Table 5) and jointly (Table 6). Tables 7 and 8 report analogous information for FDH.

The efficiencies are higher for FDH (76.74% vs. 63.57%). This result was to be expected, given the intrinsic differences between DEA and FDH—i.e. under FDH firms are efficient *by default* and, therefore, the number of efficient utilities is also much higher (66.18% vs. 26.68%). Taking into account the relatively low number of inefficient units yielded by FDH and how close the means corresponding to both estimators are, it implies that, under FDH, the inefficient utilities perform quite poorly.

When considering the *ex ante* classifications (ownership, size, geographical location), remarkable differences are perceived among groups within each of the hypotheses considered. In the case of the groups constructed according to their ownership type, the discrepancies are particularly large. In the case of the DEA efficiency scores (Table 5), the discrepancies among average efficiencies are quite large, ranging from 49.19% for the most inefficient group (privately-owned utilities) to 90.42% for the least inefficient (privately-owned utilities with a public organisation as the main indirect shareholder). Focusing on the median, in order to isolate the effects of potential outliers, these discrepancies are even higher—the medians are 48.99% and 97.78% for these two groups, respectively. Results are robust to the efficiency estimator considered, since FDH efficiencies (Table 7) also reveal remarkable discrepancies among *some* of the groups' measures of centrality. However, in this case, given the high number of efficient firms (the median is 1 for four of the five categories), the discrepancies among other groups are very low.

When the 'moderators', i.e., size and geographical location, are considered separately results vary depending on the hypothesis considered. Regarding size, large firms are particularly efficient—58.33% of them are efficient, even under the more demanding DEA (see Table 5). In contrast, small firms are quite inefficient, since only 17.97% of the firms are efficient, and the median is also quite low (29.30%). This finding is consistent with previous research that indicated the existence of economies of scale in the water industry (Romano and Guerrini, 2011; Peda et al., 2013). Results are also robust under FDH, although with a remarkably higher number of efficient firms (46.09%, 83.33% and 91.67% for small, medium and large firms, compared to 17.97%, 36.36% and 58.33% under DEA).

These discrepancies are more modest when analysing results for groups based on their geographical location. The discrepancies among groups' average efficiencies are much lower for both DEA (Table 5) and FDH (Table 7). However, for both estimators the utility firms in the centre of Italy are the least inefficient, as also highlighted by previous research (Romano and Guerrini, 2011).

5.2. The 'moderators'

As indicated in the introduction, understanding the link between ownership and performance might be particularly intricate due to the effects of 'moderators', among which Andrews et al. (2011) highlight the role of size, geographical location, and governance. The current paper has combined these factors in clusters analysis in order to take into account their effect on efficiency.

The summary statistics for the efficiencies corresponding to the five groups yielded by the cluster analysis are reported in Tables 6 and 8 for DEA and FDH, respectively. The differences are high, especially when comparing groups 2 (mixed ownership with both direct and indirect main public organisation as shareholder) and 3 (publicly owned, medium, in Northern Italy), which are the least inefficient, with clusters 4 (privately owned, small, in Southern Italy) and 5 (publicly owned, small, in Southern Italy), and this result is very robust to the convexity assumption.

Specifically, in the case of DEA (Table 6), the average efficiencies corresponding to groups 2 and 3 are particularly high (81.29% and 86.26%, respectively), analogously to the values for the medians (93.99% and 97.16%, respectively). In contrast, the behaviour is quite the opposite for clusters 4 and 5, whose medians are 52.78% and 24.93%, suggesting that the mix of privately owned and small firms in Southern Italy may be particularly problematic in terms of efficiency. This result holds when the convexity assumption is relaxed, as shown in Table 8. Therefore, this finding seems to emphasise the relevance of economies of scale and the importance of public investment in the water industry especially in areas where purification process need to be more intense, such as in the south part of the country.

5.3. Testing for the differences among IWSS efficiency scores

The analysis in the above paragraphs is based on summary statistics only and, therefore, its statistical precision is limited. In this section the methods proposed in section 4.2 are applied to test whether the differences among the efficiencies of firms in the groups formed according to different criteria are significant or not. The method employed, as indicated in section 4.2, has the interesting virtue that it does not compare summary statistics but entire distributions of efficiency, as well as being fully nonparametric (and, therefore, consistent with the nonparametric DEA and FDH estimators).

