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Ownership and Performance in Water Services Revisited: Does Private Management Really Outperform Public?

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Abstract Since the late 1970s, water services have been privatised in some developed countries in an attempt to improve performance. However, after three decades of privatisations the superiority of private management is being called into question and several cities are returning to public provision. In this paper we revisit the relationship between ownership and performance in urban water services management using directional distance functions, metafrontiers and *Data Envelopment Analysis* (DEA) techniques. The technical efficiency in the provision of water delivery services in a sample of Spanish municipalities is assessed at the level of the management of specific production factors; moreover, we discuss whether differences in efficiency between private and public decision units are due to either different capabilities of managers (managerial efficiency) or different technological restrictions (ownership efficiency). Our main finding is that private management is more efficient in the use of labour input, mainly because of the technological restrictions faced by public management units, such as legal and institutional restrictions. Conversely, private management appears to be less efficient at managing operational costs.

Keywords Urban water services · Ownership · Performance · Technological restrictions · Spain

JEL Classification C6 · L25 · L95

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1 Introduction

The issue of the relationship between ownership and performance has long been at the core of the debate in the water industry. Water is a merit good that serves economic, environmental and social purposes (OECD 2003), and displays important positive externalities. It is also a human need, so universal access should be guaranteed. Moreover, the water industry faces high fixed costs and is very capital intensive with high initial investment required, conditions which lead to a natural monopoly. Accordingly, thorough supervision and intervention on behalf of the public sector is justified as a means of preventing market failure, achieving an efficient allocation of resources and guaranteeing that welfare standards are met (Pigou 1932). Out of a number of possible options, one of the leading forms of intervention is by means of public companies. In fact, over the years, public provision has been the most common form of water services provision (Thomas et al. 2012).

However, following the wave of deregulation of economic activity that started in Anglo-Saxon economies in the late 1970s, private sector participation in the water industry became increasingly popular and nowadays it is widespread in some developed countries (see Pérard 2009). Deregulation was based on the idea that, far from pursuing the general interest, public intervention works to satisfy political interests (Niskanen 1971); accordingly, privatising water provision and introducing competition via tendering processes should promote efficiency and cost reduction. In addition, privatisation would allow the aggregation of demand, particularly in small-sized municipalities, thus achieving a more efficient scale of production (Donahue 1989). Other strands of thought have highlighted, nonetheless, that the predicted improvements in efficiency resulting from privatisation and competition can be hampered by the existence of transaction costs (Coase 1937), incomplete information, incomplete contracts or high asset specificity (Williamson 1976). Also, Donahue's argument that privatisation allows for the aggregation of demand appears to neglect the fact that intermunicipal provision is possible and in fact often does take place under public ownership, e.g., in the form of intermunicipal consortia.

Several papers have found that, although generalisations about the factors that explain privatisation in the urban water service should be drawn carefully (Ruíz-Villaverde et al. 2015), in practice this decision is mainly motivated by pragmatic reasons, including budget restrictions or searching for cost reduction and efficiency gains, rather than ideological or political issues (Bel and Fageda 2007, 2009). Furthermore, after more than three decades of research, empirical evidence as to the superiority of private management of urban water services over public is inconclusive, and several cities are moving back to public provision. Indeed, a number of municipalities in developed countries, including notable European cities such as Berlin and Paris, have remunicipalised the provision of urban water services in recent years (González-Gómez et al. 2009; Hall et al. 2013), while growing opposition to new privatisations is emerging from citizens' movements and certain political parties (Hall et al. 2005; Lobina et al. 2014). Pigeon et al. (2012) analysed a series of case studies of water services remucipalisation from a comparative international perspective, concluding that back-to-public provision largely occurred in response to the failure of the preceding privatisation.

On the other hand, as we have mentioned above and is detailed in Section 2 below, an extensive literature has focused on a comparative assessment of the operational performance of public and private operators. However, the empirical evidence is not at all conclusive. In these papers, researchers have overwhelmingly tended to assume that both categories of management –public and private– share the same production technology. To our knowledge, there are only a few cases that consider the possibility that public and private managers could face different technological restrictions (see Mbuvi 2012). However, as we argue in this paper, there are reasons to believe that the production technology might differ according to the nature of operator ownership; additionally, these differences might well have disparate effects on the management of particular production factors.

Against this background, this paper revisits the relationship between ownership and performance in water utilities using a fresh methodological approach that combines directional distance functions, metafrontiers and *Data Envelopment Analysis* (DEA) techniques. Specifically, the performance of a sample of both public and private operators in the Spanish urban water industry is assessed through the concept of *technical efficiency*, understood as their ability to reduce input usage for a given volume of output.

Our contribution to existing literature in this field is twofold. First, using metafrontiers allows us to express *technical efficiency* as the result of *managerial efficiency*, which assesses the performance of operators in the sample as compared to best practices in their group –either public or private operators– and *ownership efficiency* that measures the closeness of the technology of each group to the joint technology. In this way, differences in technical efficiency between private and public operators can be attributed to either the different capabilities of their managers (managerial efficiency), or the different technological restrictions (i.e., legal and/or institutional restrictions) faced by these two types of management (ownership efficiency). Second, and more interestingly, directional distance functions allow us to evaluate performance at the level of the management of specific production factors, including labour and other operational costs. In our opinion, there are reasonable grounds to believe that the technological constraints faced by public managers may differ from those faced by their private counterparts in terms of managing labour, which would not affect the management of other production factors. The combination of these two approaches has the potential to provide new insights into the relationship between ownership and performance in the water industry, as opposed to previous papers in which either metafrontiers or directional distance functions have been used separately.

