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An empirical analysis of efficiency in the Italian water service

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Introduction

The Italian water industry is living in a period of evolving regulatory proposals with several consequences in terms of efficiency in the distribution of water and sewerage services.

The scientific interest of this work is aimed at comparing different analytical tools and assessments of cost efficiency for a sample of 37 Italian water operators and their hypothetical mergers in the period 2005-2009.

This study is divided in four parts.

Firstly, it focuses on water resources values, through a review of the coordination activities carried out by the world's leading organizations for the assurance and dissemination of water resources on the planet.

The World Bank, for example, has a strategy aimed at improving water services in order to promote growth and reduce poverty.

The Part one of this study shows the economic situation of water sector in Italy by the reform of the integrated water service introduced by Law 36/94, mentioned the Galli Law.

The Law dated 5th January 1994 n. 36, or Galli Law, "Provisions of Water Resources", points out a complex and detailed process of territorial and functional reorganization of the "Integrated Water Service" in order to overcome the fragmentation of management, pursuing a reorganization of the same, on a more appropriate territorial basis, activating business models ensuring adequate levels of service efficiency, effectiveness and economy.

The reform introduced with the Galli Law has been carried out with significant delays and gaps. The Galli Law and the tariff method in many cases have not been fully applied.

To date, the main reform objective, i.e. the sector fragmentation reduction and the management overcoming, has not been fully achieved.

The second part of this scientific work starts with a general revision of the main concepts of microeconomic efficiency and economies till arriving at describe them in a literature review in the international water sector.

In particular, many are the studies that have empirically tested, by using different methodologies, the efficiency of the Italian and the international water sector.

The third part is empirical. Firstly, it focuses on the data underlying the empirical work carried out in the following chapters. It carefully analyzes the economic, managerial, and technical features of a sample of 37 Italian water operators. Through the use of descriptive statistics, the main economic values of data (mainly costs and revenues) and technical data (Mc of water delivered, Mc of water produced, Mc of water treated, network losses, users and Km of network) are highlighted. The values of minimum, maximum, mean obtained were evaluated and compared with those obtained from subsamples (according to the size shown by the number of employees and in accordance with the geographical distribution in North, Central and South Italy).

Then empirical efficiency is tested, by reading the presence or absence of economies of scale for the sample under investigation. Following a parametric empirical research methodology, the Translog total variable cost function is estimated with two outputs (Mc of treated water and number of users of service water distribution), two variable inputs (price of work and price of raw materials and services) and a fixed input (technical assets).

The economies of scale at the midpoint and for different levels of outputs are calculated.

In conclusion, the results obtained with this empirical work are compared with those provided by a number of important studies. An analogy has emerged as regards the presence of economies of scale for small sizes.

The same analysis of efficiency is conducted through the inclusion of dummy environmental variables in the TransLog cost function. Economies of scale are reported in the results.

The fourth part of this study investigates how Italian water companies change their efficiency when they merge and how hypothetically these potential gains or losses could be decomposed in terms of technical, scope and scale effects.

In the context of the new Reforms in the Italian water industry, the potential costs, size, and technology effects on efficiency from merging in a different contiguous way the Italian water companies belonging to the same Region are here examined.

By applying Bogetoft and Wang's (2005) not parametric DEA approach the results confirm the benefits coming from the aggregation. The hypothetical mergers are prevalently characterized by merger gains, which are decomposed into a technical effect, a harmony effect and a scale effect.

Finally, we analyze potential gains from hypothetical mergers in the water operators context by using the not parametric Data Envelopment Analysis with bias corrections by the bootstrapping method according to Simar and Wilson (2007). The results prevalently show highest efficiency improvement potentials from mergers between water utilities at the country level.

Water resource

Water is an essential and irreplaceable right. Water copiousness is an index of degree of wealth for countries and populations.

Water uses can be divided into[1]:

1. Civil use, specifically potable and not-potable civil uses (fire fighting, gardening, water sports, cooking, hygiene, religious rites);
2. Agricultural uses (irrigation);
3. Industrial uses (including source of energy in hydroelectric plants, chemical applications).

Most of the water is not directly available, but it requires treatments which are increasingly efficient: at a lower cost and with higher standards than before.

In Italy, in the nineteenth century, with the growth of urban centers the distribution of water through pipes to homes spreads. The last one resulted in a reduction of costs by the population for water provisioning, but at the same time it produced a natural monopoly for local high fixed costs associated with building water infrastructure.

The supply chain for potable water is as follows: uptake, purification, distribution and wastewater collection. The specific areas features affect the cost of providing the service and the water loss from the pipes, while the population density is reflected on the network length. Given the characteristics and the technology available, the aim is therefore to seek technical solutions that minimize the unit cost of that territory to define the size of the facilities to be used.

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[1] Source: World Water Assessment Programme (WWAP)

The involvement of the private sector is and has been the subject of careful considerations by the policy. The difficulty of defining an "excellent" optimal regulation model in the water sector reflects the heterogeneous different countries experiences.

Anglo-Saxon model has the features of regulated monopoly. The ownership of the assets are directly held by the operator to private capital, which bears the operational risk associated with providing the service. After the Great Britain, France is the country where the highest proportion of the population is served by private operators. In the French model of delegated management ownership of the assets remains on public hands, but they are assigned as a sort of rent to private operators for the provision of the service. In Germany, the public operator manages also the provision of the service (local public enterprise model). Part of the risk lies with the users paying a fee that covers the full cost of service. Furthermore, there are several variations as a mix of the foregoing factors. For instance, in the United States and Canada, the service is essentially managed by the public operator and the search for economies of scale is achieved through the establishment of operational managers in a large scale. In the Netherlands, the service is entrusted to operators with a mixed public-private participation, with a majority of stakes to the public operator[2].

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[2] Benvenuti M. – Gennari E. Il servizio idrico in Italia: stato di attuazione della lege Galli e efficienza delle gestioni, Banca d’Italia, Questioni di economia e finanza n.23, settembre 2008.

The protection of water services

The World Bank, the United Nations and its agencies ahead, through programs and interventions, improve water services in order to promote growth and reduce poverty.

The World Bank has financed projects for water infrastructure in the developing world. This is necessary in order to achieve the Millennium Development Goals that were agreed at the 2002 World Summit on Sustainable Development in Johannesburg[3]. Particularly, point 7 defined the objective to reduce by half, by 2015, the proportion of people without sustainable access to potable water.

The mission of the World Water Council[4] is to promote awareness and political commitment to facilitate the efficient conservation, protection, development, planning, management and use of water in all its dimensions on a sustainable basis for the environment and the benefit of all planet life.

The World Water Council, a World Bank- unit and multinational corporations, organized every three years since 1997 the World Water Forum, which brings together representatives of governments, local authorities, private sectors and civil societies to discuss all the important issues about the management of water resources. The 6th World Water Forum was held in Marseille between 12th and 17th March 2012 and involved the participation of 180 countries and more than 2000 experts. The proper management of water resources and the right to access were the central issues debated.

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[3] www.un.org/millenniumgoals

[4] www.worldwatercouncil.org

For the water right, according to UNICEF data, by 2015 92% of the world population should have access to improved sources of potable water, except for Africa, where the situation stays dramatic.

The World Water Day, held every March the 22th of each year, was established with the noble aim of raising public awareness on the importance of water and call on the sustainable management of water resources. Coordinated by the FAO - the United Nations Organization for Food and Agriculture – the meeting wants to reflect on the importance of the link between water and food security. In order to feed the entire population it’s essential to ensure water in a sufficient quantity and adequate quality, at everyone. The desirable solution would be to produce more food using less water, not only reducing waste and losses but also moving towards more sustainable diets, or diets with low environmental impact, helping to lead a healthy life regarding food and nutrition security for present and future generations.

The countries in developing and emerging economies are living a paradox in the field of nutrition: on one hand there are high rates of undernutrition (more than 800 million people suffering from hunger in the world) and on the other hand there are high percentages of overweight people. Both undernutrition and obesity may cause chronic debilitating diseases.

Lack of water can be a major cause of famine and malnutrition, especially in geographic areas where the population depends on agriculture for local food and income. Irregular rainfall and seasonal differences on the availability of water may cause temporary food shortages. Floods and droughts may give rise to some of the most acute food crises.

Projects sponsored by UNESCO[5] include the International Hydrological Programme (IHP) and the Institute for Water Education (IHE).

The International Hydrological Programme deals with how the climate changes affect the hydric world resources.

The Institute for Water Education aims at developing the tools and the skills necessary to achieve a better understanding of the basic processes, management, practices and policies that will help improving the supply and quality of global water resources. It's especially designed to create specialists for countries in the developing world.

The World Water Assessment Programme (WWAP) publishes the World Water Development Report (WWDR) at regular intervals.

