OWNERSHIP RELATIVE EFFICIENCY IN THE WATER INDUSTRY: A SURVEY OF THE INTERNATIONAL EMPIRICAL EVIDENCE.

1. Introduction

With the exception of France and the UK, most of the water industry in the EU countries is still under public ownership, usually at municipal level.

As a recent study realized for the European Commission[1] shows, the presence of privately owned water utilities varies across countries but, in general, it is almost negligible.

As other network utilities showed performance improvements and large price reductions in real terms after privatization and liberalization, a case could be made for privatizing the water sector. Nonetheless, the case for water privatization seems to be less compelling than for other network utilities.

In fact, while there is a huge body of theoretical and empirical evidence that seems to confirm the higher efficiency of private operators (see Shleifer, 1998, Shirley and Walsh, 2000 and Megginson and Netter, 2001, for instance) there is also some evidence which seems to suggest that often it is not privatization per se that raises efficiency and productivity, as a more important role is played by liberalization and the existence of effective competition.

But, in general, the scope for liberalization and competition in the water industry seems to be far less significant than for other network utilities such as telecommunications, gas and electricity.

In fact, the usual strategy adopted to introduce liberalization and competitive forces into other public utilities, i.e. the privatization of the state-monopolies, the liberalization of the sector through the regulation of the natural monopolistic elements and the opening to

[1] WRc (2002).

competition of the "non monopolistic" parts has not been attempted so far, for different reasons, in the water industry[2] [3].

Therefore, as competition is unlikely to determine significant efficiency gains in the water sector, the rationale for privatization would rest on better management in the private sector (mainly through the discipline imposed by capital markets through the take-over threat)[4]. The better incentives which would characterize the private sector were indeed the theoretical underpinning underlying most of the privatization programmes undertaken in Europe in the last two decades.

Nonetheless, if we consider some of the most recent literature reviews on the public-private relative efficiency differentials in natural monopolistic sectors, a well defined pattern does not seem to emerge[5]. In other words, it is not so clear whether the higher incentives provided by private ownership work well in situations, typical of some public utilities, where the company (both public and private) has not to face any product market competition and where regulatory distortions might affect the behavior of private and public operators in different ways.

In general, a better knowledge of the actual existence of a differential in the efficiency levels between public and private operators might be useful for policymakers dealing with the restructuring of their water sectors. In fact, if the incentive mechanisms which characterize a private company did not work well in heavily regulated industries like water, the efforts of policymakers should shift from the ownership issue per se to the industry design stage and to the

[2] In the UK there have been some attempts to introduce common carriage agreements that consist in considering the network as an essential facility and in requiring the incumbent firm to open it up to competitors on a non-discriminatory basis. Unfortunately, so far, their impact has been modest. For a discussion about the feasibility of product market competition in the water industry see Conti (2004).

[3] The only serious attempts to introduce competitive forces into the water sector have been only limited to the use of franchising, or competition for the market, which has been extensively used in the French experience, as well as in many developing countries.

[4] See Newbery (2004).

[5] For instance, in the context of the electricity industry, some studies (for example, Fare *et al.*, 1985; Pescatrice and Trapani, 1980 and Kwoka, 1996) indicate a higher efficiency of public operators, while others either find no significant efficiency difference between ownership types (for instance, Atkinson and Halvorsen, 1986) or find private firms more efficient (Pollit, 1994 and Ros, 1999). For a brief review, see Newbery (1999).

careful development of more "powered" regulatory mechanisms (like yardstick competition) or to the adoption of franchise competition, which thus could be the real "focal" point of the efficiency issue in public utilities rather than ownership[6].

Nonetheless, to the best of our knowledge, there is not any study reporting the available international empirical evidence on the relative efficiency of public and private operators and on the effects of privatization in the water supply industry. The aim of this study is thus to help filling this gap, by analyzing and discussing the papers which have dealt with these issues over the last 25 years.

We have decided to divide the papers into three main groups: in the first one, we have surveyed the studies dealing with US samples (the large majority, given the mixed ownership structure of the US water industry); in the second one, we have grouped the studies that have dealt with the English and Welsh water industry while the third one deals with the remaining papers. Inside each group, we have then classified papers according to the estimation methodology adopted[7] and, finally, according to the chronological order.

The structure of the paper is thus as follows: in section 2 we will very briefly review the theories underlying the debate over the relative efficiency of private versus public firms, giving special emphasis to the peculiarities characterizing public utility industries, while in section 3 we will review the international empirical evidence. Section 4, finally, will contain the conclusions of the paper.

---

[6] Newbery (1999) discusses at length why, in the long run, liberalization and high-powered regulation in network utilities might require privatization, municipal ownership (very frequent in the international experience in the water industry) being perhaps an exception to this general rule.

[7] We need to note that in this article we review only the papers that have employed econometric or linear programming techniques. Of course, the issue of public vs. private operation in the water industry has been addressed by many other studies that used financial performance measures and partial productivity indices (labor productivity, unit costs, etc) as "working tools". On the other hand, financial indicators and partial productivity measures share many drawbacks that make their results doubtful, at best: for these reasons we have decided to concentrate on papers using econometric and linear programming techniques only.

2. Public versus private provision of water services: an overview of the theory

The debate over the relative efficiency of private and public firms is an old one in economics, and it can be traced back at least to John Stuart Mill. It is not the aim of this paper to provide any comprehensive review of the existing theories on public versus private ownership relative efficiency.

Our aim is to provide the reader with some flavor of the theoretical debate, focusing in particular on the specific situation of public utility industries, which are characterized by none or weak competition[8] and where private firms are subject to economic regulation.

Property rights theory and public choice theory have been used to give a theoretical foundation to the higher efficiency of private firms. In fact, in private firms shareholders are supposed to have greater incentives to pursue objectives of cost minimization or to introduce new and more productive techniques, since they can internalize the efficiency gains thus obtained through the selling of their shares on the capital market. On the other hand, the owners of public firms (i.e. citizens-taxpayers) cannot transfer their property rights and so they have no incentives to promote the introduction of new, efficiency-enhancing techniques that can potentially increase revenues and/or reduce costs. In second place, using public choice theory, it has been argued (De Alessi, 1969) that managers of public firms, being appointed by political parties, have a shorter time horizon than their private counterparts, since they are likely to be in office no later than the next elections: this will tend to bias public managers' preferences against long term projects, for example favoring the adoption of labor intensive techniques. In third place, as it has been noted by Aharoni (1982) and Levy (1987), public managers' goals are often less well defined than those of their public counterparts and may be subject to significant changes when a new government enters in office. Moreover, in the case of private firms the presence of capital market competition and the associated presence of a take-over threat should not allow the managers to pursue objectives which are "too" in contrast with shareholders' interests: this effect (i.e. the

[8] There is in fact a strand of literature arguing that ownership per se does not matter (or at least has a second order effect) in explaining the performance of firms, while a much more important role is assigned to the existence of a sufficient degree of competition (see, among others, Caves, 1990, Kay and Thompson, 1986, Vickers and Yarrow, 1988 and Laffont and Tirole, 1991, for instance).

incentives provided by capital market competition) should offset (at least in part) the X inefficiency which is likely to characterize private regulated monopolies[9]. Furthermore, using public choice theory it has been argued (Stigler, 1971) that government-owned companies are likely to be characterized by overstaffing, since this would be a way for politicians to "compensate" their electorate.

Finally, it has been claimed (Dixit, 1997) that, in general, private firms are more efficient than public ones because in the latter multiple agency problems are more significant: the basic idea is that when an agent has to pursue different tasks (one for each principal) the incentives are likely to be less sharp because the impossibility of observing the execution of one of the tasks "pulls down the incentives for all tasks".

However, there are also theoretical arguments in support of the greater efficiency of public firms: the one which has received most of the attention in the literature (which is mainly related to the US experience of coexistence between private and public utilities) is the regulation private utilities are subject to: this, on one side, entails the usual costs of regulation, while on the other one may cause the well known Averch-Johnson[10] effect if rate of return regulation is used (see Averch and Johnson, 1962).

As it should be clear for what we have said so far, some of the arguments in support both of public and private ownership are, in some cases, at least partially related to the institutional environment public and private utilities operate in. For instance, even a government-owned company can be quoted at the stock exchange and the performance of managers monitored through the price performance of the shares[11], thus introducing some of the incentives

---

[9] Vickers and Yarrow (1988) discuss a model where the effects of capital market competition are potentially ambiguous.

[10] If the regulated firm is allowed to earn only a maximum rate of return on its capital, then the firm will have incentives to raise its profits by over-expanding its capital base. The consequence of this behavior could be the adoption of too capital-intensive techniques.

[11] This line of reasoning has more general implications: as noted by De Fraja (1993), justifying a supposed higher efficiency of private over public firms simply arguing than the institutional framework under which public managers operate does not allow to specify correctly the goals they have to pursue or does not allow the use of the wide arrays of incentive mechanisms typically used in the private sector does not mean that the institutional framework cannot be changed somewhat to parallel the private one. For instance, the transformation of many government-owned utilities in public corporations under the majority control of the government does go in this direction.

provided by capital market competition, even in the absence of a take-over threat.