In our empirical analysis, we use information about the provision of water delivery services for a sample of Spanish municipalities. Our main finding is that private management is more efficient in the use of labour, mainly because of technological restrictions faced by public operators when managing this input. Conversely, private operators appear to be less efficient at managing operational costs, although this result is statistically less robust.

The remainder of the paper is organised as follows. Section 2 briefly reviews the empirical literature on ownership and performance in the provision of water services. Section 3 presents the data and explains the methodology. Section 4 describes and discusses the results, while the final section summarises and concludes.

2 Ownership and Performance in Water Utilities: Some Empirical Evidence

Research on the effects of privatisation on the efficiency of water services management dates back to the 1970s, with the seminal works by Mann and Mikesell (1976), Morgan (1977) and Crain and Zardkoohi (1978). Those first studies focused on the water industry in the Unites States and, since then, this issue has been the subject of increasing attention. By the end of the 1980s only around thirty papers had been published, whereas in the 1990s alone about forty studies were conducted, and by 2010 there were well over two hundred and fifty publications

(Berg and Marques 2011; Carvalho et al. 2012). Moreover, the initial geographical focus quickly spread to areas with markedly different contexts, so that case studies can now be found from the five continents, and from both developing and developed economies.

Bel and Warner (2008) and Bel et al. (2010) carried out two meta-regression analyses of empirical studies finding little support for a link between privatisation and cost savings in solid waste and water services; in particular, cost savings are not found in water delivery, while they are not systematic in waste. Similarly, Lobina (2013) critically reviewed empirical literature on organisational choice and efficiency in the urban water sector, suggesting that institutional adaptability explains the efficiency and effectiveness of the public sector relative to the private sector. For the purpose of our review, empirical studies addressing the issue of differences in efficiency between publicly and privately managed urban water services will be classified into two broad groups: efficiency assessments for the same operator(s) in function of changes in ownership (through time); and efficiency assessments comparing operators under different ownership regimes (at given points of time).

Most studies in the first of the aforementioned groups focus on the massive privatisation of the water industry witnessed in the United Kingdom at the end of the 1980s, and they are in general agreement that privatisation did not lead to increased efficiency in urban water services. By way of example, Saal and Parker (2000) found no evidence supporting a relationship between privatisation and efficiency improvements in the water and sewerage industry in England and Wales. Likewise, Saal and Parker (2001) suggested that despite reduction in labour usage, total factor productivity growth in water and sewage companies did not improve following the privatisation of the industry; conversely, utilities' economic profits increased. Other papers in this line are Ashton (2000), Saal and Parker (2004) and Saal et al. (2007).[1] An exception is the paper by Estache and Trujillo (2003) that, using information from four utilities in Argentina between 1992 and 2001, found that privatisation led to important gains in total factor productivity. However, as pointed out by the authors, this result should be interpreted with caution given the small size of the sample employed.

Conclusions from the second group of studies are more diverse and even contradictory. Without aiming to be exhaustive, Table 1 shows a selection of empirical studies. Among those papers that find public management of urban water services to be superior, several explanations are adduced, such as lower costs (Mann and Mikesell 1976; Bruggink 1982; Bhattacharyya et al. 1995a) or better results in a range of performance indicators (Chong et al. 2006; Benito et al. 2010; Romano and Guerrini 2011; Guerrini et al. 2011; Da Cruz et al. 2012; Romano et al. 2013; Lannier and Porcher 2014). Other studies find that public companies are also more efficient at achieving social and development goals (Lobina and Hall 2000). Regarding analyses that found private management to be superior in terms of performance, reasons given also include lower costs (Morgan 1977; Crain and Zardkoohi 1978) and higher technical efficiency (Picazo-Tadeo et al. 2009a, 2009b). In addition, some of these papers maintain that differences in efficiency are mainly related to labour management (Crain and Zardkoohi 1978; Picazo-Tadeo et al. 2009a, 2009b; Gassner et al. 2009). Nevertheless, a substantial body of research either find no significant difference between the performance of public and private water suppliers or reach no definite conclusion. Furthermore, some papers point out that once characteristics of the operating environment are accounted for, differences in efficiency diminish (Ménard and Saussier 2000; González-Gómez et al. 2013).

[1] In addition, some papers have analysed the impact of changes in regulation on the performance of the privatised English and Welsh water industry (Erbetta and Cave 2007; Maziotis et al. 2016).

Table 1 Public *versus* private management of water services: Some empirical studies

Superiority of public management	Superiority of private management	No significant difference or inconclusive
Mann and Mikesell (1976)	Morgan (1977)	Feigenbaum and Teeples (1983)
Bruggink (1982)	Crain and Zardkoohi (1978)	Byrnes et al. (1986)
Lambert et al. (1993)	Bhattacharyya et al. (1995b)	Ménard and Saussier (2000)
Bhattacharyya et al. (1994)	Estache and Kouassi (2002)	Estache and Rossi (2002)
Bhattacharyya et al. (1995a)	Faria et al. (2005)	Kirkpatrick et al. (2006)
Lobina and Hall (2000)	Picazo-Tadeo et al. (2009a, 2009b)	García-Sánchez (2006)
Benito et al. (2010)	Lo Storto (2013)	Sabbioni (2008)
Romano and Guerrini (2011)		Zschille and Walter (2012)
Guerrini et al. (2011)		Peda et al. (2013)
Da Cruz et al. (2012)		González-Gómez et al. (2013)
Romano et al. (2013)		Hon et al. (2014)
Lannier and Porcher (2014)		