Water is becoming an increasingly scarce right for its bad management, because is not replaceable in most of its uses, as it is not economically cheap on its transport at distances bigger than a few hundred kilometers.

In semi-arid areas of the world there are some conflicts being more or less directly related to the control of water sources[6].

In poor countries where you have access to potable water, people are forced to spend on water a very high proportion of their income, as long as they can afford it.

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[5] *United Nations Educational, Scientific and Cultural Organization,* http://www.unesco.org

[6] Vandana Shiva, Le guerre dell'acqua, Feltrinelli, Milano, 2008

PART 1

The Italian water sector overview

1. The Italian water sector before 1994

Before 1994, the water service in Italy was characterized by fragmentation, ineffectiveness and cost inefficiency[7].

Before the reform dated 1994 the future operators specialized in the distribution of water, wastewater collection and treatment acted on individual stages of very limited functional and geographic areas[8]. There were several structural and qualitative deficits connected to the bad infrastructures state.

Water quality was supplied to a large part of population below the standard set by the European Union. In addition, there were large cities (including some of the northern of Italy) which did not have sufficient wastewater treatment plants.

The industry (more than 8.000 operators) was composed of municipalities and a small number of privates who received the service concession.

Tariffs were set by the local authorities themselves at a very low level, reflecting the social feature of the service, incompatible with the importance of funding the investments necessary to improve infrastructure

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[7] Muraro Gilberto, La faticosa riforma dei servizi idrici" www.lavoce.info, 13.06.2005.

[8] Source: Coviri

and provide higher levels of the service and consumer protection. The inefficiency of production, the form of direct management by the municipalities and the lack of vertical integration were reflected on a marked structural gap in terms of technology.

A turning point towards the management efficiency of the hydric service was due to the Galli Law coming into force[9].

2. The reform of the Galli Law

With the introduction of the Galli Law in 1994, the reorganization of the whole sector started, aimed at achieving economies of scale and scope by the creation of the Integrated water companies and adequate industrial investments.

The integrated water service was created, i.e. the set of integrated public services for collection, transportation and distribution of water for domestic use, sewerage and wastewater treatment.

The operator of that service had to deal with the management, within its area of jurisdiction, for:

- Aqueduct: collection, transportation and distribution of water resources for

1. households
2. public users (hospitals, schools,...)

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[9] Legge 5 gennaio 1994, n. 36, Disposizioni in materia di risorse idriche, Gazz. Uff. 19 gennaio 1994, n. 14, S.O.

3. commercial users (shops, hotels, restaurants, offices ...)
4. agricultural users
5. industrial users;

- Sewerage: collection of wastewater;
- Wastewater treatment: treatment by purification of wastewater discharged into the public sewer.

A new institutional framework was outlined, the Optimal territorial area (ATO), in which the territory of reference for the management of integrated water services was bigger than the previous municipal level of activity. The ATO was therefore the subject assigning the service. It was configured by the Region on the basis of hydrographic and administrative criteria. It aimed at overcoming the fragmentation and the inefficiencies of municipal subdivisions in order to evocate scale sizes encouraging the development of the economies of scale. The size of the ATO must be large enough to achieve economies of scale such as to ensure a more efficient and rational management.

The ATO relied the integrated water service to a single operator, on the basis of an agreement / contract.

The operator, through the custody of the service, became the responsible of the entire integrated water services including the management of water supply, sewerage and water treatment.

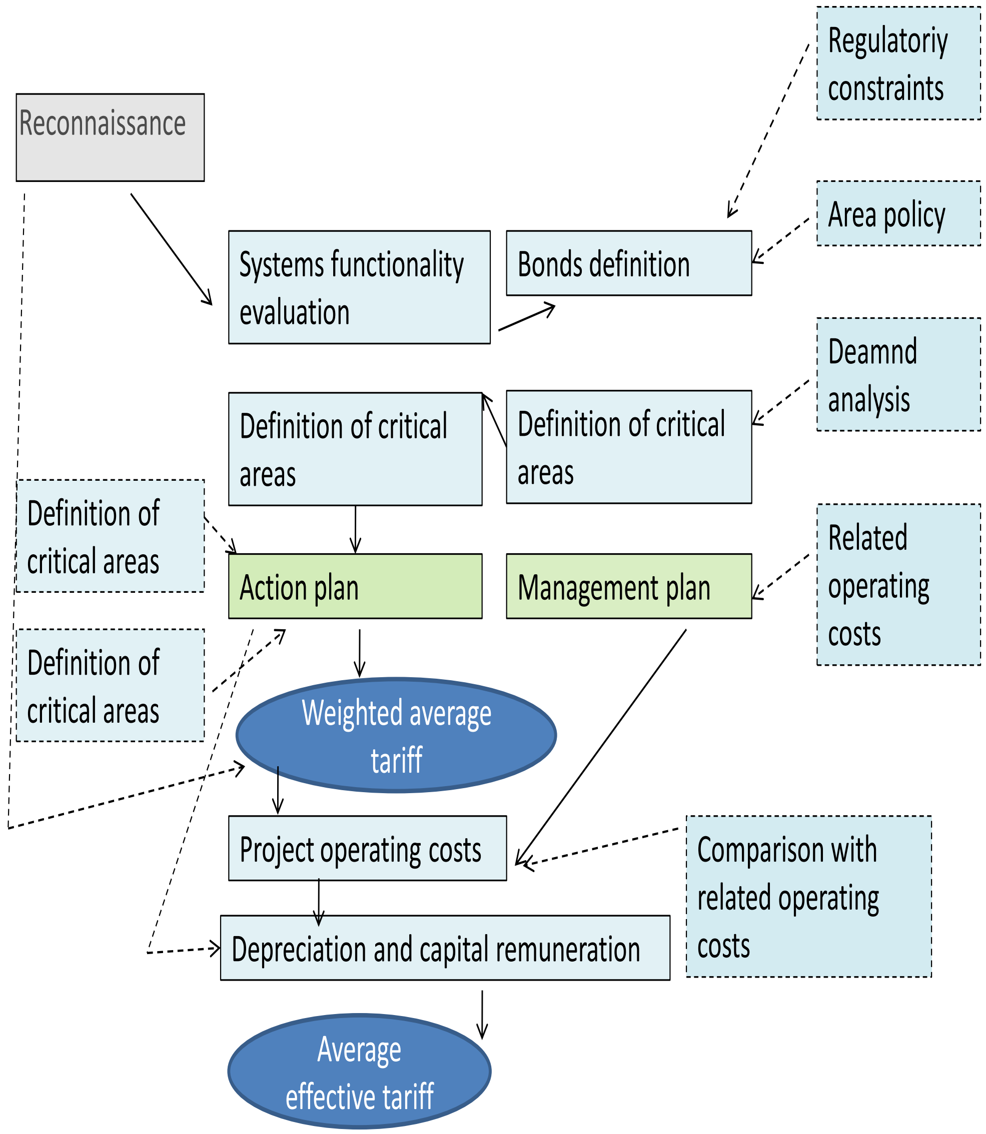
The Law dated 5 January 1994 established a clear separation between the programming task, the address one, the control and management ones.

The programming function of water resource was assigned to the Regions and the “Area Authority”, the planning and control of the management of the integrated water service was the Authority's scope.

The cost of service must be entirely covered by users.

The Area Authority set out a plan, known as “Piano d’Ambito”, for the adaptation of infrastructure and the achievement of the objectives of improving the service by the ATO.
An inspection and testing had to be carried out by the operator on the ATO.
The Area Authority defined the tariff of the new service and provided the reliance of management of integrated water services. It also checked that the manager realized the plan and monitored the implementation of the tariff.
Once settled, the ATO must provide a survey of existing service infrastructure, tariffs and costs.
The Plan (see Figure 1) allows the ATO to determine the quantitative and qualitative objectives of the services and investments to be needed for the Area.

Figure 1. The Area Plan functions.



Source: Sogesid, www.sogesid.it/allegati/varie/ricognizione.pdf and our reworking.

The tariff, the amount of water service, was unique for the ATO and it was fixed by the same ATO.

This tariff was applied by managers by taking into account the water resource quality, the granted service and the operational costs of infrastructures.

The Minister of Public Works, in cooperation with the Minister for the Environment, drew up a normalized method in order to define the cost components and to determine the tariff.

The tariff was different for the various user groups and areas: the normalized method was defined as a formula taking into account national and regional specificities related to the provision of the service. This method also provided a limit for the annual increase of the tariff (known as price-cap) that took into account in particular the inflation rate. The rate also included the one of return on capital invested up to 7%. The Galli Law reform of the water sector also established a Supervisory Committee on the use of water resources. The main task of the Committee was to verify the proper management of integrated water services with respect to efficiency, effectiveness and economy, the adjustment of tariffs and the users interests protection.

3. The normative evolution of Galli Law

The reform introduced by the Galli Law was carried out with delays and gaps.