This test compares the densities, estimated via kernel smoothing, for the unconditioned and conditioned relative series of efficiencies, where the unconditioned relative efficiency series corresponds to each firm's efficiency, divided by the average corresponding to all firms (computed yearly), and the conditioned relative efficiency series corresponds to each firm's efficiency divided by *its group* average; this average will differ depending on the hypothesis considered—ownership, size, geographical location or their combined effect.

The densities are displayed in Figures 1 and 2 for DEA and FDH efficiency scores, respectively. The lines in each sub-figure correspond to the unconditioned (solid line) and conditioned (dashed lines) relative efficiency series. Regardless of the convexity assumption, and even the unconditioned or conditioned series, the amount of multi-modality is remarkable, with pronounced modes well below the mean (which is 1, given we are dividing by the mean). This suggests there are non-negligible pockets of inefficient behaviour which do not vanish after controlling for our three factors—or their combined effects.

If the conditioning results in tighter densities and closer to the mean (i.e., unity), it would indicate that the conditioning scheme considered is relevant—i.e., efficiencies for all utility firms in the same group would be similar. However, this is only the case when conditioning for size and, to a lesser extent, ownership, whereas the effect of geography is negligible (densities almost overlap). The combined effect (the 'moderators') shows the strongest effect, as densities shift leftwards, approaching the mean (see Figures 1.d and 2.d), and corroborating the descriptive analysis carried out in the previous section.

Li's (1996) test provides statistical evidence to support this visual analysis. Results, shown in Table 9 for both DEA and FDH corroborate the analysis stemming from the visual inspection of the densities, since differences are particularly significant when considering the combined effect of the three hypotheses, or size alone. In contrast, in the case of geographical location the differences are not significant, whereas in the case of the type of ownership the effect is only significant at the 5% significance level.

6. CONCLUSIONS

The purpose of this study has been to analyse the influence of local public ownership on the efficiency of Italian water utilities. The study was motivated by the puzzling relationship between the different types of ownership and efficiency. In addition, the literature has identified a gap in understanding the effect of 'moderators' on the performance of water supply services. This paper focused on a relevant public service, namely, water supply services.

We have considered the case of Italy, where these services have traditionally been provided by local governments, but changes in regulation and the acceptance of paradigms such as New Public Management have resulted in such services being provided by different organisations. The current study has gone beyond the conventional classification in three ownership types (public, private and mixed), identifying five types and reflecting better the complexity of public service organisation in Italy and in other countries. In this context, the relationship between types of ownership and efficiency is further involved due to the disparate sizes and geographical locations of the utilities. Although previous studies considered the effect of ownership type, geographical location and size separately, this study explored the effect of these three factors on efficiency simultaneously.

From a methodological point of view, it can be argued that cluster analysis and appropriate nonparametric tests help to better discriminate among the different factors that can affect the efficiency of water utilities. Specifically, we measure efficiency by applying both Data Envelopment Analysis and Free Disposal Hull, and tests based on kernel smoothing to ascertain whether the differences between the different clusters were significant or not. Using these methods the current study has found statistically significant differences in efficiencies across ownership types, and even stronger results when considering groups based on size or the groups yielded by cluster analysis—which combine all the three factors, namely, ownership type, size and geographical characteristics.

Furthermore from the results, it can be argued that privately owned utilities indirectly controlled by public organisation reach the highest level of efficiency when size and geographical location are not considered. However the combined effect of ownership, size and geographical location has a stronger effect on efficiency. In this case, mixed-owned water utilities, in which a public organisation has direct or indirect control, are those with higher efficiency levels.

Our results might therefore be suggesting that policy makers and regulators should carefully consider the intrinsic characteristics of each industry in order to achieve better performance for public services. In particular, in the water industry, both public-private partnerships as well as the role of economies of scale seem to be important aspects to take into consideration, particularly when evaluating them simultaneously.