Regarding the methodological approach employed to assess efficiency, until the beginning of the twenty-first century there was a predominance of parametric techniques using cost (Mann and Mikesell 1976; Morgan 1977; Bruggink 1982; Feigenbaum and Teeples 1983; Bhattacharyya et al. 1994) and production (Crain and Zardkoohi 1978) functions, and/or *Stochastic Frontier Analysis* (SFA) (see Aigner et al. 1977, and Meeusen and van den Broeck 1977 for details). However, most studies these days are based on estimates of non-parametric frontiers and performance indicators by means of *Data Envelopment Analysis* (DEA) techniques, with only a few studies using other techniques (Byrnes et al. 1986; Saal and Parker 2001; Lobina and Hall 2000; Estache and Trujillo 2003). DEA is a well-known non-parametric approach to efficiency measurement based on mathematical programming pioneered by Charnes et al. (1978) that has been used in hundreds of empirical papers (Cook and Seiford 2009 and Liu et al. 2013 review this literature). This technique provides a simple way to measure the gap that separates individual producers' behaviour from best productive practices, which are assessed from actual observations of efficient producers' production processes. DEA offers an important advantage over the econometric approach to efficiency measurement, as it allows the technological frontier representing best-observed practices to be flexibly constructed without imposing a given functional form on either technology (e.g., the Cobb-Douglas or the translog production functions) or inefficiencies (e.g., distribution functions such as the half-normal). More details on DEA techniques can be found in Cooper et al. (2007).

On the other hand, performance differences between public and private management units have been evaluated using two main methodological approaches. The first consists of using conventional *ANOVA*, *Mann-Whitney*, *Kolmogorov-Smirnov* or *Kruskal-Wallis* tests, among others, to test for differences in efficiency scores obtained from either DEA-based analyses or cost and production function estimates with SFA. The second approach relies on directly including dummy variables reflecting ownership in the estimation of cost and production functions with SFA, or including them in second- or third-step regression analyses of DEA-based efficiency scores.

In summary, we believe that the lack of conclusive evidence in previous literature calls for fresh methodological and empirical approaches to assessing the relationship between efficiency and ownership in the water industry, and consequently we attempt such an approach in this paper.

3 Data, Variables and Methodology

3.1 Data and Sample

In this paper we use data relating to the provision of urban water delivery services[2] in 70 Spanish municipalities of under 50,000 inhabitants. In 37 of these municipalities either the city council itself or a public utility manages water delivery (public management units), while in the other 33 cases the service is privately managed by either a contractual public-private partnership (PPP) or an institutionalised PPP (private management units).[3] The data are from 2013 and were collected, when available, from web pages of municipalities and utilities as well as by direct contact with city councils and utilities' managers, in the framework of a wider project supported and financed by the Spanish *Ministry of Economy and Competitiveness*.[4]

Two outputs and three inputs are used to characterise the productive process of both public and private operators. The two outputs are water delivered and population served. Of the three inputs, one is fixed –the length of the delivery network–, and two are variable –labour and operational costs[5] (see Picazo-Tadeo et al. 2008). Table 2 provides measurement units and some descriptive statistics for the data.

[2] In addition to water delivery, some water utilities in Spain also provide sewage treatment services; however, this is not the case with the operators in our sample.

[3] García-Valiñas et al. (2013) provides a detailed description of legal forms for the management of urban water services in Spain. Furthermore, following previous literature, institutionalised PPPs have been considered as private management units given that day-to-day management is carried out by the private partner (see García-Valiñas et al. 2013; Picazo-Tadeo et al. 2012). Finally, it is worth mentioning that in compliance with Spanish law only the management of the urban water service can be privatised, while infrastructures always remain under public property.

[4] Spanish legislation prevents data on inputs and outputs of water suppliers from being made public. When creating our database, we submitted information requests to nearly 1000 Spanish municipalities, either via web pages or directly to city councils and utilities. Of these, we received 141 positive responses. After discarding observations with deficient or incomplete information, we selected 70 operators that are exclusively dedicated to water service delivery. Unfortunately, the aforementioned lack of publicly-available information makes it very difficult to obtain reliable and largely representative data on the production processes of Spanish water services operators. This is reflected in previous studies on Spanish water utilities, which make use of samples of similar size (Picazo-Tadeo et al. 2011; Picazo-Tadeo et al. 2009a, 2009b).

[5] Operational costs include all expenses required for day-to-day management of the service, e.g., raw water, chemicals employed to make water suitable for human consumption, energy and office expenses, among others. Conversely, wages and other labour costs are excluded. Furthermore, the fee paid by utilities to the local government when they are first awarded the service management contract is also excluded from operational costs. Finally, it is worth highlighting that operational costs are measured in euros, which means that computed technical efficiency might also include a component of allocative (price) efficiency. This is, however, a common problem in efficiency analyses that would have only a minor impact on the measurement of technical efficiency if production factor markets are assumed to be competitive with small price differences.