Article 22 of Law 142/90[10] (which takes over the art. 113 of Legislative Decree 267/2000[11]) establishes three possible forms of service management:

• concessions to third parties;

• by a special company;

• by a company with the majority public capital.

According to the provisions as of art. 113, c. 5 of Legislative Decree no. 267/2000[12], referred to as art. 150 of Legislative Decree no. 152/2006[13] the integrated water service entrusting can be mainly through:

a) concession to a private part by tender.

b) direct award to a public-private society by SpA with a public evidence procedure for the selection of the private partner.

c) entrusting or delegation "in house" to companies with wholly public capital. The entrusting “in house", are introduced with the Law Decree 269/2003[14].

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[10] Law 8 giugno 1990, n. 142**,** Ordinamento delle autonomie locali, Pubblicata in Gazz.Uff. 12 giugno 1990, n. 135, S.O.).

[11] Legislativo 18 agosto 2000, n.267, Testo unico delle leggi sull’ordinamento degli enti locali, Gazz. Uff. 28 settembre 2000, n227.

[12] Decreto Legislativo 18 agosto 2000, n. 267 , "Testo unico delle leggi sull'ordinamento degli enti locali"**,** *Gazzetta Ufficiale* n. 227 del 28 settembre 2000 - Supplemento Ordinario n. 162.

[13] Decreto Legislativo 3 aprile 2006, n. 152 , "Norme in materia ambientale"**,** *Gazzetta Ufficiale* n. 88 del 14 aprile 2006 - Supplemento Ordinario n. 96.

[14] Decreto-legge 30 settembre 2003, n. 269 "Disposizioni urgenti per favorire lo sviluppo e per la correzione dell'andamento dei conti pubblici", *Gazzetta Ufficiale* n. 229 del 2 ottobre 2003 - Supplemento Ordinario n. 157.

Legislative Decree dated April 3, 2006 redefines the public integrated water service sustaining that, in such a territorial area, one company manages water distribution, sewerage and wastewater treatment in an efficient, effective and economic way. In this period there is a push towards public control of water, which would take place through the elimination of the tender and a possible return to management in the economy. On the other hand there are people opting for the "privatization" of the industry. However, the tax decree related to the 2008 Budget provides "a moratorium on water." By this measure all the pressure towards privatization is defeated. The moratorium involves the suspension of credit to the private management of water services. and the tenders suspension.

Ronchi Decree dated September 25, 2009, defines new normative and management aspects: the water management is entrusted through public tenders and companies having private partner with participation being lower than 40%; the in-house trust is allowed in an exceptional way.

The Law March 26, 2010 decrees the ATO abolition.

Referendum dated 2011 June 12,13 abolishes the prospective way of trust for public local services of economic relevance in general and it cancels the new proposed method of tariff determination in the water industry.

Next, the planning and control of the management of the integrated water service became the Regulatory Authority for electricity and gas (AEEG)'s scope. AEEG furthermore has the purpose of defining and monitoring a reliable and transparent tariff system.

In the future Italian sector other normative changes will be surely on move.

To date the water quality is different in the various parts of Italy because of the better or worse infrastructures status. Network losses are higher in the South than in the North of Italy.

The largest voices of revenues and operative costs respectively concern water distribution, service and labour costs[15].

[15] http://www.bancaditalia.it/pubblicazioni/econo/quest_ecofin_2/qef_23/QEF_23.pdf

PART 2

The water sector efficiency

1. Introduction

What is efficiency? The efficiency is a feature recognized to a production process when there is not any other allowing to produce at least a better output at the same input factor, or allowing to obtain the same output with the least use of at least one input.

Farrell, in 1957, introduced the concept of frontiers "best practices" and the first measures of efficiency.

In the economic literature "productive efficiency" of a company means:

1. the correspondence between the output produced and the maximum potential output, given the technology and the combination of input ("output oriented");
2. the correspondence between the amount of input actually used and the minimum amount of potentially usable input, given the technology and the output level ("input oriented").

From a theoretical point of view when you are faced with a situation where there is not a correspondence between the amount of current and potential good amount it is necessary to explain the causes of this difference. It may in fact be due to the technique or allocative inefficiencies.

The allocative efficiency is achieved when the combination of inputs is such as to minimize the cost of production, for a given level of output, or such as to maximize the output, for a given level of total cost; these points are on the cost frontier.

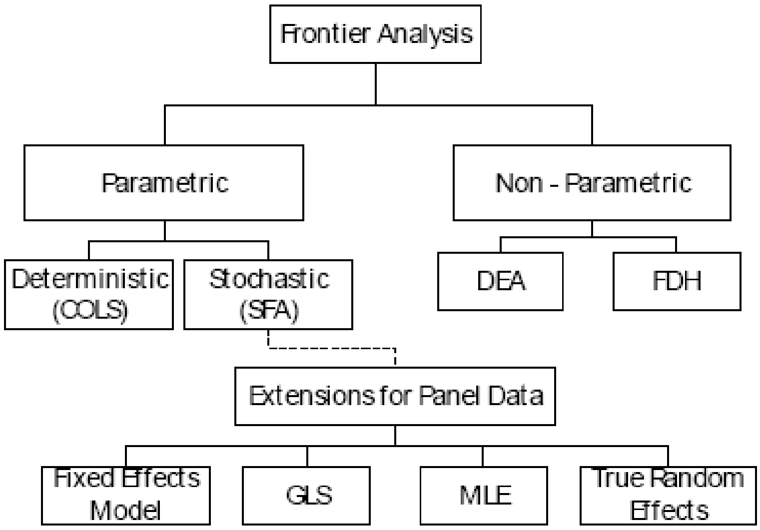
The technical efficiency occurs, however, when there is not an excessive use of both factors and the company gets the maximum output given a certain combination of input, i.e. when producing on the production possibility frontier. In both cases, the measure of the efficiency varies between 0 and 1: efficient production is shown by the unit.

If an economic unit operates on the border, is technically efficient.

2. The efficiency measurement methods

A brief review of the efficiency analysis methods is provided in Figure 2 (by Farsi, Fetz, Filippini (2007)).

Figure 2. A brief review of the efficiency methods



Source: Farsi M., Fetz A., Filippini M., *Benchmarking and Regulation in the Electricity Distribution Sector*, CEPE Working Paper CEPE Zurichbergstrasse 18 (ZUE) CH-8032 Zürich, 2007.

As basically displayed, empirical methods to estimate economic efficiency refers to parametric or not parametric approaches. Parametric method has a parametric form in the cost/production frontier and they are classified into deterministic methods (COLS) and stochastic techniques (SFA). Deterministic technique (COLS) assumes a deterministic element for its frontier functional form, whereas Stochastic Frontier Analysis (SFA) has a stochastic element in its frontier function. Within Stochastic frontier analysis for Panel Data according to the specific necessity it is possible to choose between these methods: fixed Effects Model, GLS, MLE, True Random Effects. Non parametric approaches are instead divided into Data envelopment analysis (DEA) and Free Disposal Hull (FDH).

A correct specification of the model is therefore a key element in the econometric efficiency analysis. This step becomes particular in the water sector, characterized by a lack of technical and environmental homogeneity (Fraquelli-Fabbri, (1997)). The industries covering the entire water cycle (water supply, transport and distribution, water treatment) are internally characterized by different levels of specialization and vertical integration, and are particularly subjected to the influence of external environmental factors. Every company has therefore a particular structure of operating costs, for which a single model hardly provides an estimate being perfectly valid for all elements of the sample considered.

2.1 The Translog cost function estimate

The economic literature is rich in studies on the identification of economies of scale in different industries. The methods most widely spread and shared are the study of the production functions through the analysis of the dual problem, i.e. the relationship between costs and prices of inputs for a given level of output.

The functional form that gave the best results in the econometric estimation of the cost structure of an industry was the Translog. This type of functional forms offers the possibility to approximate sufficiently and precisely a cost function being analytically complex. In other words a flexible functional form avoids imposing a priori restrictions on cost function shape and features, namely as regards the relations that bind input and output to the costs. The elasticity of substitution between inputs and returns to scale may vary from both levels of output and the input combinations.

In the water sector the study of economies of scale through the Translog specification has been addressed for example by Fabbri and Fraquelli (2000 - Translog function of total cost with hedonic variables), Saal and Parker (2001 - Translog function of the total cost), Stone & Webster Consultants - Saal (2004 - Translog variable cost function and generalized quadratic function of the total cost), and Fraquelli Moiso (2005 - Frontier stochastic total cost - Translog).

2.2 The Data envelopment analysis method

DEA method for efficiency estimate is largely used in the widespread benchmarking field.