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Table 1: Italian water service utilities, distribution according to ownership, size and geographical location

Ownership	#	#	%
Publicly owned utilities (ownership type 1)	32	128	47%
Privately owned utilities (ownership type 2)	15	60	22%
Mixed owned utilities with public organisation that owns 50% or more (ownership type 3)	12	48	18%
Mixed owned utilities with private organisation that owns 50% or more (ownership type 4)	3	12	4%
Privately owned utilities with main a public organisation as indirect shareholder (ownership type 5)	6	24	9%
Total	68	272	100%
Size	#	#	%
Small	32	128	47.1%
Medium	33	132	48.5%
Large	3	12	4.4%
Total	68	272	100%
Geographical Location	#	#	%
North	39	156	57.4%
Centre	10	40	14.7%
South	19	76	27.9%
Total	68	272	100%

Table 2: Italian water service utilities, characteristics of the clusters based on ownership, size and geographical location[a]

Variables		**Cluster 1**		**Cluster 2**		**Cluster 3**		**Cluster 4**		**Cluster 5**	
Cluster label		**Public owned, medium-large, in Center-Southern Italy**		**Mixed ownership with public organisations as main shareholders and privately owned with a public organisation as main indirect shareholder**		**Publicly owned, medium, in Northern Italy**		**Privately owned, small, in Southern Italy**		**Public owned and mixed owned utilities, small, in Northern Italy**	
		#	%	#	%	#	%	#	%	#	%
Ownership	Publicly owned utilities	13	100%	0	0%	11	100%	0	0%	8	44%
	Privately owned utilities	0	0%	2	13%	0	0%	10	91%	3	17%
	Mixed owned utilities with public organisation that owns 50% or more	0	0%	6	40%	0	0%	1	9%	5	28%
	Mixed owned utilities with private organisation that owns 50% or more	0	0%	2	13%	0	0%	0	0%	1	6%
	Privately owned utilities with public organisation as main indirect shareholders	0	0%	5	33%	0	0%	0	0%	1	6%
Size	Small	3	23%	0	0%	0	0%	11	100%	18	100%
	Medium	7	54%	15	100%	11	100%	0	0%	0	0%
	Large	3	23%		0%		0%		0%		0%
Geographical location	Northern Italy	1	8%	9	60%	11	100%	0	0%	18	100%
	Central Italy	5	38%	5	33%	0	0%	0	0%	0	0%
	Southern Italy	7	54%	1	7%	0	0%	11	100%	0	0%
# of utilities in the cluster		13	100%	15	100%	11	100%	11	100%	18	100%

[a] We conducted a χ^2-test in order to assign the variables to the clusters. For all the variables the test was significant (5%), except for the type of ownership #4 (mixed owned utilities with private organisation that owns 50% or more).

Table 3: Description of the clusters

Cluster	**Description**	**# of firms in the cluster**	**% of the total number of firms**
Cluster 1	Publicly owned, medium-large, in Central-Southern Italy	13	19%
Cluster 2	Mixed owned with both direct and indirect main public organisation as shareholder	15	22%
Cluster 3	Publicly owned, medium, in Northern Italy	11	16%
Cluster 4	Privately owned, small, in Southern Italy	11	16%
Cluster 5	Publicly owned and mixed owned utilities, small, in Northern Italy	18	26%
Total		68	100%

Table 4: Definition of inputs and outputs

Variable	Variable name	Description
Output		
y_1	Total revenue	Accrued revenue recorded in the income statement
Inputs		
x_1	Cost of materials	Accrued cost of raw material recorded in the income statement
x_2	Cost of labour	Accrued cost of labor recorded in the income statement
x_3	Cost of services	Accrued cost of services recorded in the income statement
x_4	Cost of leases	Accrued cost of rented asset and in operating leasing recorded in the income statement

Table 5: DEA efficiency scores for Italian water service utilities, distribution according to ownership, size and geographical location

Classification	Group	Mean	1st quartile	Median	3rd quartile	Std.dev.	% efficient firms
Ownership	Type 1	0.6567	0.3149	0.7587	1.0000	0.3404	26.56
	Type 2	0.4919	0.1532	0.4899	0.8770	0.3634	21.67
	Type 3	0.6397	0.2076	0.7183	1.0000	0.3781	39.58
	Type 4	0.5774	0.2890	0.5375	0.8670	0.3033	16.67
	Type 5	0.9042	0.8035	0.9778	1.0000	0.1224	41.67
Size	Small	0.4572	0.1416	0.2930	0.7944	0.3584	17.97
	Medium	0.7818	0.6717	0.8737	1.0000	0.2656	36.36
	Large	0.9311	0.8871	1.0000	1.0000	0.1196	58.33
Geography	North	0.6371	0.2451	0.7382	1.0000	0.3483	28.21
	Centre	0.7115	0.4676	0.9037	1.0000	0.3651	35.00
	South	0.5929	0.2073	0.6001	1.0000	0.3518	26.32
Total		0.6357	0.2451	0.7478	1.0000	0.3524	28.68