Table 2 Sample descriptive statistics

	Measurement unit	Mean	Standard deviation	Maximum	Minimum
Public management					
Water delivered	Thousands of m^3	510.4	526.6	2365.3	55.0
Population served	Thousands	7.4	7.2	25.3	1.1
Labour	Full-time workers	4.5	2.7	11.0	0.5
Operational costs	Thousands of €	415.5	532.2	2351.9	44.5
Distribution network	Kilometres	43.6	33.6	163.7	7.7
Private management					
Water delivered	Thousands of m^3	1561.0	1120.0	3475.5	113.4
Population served	Thousands	21.2	13.9	43.8	1.6
Labour	Full-time workers	12.6	10.5	43.0	1.6
Operational costs	Thousands of €	1414.9	986.9	3767.9	74.1
Distribution network	Kilometres	157.2	230.0	1330.8	24.1

3.2 Methodological Issues

3.2.1 The Metatechnology and the Group Technology

Our methodological approach is based on Sáez-Fernández et al. (2012), which uses directional distance functions (Chambers et al. 1998) to extend the metafrontier approach by O'Donnell et al. (2008) to the measurement of technological differences in the management of specific inputs.[6] In order to develop the main insights of this approach, let us assume that our $k = 1\ldots70$ decision units (operators) use the set of inputs $x = (x_f, x_v)$, where the fixed input x_f is the length of the delivery network, and variable inputs x_v are labour and operational costs, to produce the vector of outputs y, which includes water delivered and population served.

Transformation of inputs into outputs requires the use of a *metatechnology* that is represented by the *short-run input requirement set*. This set includes all combinations of variable inputs x_v that, given a fixed input endowment x_f, allow production of at least a level of outputs y. It is formally defined as:

$$L\left(x_f, y\right) = \left[x_v \middle| \left(x, y\right) \in T\right] \tag{1}$$

where T represents all combinations of inputs and outputs attainable with the present state of knowledge. It is assumed that the metatechnology satisfies the standard properties suggested by Shephard (1970).

The instrument used to compare the production plan of each decision-making unit in our sample with respect to best available practices[7] in the metatechnology, i.e., the

[6] See Beltrán-Esteve (2013), Beltrán-Esteve et al. (2014) and Picazo-Tadeo et al. (2014) for recent empirical applications of this approach.

[7] In this general setting, best practices are determined by those productive plans, either observed productive plans or resulting from their linear combinations, which obtain more outputs with fewer variable inputs usage, always for given endowment of the fixed input.

technological frontier, is the *directional metadistance function* defined as (Färe and Grosskopf 2000):

$$M\vec{D}=\left[x,y;g=\left(-g_{x_v},g_y\right)\right]=Sup\left\langle\delta|\left(x_v-\delta g_{x_v}\right)\in L\left[x_f,\left(y+\delta g_y\right)\right]\right\rangle \quad (2)$$

with $g = (-g_{x_v}, g_y)$ being the so-called direction vector.

This function has a lower bound of zero (other properties are in Chambers et al. 1998), and models inputs and outputs jointly by seeking the maximum attainable expansion of outputs in the g_y direction and the largest feasible contraction of variable inputs in the $-g_{x_v}$ direction. Furthermore, the directional metadistance function is a very flexible tool for assessing efficiency as it allows the technological frontier to be approached via alternative paths which focus on different facets of performance (Picazo-Tadeo et al. 2012).

These paths might represent the preferences of utilities' managers and/or policymakers regarding performance. If we were interested in assessing the maximum proportional (radial) feasible reduction of variable inputs labour and operational costs, given the endowment of the fixed input delivery network and also maintaining the level of outputs, the directional metadistance function would be:

$$M\vec{D}_{\text{radial}}=\left[x,y;g_{\text{radial}}=\left(-x_v,0\right)\right]=Sup\left[\delta_{\text{radial}}|(1-\delta_{\text{radial}})x_v\in L\left(x_f,y\right)\right] \quad (3)$$

By way of example, a score of 0.1 for a particular operator in our sample would mean that, given the length of its delivery network, it could reduce both labour and operational costs by 10 % without any decrease in the amount of water delivered or the population served.

Furthermore, it might be of interest to assess the potential reduction of variable input *i*, either labour or operational costs, while maintaining the other input *–i*, always for given fixed input and outputs, i.e., assessing technical efficiency in the management of variable input i. In this scenario, the directional metadistance function becomes:

$$M\vec{D}_i=\left\langle x,y;g_i=\left[\left(-x_{v_i},0_{v_{-i}}\right),0\right]\right\rangle=Sup\left\langle\delta_i|[(1-\delta_i)x_{v_i},x_{v_{-i}}]\in L\left(x_f,y\right)\right\rangle \quad (4)$$

In this case, a score of, say, 0.2 for the directional metadistance function and labour input would indicate that the number of full-time workers could be reduced by 20 % without increasing operational costs and, importantly, while still maintaining the amount of water delivered and population served.

The directional distance functions of expressions (3) and (4) can also be computed with respect to the technology of the two groups of operators considered in this research, namely, public and private. Accordingly, the technology of group *h* (with *h* = public, private) is based only on observations of decision units within this group, and can also be represented by the *short-run input requirement set* defined as:

$$L^h\left(x_f,y\right)=\left[x_v|\left(x,y\right)\in T^h\right] \quad (5)$$

with T^h representing all the combinations of inputs and outputs attainable by operators in group *h*, i.e., the state of knowledge for units in that group. The key issue here is that some productive plans, i.e., combinations of inputs and outputs, included in the metatechnology may not be possible given the technology of a particular group.