In second place, it has been argued in the literature that the existence of a take-over menace could push the managers to concentrate on short term, safe projects, in order to keep profits at the highest possible level, reducing in this way the expenditure on long run projects (like R&D) at a sub-optimal level, while a manager in a public firm could be characterized by a more long term aptitude and, consequently, government-owned companies should not suffer of any short term bias[12].

In addition to this, it could be noted that in large private utilities, with dispersed ownership, monitoring problems are likely to be significantly higher than in smaller private utilities, where often the manager is also the owner or an important shareholder, thus weakening one of the arguments often invoked to demonstrate the greater efficiency of private firms, i.e. the lower dispersion of property rights in private firms with respect to public ones. In fact, in large private corporations managers are in charge of the everyday operations, and the relationship between them and shareholders parallels in many respects the one existing between the government and public managers. De Fraja (1993), for instance, has proposed a model, well rooted into the framework of the mechanism design literature, where he shows that a government with the aim of maximizing consumers surplus can be more effective in inducing efficient production (in the form of a reduced consumption of perquisites) than a group of shareholders aiming to profit maximization, since the fact of having consumer surplus in its objective function can make more valuable to the government itself the cost reduction activity, for which it will be ready to compensate more the manager-agent[13] (see De Fraja, 1993).

Sappington and Stiglitz (1987) have proposed a "theorem" which -paralleling the first fundamental welfare theorem- sets up the conditions under which the government, through an appropriate mechanism design system, can auction off to the private sector the provision of every good and service. The main point of their analysis is that the conditions for the auctioning to work efficiently are in most

[12] Furthermore, investor-owned public utilities could suffer of underinvestment if they were regulated with high- powered incentive schemes and the regulator lacked precommitment.

[13] The effect is even stronger if the manager's utility enters into the government objective function.

cases not met in practice, so that the relative convenience of public versus private provision of goods and services has to be decided on a case by case basis, depending on the nature of the goods produced, the technology involved, the existence of effective competition in the bidding phase, and the trade-off between the benefits of public intervention in the production and contractual arrangements versus the costs in terms of dilution of incentives, etc.

A special attention should be devoted to the issue of municipal ownership, because it is so widespread in the water industry. In fact[14], it has been argued that municipal ownership of public utilities could be characterized by a higher degree of efficiency with respect to government ownership because municipalities often have harder budget constraints than the state and usually use the profits of their public utilities to finance other local services. In other words, the incentives for political bodies to monitor managers could be higher in municipally than in government-owned utilities (see Bhattacharyya *et al.*, 1995a). Furthermore, the presence of many municipalities, each with their public utility, should make more "credible" the introduction of competition or regulation by a central authority than in the case of many government-owned public utilities (Newbery, 1999). On the other hand, it could be argued that municipal ownership could limit the potential exploitation of all the available scale economies[15].

From this very brief discussion, we should have made clear that there are theoretical arguments that may, in the case of public utilities, at least in part, confound the theories supporting the greater efficiency of private firms[16], especially when public ownership is at the municipal level. This lack of "decisive" arguments from a theoretical point of view is, at least in part, supported by the empirical literature: in fact, while a great majority of studies seem to favor the hypothesis

[14] See, among others, Newbery (1999).

[15] The available empirical evidence in the water industry does not support the hypothesis of the existence of large, unexploited scale economies. A company serving a medium sized town or province (about 300-500 thousands people) is likely to have, on average, the right scale. See Fabbri and Fraquelli (2000), Saal and Parker (2001b) and Bottasso and Conti (2003) among the others.

[16] The above discussion should have also made clear the difficulties of extending an empirical finding to a different "institutional environment", where public ownership can be characterized by different rules (for instance, more or less political interventionism, shares quoted at the stock exchange, prohibition of government subsides, clear rules protecting the independence of public managers, etc.) and different types of economic regulation may apply.

of a greater efficiency of private firms, this evidence is less clear cut in the case of regulated utilities.

3. The empirical evidence[17]

3.1 The US evidence

One of the first articles studying the cost structure of water utilities using a cost function well-rooted into the theory of production[18] was Crain and Zardkoohi's 1978 paper, where they employed a two inputs Cobb-Douglas total cost function to study the relative efficiency of a sample of public and private US water utilities. By simply inserting an ownership dummy variable into the cost function, they found that in private firms costs were, on average, about 28% lower than in public ones. This result was corroborated by a Chow test that allowed rejecting the pooling of the two samples (i.e. private and public water utilities). These results were interpreted as evidence supporting the view that private firms had more incentives to minimize costs and, hence, were more efficient than public ones[19].

On the other hand, Crain and Zaardkoohi's analysis had some drawbacks that soon attracted the attention of many authors. The first kind of objection moved to their paper was the adoption of a restrictive functional form: in fact, the Cobb-Douglas production (and its dual cost) function arbitrarily imposes homogeneity and unitary elasticity of substitution between inputs. If this is not the true technology under which water utilities operate, then a Cobb-Douglas cost function is a misspecified model. In second place, the production process carried on by a water utility cannot be analyzed as a simple combination of capital and labor (and maybe other inputs as energy and materials) to produce the output water, but has more correctly to be seen as a process that transforms the quality of water (in the treatment phase) as well as the space (through the

[17] Details about the sample size, inputs and technical variables used are reported in Table 1 in the appendix.

[18] Before the Crain and Zardkoohi's paper, the few studies one may find in the literature (see, for instance, Ford and Warford, 1969) used to regress costs on some polynomial function of output plus, in some cases, on some technical variables, in order to find the functional form which fitted the data better.

[19] Furthermore, their results showed a larger marginal product of labor in private firms, supporting the view that public firms are likely to be characterized by overstaffing.

transmission and distribution stage) and time (through the storage in reservoirs and towers) of its consumption (Feigenbaum-Teeples, 1983). So, given factor prices, the simple physical output level is only a poor proxy of each firm's production. In fact, water utilities differ greatly in the quality and availability of the row water they use, in the topology of their service area, in the dispersion of consumers, in the "typology" of customers they face (given the level of output, it is not the same to supply few, large industrial customers or a myriad of small consumers), in network characteristics, etc. These features of the production process thus make standard textbook cost functions very unreliable. If one wants to assess the relative efficiency of different firms, it has to be acknowledged that the output they produce can be different along many dimensions, with its physical level being only one. The first paper to tackle this pitfall of the Crain and Zardkoohi's paper was a study by Bruggink (1982) who employed a sort of hedonic Cobb-Douglas cost function to model the operating, maintenance and administrative costs of a sample of US water utilities in 1960. He explicitly acknowledged the necessity of modeling the cost function of water utilities as hedonic[20], and in fact in his regression he controlled for variables such as population density, the relative importance of residential users, the type of water sources, etc. Bruggink's main result was that, using a dummy variable approach, operating costs of public operators resulted to be about 27% lower than their private counterparts. On the other hand, the only factor price used was the price of labor: for this reason, the cost function used by Bruggink cannot be seen neither as a proper neoclassical cost function derived from a cost minimization framework (as the one estimated by Crain and Zardkhooi, 1978) nor as a flexible functional form, which was the first kind of objection that can be moved to Crain and Zardkhooi's paper. Feigenbaum and Teeples

[20] Originally, the hedonic approach (which was pioneered by Spady and Friedlander, 1978 for the US regulated trucking industry) was proposed as a way to employ econometric specifications that were more parsimonious than a pure multiproduct cost function. In fact, the multidimensional nature of the physical output produced and delivered along the network and the continuous nature of the physical attributes of the output would require, at least in principle, an infinity of products if a multioutput technology were to be adopted: the hedonic approach is a way to circumvent this problem. Furthermore, as it has been argued by Neuberg (1978), these physical attributes are not separately priced and sold on a market, and thus their treatment as separate outputs could be inappropriate. The hedonic approach is, in a sense, a way to acknowledge the multioutput nature of the good produced without taking it to "its extremes".

(1983) was the first study to address together all these issues: they did so using a hedonic cost function, where the volume of water produced was only one of the possible dimensions of output. They employed this methodology, embedded in a 3 input translog cost function, to the Crain and Zaardkoohi's data set: they found that in no case they were able to reject the pooling of private and public firms, both for the hedonic and non-hedonic specification[21] and for any restriction imposed to the translog cost function[22]. The cost differences between public and private provision of water services found by Crain and Zardkoohi should thus be seen as a consequence of omitting variable bias (the price of electricity) and functional form misspecification.

This kind of approach was subsequently used in virtually all the studies whose aim was to estimate the (relative) efficiency of water utilities.

For instance, one paper very close in spirit to Feigenbaum and Teeples (1983) was Teeples and Glyer (1987a). They estimated the relative efficiency of private and public[23] water utilities for a South Californian sample in 1980 employing different kinds of models, from very restricted ones -very similar to the one employed by Crain and Zaardkoohi (1978) - to the most general, which can be seen as an extension of the Feigenmbaum and Teeples (1983) one. The most important result of the paper is that differences in costs of public and private utilities do exist, but that their magnitude is decreasing in the specification of the model, i.e. the more general the model is, the lower the cost advantage of private over public water utilities. In the more general specification[24] -even if a Chow type test led to a rejection of the hypothesis of pooling the two subsamples[25]- no ownership dummy was significantly different from zero, thus indicating that the higher efficiency of private firms found in the restricted models was simply due to functional form misspecification and omitted variable bias. An additional interesting finding of this paper is that, once ownership dummies were interacted with the

[21] Once the price of electricity was included.