Table 6: DEA efficiency scores for Italian water service utilities, distribution according to clusters

Classification	Group	Mean	1^{st} quartile	Median	3^{rd} quartile	Std.dev.	% efficient firms
	Cluster 1	0.6366	0.3786	0.7589	0.9142	0.3407	19.23
	Cluster 2	0.8129	0.7198	0.9399	1.0000	0.2555	41.67
Clusters	Cluster 3	0.8626	0.7514	0.9716	1.0000	0.1862	47.73
	Cluster 4	0.5161	0.1532	0.5278	0.9687	0.3729	25.00
	Cluster 5	0.4216	0.1423	0.2493	0.6648	0.3425	15.28
Total		0.6357	0.2451	0.7478	1.0000	0.3524	28.68

Table 7: FDH efficiency scores for Italian water service utilities, distribution according to ownership, size and geographical location

Classification	Group	Mean	1st quartile	Median	3rd quartile	Std.dev.	% efficient firms
Ownership	Type 1	0.7989	0.7392	1.0000	1.0000	0.3457	68.75
	Type 2	0.6159	0.2189	0.6494	1.0000	0.3914	46.67
	Type 3	0.7492	0.2468	1.0000	1.0000	0.3991	66.67
	Type 4	0.7959	0.6439	1.0000	1.0000	0.3281	66.67
	Type 5	1.0000	1.0000	1.0000	1.0000	0.0000	100.00
Size	Small	0.6008	0.1943	0.6869	1.0000	0.4051	46.09
	Medium	0.9095	1.0000	1.0000	1.0000	0.2479	83.33
	Large	0.9822	1.0000	1.0000	1.0000	0.0617	91.67
Geography	North	0.7750	0.4696	1.0000	1.0000	0.3563	65.38
	Centre	0.8237	1.0000	1.0000	1.0000	0.3585	80.00
	South	0.7221	0.2630	1.0000	1.0000	0.3782	60.53
Total		0.7674	0.4276	1.0000	1.0000	0.3630	66.18

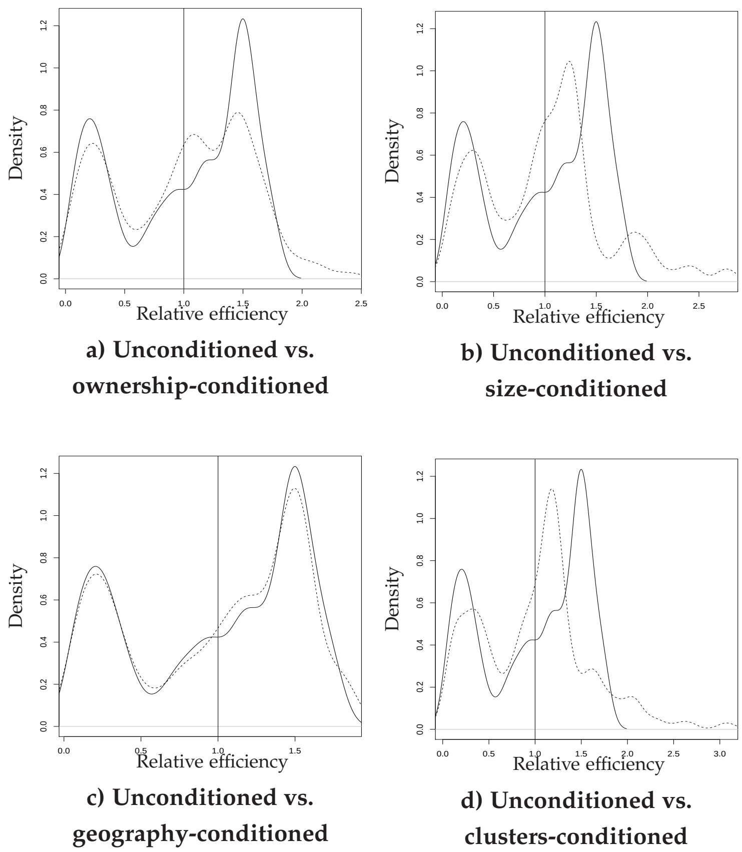
Table 8: FDH efficiency scores for Italian water service utilities, distribution according to clusters