Data envelopment analysis (DEA) is the linear programming-based methodology measuring the economic efficiency of a set of decision-making units (DMUs) by comparing their input-output combination with the technology frontier composed of the most efficient units, according to a different multiplicity of inputs and outputs. Any production units not on the frontier are considered inefficient. The efficiency score for the DMUs lying on the frontier is equal to 1, while the DMUs units located below the frontier have an efficiency score between 0 and 1, according to their distance from the frontier.

There are many kinds of DEA, assuming constant returns to scale (CRS), defined as the change of outputs due to a proportional variation of inputs, or variable returns-to-scale (VRS), exploiting the possibility for the production technology of increasing, constant and decreasing returns to scale.

There is a series of advantages and disadvantages from applying the DEA method to measure efficiency.

The main advantage is the absence of the specification in the mathematical form for the production function, accomodating several multiplicity of inputs and outputs without requiring financial or price data. Moreover DEA allows the sources of inefficiency be investigated and quantified for all evaluated units also taking into consideration returns to scale in order to measure efficiency in small data set.

It is also useful because it takes into consideration returns to scale in calculating efficiency, allowing for the concept of increasing or decreasing efficiency based on size and output levels. Some of the disadvantages of DEA are also suggested. Results are affected from the selection of inputs and outputs, in particular because the number of efficient firms on the frontier tends to increase with the number of inputs and output variables. The efficiency score are then sensible to outliers and it is not possible to distinguish the inefficiency score from the statistical noise, requiring re-sample methods such as bootstrapping in DEA analysis[16].

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[16] Bootstrapping is s a computer-based re-sampling method for improving the sample estimates measurement.

3. A review on efficiency literature

3.1 The DEA literature in the water industry

Recalling the previous international studies on efficiency, we followed two lines of study: the efficiency investigation with Data envelopment analysis (DEA) and the economies of scale (the cost advantages that a business obtains due to expansion) findings.

Many studies employ the DEA not-parametric frontier approach to investigate the economic efficiency of water services in order to sometimes value their regulation.

Table 1 shows a list of international papers using DEA method in the efficiency investigation.

Thanassoulis (2000) described the employment of DEA in the estimate of potential cost savings at water companies in the context of the price review conducted by the regulator of 10 water companies in England and Wales in 1994.

The study of Shih, Harrington, Pizer and Gillingham (2004) measured the technical not parametric efficiency and estimated the economies of scale in the U.S. municipal water services. The finding was that business size could be an obstacle to the technical efficiency because the production costs were high and the differences of costs between companies with the same structure of inputs were large.

Erbetta and Cave (2006) in the DEA evaluation of the effect of the tightening in price cap by OFWAT and of other operational factors on the efficiency of water and sewerage companies in England and Wales found that regulatory changes resulted in reduction as of technical efficiency.

Price-cap regulation brought inputs almost close to their cost-minimizing levels.

García-Sánchez (2006) in a sample of 24 Spanish water utilities, 1999, through the DEA not parametric method, discovered that network and population density had a significant influence on efficiency.

The aim of the work of Benvenuti, Gennari (2008) was to provide a survey on the implementation of Galli Law through not parametric analysis of efficiency. The estimate showed a low presence of economies of scope and a significant variability in the degree of technical efficiency of individual operators.

Reznetti and Dupont (2009), using data of municipal water agencies in Ontario, Canada, during 1996 found that environmental factors explained some of the observed variation in efficiency scores and that water agencies' relative efficiency scores were substantially changed after controlling the environmental factors.

Munisamy (2010) discovered scale inefficiencies in (smaller) private sector utilities, technical inefficiencies in public providers from a sample of 6 water supply authorities and 11 privatised water companies, Malaysia, 2005.

Table 1. A list of international papers using DEA method in the efficiency investigation.

Author(s)	Year	Methodology	Sample	Results
Thanassoulis	2000	DEA	10 water companies in England and Wales in 1994	It gave an account of the use of DEA to estimate potential cost savings at water companies in the context of the price review conducted by the regulator of water companies.
Shih, Harrington, Pizer and Gillingham	2004	DEA	Datasets from the 1995 and 2000 Community Water Supply surveys	Business size could be an obstacle to the technical efficiency because of the high production costs and large differences of costs between companies with the same structure of inputs.
Erbetta and Cave	2006	DEA	10 water and sewerage companies in England and Wales from 1993 to 2005	Regulatory changed resulted in reduction as for technical efficiency. Price-cap regulation brought inputs almost close to their cost-minimizing levels.

García –Sánchez	2006	DEA	24 Spanish water utilities 1999	Network and population density had a significant influence on efficiency.
Benvenuti, Gennari	2008	DEA	The information sources included two Bank of Italy surveys carried out during 2007 on local public water authorities and local water service providers	A low presence of economies of scope and a significant variability in the degree of technical efficiency of individual operators resulted..
Reznetti and Dupont	2009	DEA	Data were from a cross-section of municipal water agencies in Ontario, Canada, during 1996	Environmental factors explained some of the observed variation in the efficiency scores and that water agencies' relative efficiency scores were substantially changed after controlling for environmental factors.
Munisamy	2010	DEA	6 water supply authorities and 11 privatised water companies, Malaysia 2005	Scale inefficiencies in (smaller) private sector utilities, technical inefficiencies in public providers resulted.

3.2 The economies of scale in the water sector: recent international studies review

The existence of economies of scale can be used as a first indicator for potential efficiency gains from mergers (Zschille (2012)). Economies of scale (diseconomies of scale) exist when cost increases less (more) than proportionately to the output growth.

Table 2 summarizes a selection of international studies reporting evidences on scale economies. Below, we discuss the most important features.

Fabbri and Fraquelli (2000), collected data on a sample of 173 Italian Utilities, with the aim of evaluating the economies of scale presence and identifying the best functional form. They showed that the best one was Trans-logarithmic model with hedonic variables.

Saal and Parker (2000) discovered the absence of economies of scale on a sample of 10 privatised companies in England and Wales over the period 1985-1999.

Antonioli and Filippini (2001) analyzed costs structure and economies of scale on a sample of 32 Italian water companies over the period 1991 - 1995. They found strong economies of output density and absence of economies of scale.

Fraquelli and Giandrone (2003) discovered strong economies of scale for the smaller structure on a sample of 103 plants processing urban waste waters in Italy in 1996 and scope economies from vertical integration.

Bottasso and Conti (2004) estimated high economies of scale for the smaller structure on the short run in the whole English and Welsh water industry over the period 1995-2001.

Stone and Webster (2004) used econometric modeling of industry cost functions to investigate economies of scale and scope for the water industry in England and Wales. There was no evidence of overall economies of scope. The findings were diseconomies of scale for water and sewerage about 2 million water connections and 2.3 million for sewerage, economies of scale for small water only companies about 350,000 connections.

Saal and Parker (2005) examined a sample of thirty water utilities from 1994 to 2003, using a TransLog cost function and the Malmquist generalized index. They found economies of scale in 1993 and absence of the last ones in 2003.

Saal and Parker (2007), studying a sample of 10 English water utilities from 1985 to 2000, showed that privatization had a positive impact on minimum levels of efficiency.

Filippini, Hrovatin and Zoric (2008) on a sample of 52 Slovenian water distribution utilities from 1997 to 2003 compared different TransLog Frontier cost models of long period to evaluate costs efficiency. They found a wide potential for cost savings and the observed heterogeneity was not very significant.

The literature reported provides no general conclusions on optimal size. Results depends on the analyzed country, on the characteristics of the operating environment and on firm characteristics like the joint provision of the water and sewerage services (Zschille (2012)).

Table 2. A selection of international working-papers reporting evidences on scale economies.

Author(s)	Year	Methodology	Sample	Results
Fabbri and Fraquelli	2000	TansLog, Cobb-Douglas, with the inclusion of hedonic variables	173 Italian utilities members of Federgasacqua, representing about 50% of water yearly delivered	The choice of the functional form and inclusion of hedonic variables affected the studies about economies of scale. The better form in the empirical applications on size effect resulted the Translog with hedonic variables.
Saal and Parker	2000	Index number approach: TFP and labour productivity	10 privatised companies in England and Wales over the period 1985-1999	Absence of economies of scale
Antonioli and Filippini	2001	Cobb-Douglas cost Function	32 Italian companies over the period 1991-1995	Strong economies of output density and absence of economies of scale
Fraquelli, Giandrone	2003	Cobb-Douglas cost function	103 plants processing urban waste waters in Italy in 1996	Strong economies of scale for the smaller structure and scope economies from vertical integration

Bottasso and Conti	2004	Heteroskedastic stochastic variable cost frontier	The whole English and Welsh water industry over the period 1995-2001	High economies of scale for the smaller structure on the short run
Stone and Webster	2004	Multi-product hedonic translog cost function	England and Wales 10 water and sewerage companies, 38 water only companies, 1992/3-2002/3	diseconomies of scale for water and sewerage about 2 million water connections and 2.3 million for sewerage, economies of scale for small water only companies about 350,000 connections
Saal, Parker	2005	TransLog cost function and the Malmquist generalized index	30 water utilities from 1994 to 2003	Economies of scale in 1993 and absence of these last in 2003
Saal, Parker	2007	Translog input distance Function	10 water English utilities from 1985 to 2000	Privatization has a positive impact on the minimum levels of efficiency
Filippini, Hrovatin, Zoric	2008	TransLog Frontier cost models of long period	52 Slovenian water distribution utilities from 1997 to 2003	Wide potential for cost savings and the observed heterogeneity was not very significant

3.3. Economies in the merging literature review

Merging involves efficiency. Many investigated aspects on this type of analysis on the mergers efficiency concern the economies of scale, prevalently studied applying DEA methods and post-mergers or ante-mergers economies of scope.