[22] Their preferred final specification was a hedonic Cobb-Douglas cost function.

[23] Public water utilities were analyzed as a group as well as divided according to the type of (public) ownership.

[24] All the functional forms nested into it were rejected by appropriate statistical tests.

[25] This result might suggest that in that sample, public and private water utilities either operate under different technologies or face different regulatory constraints.

variables' first order coefficients in the most general model, ownership specialization according to scale and service area characteristics did occur in the data. This suggests that perhaps ownership was not randomly distributed across mixes of output and technical variables, which might be the effect of a simultaneity problem between cost efficiency and ownership type.

A different approach was followed instead by Raffiee *et al.* (1993) who estimated the relative efficiency of public versus private water utilities for a US sample of 271 firms in 1989 employing a methodology based on the weak axiom of cost minimization (Varian, 1990). The basic idea of this methodology is to compare actual costs with the optimal ones derived from cost minimization: by regressing total costs on four inputs expenditures and inserting an ownership dummy variable they were able to show that, on average, total costs in public water utilities were about 12% higher than in private ones[26]. They then built, for each firm, an efficiency index which gives the percentage difference between observed costs and the minimum costs derived from the regressions[27] and found that the mean value of that index was 72.2% and 22.2% for public and private utilities respectively, confirming the greater efficiency of private operators[28]. Unfortunately, Raffiee *et al.* (1993) failed to control for the exogenous environmental conditions in which the utilities operated and, furthermore, it is likely that the input expenditures are endogenous, thus suggesting a further reason for the OLS estimates to be biased.

One common feature of the papers just described is that they compare the average performance of public and private utilities as a whole, without any regard to the best practice, efficient frontier in the industry. Without entering into the details, we can basically find two approaches to deal with efficiency frontier measurement: parametric and non-parametric[29] methodologies. In the non-

[26] A Chow test rejected the null hypothesis of pooling the two samples.

[27] Since the Chow test did not allow to pool, two equations for public and private utilities respectively were used.

[28] We note that, for an efficient utility, with observed costs equal to the theoretical minimum costs, the efficiency index would be equal to zero.

[29] Non parametric methodologies, like DEA, employ linear programming techniques to estimate the efficient industry frontier, and have, upon the more traditional econometric frontiers, some advantages (for instance, they do not impose any functional form) as well as some drawbacks (they are mainly deterministic frontiers, with no role for random noise and are very sensitive to the existence of outliers). See, for an introduction, Coelli *et al.* (1998).

parametric literature, there are two papers which, employing linear programming techniques, study the issue of public versus private efficiency in the water utility industry. The first is a study by Byrnes *et al.* (1986) that estimated the technical[30] and scale efficiency[31] of a sample of 127 US water utilities in 1976. They employed the total amount of water distributed as the only output, and the quantity of ground water, surface water, length of mains, part time labor, full time labor and storage capacity as inputs. The main findings are that firms are almost close to scale efficiency and that private ones have a slightly higher technical and scale efficiency than their public counterparts, even if these differences were not statistically significant[32]. A similar approach was followed by Lambert *et al.* (1993) who estimated the technical and scale efficiency of a sample of 271 US water utilities in 1989 and found that public water utilities were both more technical and scale efficient than private ones. Statistical tests like the Wilcoxon allowed rejecting the null that in the case of technical and overall efficiency[33] the samples were drawn from the same distribution. The main limitation of this study is that it does not control for environmental conditions that may affect input usage, thus making the results suspect. On the other hand, an interesting feature of this paper is that it uses the same sample of Raffiee *et al.* (1993): since Raffiee *at al.* (1993) reached an opposite conclusion regarding the efficiency of private and public water utilities (i.e. private firms more efficient) we can note in this case the occurrence of a fact already investigated in the literature on efficiency measurement, i.e. the possibility that different estimation methods yield different conclusions about the efficiency levels, thus raising the important points of the choice of the estimation methodology in efficiency analysis and of the robustness of the main results to the choice of different estimation techniques (see Conti, 2004).

[30] With technical efficiency it is meant "how far" a firm is from the isoquant, i.e. how much a firm could reduce its input usage without any reduction in the output(s) level (or, by converse, how much a firm could raise the output level holding input quantities fixed).

[31] With scale efficiency it is meant how much a firm's scale of operation deviates from the long run least cost equilibrium of a competitive industry, which is given by production at constant returns to scale corresponding to the minimum point of a U shaped-average cost curve.

[32] Using both parametric and non-parametric tests.

[33] The overall efficiency is the product between scale and technical efficiency.

To be more correct, Raffiee *et al.* (1993) and Lambert *et al.* (1993) employed a different concept of efficiency, with the former analyzing cost efficiency, and the last technical efficiency only: on the other hand, technical efficiency coincides with overall economic efficiency only if there is not allocative inefficiency. This could explain why, using the same data set, the papers of Raffiee *et al.* (1993) and Lambert *et al.* (1993) reached opposite conclusions, the reason being, perhaps, a higher allocative inefficiency of public firms.

Another point that it may be worth noting is the fact that both the two papers employing linear programming techniques fail to identify higher technical efficiency of private water utilities: this result could in fact be seen as evidence against the property rights explanation we recalled in section 2 above: in fact, some possible explanations often invoked to justify the failure of detecting higher cost efficiency in private water utilities -namely the existence of the Averch-Johnson effect and/or non-measurable advantages for government owned companies in the access to the capital markets- are more likely to be important in studies analyzing overall economic efficiency rather than technical efficiency only. Furthermore Lambert *et al.* (1993) showed that the different levels in slack of capital between private and public water utilities were not statistically significant, and they interpreted this result as further evidence against the possibility that the higher technical efficiency of public water utilities could be explained with "government intervention in the capital markets that benefit the public utilities".

The main drawback of linear programming methods is their being deterministic efficiency measurement techniques, as they entirely explain the departure from the efficiency frontier with the existence of inefficiency, with no role for random noise.

The possibility of explaining departures from the frontier both with random noise and with inefficiency is the main advantage of the stochastic frontier approach (see Kumbhakar and Lovell, 2000). As a consequence, stochastic frontier methodologies allow for both the existence of random noise and inefficiency without the "necessity" of attributing the statistical significance of the ownership dummy to different levels of inefficiency in the two groups of firms (private and public).

The first to employ stochastic frontier techniques in the analysis of the efficiency of public and private water utilities were, at least to our knowledge, Fox and Hofler (1986). They used a Cobb-Douglas dual output production function and the cost minimizing factor proportions derived from the associated dual cost function to estimate the technical and allocative efficiency of a sample of 176 US rural water utilities in 1981.

They considered the quantity of water produced and length of pipelines, as a proxy for the output of the production and distribution stage, respectively.

The inputs considered were labor and capital, proxied by maximum treatment capacity. They tried to account for exogenous environmental conditions using different variables but, since a simple OLS estimation of their dual output production function found only two variables as significantly different from zero, only a regional dummy variable and the percentage of potable water delivered to non residential customers were retained in the stochastic production frontier. They estimated the stochastic production frontier and the cost minimizing factor proportions jointly as a system employing a maximum likelihood technique. The extent of technical efficiency for each firm was computed using the usual Jondrow *et al.* (1982) decomposition technique, while the allocative efficiency was derived by estimation of the stochastic disturbance appended to the cost minimizing factor proportions (see Fox-Hofler, 1986 for a in depth discussion). The main results of the paper are that technical efficiency is not significantly different between the two groups, while private firms exhibit higher allocative inefficiency, with an excess of overcapitalization with respect to their public counterparts, thus suggesting the existence of the Averch-Johnson effect for the private water utilities in the sample. Fox and Hofler were then able to identify for each firm the percentage of costs due to inefficiency, which was equal to 43.3% and 45.8% for public and private firms respectively, with allocative inefficiency counting for about two thirds of the total.

Bhattacharyya *et al.* (1995a) present a model where they used an indirect production frontier to estimate the technical efficiency of a sample of 26 public and private rural water utilities in Nevada. The estimation of an indirect production function is justified in terms of the institutional arrangements typical of many US local jurisdictions, where local jurisdictions first decide the maximum expenditure they can devote to the production of each service, and then the (private or public) utility has the duty to use that expenditure to maximize output, so that the utility optimization problem can be seen as the maximization of output (which depends on inputs and technical variables) subject to a maximum expenditure constraint. By solving this maximization program, it is possible to obtain an indirect production function, with expenditure, factor prices and technical variables as arguments, thus solving the endogeneity problems plaguing the estimation of production functions. To estimate technical inefficiency, the usual two components error term is appended to the indirect production frontier, with one being a pure random term, and the second a one side, non-positive error term which accounts for technical inefficiency. The inefficiency effects are not assumed to be independently distributed, but are made dependent on technical variables which explain the departure of firms from the best practice frontier[34]. The parameters of the indirect production frontier (with the exception of the intercept), as well as the input shares equations, were jointly estimated, without any distributional assumption for the inefficiency effects; then the remaining parameters (the constant and the technical inefficiency ones) were estimated with maximum likelihood assuming for the inefficiency effects the half normal, the truncated normal and the exponential distribution, using model selection criteria to discriminate between models[35]. The main result of the paper is that private utilities are characterized by the highest technical efficiency (91%), followed by municipally owned (88%), county governed (87%) and water districts (86%).