Formally, the directional distance functions computed with respect to the technology of group h in the case of radial and specific reduction of inputs are, respectively[8]:

$$\vec{D}^h_{\text{radial}} = \left[x, y; g_{\text{radial}} = \left(-x_v, 0\right)\right] = Sup\left[\delta^h_{\text{radial}} | \left(1-\delta^h_{\text{radial}}\right)x_v \in L^h\left(x_f, y\right)\right] \quad (6)$$

and,

$$\vec{D}^h_i = \left\langle x, y; g_i = \left[\left(-x_{v_i}, 0_{v_{-i}}\right), 0\right]\right\rangle = Sup\left\langle \delta^h_i | \left[\left(1-\delta^h_i\right)x_{v_i}, x_{v_{-i}}\right] \in L^h\left(x_f, y\right)\right\rangle \quad (7)$$

Figure 1 provides a graphical illustration of our directional functions. For the sake of simplicity, this is a hypothetical scenario in which we observe a set of four private management units represented by dots, and another set of six public management units identified by crosses. The short-run metatechnology or joint technology is represented by the lower envelope of all these observations regardless of their private or public character, i.e., the isoquant represented by the continuous line. Similarly, the technologies of private and public units are represented by the dotted and dashed isoquants, respectively. Projecting the inefficient public operator, i.e., the one located in the interior of the input requirement set, onto the metatechnology with a direction that reduces both labour and operational costs simultaneously yields point A; furthermore, projection onto the technology of the group of public units would yield point B. Accordingly, the segment BA measures the distance that separates the public technology from the metatechnology evaluated at this projection, i.e., the metatechnology ratio. Similarly, the segment DC measures the distance that separates the public technology from the metatechnology, assessed in a direction that reduces labour input whilst operational costs are maintained.

3.2.2 Computation of the Metatechnology Ratios

Using the directional distance/metadistance functions defined in Section 3.2.1, we have computed the metatechnology ratios proposed by O'Donnell et al. (2008). In particular, the *metatechnology ratio* of group h in our radial scenario can be defined as:

$$\text{Metatechnology ratio}^h_{\text{radial}}\left[x, y; g_{\text{radial}} = \left(-x_v, 0\right)\right] = \frac{\text{Techical efficiency}_{\text{radial}}}{\text{Techical efficiency}^h_{\text{radial}}} = \frac{\left(1-\delta_{\text{radial}}\right)}{\left(1-\delta^h_{\text{radial}}\right)} \quad (8)$$

It is worth noting that the metatechnology ratio has been defined using technical efficiency scores with an upper bound of one –a score that indicates full efficiency– and can be interpreted as conventional Farrell-type technical efficiency measures (Farrell 1957).[9,10] Furthermore, technical efficiency scores computed with respect to the technology of group h will be equal to or higher than those computed relative to the metatechnology.

The metatechnology ratio provides a measure of how close the technology of group h is to the metatechnology, assessed in a direction that reduces all variable inputs proportionally. For example, a metatechnology ratio of 0.85 means that the efficient level of variable inputs usage needed to

[8] By construction, directional distance functions computed relative to the technology of group h will always be equal to or lower than directional metadistance functions computed with respect to the metatechnology.

[9] The reason for this choice is that, although directional metadistance/distance functions can also be directly interpreted as measures of technical efficiency, distances for efficient management units are equal to zero and, thus, metatechnology ratios would not be defined for these operators (Sáez-Fernández et al. 2012).

[10] For example, a score for the directional distance function in the radial scenario of 0.1 would indicate, as already mentioned, that outputs could be maintained while reducing labour and operational costs by 10 %. In this case, the technical efficiency score would be 0.9, indicating that it would be possible to maintain the same level of water delivered and population served with only 90 % of observed inputs usage.

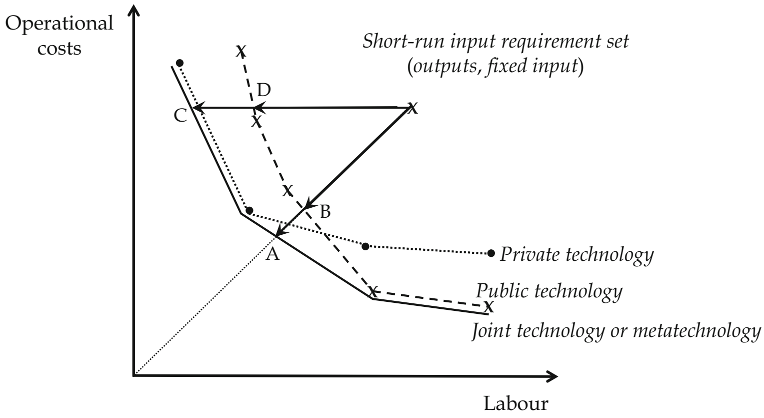

Fig. 1 Metatechnology, group technologies and metatechnology ratios

produce a given level of outputs relative to the joint technology is 85 % of the efficient usage relative to the technology of the group h, i.e., either public or private management units. According to O'Donnell et al. (2008, p. 237), this approach provides a suitable decomposition of technical efficiency assessed with respect to the metafrontier (representing the existing state of knowledge), into the product of technical efficiency measured with respect to the frontier of group h (that represents the state of knowledge as well as physical, regulatory and other restrictions faced by units in that group) and the metatechnology ratio for group h (which measures how close the technology of this group is to the joint technology). Formally:

$$\text{Technical efficiency}_{\text{radial}} = \text{Technical efficiency}^{h}_{\text{radial}} \cdot \text{Metatechnology ratio}^{h}_{\text{radial}} \tag{9}$$

In less technical terms, this approach allows the decomposition of *technical efficiency* into *managerial efficiency*, which assesses the performance of operators in the sample as compared to best practices in their group, and *ownership efficiency*, which measures the closeness of the technology of group h to the joint technology.