Table 3 reviews a list of some studies about the effects of ex-ante and ex-post merging on efficiency. Firstly Kao and Yang (1992) applied the Data Envelopment Analysis (DEA) approach to find the inefficient forest districts in Taiwan, ROC. There were three alternatives for reorganizing the thirteen districts into the eight ones, also appraised by the DEA approach. The new districts were merged from the old ones seeking districts being similar in terms of efficiency.

Akhaven, Berger and Humphrey (1997), using a frontier profit function on data about bank 'megamergers', studied the efficiency and price effects of mergers. They showed that merged banks had increased the profit efficiency rank relating to other large banks.

Chapin and Schmidt (1999) used DEA approach to estimate efficiency for US rail firms since deregulation and to assess the positive change of efficiency for mergers. The production process was divided into two steps. Estimates suggested that the first mergers had a positive impact on technical efficiency and a negative one on size effect, whereas didn't affect efficiency in the second mergers.

Bogetoft and Wang (2005) decomposed the potential gains from merging into technical efficiency, size (scale) and harmony (mix) gains using the not-parametric Data Envelopment Analysis (DEA) approach, from merging 71 agricultural extension offices in Denmark.

Bottasso, Conti (2007), in order to estimate technical efficiency change in the English water sector over the 1995 – 2005 period, used a double heterosckedastic cost frontier. They considered both the vertical and horizontal sizes of water utilities. Results showed unexploited output economies and customer density and small-sized scale economies proportionally increasing with population density. Benefits of merging water utilities might be higher in more densely populated urban areas. Technical change was increasing over the entire period.

Walter, Cullman (2008) analyzed potential gains from hypothetical mergers on local public transport using the not-parametric Data Envelopment Analysis with bias corrections by means of bootstrapping. Their sample consisted of 41 public transport companies from Germany’s most densely populated region, North Rhine-Westphalia. Their empirical findings suggested that substantial gains up to 16 percent of factor inputs existed, mainly resulting from synergy effects.

Zschille (2012), focusing on a hypothetical restructuring of the German potable water supply industry, applied DEA through bootstrapping to analyze the potential efficiency gains from mergers between water utilities. The majority of the 84 merger cases was characterized by merger gains, so the results suggested to improve incentives for efficient operations in water supply and a consolidation of the industry structure.

Table 3. Merging literature review.

Author(s)	Year	Methodology	Sample	Results
Kao and Yang	1992	DEA	30 forest districts in Taiwan	There were three alternatives for reorganizing the thirteen districts into the eight ones. The new districts were merged from the old ones seeking districts being similar in terms of efficiency
Akhaven, Berger and Humphrey	1997	frontier profit function	Data on bank 'megamergers'	The merged banks had increased the profit efficiency rank relating to other large banks
Chapin and Schmidt	1999	DEA	US rail firms	First mergers had a positive impact on technical efficiency and a negative effect on the size one, while didn't affect efficiency in the second mergers
Bogetoft and Wang	2005	DEA	71 agricultural extension offices in Denmark.	Considerable production economic gains from mergers could be expected. In many cases, the gains from individual improvements and improved harmony effects were of the same order of magnitude

Bottasso, Conti	2007	A double heterosckedastic stochastic cost frontier	The English water only sector over the 1995 – 2005 period	Unexploited economies of output and customer density and small - sized scale economies proportionally increasing with population density. Benefits of merging water utilities might be higher in more densely populated urban areas. Technical change was increasing over the entire period.
Walter, Cullman	2008	DEA	41 public transport companies from Germany's most densely populated region, North Rhine - Westphalia.	Substantial gains up to 16 percent of factor inputs mainly existed, resulting from synergy effects.
Zschille (2012)	2012	DEA with bias correction through bootstrapping	84 merger cases in the German potable water supply industry.	The majority of the 84 merger cases was characterized by merger gains, so the results suggested to improve incentives for efficient operations in water supply and a consolidation of the industry structure.

PART 3

The first empirical application. The cost efficiency and the evidence of the economies of scale

1. The sample

The sample consisted of thirty-seven companies operating in the distribution, sewerage and treatment of integrated Italian water service over the period 2005 - 2009.

The data collected for each operator of the sample were essentially of two types:

• Economic data (costs, revenues and prices).

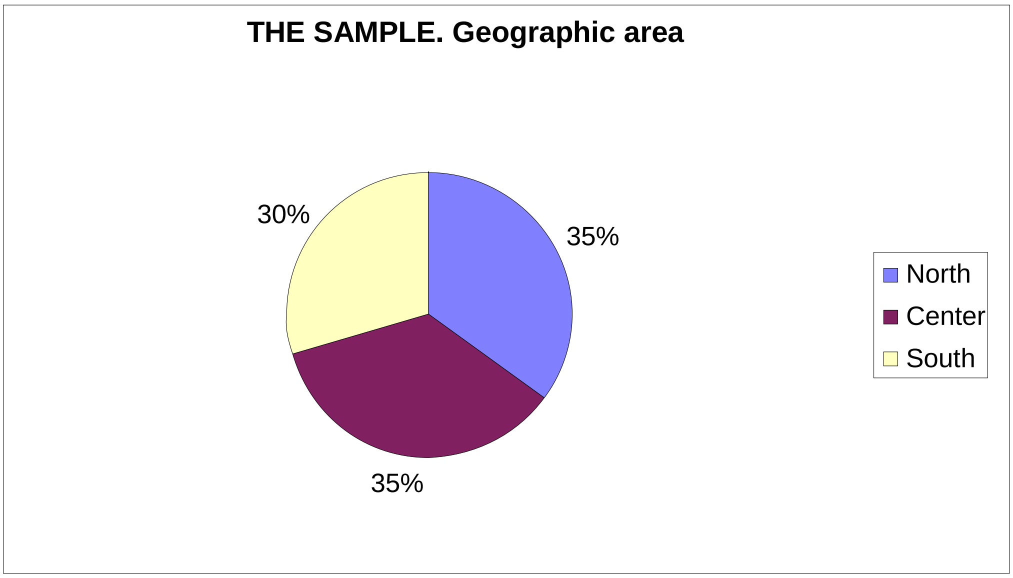
• Technical management data (Mc of water delivered to users, Mc of water treated, number of users, Km of network of water distribution and sewerage).

The data collected were extracted from the company balance sheet or directly requested to operators.

Thirteen water managers (35%) operate in the North of Italy, thirteen in the Center (35%) and eleven (30%) in South.

The following Figure 3 shows the sample geographical differences of Italian area.

Figure 3. The sample. Geographic area.

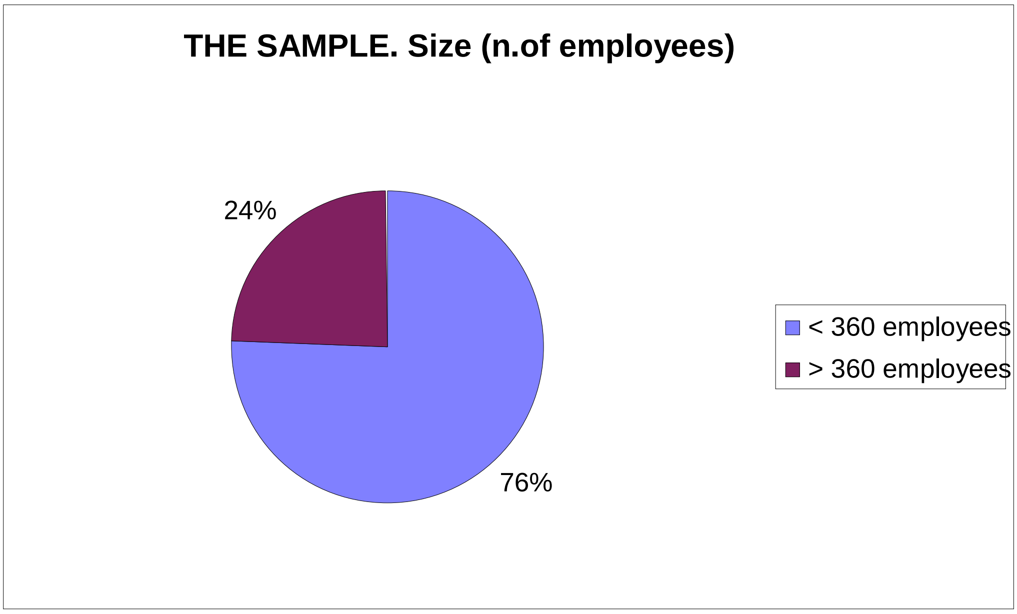


The average size of workers on the sample is about 360 employees.