Bhattacharyya *et al*. (1995c) used a stochastic variable cost frontier to estimate the cost efficiency of a sample of 190 public and 31 private utilities in the USA. One of the most notable features of this paper is that in both the cost shares and in the cost function, ownership dummy variables were inserted, in order to take account of "unobserved factors that affect firms under similar ownership" and which influence the firms' decisions regarding input utilization: this is done interacting the input price variables as well as the output and capital variables with ownership dummies.

Furthermore, as in Bhattacharyya *et al*. (1995a) the inefficiency effect was made firm specific, i.e. the inefficiency effect was specified as a function of variables reflecting ownership type, the vintage of operations and the length of pipelines[36].

The estimation followed a complex multistep procedure, based on a SURE technique corrected for heterosckedasticity in the first step, followed by maximum likelihood for the estimation of the

[34] An in depth discussion about the more appropriate methods to incorporate in the models the effects of technical variables on firms' efficiency can be found in Coelli *at al*. (1999) and Kumbhakar and Lovell (2000).

[35] The preferred model was the one assuming a truncated normal distribution.

[36] Interactions between the ownership dummy and the other individual firms characteristics were used.

constant term and the "inefficiency variables" (for the details see Bhattacharyya *et al.*, 1995c).

The results presented show that ownership-specific attributes do affect the technology of operations of water utilities (almost all the ownership dummies are in fact significant), and the specification described above for the inefficiency effects is preferred, on statistical grounds, to one without ownership dummies. The analysis of short run returns to scale[37] reveals that the private utilities analyzed in the sample underutilize their capacity, given the capital stock, while the opposite happens for public utilities, thus suggesting the existence of an Averch-Johnson effect which creates incentives for private firms to over expand their capital stock. Cost inefficiency in public water utilities is 9.8%, while for their private counterparts is about 19%, which suggests that, once again, in the water industry the issue of attenuation and non transferability of property rights in public firms have not resulted in a lower cost efficiency as compared with private operators. The last result of this paper we believe it is worth to signal is that, from a given level of output onwards (5 to 10 BG/Y)[38], the level of cost inefficiency is positively linked with the dimension of the firm (taking the volume produced as the scale variable) but that for private firms inefficiency grows with firm dimension much faster: in fact, in the lowest dimension group, private firms are more efficient than public ones. This finding can be consistent with the view that, as the company dimensions grow, ownership dispersion in private firms usually tends to grow as well, thus reducing the incentives for the owners to monitor managers. In second place, it is possible that government owned water utilities have greater inefficiency problems especially in firms operating at low scale because of lack of well educated workers, financial problems of small communities and so on; an explanation which is consistent with the results presented in the paper by Bhattacharyya *et al.* (1995a) discussed above.

A different methodology to evaluate the efficiency of public and private firms was followed by Bhattacharyya *et al.* (1994) using a 1992 sample of 257 water utilities in the USA. Instead of introducing inefficiency effects by inserting an additional one-sided error term in the cost function, as in the stochastic frontier methodology, they modeled inefficiency parametrically, introducing more parameters to estimate in the cost function. Technical inefficiency can be introduced in a cost function framework by simply shifting the intercept with

---

[37] See Cowing and Holtmann (1983).

[38] A US gallon is equivalent to 3.785 litres.

dummies and or technical variables. Allocative inefficiency can be instead introduced by allowing firms to minimize costs with respect to shadow factor prices, which can be assumed to depend on individual firm characteristics such as ownership type, scale of operations, etc. They estimated a short run (assuming capital as a quasi-fixed factor) shadow variable cost function. In the translog approximation they adopted, the intercept was assumed to depend on an ownership dummy variable and on the number of distribution system breakdowns[39]. Furthermore firms, for the existence of unobserved constraints[40], could fail to optimize with respect to observed market prices, but they do optimize with respect to shadow prices: Bhattacharyya *et al.* (1994) assumed that the shadow/observed input price ratios depend on ownership and scale of operations. Through likelihood ratio tests they could reject the joint hypothesis that public and private firms were equally price and technically efficient[41] and that private and public utilities were (separately) price efficient. Nonetheless, the technical as well as the price and scale efficiency index they built do not show large differences among the two groups, with public water utilities displaying a larger technical (0.37 vs. 0.35) and price efficiency (0.85 vs. 0.81) and private ones a larger scale efficiency (0.67 against 0.64), with public operators being slightly more "overall" efficient: 0.20 against 0.19[42]. Through a heterosckedasticity test they could verify that public utilities had the greatest residual dispersion, thus suggesting that, though they were slightly more efficient than their private counterparts, they also showed the greatest variation between best and worst practice. Also this paper, as well as Bhattacharyya *et al.* (1995b), presents evidences that are consistent with the existence of the Averch-Johnson effect, since the elasticity of variable costs with respect to capital is positive.

3.2 The English and Welsh water experience

So far, the discussion has been centered on the US experience because, given its mixed ownership structure, most papers dealing with the issue of public-private efficiency in the water industry used US samples.

[39] Which can be seen as a proxy for the vintage of operational assets.

[40] Regulatory constraints, market distortions, unions power and so on.

[41] This is equivalent to test if the ownership dummy used to shift the intercept and the ownership dummies for the two shadow price ratios (one is normalized to unity for allowing identification) are jointly equal to zero.

[42] See Bhattacharyya *et al.* (1994) for the details on the construction of these indexes.

One partial exception is the water industry in England and Wales where, until the 1989 privatization, the industry was made up of 10 large integrated water and sewerage companies and 29 small private water only operators. Unfortunately we have not found any study which analyzed the relative efficiency of private and public operators: actually, Lynk (1993) estimated two distinct cost frontiers, one for public and the other for private water utilities: on the other hand, the higher efficiency found for public water companies is inconclusive, since the mean efficiency is built taking the average of the individual efficiencies of the firms in the sample, which are a function of the departure of individual firms from the frontier of the sample under analysis. In other words, it is wrong to compare the mean efficiency of two distinct samples: the only thing it can be said regards the greater or lower deviation from the best practice frontier of each sample.

A more recent paper by Saal and Parker (2001b) studies, among other things, the impact of privatization on the economic efficiency of the ten water and sewerage companies in England and Wales analyzed between 1985 and 1999. They employed a two outputs translog total cost function augmented with a time trend and a privatization dummy to take into account the effect of privatization on the growth rate of total costs[43]. An additional dummy was then inserted to take into account the effect of the tightening in price regulation that took place after the 1994-95 regulatory review[44]. The translog cost function as well as the factor shares were jointly estimated using a non-linear SURE technique. Basing their analysis on the estimation results, Saal and Parker could reject the null joint hypothesis that privatization and the 1994-95 regulatory review did not significantly affect the trend growth rate of total costs. On the other hand, the parameter estimates show that the reduction in the trend growth rate of total costs seems to be explainable only with the tightening of price regulation, which occurred after 1994-95, with no role played by privatization per se. This finding can have different explanations. For instance, since the privatization of the industry had been envisaged by the Government at least since 1986, it is possible to argue the existence of an "anticipation effect" (Martin and Parker, 1997), which would explain why the data do not

[43] The two outputs, one for the water supply and one for the sewerage service, were corrected to reflect the change in quality of both water supply and sewerage services.

[44] The first price limits imposed after privatization had been considered as too lax, while the subsequent price review is generally believed to have been tighter.

show any significant reduction in the growth rate of total costs in the very first years after privatization. In second place, it is possible to argue, as Vickers and Yarrow (1988) did, that competition is far more important than ownership per se in explaining economic efficiency: in fact, after 1994, a tighter price cap was decided for most of the former water authorities, and a form of yardstick competition was applied for the first time in the industry. This tightening would have provided the water company managers the right incentives to promote an effective improvement of their companies' performance: the simple privatization per se, without an effective regulatory system would have not been leading to any significant improvement, for the existence of slack deriving by the monopolistic nature of the industry and by the lack of competition in the capital markets[45]. On the other hand, Morrison (1998) argued that, for the existence of adjustment costs, it is possible that the effects of a reform (in the ownership rather than in the competitive structure of an industry, or both) are captured only with a lag, which in some instances can take even some years[46]: thus one may argue that the post 1994 efficiency improvement is the effect of privatization only, with the time period between privatization and the efficiency improvement being only an adjustment lag.

The effect of privatization on the productivity of the ten water and sewerage companies in England and Wales was also investigated in a paper by Ashton (2000). Using a translog cost function with the number of connected properties as the only output and labor, capital and materials as inputs for the period 1989-1997, he actually found a decline in total factor productivity since 1989. In particular, he found

[45] In fact the incentive mechanisms provided by capital market competition were not yet operative, for the golden shares mechanisms put in place by the government at privatization, which were removed only after 1994. This, as well as the efficiency improvements after the 1994/95 regulatory tightening, can be red in support of who argue that, in the case of a natural monopolistic industry, the simple transfer of the assets to the private sector is not sufficient to yield significant improvements in the company efficiency. More is called for: a careful design of the regulatory framework is the first need. In second place, it is necessary to avoid that the government retains in its hands "too strong" discretionary powers of intervention, since this can blunt managerial incentives to run the firm as efficiently as possible.