Similarly, the *input-specific metatechnology ratio* for variable input i and group h is:

$$\text{Metatechnology ratio}_i^h \left\langle x, y; g_i = \left[\left(-x_{v_i}, 0_{v_{-i}}\right), 0\right] \right\rangle = \frac{\text{Technical efficiency}_i}{\text{Technical efficiency}_i^h} = \frac{(1-\delta_i)}{\left(1-\delta_i^h\right)} \tag{10}$$

The interpretation of this metatechnology ratio is analogous to that in expression (8), with the difference that now the closeness of group h's technology to the metafrontier is assessed in a direction that only reduces input i without increasing the usage of input $-i$ and maintaining outputs. The abovementioned decomposition of technical efficiency also holds.

Lastly, the directional metadistance/distance functions involved in our analysis have been computed with *Data Envelopment Analysis* (DEA) techniques, using the programs detailed in the *Appendix*.

4 Results and Discussion

In the conventional scenario that assesses potential proportional reductions of variable inputs given the fixed input endowment and, also, maintaining outputs, the average for radial efficiency calculated with respect to the metatechnology or joint technology is 0.568 (Table 3).[11] This score suggests that when all operators in our sample are compared with best available practices, labour and operational costs could both be proportionally reduced by an average of 43.2 %.[12] For public and private units considered separately, averages of radial technical efficiency are 0.576 and 0.561, respectively; this difference is not statistically significant at standard confidence levels, according to the results from the *Kolmogorov-Smirnov* and *Mann-Whitney* non-parametric tests (Conover 1999), and the *Simar-Zelenyuk-Li* test (Simar and Zelenyuk 2006; Li 1996). As for managerial efficiency scores, i.e., those computed with respect to the group technologies, averages are 0.669 and 0.682 for public and private operators, respectively. However, it is important to point out that these scores are not directly comparable to each other because they have been obtained with respect to different technological frontiers, and it is well known that efficiency is a relative concept (Färe et al. 1994). Lastly, averages for the metatechnology ratios of public and private units are 0.833[13] and 0.838, respectively, and they are not statistically different according to the results from the tests included in Table 4. The *Kernel* density function represented in Fig. 2 provides a graphical illustration of this finding.[14]

The abovementioned results are in line with most studies in this field, and suggest that there is no significant difference in technical efficiency between public and private management. Nonetheless, the picture is rather different when performance is evaluated at the level of the management of specific production factors, i.e., non-radial measures, which reinforces the relevance of our approach.

In the scenario where only labour input is reduced, technical efficiency averages computed with respect to the metatechnology are 0.402 and 0.480 for public and private decision units, respectively (Table 4); moreover, the difference is statistically significant pointing to the higher efficiency of private management. But what are the reasons for the better performance of private units at managing labour? On the one hand, managerial efficiency scores for public and private units are 0.598 and 0.613, respectively. Although, as mentioned above, these scores are not directly comparable to each other, private units seem to be slightly closer to their technological frontier, on average, than public ones are to theirs. On the other hand, and more interestingly, the metatechnology ratios for public and private units average 0.651 and 0.778, respectively, i.e., the technology of private management units is closer to the

[11] Note that the exactness of the decomposition of technical efficiency presented in this table does not hold at the aggregate level due to the use of arithmetic means.

[12] This does not necessarily mean that all inefficient operators could adopt the best practices irrespective of the local context in which they develop their productive activity, or without undermining variables such as quality or sustainability. In this sense, research in this field has highlighted how the characteristics of operating environments can affect the technical efficiency of water utilities (Picazo-Tadeo et al. 2009a, 2009b; Ménard and Saussier 2000; González-Gómez et al. 2013); likewise, service quality also matters in measuring the performance of water utilities (Picazo-Tadeo et al. 2008).

[13] This means, by way of example, that the efficient level of labour input usage needed to produce a given output vector relative to the joint technology is 83.3 % of the efficient usage relative to the technology of the group of privately managed units.

[14] Table 4 and Figure 2 also include results and *Kernel* density functions obtained in the scenarios of input-specific performance assessment, which are discussed later; *Kernels* have been drawn directly using the metatechnology ratios obtained from expressions (8) and (10).

Table 3 Estimates of radial technical efficiency

	Mean	Standard deviation
Technical efficiency with respect to the metafrontier	0.568	0.282
Public management	0.576	0.317
Private management	0.561	0.251
Technical efficiency with respect to the group frontier (managerial efficiency)		
Public management	0.669	0.229
Private management	0.682	0.312
Metatechnology ratio (ownership efficiency)		
Public management	0.833	0.185
Private management	0.838	0.199

metatechnology than the technology of public units is. Moreover, the difference is statistically significant (see Table 5; see also the *Kernel* density functions in Fig. 2). In less technical terms, the technology of private operators appears to be more efficient in the management of labour input.[15] This result is in line with Gassner et al. (2009), which examined the impact of private sector participation in water distribution in more than 70 developing and transition economies. One of the main findings of that paper is that private participation is associated with gains in performance and labour productivity, which are linked to a reduction in staff numbers. Furthermore, the authors find that private sector also fares better than the public sector in terms of price efficiency. However, efficiency gains under private management are not followed by reduced prices or increased investments, suggesting that '... *the private operator reaps all the gains through profits*' (Gassner et al. 2009, p. 5). Accordingly, efficiency gains from privatisation would not benefit citizens through lower water prices and/or better service quality linked to increased investments, but just to private operators through higher returns.