Exactly 28 (76%) are operators which fall below this threshold and 9 (24%) operators are above it.

The following chart (Figure 4) represents the sample size.

Figure 4. The sample. Size (n. of employees).



Each company deals with a set of rules, laws and regulations governing its management.

The term "corporate governance" not only refers to as this set of standards, but also to the relationships between the actors involved and the objectives of company.

The main players of governance on the sample are the shareholders, the management and the Board of Directors.

The members of the Board of Directors (BoD) are the administrators usually elected by the shareholders.

Thirty-six operators are "limited companies". (company or holding), where the holdings of the shareholders are actions in which the share capital is divided. One firm is a limited responsibility company granting the social obligations with its capital only.

1.1 The economic data

Total revenues

Total revenues for the sample examined (thirty-seven firms) include total revenue from water service: it is especially composed of revenues from water distribution, sewage and treatment;

• Operating revenues;

• Other revenues.

Total revenues of water distribution represent the highest percentage of revenues.

Total costs

The main cost voices are:

- Cost of raw materials;
- Cost of labour
- Cost of services;
- Depreciation of material and not material goods
- Other management costs

Table 4 shows their descriptive statistics.

Table 4. Total costs (000 €).

Variables	N	Min	Max	Mean
Cost of raw materials	37	146.000	33.367.000	5.935.232
Labour cost	37	701.000	97.273.000	16.546.611
Cost of services	37	481.000	213.436.000	30.957.876
Depreciation of material goods	37	2.000	21.922.000	3.818.859
Depreciation of not material goods	37	6.000	67.495.000	6.191.141
Other management costs	37	13.000	39.812.000	2.275.368

The total costs are mainly composed (48%) of the costs for the provision of services and the cost of raw materials (25%).

The number of employees

The average number of employees of the sample, as already mentioned previously, turns out to be 360.

The price of labour

The price of labour is obtained as the ratio between the cost of staff and the number of employees in the service water system.

The average cost per employee gives an indication on the economy of management. In fact, it allows to assess whether personnel costs are higher compared to those of other operators.

On the sample under investigation it can be said that the size does not affect the cost of labour, while there is a difference depending on the region (Northern, Central and Southern Italy) in which the firm operates.

However, the mean cost per employee by region is not so much away from each other and therefore should not be subject to high attention, in contrast to the high levels of disparities between companies operating in developed countries and those operating in not developed countries. The interregional difference in the price of labour is not relevant.

It is also important noting that the average cost per employee calculated on this way does not take into account the number of managers, employees, workers and therefore represents a general average both for small than for large firms. This is because the available data in many cases don’t distinguish the type of employee.

1.2 The technical data

The technical data provide the size of the service managed.

They concern the number of users, the Km of water delivered and sewerage, the Mc of water fed into the grid, the Mc of water supplied, the Mc of water treated, the network losses.

Users

Users are people who get water for:

- civil home use;
- not home civil use, defined as consumption (schools, public buildings, railway stations, etc.).
- other uses relating to the business and commercial areas and general office buildings.

The Km of network

The pipes distributing water to users are a crucial element to take into account whenever we discuss on the problems of inefficiency characterizing the water distribution system.

In Italy, a large amount of water is lost on a journey along the pipeline.

The water service sector shows serious deficiencies; these ones are particularly serious in some areas of the country: the South and the two main Islands suffer from severe infrastructure deficits.

The water injected into the network, the network losses and Mc treated

The integrated water cycle consists of three basic steps: collection of water, grid for distribution to users, purification of wastewater collected from the sewer system.

The users receive only a part of the water fed into the grid, because there are usually infrastructure network losses. The treated water coming in a year to users takes the name of water delivered.

The growing attention towards a sustainable water is of primary importance in order to achieve a more efficient management of water systems.

However a distribution network, without loss, is a goal both technically and economically unfeasible. The manager should know the level of losses being economically acceptable implementing a network management allowing water to reach optimum levels of efficiency for its water system.

The sewerage service, the last step of the water cycle, consists of the collection (catchment) of wastewater from private homes, industrial sites, urban areas, roads and public areas.

1.3 The descriptive statistics

The descriptive statistics, shown in Table 5, summarize the average values of minimum, maximum, average and standard deviation of the analyzed data, previously collected on the entire sample composed of thirty-seven firms operating in the Italian water period 2005-2009.

The average revenue has a mean value greater than that of cost. Consequently, the operating income was weakly positive summarizing the tenuous ability of the manager to generate income by this business.

The average price of labour greatly varies between its minimum and its maximum value; this may be due to an absent indication of the number of employees, workers rather than managers. Many indicators of efficiency, economy and productivity losses are affected by the management size.

It should be noted that the size and the geographical area of the territory, where the water utility operates, is determined by its own features, such as the infrastructure status.

Table 5. Descriptive statistics.

Variables	N	Min	Max	Mean
Total revenues (000€)	37	1.822	441.045	71.036
Total costs (000€)	37	1.692	325.949	53.432
Employees (n. of employees)	37	18	2.113	357
Mean cost for employee (000€)	37	33	85	45
Users (n. of users)	37	4.690	1.231.460	206.157
Water network (Km)	37	100	20.500	3.693
Km of sewerage (Km)	37	21	10.374	1.792
Water delivered (000000Mc)	37	1	447	55
Mc of water produced (000000Mc)	37	1	634	95
Percentage of network losses (%)	37	7	72	39
Water treated (000000Mc)	37	0.44	352	40

As shown in table 6, the correlation between the water supplied and the water fed into the grid or distributed is high (0.95). In any case, as operators taken into consideration both distribute and purify the water, the correlation values of the outputs belonging to these two different branches of activity are closely most high.

Table 6. Correlations.

Correlations	
Employees and cost of labour	0.99
Delivered water and produced water	0.95
Treated water and produced water	0.80
Users and treated water	0.69
Treated water and Km of sewerage network	0.79
Delivered water and Km of water network	0.63
Water produced and Km of water network	0.80
Km of water network and Km of sewerage network	0.93
Delivered water and sewerage Km of network	0.73
Water produced and Km of sewerage network	0.85
Water treated and Km of water network	0.65
Users and water produced	0.94
Users and delivered water	0.91
Delivered water and treated water	0.81

The following Table 7 shows the average values of the main variables collected on the sample according to the geographical area (Northern, Central and South of Italy).

As shown by economic variables (revenue and costs) and technical variables (Mc of water delivered, ...) the North has operators of smaller size than those located in the Central and South of Italy. Moreover, as stated previously the average cost for employee does not show significant differences for area, whereas the most interesting variation existing in the different geographical areas is represented by the amount of water network losses. The South evidences the highest percentage of loss of water fed into the grid (42%).

Table 7. Descriptive statistics of subsamples.

Variables	Mean North (N.=13)	Mean Center (N.=13)	Mean South (N.=11)
Total revenues (000€)	35.798	87.143	65.081
Total costs (000€)	26.337	61.660	75.731
Employees (n. of employees)	155	410	532
Mean cost for employee (000€)	45	43	47
Users (n. of users)	80.453	270.738	278.392
Km of water network (Km)	2.011	3.983	5.336
Km of sewerage (Km)	841	1.903	2.768
Water delivered (000000Mc)	29	63	0.77
Water produced (000000Mc)	42	104	148
Percentage of network losses (%)	33	41	42
Water treated (000000Mc)	30	36	56

2. The estimate of the Translog short run cost function

Before the introduction of the Galli Law the integrated water service was characterized by a high and excessive management fragmentation and inefficiency, as well as structural weakness.

By the Galli Law reform, 1994, on one hand the management organization of the sector improves, on the other the operators are able to reach a better dimension in order to make economies of scale possible.

The Galli Law has therefore promoted the reorganization of the entire water cycle by overcoming fragmented management, seeking the economies of scale and scope through both horizontal and vertical integrations.

Many recent studies have demonstrated the existence of economies of scale in the water sector.

The water sector like the other ones of public utilities is characterized by high fixed costs, where economies of scale should be expected. In fact, how big is the incidence of fixed costs in relation to the total costs, bigger is the chance of detecting the presence of economies of scale. Scale returns are increasing.