[46] This can happen because it can take time for managers to adapt to the new industry structure or to the new incentives provided by the new ownership or regulation regime. The inability of finding any efficiency improvement in the very first years after the reform can thus be explained by arguing that the researcher is actually measuring adjustment costs.

that TFP growth declined from –0.029 % in the period 1989-91 to –0.063% in the period 1995-97 with an average of –0.046% over the entire sample period: this picture thus shows no total factor productivity improvement in the first eight years following privatization[47] [48].

A recent working paper by Saal *et al.* (2004) sheds some additional evidence on the TFP performance in the English and Welsh water industry after the privatization of the ten water and sewerage companies. The estimation of a stochastic input distance function[49] for the same sample period of Saal and Parker (2001b) allowed the authors to compare TFP growth rates before and after privatization and to isolate out the separate contributions due to technical change, scale effects and technical efficiency change[50]. The main result of the paper is that the TFP growth rate was not significantly affected neither by privatization nor by the regulatory tightening of the 1995 price review. Nevertheless, technical change was significantly higher after privatization. The divergent behavior between TFP and technical change is explained by the negative contribution to TFP growth brought about by the existence of diseconomies of scale and the positive output growth which prevailed over the sample period[51].

3.3 The remaining international experience

The remaining international empirical evidence we have been able to find is given by the papers by Estache and Kouassi (2002), Kirkpatrick *et al.* (2004) -who used different samples of African utilities-, Menard and Saussier (2000), Boyer and Garcia (2004) –who have analyzed French samples-, Estache and Rossi (1999), who used a sample of Asian water utilities and Coelho Faria *et al.* (2005), who used Brazilian data.

Estache and Kouassi (2002) have estimated an unbalanced panel random effects (GLS) production frontier for a sample of 21 African

[47] The failure to control for quality changes that took place after privatization might have biased TFP estimates downwards. Furthermore, this paper does not estimate a “true” total cost function, as the capital costs just include depreciation but not the opportunity cost of capital.

[48] Saal and Parker (2001a), using an index numbers approach, did not find any total factor productivity improvement after the 1989 privatization.

[49] They used the exponential distribution for the one-sided inefficiency error.

50 See Kumbhakar and Lovell (2000) for a discussion of the decomposition of TFP growth indexes.

[51] Furthermore, the technical efficiency levels were somewhat lower after privatisation than under public ownership.

water utilities observed over the 1995-97 period. They estimated the relative efficiency of public versus private operators[52] by regressing the efficiency scores on some institutional factors (ownership being one of these) using Tobit analysis to deal with censoring problems and they found that efficiency was negatively correlated with public ownership, even if the small sample size[53] and the theoretical drawbacks of this two step approach[54] cast some doubts on this result.

Kirkpatrick *et al.* (2004) estimated a Cobb Douglas stochastic cost frontier for a sample of 76 African water utilities observed in the year 2000. They tried to measure the existence of efficiency differences by inserting an ownership dummy in the cost function, which turned out to be insignificant. They also used the ownership dummy to test if the mean of inefficiency could be explained by ownership status, but also in this case they could not reject the hypothesis that inefficiency was not correlated with ownership. On the other hand, they also used a simple DEA model (with number of staff and number of connections (as a proxy for capital stock) as inputs and adopting an input orientation, and volume as the only output) as a robustness check and they found some mild evidence of private operators outperforming their public counterparts.

Estache and Rossi (1999) have estimated the cost efficiency of a sample of South East Asian water firms employing stochastic frontier analysis: on the basis of the insignificance of a ownership dummy inserted in the cost function they could not reject the null hypothesis that the ownership effect was equal to zero[55].

Menard and Saussier used regression analysis to test the existence of a statistical significant difference in the compliance to water quality

---

[52] As they have estimated a production frontier, their measure of efficiency is limited to technical efficiency only.

[53] The private operators where 2 out of 21 firms in the sample.

[54] See Kumbhakar and Lovell (2000).

[55] Using a stochastic frontier methodology, the ownership dummy could be either inserted as a technology shifter in the cost function specification, or as an inefficiency explanatory factor in the mean (or variance) of the inefficiency effects (see Kumbhakar and Lovell, 2000), or both. In other words, if there are reasons to believe that public and private operators operate under different technologies or face different constraints, the ownership dummy should be included as a technology shifter (which in practice determines the estimation of separate, parallel frontiers, for public and private companies). However, the existence of an efficiency differential between ownership types should be inferred by the significance of the ownership dummy in the inefficiency effects, or simply by comparing the average inefficiency of the two groups (for a discussion of this issue, see Coelli *et al.*, 1999).

regulations between public operators and private concessionaries in a sample of 2109 water supply units serving 72.6 % of the French population over the period 1993-95. The econometric analysis shows that significant differences do exist, and that, in particular, direct public production seems to be outperformed by delegation to private operators. On the other hand, when in house production can be regarded as the appropriate mode of governance (in particular, when heavy investments are required or when the quality of row water is low)[56], these differences disappear, and the performance of public operators is similar to that of private utilities operating in similar conditions.

Boyer and Garcia (2004) estimated a translog stochastic variable cost frontier for a sample of public operators and private concessionaries observed in France over the period 1995-98. The cost function was estimated along with cost shares with a Within-Sure methodology and with ML following the methodology first proposed by Battese and Coelli (1992). They inserted an ownership dummy into the translog specification, which they correctly interpreted as a technology shifter, and which was found not significant.

As far as it concerns the existence of efficiency differentials between public and private operators, the efficiency scores derived from the Within-Sure methodology showed that public operators were slightly more efficient on average (0.92 against 0.90), while the Battese and Coelli model yielded a reverse picture, with private concessionaries slightly more efficient (0.93 against 0.91). Overall, the authors conclude that their results do not show any robust evidence about the existence of an efficiency differential between ownership types.

Finally, Coelho Faria *et al.* (2005) estimated a stochastic production frontier using a sample of 148 water firms (135 public and 13 private) accounting for more than 70% of the Brazilian population.

Their results offer some support for the higher efficiency of private operators: in fact, the average efficiency is higher for private companies (0.88 against 0.72)[57]. Unfortunately, the estimation might suffer of endogeneity bias for the decision to estimate a production

---

[56] These "a priori" assumptions can be justified recurring to transaction costs arguments.

[57] We can note that the ownership dummy included in the model to explain the departure from the frontier is not statistically significant at the usual levels of confidence.

rather than a cost frontier. Finally, the private operators in their sample are private concessionaries selected by local authorities: if the level of efficiency played a role in suggesting privatization, then the results could suffer of sample selection bias.

3.4 Final comments

From the papers just surveyed, we can note, to sum up, that the often-claimed higher economic efficiency of private over public provision of goods and services is not confirmed in the case of the water utility industry. In fact we can see from Table 1 that only 5 studies report higher efficiency for private firms[58] with the others failing to detect any difference (7) or finding a higher efficiency in the case of public operators (5 studies). Furthermore, three studies find mixed evidence regarding the existence of any increase in total factor productivity growth or technical change following privatization in the English and Welsh water industry.

On the other hand, any work on the relative efficiency of water utilities can, to a higher or lower extent, suffer of a series of measurement problems: we thus think, concluding this section, that it is worth to signal some of the limitations of most econometric studies, with particular emphasis on the data issues in the water industry.

In particular, we can note that to estimate correctly the cost efficiency of water utilities[59], the correct cost concept to consider is total costs, i.e. operating expenditure plus depreciation and the return to capital[60]. Unfortunately, measuring the cost of capital in regulated industries is not straightforward. In fact, the current cost operating profits, as they appear in the balance sheet, are a measure of the

---

[58] One of those papers limits the analysis to technical efficiency only, two fail to control for operating conditions, one is likely to suffer of endogeneity problems and the remaining one relies on the criticized two-step procedure to explain efficiency differentials.

[59] Of course, the observation we are going to raise can also be extended to the estimation of the technology parameters of the cost or production function.

[60] Renzetti (1992) reports marked differences between short and long run marginal costs for a (time series of a) Canadian water utility, the difference being explainable with the importance of capital costs in the water industry (which are not included in the short run variable costs).

actual return, rather than of the real cost of capital, and a measure of total costs which should employ current costs operating profits as a proxy for the cost of capital could lead to misleading results. This is especially true in efficiency evaluations for regulatory purposes, where the use of current cost operating profits could cause circularity problems (see Stewart, 1993 and Bosworth *et al.*, 1996). A second option is in principle feasible, i.e. the application of estimates of the cost of capital in the industry to (current cost, depreciated) asset values (Stewart, 1993), even if there can be doubts on the accounting conventions and in the methodologies employed to compute the asset base between companies. The different papers have dealt with these issues in different ways, for which we refer to the data appendices of the papers themselves. One "radical" way of solving the problems surrounding the definition of total costs in the water industry would be to estimate a variable cost function, for which the data should be more accurately defined.

On the other hand, this solution opens up another problem: studying the efficiency of water utilities confining the analysis to variable operating costs only, can be misleading (and the empirical studies should be critically evaluated bearing the cost measurement issues firmly in mind), especially in industries where capital costs account for a large fraction of total costs, and this for different reasons. First of all, there may be different accounting conventions between firms, so that some cost items could be considered as operating costs by one company and capital costs by another[61]. Unless one does not believe that these accounting conventions are randomly distributed across ownership types, limiting the analysis to operational efficiency only could yield a distorted picture of the real, overall efficiency.