Classification	Group	Mean	1st quartile	Median	3rd quartile	Std.dev.	% efficient firms
Clusters	Cluster 1	0.7752	0.5834	1.0000	1.0000	0.3685	67.31
	Cluster 2	0.9454	1.0000	1.0000	1.0000	0.2058	90.00
	Cluster 3	0.9610	1.0000	1.0000	1.0000	0.1418	86.36
	Cluster 4	0.6254	0.2176	1.0000	1.0000	0.4070	52.27
	Cluster 5	0.5819	0.1943	0.6086	1.0000	0.4003	41.67
Total		0.7674	0.4276	1.0000	1.0000	0.3630	66.18

Table 9: Testing the closeness between unconditioned and conditioned relative efficiency series (Li, 1996)

Null hypothesis	DEA T-statistic	DEA p-value
$H_0 : f(\text{Unconditioned}) = g(\text{Ownership-conditioned})$	2.1631	0.0153
$H_0 : f(\text{Unconditioned}) = g(\text{Size-conditioned})$	26.1374	0.0000
$H_0 : f(\text{Unconditioned}) = g(\text{Geographical location-conditioned})$	–1.0027	0.8420
$H_0 : f(\text{Unconditioned}) = g(\text{Combined effect})$	22.5473	0.0000

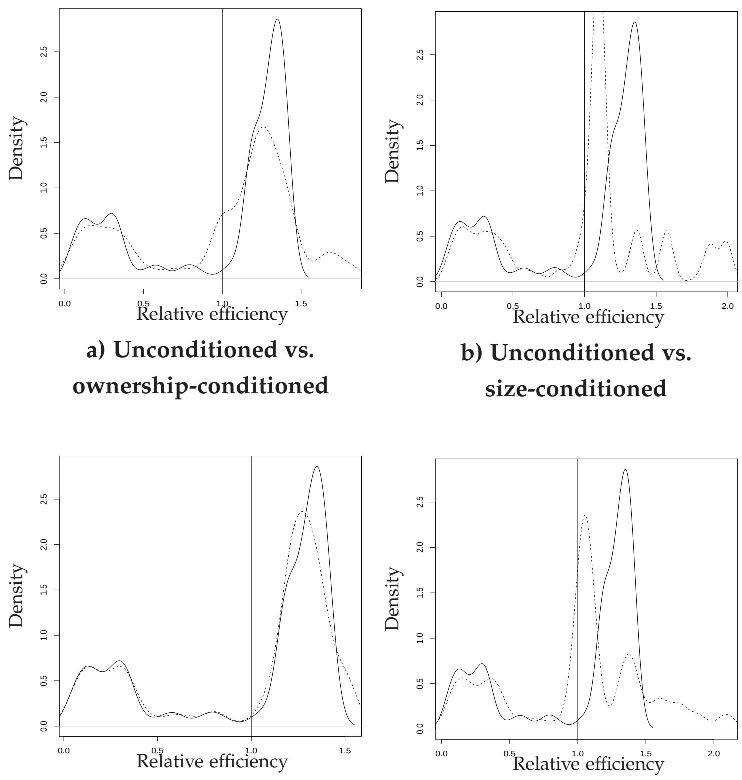
Figure 1: Kernel density plots of the unconditioned vs. conditioned efficiencies, DEA



Unconditioned ——— Conditioned ------

Notes: All figures contain densities estimated using kernel smoothing for unconditioned and conditioned DEA efficiency scores. The vertical lines in each plot represent the average for all series, since we divide by the corresponding (group) mean. A Gaussian kernel and the Sheather and Jones (1991) plug-in bandwidth were chosen.

Figure 2: Kernel density plots of the unconditioned vs. conditioned efficiencies, FDH



a) Unconditioned vs. ownership-conditioned

b) Unconditioned vs. size-conditioned

c) Unconditioned vs. geography-conditioned

d) Unconditioned vs. clusters-conditioned

Unconditioned ——— Conditioned ––––––

Notes: All figures contain densities estimated using kernel smoothing for unconditioned and conditioned FDH efficiency scores. The vertical lines in each plot represent the average for all series, since we divide by the corresponding (group) mean. A Gaussian kernel and the Sheather and Jones (1991) plug-in bandwidth were chosen.