The following empirical task work is focused on the research of these economies on the sample of thirty-seven water firms, which in most cases do not operate on the whole territorial area.

2.1 The cost function

The created database contains economic and management data of a sample of thirty-seven water firms in the period 2005 - 2009.

The functional form chosen to econometrically estimate the cost function is the Translog.

The Translog function built operates on the short term[17].

The choice of using fixed technical assets as short-term invariable input reflects the costly modifications in the capital stock.

[17] The cost function is a short period one, where a single factor is fixed and the others can be varied by the water operators. In this case the company does not minimize all the total costs, but the variable costs only.

Table 8 shows the correlations between the available variables in the next analysis.

Table 8. Correlations

Correlations	
Mc of delivered water and Mc of produced water	0.95
Mc of treated water and Mc of produced water	0.80
Users and treated water	0.69
Technical assets and users	0.71
Technical assets and Mc of treated water	0.67
Km of water and sewerage network and users	0.78
Km of water and sewerage network and Mc of treated water	0.72

Furthermore, we emphasize the sector management dimension by including in the cost function all the outputs of water service tasks: sewerage and water distribution. We have not used the level of water losses, often an index of a bad state of infrastructures, as a proxy of water distribution because the variable "Users" is not so lead to the production setting.

All the variables used in the cost function have been normalized by dividing them by their geometric mean.

In addition, the total variable cost and the prices were further divided by the price of labour before their transformation into logarithms, because the TransLog cost function must be linearly homogeneous in factor prices. It must also be not-decreasing in factors prices and output, symmetric and concave.

The variables used are summarized in the following Table 9, by distinguishing the outputs, the inputs and the fixed factor.

Table 9. The variables.

Variables		
Outputs	**Inputs**	**Fixed factor**
Users (yut)	Price of labour (pw)	Technical assets (k)
Mc of water treated (ydep)	Price of raw materials and service (pms)	

The short-term total variable cost is the sum of labour costs and the ones of raw materials and services.

The outputs considered are the number of users of the water distribution service and the Mc of treated water in order to be cleaned. The input variables are the price of labour and the one of raw materials and services.

The price of labour was calculated as of the ratio between the cost of labour and the number of employees.

The price of raw materials and services is given by the division between the respective variable costs and the volume of water injected into the network.

The fixed factor concerns the technique assets including the assets fund.

The short period total variable cost function is constructed using the linear logarithmic terms of output and logarithmic interactions between the price of inputs and outputs.

The cost function to estimate is as follows:

$$\begin{aligned} \ln\_ctv = \; & \beta_0 + \beta_{ydep} \ln\_ydep + \beta_{yut} \ln\_yut + \beta_{pms} \ln\_pms \\ & + \beta_k \ln\_k + \beta_{ydep\ pms} \ln\_ydep\_pms + \beta_{yut\ pms} \ln\_yut\_pms + \\ & + \beta_{k\ pms} \ln\_k\_pms + \beta_{yut\ dep} \ln\_yut\_ydep + \\ & + \beta_{ydep\ k} \ln\_ydep\_k + \beta_{yut\ k} \ln\_yut\_k + \\ & + 1/2\, \beta_{yut\ yut} (\ln\_yut)^2 + 1/2\, \beta_{ydep\ ydep} (\ln\_ydep)^2 + \\ & + 1/2\, \beta_{k\ k} (\ln\_k)^2 + 1/2\, \beta_{pms\ pms} (\ln\_pms)^2 \end{aligned}$$

where:

ctv = variable total cost being standardized to the price of labour;
ydep = Mc of treated water;
yut = users of the distribution water service;
pms = price of raw materials and services being standardized to the price of labour;
k = technical fixed assets.

2.2 The estimate

The estimate of the cost function has been realized through the software econometric STATA using the iterated SUR method (Seemingly Unrelated Regression), where the system is composed of cost equation and cost share equation (cost-share) of the raw materials and service factor, obtained by applying "Shephard's Lemma" to the variable total cost function.

$$\frac{\partial \ln\_ctv}{\partial \ln\_pms} = \frac{\partial cvt}{\partial pms}\frac{pms}{ctv} = \frac{MS(pms)}{ctv}$$

Share MS=β_{pms}+ $\beta_{ydep\ pms}$ ln_ydep+$\beta_{yut\ pms}$ ln_yut +$\beta_{yut\ k}$ ln_k + $\beta_{pms\ pms}$ ln_pms

The results of the SUR estimate of the cost function are shown in Table 10.

Table 10. The SUR estimate of short run cost function.

Seemingly unrelated regression

	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
ln_ctv						
ln_yut	.7599304	.0482757	15.74	0.000	.6653118	.8545491
ln_ydep	.1075347	.0433583	2.48	0.013	.0225541	.1925154
ln_pms	.6365333	.0105792	60.17	0.000	.6157985	.6572681
ln_k	-.0873441	.0269496	-3.24	0.001	-.1401644	-.0345237
ln_yut_2	.8137844	.0724598	11.23	0.000	.6717659	.955803
ln_ydep_2	.3738992	.0415537	9.00	0.000	.2924554	.455343
ln_pms_2	.0825603	.0132969	6.21	0.000	.0564988	.1086218
ln_k_2	-.0252142	.0289439	-0.87	0.384	-.0819431	.0315148
ln_yut_pms	.0663227	.0153591	4.32	0.000	.0362194	.0964261
ln_ydep_pms	-.0452434	.013024	-3.47	0.001	-.07077	-.0197168
ln_k_pms	-.0008756	.0079363	-0.11	0.912	-.0164304	.0146792
ln_yut_k	-.1166974	.0379295	-3.08	0.002	-.1910377	-.042357
ln_ydep_k	.1548543	.0230254	6.73	0.000	.1097253	.1999833
ln_yut_ydep	-.5822565	.0479107	-12.15	0.000	-.6761598	-.4883532
_cons	-.2052006	.0440333	-4.66	0.000	-.2915043	-.1188969
share						
ln_pms	.0825603	.0132969	6.21	0.000	.0564988	.1086218
ln_k	-.0008756	.0079363	-0.11	0.912	-.0164304	.0146792
ln_yut	.0663227	.0153591	4.32	0.000	.0362194	.0964261
ln_ydep	-.0452434	.013024	-3.47	0.001	-.07077	-.0197168
_cons	.6365333	.0105792	60.17	0.000	.6157985	.6572681

Seemingly unrelated regression

Equation	Obs	Parms	RMSE	"R-sq"	chi2	P
ln_ctv	180	14	.3612376	0.9087	6099.25	0.0000
share	180	4	.0857571	0.1951	72.36	0.0000

(1) [ln_ctv]ln_pms - [share]_cons = 0

(2) [ln_ctv]ln_yut_pms - [share]ln_yut = 0

(3) [ln_ctv]ln_ydep_pms - [share]ln_ydep = 0

(4) [ln_ctv]ln_k_pms - [share]ln_k = 0

(5) [ln_ctv]ln_pms_2 - [share]ln_pms = 0

Where

1. in the function *ln_ctv* the coefficients:

   ln_yut, ln_pms, ln_k, ln_yut_2, ln_ydep_2, ln_pms_2, ln_yut_pms, ln_ydep_pms, ln_ydep_k, ln_yut_ydep, _cons are significant at the 1% level.

   - *ln_ydep*, *ln_yut_k* are significant at the 5% level

   - *ln_k_2*, *ln_k_pms* are not significant

2. in the share function the coefficients:

   - *ln_pms*, *ln_yut*, *ln_ydep*, *_cons* are significant at the 1% level

   - *ln_k* is not significant

The value of t-statistic for each variable, easily calculated as of the ratio between the coefficient value and the standard-error (z in the results shown), provides the information on the data reliability. Particularly, it is useful to test the hypothesis of significance of parameters. The null hypothesis of the i-th coefficient equal to zero is rejected in favour of the alternative hypothesis (the significance of the parameters) if the value of z falls outside the confidence interval of the sample. The significance of the parameters is valued to the confidence levels of 1%, 5% and 10%.

Almost all the estimated coefficients are significantly different from zero and with the expected sign. In particular, all parameters are significant at the 1% level except for:

1. the coefficient on the treatment, which is significant at the 5% level,

2. the square coefficient of the fixed factor

3. the interaction between technical assets and the price of materials and services that are both not significant (table 10).

With regard to:

- **Outputs:**

β_{yut} = 0.75: an increase of 10% of users means an increase of 7.5% of total costs.

β_{ydep} = 0.11: an increase of 10% of Mc of treated water means an increase of 1.1% of variable total costs.

- **Prices**

β_{pms} = 0.64: an increase of 10% of raw materials and service price means an increase of 6.4% of total costs.

β_k = 0.09: an increase of 10% of technical assets means a decrease of 0.9% of total costs.