In second place, it has been argued (McGuire and Ohsfeldt, 1987) that, in the US experience, there are differences between public and private utilities regarding to taxes (which are not paid by public operators), subsidies and borrowing constraints (which seems to be less binding for public operators).

In third place, not only should accounting costs be considered, but "true" economic costs as well, such as the opportunity costs of land and the water consumed. For instance if, say, public utilities would indulge in greater leakage, this should be considered when

[61] See the critiques raised to the decision of Ofwat (the water regulator in England and Wales) to benchmark operating and capital maintenance efficiency separately.

measuring their relative efficiency with respect to their private counterparts (see, for instance, the papers by Feigenbaum and Teeples, 1983, Teeples and Glyer, 1987a and 1987b which used water input either as a control variable or directly as a cost component, using shadow prices for companies using self supplied water).

Furthermore, unless one does not suppose that capital is separable from variable inputs such as labor and materials, the analysis of variable costs only can give biased results, a part from the existence of different accounting conventions. Moreover, the estimation of a variable cost function controlling for the capital stock, though entirely appropriate from a theoretical point of view, presents again the problem of giving a measure to the capital stock.

Finally, there is some empirical evidence (Teeples and Glyer, 1987a and Menard and Saussier, 2000 for the water utility industry) that seems to suggest that ownership and efficiency levels could be jointly determined: for instance, it is possible that municipalities privatize only when their utilities are characterized by financial problems or low quality and efficiency, so that it would be more likely to find, in a cross sectional application, a private utility less efficient. Of course, the converse might be true as well, i.e. private investors buying only profitable utilities, with no need of large investment programs, etc., or private investors buying relatively inefficient companies for which it is easier to generate efficiency gains which could show up in a panel context. This sort of self-selection problems thus might affect the conclusions of some studies dealing with ownership relative efficiency measurement issues.

4. Conclusion

In this paper we have surveyed the international empirical evidence on the relative efficiency of private and public operators in the water supply industry.

From a methodological point of view, the survey of the literature has highlighted the importance of using flexible functional forms, of acknowledging the "multi-dimensional" nature of the water supply industry and the role played by environmental variables in "shaping" both the technology and the efficiency levels of the water utility industry.

The review of the literature has shown that in the water supply industry the empirical evidence can not support the hypothesis of a higher efficiency of private over public operators. Indeed, the evidence seems to suggest that a decisive answer to the public-private relative efficiency debate cannot be found in the case of the water utility industry. In fact, the papers analyzed in this study are almost evenly split between those that support the higher efficiency of public operators and those supporting the better performance of private utilities, with the remaining papers (seven out of seventeen) that have found an equal level of efficiency between private and public firms. This pattern that seems to exclude the superior efficiency of private operators in the water utility industry has been confirmed using different techniques (parametric and non parametric), considering different types of efficiency (technical, allocative and economic), employing different types of costs (variable, operating, total) and typology of samples (rural and urban, for instance) as well as considering different countries.

Overall the empirical evidence thus suggests that in the water utility industry the ownership structure does not seem to matter as far as it concerns the relative efficiency levels: the reasons could be many and we have analyzed them in both section 2 and 3 above.

As we recalled in the introduction, the main implication one can draw from this result is that in the context of a monopolistic structure like the one prevailing in the water supply industry, private ownership seems incapable of delivering significant efficiency gains with respect to public operation. Thus the focus of policymakers should shift from the ownership issue per se to the industry design stage (the water industry is in fact largely fragmented in many western countries) and to the setting up of effective regulatory mechanisms and/or to the introduction of franchise competition as well as to the "efficient" degree of vertical integration that can make it feasible.

Nevertheless, the conclusions of this literature review have to be taken with care, for a variety of reasons. First of all, from a more methodological point of view, the accurate measurement of costs in the water industry is problematic, not only for the difficulties of measuring capital costs, but also for the "social" costs often involved in an "environmental" industry like water supply, where the opportunity costs of the (scarce) natural resources employed should be evaluated along with the expenditures in the usual factors of production. Some studies (Teeples and Glyer, 1987a and 1987b, Bhattacharyya *et al.*, 1995c, for instance) have tried to tackle this issue, even if the proxies used can suffer of measurement problems. Of course, if these opportunity costs are not randomly distributed across ownership types, this can create a bias in the efficiency estimates.

In second place, most of the existing evidence is referred to the US experience: how much the US results could be extended to different institutional settings, with different regulations and historical developments, is still an open question, for which no immediate answer exists, even if the non-US results we have reviewed (and which refer both to developed and developing countries) seem to confirm the US picture.

Maurizio Conti

Università di Genova, DIEM, Facoltà di Economia, Genova, Italy

REFERENCES

Aharoni, Y., "State-Owned Enterprise: An Agent Without a Principal", in Jones, L.P. (ed), *Public Enterprise in Less Developed Countries*, Cambridge University Press, Cambridge, UK, 1982.

Ashton, J.K., "Total Factor Productivity Growth and Technical Change in the Water and Sewerage Industry", *The Service Industries Journal*, 20, 4, 2000.

Atkinson, S. and R. Halvorsen, "The Relative Efficiency of Public and Private Firms in a Regulated Environment: the Case of US Electric Utilities", *Journal of Public Economics*, 29, 1986.

Averch, H. and L. Johnson, "Behavior of the Firm Under Regulatory Constraint", *American Economic Review*, 52, 1962.

Barraquè B., *Politique De l'Eau en Europe*, Paris, 1995.

Battese, G. E. and T. J. Coelli, "Frontier Production Function, Technical Efficiency and Panel data: with Application to Paddy Farmers in India", *Journal of Productivity Analysis* 3: 153-169, 1992.

Bhattacharyya, A., E. Parker and K. Raffiee, "An Examination of Effect of Ownership on the Relative Efficiency of Public and Private Water Utilities", *Land Economics*, 70, 1994.

Bhattacharyya, A., T.R. Harris, R. Narayanan and K. Raffiee, "Technical Efficiency of Rural Water Utilities", *Journal of Agricultural and Resource Economics*, 20, 2, 1995 (a).

Bhattacharyya, A., T.R. Harris and R. Narayanan, "Allocative Efficiency of Rural Water Systems: A Hedonic Shadow Cost Function Approach", *Journal of Regional Science*, 35, 1995 (b).

Bhattacharyya, A., T.R. Harris, R. Narayanan and K. Raffiee, "Specification and Estimation of the Effect of Ownership on the Economic Efficiency of the Water Utilities", *Regional Science and Urban Economics*, 25, 1995 (c).

Bosworth, D., P. Stoneman and E. Thanassoulis, "The Measurement of Comparative Total Efficiency in the Sewerage and Water Industry: an Exploratory Study", *Report to OFWAT*, Birmingham, 1996.

Bottasso, A. and M. Conti, "Cost Inefficiency in the English and Welsh Water Industry: A Heteroskedastic Stochastic Cost Frontier Approach", *University of Essex Discussion Papers*, 573, 2003.

Boyer, M. and S. Garcia, "Régulation et Mode de Gestion: un Etude Econometrique sur le Prix et la Performance dans le Secteur de l'Eau Potable", 2004.

Bruggink, T.H., "Public Versus Regulated Private Enterprise in the Municipal Water Industry: A Comparison of Operating Costs", *Quarterly Review of Economics and Business*, 22, 1982.

Byrnes, P., S. Grosskopf and K. Hayes, "Efficiency and Ownership: Further Evidence", *The Review of Economics and Statistics*, 68, 1986.

Caves, R.E., "Lessons from Privatization in Britain: State Enterprise Behavior, Public Choice and Corporate Government", *Journal of Economic Behavior and Organization*, 13, 2, 1990.

Coelho Faria, R., G. Da Silvas Souza, and T. Belchior Moreira, "Public versus Private Water Utilities: Empirical Evidence for Brazilian Water Companies", *Economic Bulletin*, 8, 2005.

Coelli, T., S. Perelman, and E. Romano, "Accounting for Environmental Influences in Stochastic Frontier Models: with Application to International Airlines", *Journal of Productivity Analysis*, 11, 3, 1999.

Coelli, T., D.S. Prasada Rao, and G. Battese, *An Introduction to Efficiency and Productivity Analysis*, Kluwer, Boston, 1998.

Conti, M., *Essays in Empirical Industrial Organization*, Unpublished PhD dissertation, University of Essex, 2004.

Cowing, T.G. and A.G. Holtmann, "Multiproduct Short Run Hospital Cost Functions: Empirical Evidence and Policy Implications from Cross Section Data", *Southern Economic Journal*, 49, 3, 1983.

Crain, W.M. and A. Zardkoohi, "A Test of the Property Rights Theory of the Firm: Water Utilities in the United States", *The Journal of Law and Economics*, 21, 1978.

De Alessi, L., "Implications of Property Rights for Government Investment Choices", *American Economic Review*, 59, 1, 1969.

De Fraja, G., "Productive Efficiency in Public and Private Firms", *Journal of Public Economics*, 50, 1993.

Dixit, A., "Power of Incentives in Private versus Public Organizations", *American Economic Review*, Papers and Proceedings, 87, 2, 1997.

Estache, A. and M.A. Rossi, "Comparing the Performance of Public and Private Water Companies in Asia and Pacific Region. What a Stochastic Cost Frontier Shows", *World Bank Research Working paper*, 2152, 1999.