The superiority of the technology used by private units in the management of labour might be due to certain regulatory and institutional restrictions faced by public management units that could reduce their flexibility in adjusting this production factor. In general, public managers are constrained by more stringent labour regulation which makes it more difficult to fire employees, and they also face higher levels of absenteeism (Meier and O'Toole 2011). In addition, local governments, particularly those ruled by left-wing parties, tend to develop policies to promote employment stability (Botero et al. 2004; Emmenegger 2011), as they consider the political costs of cutting jobs to be extremely high. Furthermore, public workers could also emerge as a lobby with a high negotiating power. Finally, creating overemployment when public services are delivered in-house might also form part of local politicians' *rent-seeking* strategy (Hart et al. 1997). Nevertheless, our findings do not allow us to establish a direct causal relationship between these conjectural factors and the superiority of the private technology in managing labour. Nor are a number of further related issues addressed in our

[15] Picazo-Tadeo et al. (2009b) also used a methodological approach based on the computation of input-specific scores of technical efficiency to provide evidence of the superiority of private utilities regarding the management of labour. However, here we go one step further by decomposing technical efficiency into managerial efficiency and ownership efficiency.

Table 4 Differences in the metatechnology ratio: Public versus private management

	Kolmogorov-Smirnov test [a] KS-statistic (p-value) [d]	*Mann-Whitney* test [b] Z-statistic (p-value) [e]	*Simar-Zelenyuk-Li* test [c] Li-statistic (p-value) [f]
Radial technical efficiency	0.117 (0.937)	0.445 (0.656)	-0.909 (0.818)
Input-specific technical efficiency			
Labour	0.346 (0.021)**	2.442 (0.014)**	2.989 (0.001)***
Operational costs	0.322 (0.039)**	-2.289 (0.022)**	0.729 (0.232)

** and *** stands for statistical significance at 5 and 1 %, respectively

[a] The null hypothesis is that the distribution of the two samples is the same

[b] The null hypothesis is that the two samples are drawn from the same population

[c] The null hypothesis is that the two samples have the same probability distribution function

[d] Exact *p*-values are provided

[e] Statistics are adjusted for ties

[f] Original estimates of the metatechnology ratio have been smoothed using Algorithm II in Simar and Zelenyuk (2006)

research, such as the potential impact of reducing labour usage on the quality of the service offered by private operators. It might, for example, be the case that public operators employ more full-time workers simply because they are essential to delivering higher service quality, a variable that is omitted in our analysis.[16]

Regarding the scenario where only operational costs are reduced, technical efficiency computed with respect to the metatechnology averages 0.493 and 0.505 for public and private operators, respectively (see also Table 4); however, the difference is not statistically significant at the standard confidence levels. This outcome is, nonetheless, the consequence of two contrasting factors. On the one hand, private managers are operating, on average, closer to their own technological frontier than their public counterparts –average scores of managerial efficiency for public and private operators are 0.539 and 0.620, respectively. On the other hand, however, private technology is found to be less efficient at managing operational costs than the technology of public management units: metatechnology ratios for public and private decision units are 0.920 and 0.806, respectively, with the difference being statistically significant according to the *Kolmogorov-Smirnov* and *Mann-Whitney* tests but not the *Simar-Zelenyuk-Li* test (see Table 5; also see Fig. 2).

This latter result is then less robust than that obtained in the case of the specific management of labour input and should thus be interpreted with caution. However, several factors could go some way to explaining this. In the first place, cost-sharing activities may take place, especially under in-house public provision. In other words, some operational costs such as administrative costs or energy consumption could be included in the budget item for general

[16] There is no consensus about the effect of privatisation on the quality of the urban water service, either. In this respect, Galiani et al. (2005) found that the privatisation of local water companies in Argentina lead to a significant reduction in child mortality from causes directly related to water conditions such as infectious and parasitic diseases; also Marin (2009) suggested that privatisation in developing countries leads to improved service quality, especially by reducing water rationing. Conversely, Barrera-Osorio et al. (2009) showed that privatization in Colombia has strong negative effects on the access to water in rural areas. Furthermore, some papers suggest that privatisation has been followed by deterioration in service quality in the United Kingdom in such aspects as supply continuity and leakage control (Lobina and Hall 2000; Lobina and Hall 2001).