Estache, A. and E. Kouassi, "Sector Organization, Governance and the Inefficiency of African Water Utilities", *World Bank Research Working paper*, 2890, 2002.

Fabbri, P. and G. Fraquelli, "Costs and Structure of Technology in the Italian Water Industry", *Empirica*, 27, 1, 2000.

Fare, R., S. Grosskopf and J. Logan, "The Relative Performance of Publicly-Owned and Privately- Owned Electric Utilities", *Journal of Public Economics*, 26, 1985.

Feigenbaum, S. and R. Teeples, "Public Versus Private Water Delivery: a Hedonic Cost Approach", *The Review of Economic and Statistics*, 64, 4, 1983.

Ford, J.L. and J.J. Warford, "Cost Functions for the Water Industry", *Journal of Industrial Economics*, 1969.

Fox, W. F. and R.A. Hofler, "Using Homothetic Composed Error Frontiers to Measure Water Utility Efficiency", *Southern Economic Journal*, 1986.

Kay, J. and D. Thompson, "Privatization: A Policy in Search of a Rationale", *Economic Journal*, 96, 381, 1986.

Kirkpatrick, P., D. Parker and Y.F. Zang, "State versus Private Sector Provision of Water Services in Africa: a Statistical, DEA and Stochastic Cost Frontier Analysis", *Centre on Regulation and Competition Working Paper*, 70, 2004.

Kumbhakar, S.C. and K.C.A. Lovell, *Stochastic Frontier Analysis*, Cambridge University Press, 2000.

Kwoka, J.E., *Power Production: Ownership, Integration and Competition in the United States Electricity Industry*, Kluwer, 1996.

Jondrow, J., K.C.A. Lovell, Materov, Z. and Schmidt, P., "On the Estimation of Technical Efficiency in the Stochastic Frontier Production Function Model", *Journal of Econometrics*, 19, 1982.

Lambert, D.K., D. Dichev, and K. Raffiee, "Ownership and Sources of Inefficiency in the Provision of Water Services", *Water Resources Research*, 29, 6, 1993.

Laffont, J.J. and J. Tirole, "Privatization and Incentives", *Journal of Law, Economics and Organization*, 7, 1991.

Levy, B., "A Theory of Enterprise Behaviour", *Journal of Economic Behaviour and Organization*, 8, 1987.

Lynk, E., "Privatisation, Joint Production and the Comparative Efficiencies of Private and Public Ownership: The UK Water Industry Case", *Fiscal Studies*, 14, 2, 1993.

Martin, S. and D. Parker, *The Impact of Privatisation: Ownership and Corporate Performance in the UK*, London: Routledge, 1987.

Megginson, W.L., and J.M. Netter, “From State to Market: a Survey of Empirical Studies on Privatization, *Journal of Economic Literature*, 39, 2, 2001.

Menard, C. and S. Saussier, “Contractual Choice and Performance: the Case of Water Supply in France”, *Revue d’ Economie Industrielle*, 92 (2-3), 2000.

McGuire R.A. and R. Ohsfeldt, “Public Delivery Versus Private Water Delivery: a Critical Analysis of a Hedonic Cost Approach”, *Public Finance Quarterly*, 14, 3, 1986.

Morrison, C., “Construction and Use of Measures to Guide Microeconomic Reforms”, in Productivity Commission, *Microeconomic Reform and Productivity Growth*, 1998.

Neuberg, L.G., “Two Issues in the Municipal Ownership of Electric Power Distribution Systems”, *Bell Journal of Economics*, 9, 1978.

Newbery, D.M., *Privatization, Restructuring and Regulation of Network Utilities*, MIT Press, 1999.

Newbery, D.M., “Privatising Network Industries”, *CESifo Working Paper*, 1132, 2004, Ofwat, *The Current State of Market Competition*, 2004.

Pescatrice, D.R. and J.M. Trapani, “The Performance and Objectives of Public and Private Utilities Operating in the United States”, *Journal of Public Economics*, 13, 2, 1980.

Pollit, M.G., “Technical Efficiency in Electric Power Plants”, *DAE working paper* 9422, Cambridge University, 1994.

Raffiee, K., R. Narayanan, T.R. Harris, D. Lambert and J. Collins, “Cost Analysis of Water Utilities: a Goodness of Fit Approach”, *Atlantic Economic Journal*, 1993.

Renzetti, S., “Evaluating the Welfare Effects of Reforming Municipal Water Prices”, *Journal of Environmental Economics and Management*, 22, 1992.

Ros, A.J., “Does Ownership or Competition Matter?”, *Journal of Regulatory Economics*, 15, 1, 1999.

Saal, D. and D. Parker, “Productivity and Price Performance in the Privatized Water and Sewerage Companies of England and Wales”, *Journal of Regulatory Economics*, 20, 1, 2001a.

Saal, D. and D. Parker, “The Impact of Privatization and Regulation on the Water and Sewerage Industry in England and Wales: a Translog Cost Function Model”, *Managerial and Decision Economics*, 21, 2001b.

Saal, D., D. Parker and T. Weyman-Jones, “Determining the Contribution of Technical, Efficiency and Scale Change to Productivity Growth in the Privatized English and Welsh Water and Sewerage Industry: 1985-2000”, *Aston Business School* RP0433, 2004.

Sappington, D.E.M. and J.E. Stiglitz, “Privatization, Information and Incentives”, *Journal of Policy Analysis and Management*, 6, 4, 1987.

Shirley, M. and P. Walsh, "Public vs. Private Ownership: The Current State of the Debate", Mimeo, *World Bank*, 2000.

Shleifer, A., "A Theory of Yardstick Competition", *Rand Journal of Economics*, 16, 3, 1985.

Shleifer, A., "State versus Private Ownership", *Journal of Economic Perspectives*, 12, 4, 1998.

Spady, R. and A.F. Friedlaender, "Hedonic Cost Functions for the Regulated Trucking Industry", *Bell Journal of Economics*, 9, 1, 1978.

Stewart, M., *Modeling Water Costs 1992-93. Further Research into the Impact of Operating Conditions on Company Costs*, report prepared for Ofwat, 1993.

Stigler, G.J., "The Economic Theory of Regulation", *Bell Journal of Economics*, 2, 1971.

Teeples, R. and D. Glyer, "Cost of Water Delivery Systems Specification and Ownership Effects", *The Review of Economics and Statistics*, 69, 1987a.

Teeples, R. and D. Glyer, "Production Functions for Water Delivery Systems: Analysis and Estimation Using Dual Cost Function and Implicit Price Specifications", *Water Resources Research*, 23, 1987b.

Varian, H., "Goodness of Fit in Optimizing Models", *Journal of Econometrics*, 46, 1-2, 1990.

Vickers, J. and G. Yarrow, *Privatization: An Economic Analysis*, Cambridge, Mass., MIT Press, 1988.

WRc, *Study on the Application of the Competition Rules to the Water Sector in the European Community*, Report for the European Commission, 2002.

ABSTRACT

While there seems to be a strong consensus on the superior performance of private firms over government-owned ones in competitive industries (Shleifer, 1998, Megginson and Netter, 2001), the evidence in network utilities is less clear cut (Newbery, 1999). However, most of the papers (and the surveys) on the public-private relative efficiency in public utilities that can be found in the literature deal almost exclusively with the electricity industry, with almost no reference to the evidence in the water sector. The aim of this paper is thus to help filling this gap in the literature, analyzing and critically evaluating the international empirical evidence on the relative efficiency of public and private operators in the water utility industry. The water industry is of particular interest in its own because in all countries it is, by far, one of the least competitive of the network utility industries and with the largest share of public operators. The main findings of the paper can be summarized as follows: the large majority of studies analyzed either find private operators less efficient or are unable to find any significant difference with their public counterparts;

and this conclusion appears to be robust to the time period, the sample and the estimation methodology employed. Those results are then briefly discussed arguing that policymakers should focus more on competition and incentive regulation issues rather than on ownership per se.

Keywords: Ownership efficiency, privatization, water industry

JEL Classification: L25, L33, L95

RIASSUNTO

Efficienza relativa pubblico-privato nel settore idrico: una rassegna della evidenza empirica a livello internazionale

Mentre sembra esistere in letteratura un forte consenso sulla migliore performance delle imprese private nei settori concorrenziali (Shleifer, 1998, Megginson and Netter, 2001), l'evidenza empirica è meno univoca nel caso delle public utilities (Newbery, 1999). Tuttavia la maggior parte dei lavori empirici e delle rassegne che hanno affrontato la tematica dell'efficienza relativa fra imprese pubbliche e private si è concentrata prevalentemente sul settore elettrico, sfiorando solo marginalmente l'industria idrica. Lo scopo di questo lavoro è analizzare e valutare criticamente l'evidenza empirica in merito all'efficienza relativa della proprietà pubblica e privata nel settore idrico. Il caso dell'industria idrica è di particolare interesse in quanto è uno dei settori caratterizzati da minor concorrenza e da una significativa prevalenza di operatori pubblici in quasi tutti i paesi industrializzati. I principali risultati di questo studio possono essere riassunti come segue: la maggioranza dei lavori esaminati riscontra una minor efficienza fra gli operatori privati o non è in grado di riportare alcuna differenza significativa fra i due gruppi; questo risultato non sembra dipendere dal periodo in cui è stato realizzato il lavoro, dal campione utilizzato e dalla metodologia adottata. Questi risultati sono quindi brevemente discussi, in particolare notando come i policymakers dovrebbero focalizzare la propria attenzione sull'introduzione di forme di concorrenza nel settore e/o sulla predisposizione di politiche di regolamentazione incentivanti piuttosto che sulla questione della forma proprietaria.

APPENDIX

TABLE 1 - *Sample Statistics and Main Results of the Papers Surveyed*

Paper	*year*	*sample*	*Type of approach, functional form and estimation method*	*Dependent variable*	*Output(s)*
Crain-Zardkoohi	1978	USA: 88 public and 24 private utilities in 1970.	Econometric (cost function); Cobb-Douglas (log-log); OLS.	Operating plus maintenance, administrative and depreciation costs.	Volume produced.
Bruggink	1982	USA: 77 public and 9 private utilities in 1960.	Econometric (cost function), hedonic Cobb-Douglas, quadratic in output, OLS.	Operating plus maintenance, administrative and depreciation costs.	Volume produced.
Feigenbaum-Teeples	1983	USA: 57 private and 262 public utilities in 1970.	Econometric (cost function); hedonic Translog; ML.	Operating and maintenance costs.	Volume of water produced.
Byrnes *et al.*	1986	USA: 68 public and 59 private utilities in 1976.	Non-parametric; DEA (technical efficiency only).	Volume distributed.	Volume distributed.
Fox-Hofler	1986	USA: 156 public and 20 private utilities in 1981.	Econometric (stochastic frontier); dual output production frontier and factor shares; ML.	Volume produced and length of pipelines.	Volume produced and length of pipelines.
Teeples-Glyer	1987	South California: 87 public (different types) and 52 private utilities in 1980.	Econometric (cost function); different functional forms, hedonic Translog the preferred one; SURE.	Total costs.	Volume delivered.
Lambert *et al.*	1993	USA: 238 public and 33 private utilities in 1989.	Non-parametric, DEA (technical and scale efficiency only).	Volume delivered.	Volume delivered .
Raffiee *et al.*	1993	USA: 238 public and 33 private in 1989.	Econometric (cost function with input expenditure as regressors); Cobb-Douglas (log-log); OLS.	Total costs.	/
Lynk	1993	England and Wales: 10 water and sewerage companies between 1980 and 1988 and, separately, 22 water companies from 1985 to 1988.	Econometric (stochastic cost frontier); log-log; COLS.	Operating costs (no depreciation).	Water produced; trade effluent; environmental services.
Bhattacharyya *et al.*	1994	USA: 225 public and 32 private utilities in 1992.	Econometric (shadow cost function); hedonic Translog; NLSURE.	Sum of labour, energy and materials costs.	Water delivered.
Bhattacharyya *et al.*	1995a	Nevada: 26 rural utilities in 1992.	Econometric (indirect production frontier); Translog; 2 step ML.	Water supplied.	Water supplied.
Bhattacharyya *et al.*	1995c	USA: 190 public and 31 private utilities in 1992.	Econometric (stochastic cost frontier); Translog; SURE corrected for heterosckedasticity and separate estimation for parameters affecting inefficiency.	Sum of labour, energy and materials costs.	Water supplied
Estache-Rossi	1999	South East Asia: 49 firms in 1997.	Econometric (stochastic cost frontier); hedonic log-log, estimated by both COLS and ML both with half-normal distribution.	Operating and maintenance costs.	Properties served.
Ashton	2000	England and Wales: 10 water and sewerage companies between 1989 and 1997	Econometric (cost function); Translog; SURE.	Total costs (capital computed as expenditure on tangible assets + depreciation)	Properties served
Saal-Parker	2001	England and Wales: 10 water and sewerage companies between 1985 and 1999.	Econometric (cost function); Translog; SURE.	Total costs.	Resident water population; population connected to sewerage treatment works.
Estache-Kouassi	2002	Africa: 21 firms in 1995-97.	Econometric (stochastic production frontier) estimated by random effects (GLS).	Volume delivered.	Volume delivered.
Kirkpatrick *et al.*	2004	Africa: 76 utilities in 2000	Econometric (stochastic cost frontier) estimated by ML and DEA	Operating and maintenance costs for stochastic frontier; staff and connections for DEA	Water delivered for stochastic frontier, water delivered and quality for DEA
Boyer and Garcia	2004	France: 47 private utilities (1995-98) and 52 public (1995-97)	Econometric (stochastic cost frontier) estimated by ML with time varying inefficiency and Within-Sure	Electricity, treatment and other variable costs	Water produced
Saal *et al.*	2004	England and Wales: 10 water and sewerage companies between 1985 and 1999.	Econometric (stochastic input distance function), translog, ML.	/	Water and sewerage volumes and connections.
Coelho Faria *et al.*	2005	Brasil: 135 public and 13 private utilities in 2002	Econometric (stochastic production frontier) estimated by ML	Water produced	Water produced

TABLE 1 (*continued*) - *Sample Statistics and Main Results of the Papers Surveyed*

Paper	*Year*	*Inputs*	*Main hedonic variables*	*Main results*
Crain-Zardkoohi	1978	Capital, labour.	/	Private firms more efficient, on the basis of a Chow test and a dummy variable approach.
Bruggink	1982	Labor.	Index for water treatment, % of water purchased, population density, staff size per million of gallons, % of resid. Population, % of underground sources.	Public firms more efficient, on the basis of a dummy variable approach. Poolability cannot be refused on the basis of a Chow test.
Feigenbaum-Teeples	1983	Capital, labour, electricity.	Index for water treatment, % of water metered, connection density; storage capacity/daily average production, average size of metered account; % of water purchased.	No differences in the cost function of public vs. private utilities. The preferred specification is hedonic-Cobb-Douglas.
Byrnes *et al.*	1986	Quantity of ground water, quantity of surface water, purchased water, miles of pipelines, labour (part time and full time), storage capacity.	/	On the basis of parametric and non-parametric tests, no difference is found in the technical efficiency of private and public utilities.
Fox-Hofler	1986	Labour, capital.	% of water delivered to non-residents, regional dummies.	No differences in the technical efficiency, but private firms more allocatively inefficient than public utilities.
Teeples-Glyer	1987	Capital, energy, labour (disaggregated according to: pumping, distribution/ maintenance, office/billing and management/engineering), own water, purchased water.	Connections, water storage capacity per average daily delivery, connections per mile of line, % of connections metered.	In the most general (and preferred) specification, no statistically significant difference is found between private and different types of public utilities.
Lambert *et al.*	1993	Labour, energy, value of capital, value of materials.	/	Using a non-parametric test, the technical and whole efficiency (technical +scale) of public firms is higher.
Raffiee *et al.*	1993	Labour, energy, materials, capital.	/	A dummy variable shows a greater efficiency for private utilities.
Lynk	1993	Labour.	Regional dummies.	The cost efficiency in the sample of public operators is higher then in the private one, even if the results are not directly comparable.
Bhattacharyya *et al.*	1994	Labour, energy, materials.	Capital stock; number of distribution system breakdowns.	Public utilities are slightly more technically and price efficient than private one. On the other hand, private operators' efficiency is less dispersed and they are more scale efficient.
Bhattacharyya *et al.*	1995a	Labour, energy, materials.	Water input, capital stock, density of operations + variables explaining the inefficiency effect (% of metered connections, mains length, system water loss, dummies for water origin, sewerage dummy variables, dummy for firms treating water.	Private utilities are the most efficient, even if the extent of the difference in efficiency depends on the type of government ownership.
Bhattacharyya *et al.*	1995c	Labour, energy, materials.	Capital stock, water purchased, total system loss, dummies to indicate water origin +variables explaining inefficiency (dummies to indicate wholesale firms, emergency breakdowns, length of distribution mains).	Cost inefficiency higher for private (18%) than for public operators (9%). Between the smallest firms, the private are more efficient.
Estache-Rossi	1999	Labour.	Number of connections, density of operations, market structure, hours of water availability.	An ownership dummy is not found significant in the regressions.
Ashton	2000	Labour, Capital, materials	/	Slight decline in TFP over the sample period.
Saal-Parker	2001	Labour, capital, index for fuel, materials and other services.	/	Privatisation did not lead to any significant reduction in the trend growth rate of total costs, which did occur, but only after the regulatory tightening which took place in 1994.
Estache-Kouassi	2002	Real Capital, materials, energy (in $) and labour.	Number of connections, capacity utilization.	A Tobit regression of efficiency scores on an ownership dummy find public ownership and efficiency negatively correlated.
Kirkpatrick *et al.*	2004	Labour	Hours of water availability, density, gdp per capita, freedom index, ownership dummy	No significant difference between private and public utilities in the stochastic frontier case, private slightly more efficient in the DEA case.
Boyer and Garcia	2004	Electricity, treatment costs, other variable costs	Density, consumption per connection, ownership dummy, network length (proxy for capital), water sold wholesale, water bough wholesale	No significant differences between private and public utilities.
Saal *et al.*	2004	Labor, capital, other opex costs	% of metered water properties, bathing water intensity, % underground sources, ratio between trade effluent load to resident population	No TFP growth difference after privatization, increase in technical change after privatization.
Coelho Faria *et al.*	2005	Capital (length of mains), labour (number of employees)	Ownership dummies as explanatory factor of the inefficiency effects	Very weak evidence of higher efficiency for private firms.