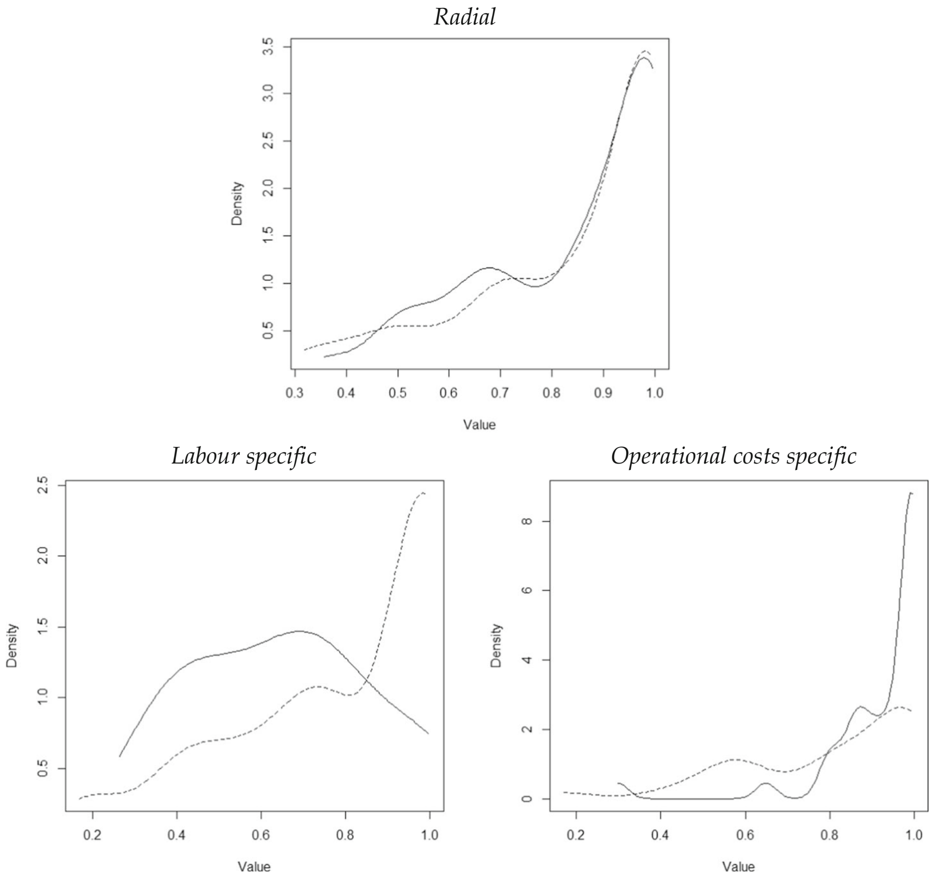

Fig. 2 Kernel density estimation functions of metatechnology ratios: public (*continuous line*) versus private (*dashed line*) management

Table 5 Estimates of input-specific technical efficiency

	Labour		Operational costs	
	Mean	Standard deviation	Mean	Standard deviation
Technical efficiency with respect to the metafrontier	0.439	0.325	0.499	0.325
Public management	0.402	0.292	0.493	0.294
Private management	0.480	0.358	0.505	0.361
Technical efficiency with respect to the group frontier (managerial efficiency)				
Public management	0.598	0.264	0.539	0.305
Private management	0.613	0.358	0.620	0.373
Metatechnology ratio (ownership efficiency)				
Public management	0.651	0.220	0.920	0.134
Private management	0.778	0.259	0.806	0.214

municipality expenses, and it would be very difficult to get accurate estimates of the share corresponding to water services. Secondly, it has been shown that there is a tendency to privatise water services operating in more complex environments (González-Gómez et al. 2011), which might imply higher operational costs. For example, some factors that could have an impact on operational costs include the state of conservation of the delivery network, the source of raw water and its quality, and network efficiency.[17]

5 Conclusions and Suggestions for Further Research

Since the 1980s, a number of papers have studied the relationship between ownership and urban water operators' performance, using a range of conceptual and methodological approaches. Nevertheless, after more than three decades of research, empirical evidence is still inconclusive. Our main contribution to this literature is the use of a fresh approach to assess technical efficiency in the management of water delivery, based on the use of directional distance functions, metafrontiers and *Data Envelopment Analysis*. Unlike extant research, which has used either metafrontiers or directional distance functions separately, combining the two approaches allows us to account for the possibility that public and private operators face different technological restrictions affecting the management of particular production factors. The main advantage of this combined approach is that it allows us to distinguish between managerial efficiency and ownership efficiency at the level of the management of specific inputs, with the latter representing the effect on performance of technological restrictions faced by either public or private ownership regimes.

Furthermore, we focus our empirical analysis on urban water service provision in Spain. Regarding our results, in a conventional scenario based on assessing radial efficiency, as is the case with most previous research, we find no differences of performance between public and private operators; however, when performance is evaluated at the level of the management of specific production factors the picture is somewhat different. On the one hand, the technology of private operators is found to be more efficient in the management of labour, which might be due to certain institutional, regulatory and also political restrictions faced by public management units. Conversely, private operators' technology appears to be less efficient in the management of operational costs, perhaps because they operate in more complex environments, which probably leads to higher operational costs. However, this latter outcome is statistically less robust. In summary, our approach seems to be successful in uncovering new insights hidden to more conventional approaches based on the simple calculation of radial or overall measures of performance in the provision of the urban water service (some exceptions are, however, Picazo-Tadeo et al. 2009b or the abovementioned paper by Gassner et al. 2009, which also evaluate the performance of water operators at the level of particular production factors). It is our belief that these results might be of interest to managers and policymakers responsible for policies aimed at regulating the water industry.

Finally, it is worth mentioning some limitations of our approach that also constitute lines for future research. In the first place, it would be worth extending our methodology to incorporate

[17] These hypotheses would need, however, to be empirically tested. Using an indirect approach, we have found that private management is positively correlated with certain variables representing the complexity of operating environments, e.g., a dummy variable that characterises municipalities where intensive treatment is required to make raw water suitable for drinking, and an index of delivery network density computed as kilometres of network per 1000 inhabitants.

non-controllable inputs and/or other environmental factors in order to attain more precise evaluations of performance. In this regard, it would be highly advisable to account for the quality dimension in urban water service provision; as mentioned above, if the analysis disregards quality it may overlook the fact that cutting the number of workers could result in lower service quality. Furthermore, it would also be worthwhile to integrate social aspects of water provision such as affordability into our analysis; e.g., it may be the case that if private operators reduce labour usage it could result in a less satisfactory achievement of social objectives such as affordability. A second interesting line for future research would be extending our approach to the analysis of both technical efficiency and price efficiency, e.g., it might be possible for a particular operator to score highly in terms of price efficiency but poorly for technical efficiency or vice-versa, and also to the study of how supposed efficiency gains from privatisation are distributed. Third, our manuscript suggests some factors and/or institutional restrictions that could explain the superiority of the private technology in managing labour; testing these hypotheses empirically would provide managers and regulators with sound information helping them to improve both management and water policies. And finally, replicating our analyses with larger samples of Spanish water utilities as well as for other developed countries would also be very welcome addition to this field of research.

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