- **Input-output interactions**

There is a majority of cases where, as a result of an increase in the interactions of the logarithmic variables, the total costs decrease (the negative sign of the coefficients prevails).

Water operator have to answer to all the demand modifications, in order to account for the seasonal presence of users or for the territorial complexity (mountains,...). All these last ones affect the water consumption and the disposal of fixed material assets, by justifying the negative sign of fixed factor parameter in the cost function estimate.

2.3 The estimated economies of scale

In the water supply sector, the presence of high fixed costs and low marginal ones typically generates a downward trend in the average costs according to the increase in the production scale.

The estimate of the cost function enables us to derive information on the impact of the outputs on costs, as well as on other important characteristics in the water sector such as the economies of scale, with generate several implications for the market structure and welfare[18].

From the econometric estimate of the variable total cost function it is possible, by calculation, to test the presence of economies of scale.
Economies of scale (diseconomies of scale) exist when cost increase less (more) than proportionately to the output growth.

Since the estimate was made by normalizing all the variables by their geometric mean, the elasticity of cost with respect to each output variable is considered coefficient of the first order in their mid-point of the respective expansion.
The economies of scale of short period (ESBP) for the average operator of the industry are calculated as the reciprocal of the sum of the elasticity of cost with respect to each of the two outputs.

$$ESBP = \frac{1}{(\varepsilon_{yut} + \varepsilon_{ydep})}$$

Where:

ε_{yut} is the elasticity of variable total cost with respect to users of water distribution service, while ε_{ydep} is the elasticity of variable total cost with respect to Mc of treated water.

[18] Ernst R. Berndt, *The Practise of Econometrics: Classic and Contemporary*, Addison-Wesley Publishing Company, (1991).

It is possible to calculate the economies of scale in the long run:

$$ESLP = \frac{(1-\varepsilon_k)}{(\varepsilon_{yut} + \varepsilon_{ydep})}$$

Where:

ε_K is the elasticity of variable total cost with respect to the fixed assets.

The values of the economies of scale on the short and long-run at the midpoint of the sample are shown in the following Table 11:

Table 11. The economies of scale.

Short run		**Long run**	
ESBP	1.15	**ESLP**	1.25

Where:
ESBP = economies of scale of short-run
ESLP= economies of scale of long-run

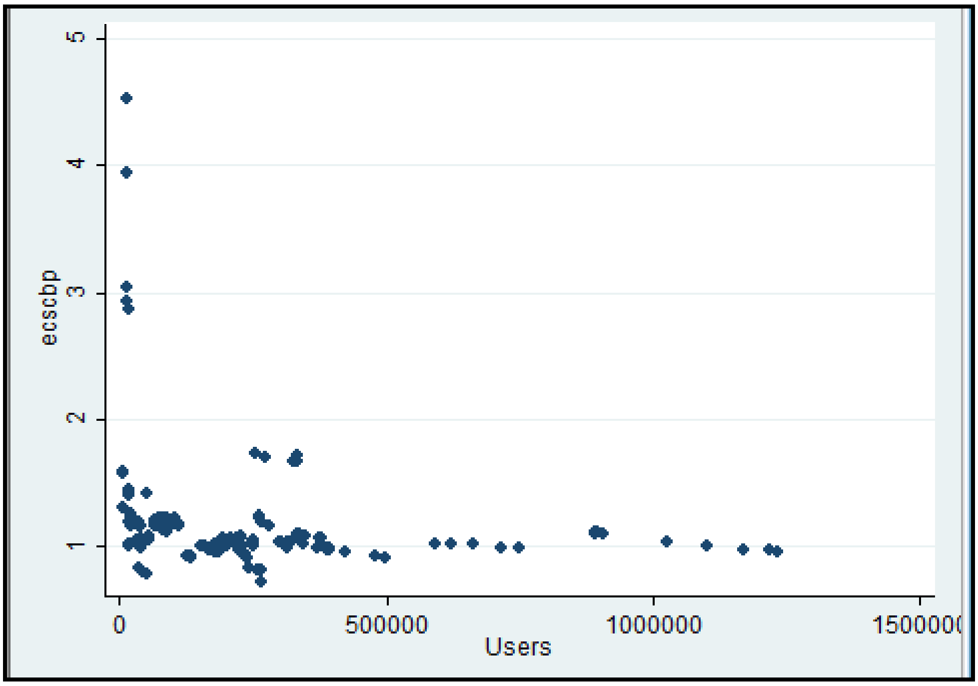
The values of the long period economies of scale are higher than those of short period.
The average short period economies of scale are estimated to 1.15. This value indicates the existence of economies of scale: the operator, by proportionally increasing the output, encounters a saving in the average cost of production.
Also the long run shows economies of scale (1.25).

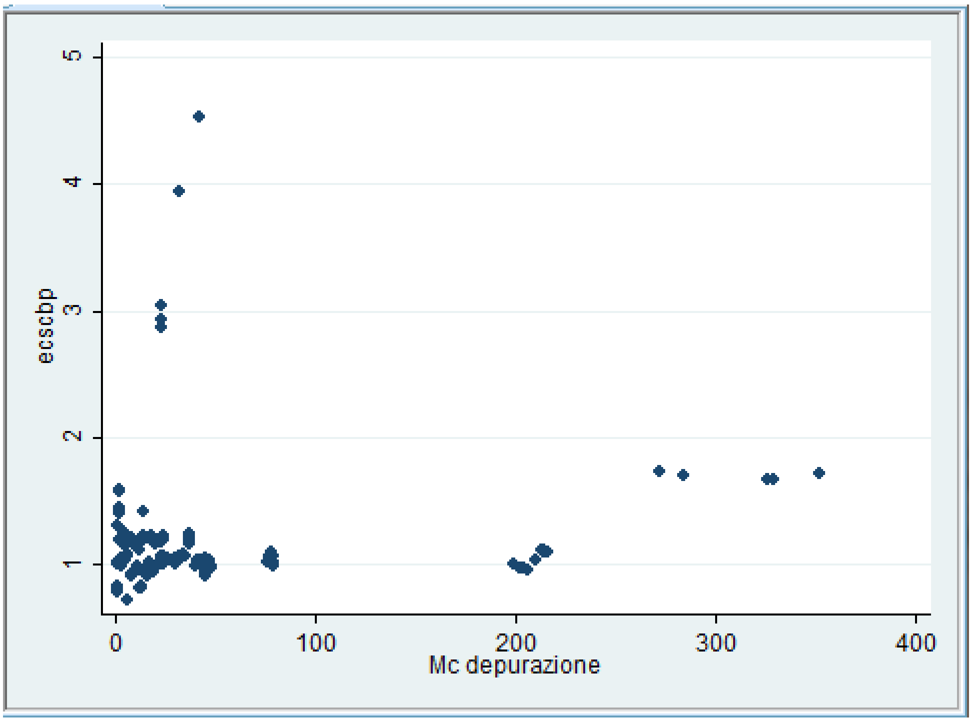
The results show the presence of relevant scale economies. Table 12 shows the punctual values of the economies of scale of short period according to the outputs for all the observations

As we can focus, economies of scale of short run decrease enlarging the values of output (the scale).

The lowest size to have diseconomies of scale in the short period correspond to 37000 users.

Table 12 . The economies of scale of short run.





In the Italian water industry it is interesting to distinguish cost changes that occur because of one output expansions only and cost changes that occur because of a proportional assets and all the output expansion. We consider the output users an important cost driver: we are interested to study the management synergies. The output users change is specified as trend which end to constant returns to scale with respect to cost minimizing input both in the short and in the long-run.

Other scientific investigations CERIS - Hermes (Fabbri et al, (2000); Erbetta and Fraquelli, (2003)) found significant economies of scale for small units and constant or decreasing returns for the largest.

Here the results emphasized, therefore, that a large number of companies will continue benefit from cost advantages as a result of dimensional increase.

As the operators have a provincial-sized configuration it will be interesting to enlarge the analysis with studies about what will happen to the economies of scale trend by merging existing firms.

2.4 Accounting for the water operator environment

Water distribution heavily depend on the operating environment and on the features of a service area. For this reason the operating environment is fundamental when analyzing the cost efficiency for water utilities even at the country level. The literature provides different approaches for the consideration of environmental variables. In this work the previous application (Chapter 2.2 and 2.3) for the determination of the cost efficiency is given by considering also environmental variables denoting them as dummy variables taking the value 0 or 1 to indicate the absence or presence of some categorical data.

This methodological analysis is the same described in Chapter 2.2 including the new environmental variables.
For the representation of the main availability of water resource in the served area, the output measure in the model is an index of commerce of water between areas (ydisp). Other environmental variables collected are the geographical collocation (ylocu and ylocd), the water losses (yper) and the area population density (ydens). To control for network quality, water losses are defined as the difference between the water injected in the network and the water deliveries to final customers. We define population density as the number of served population for Km^2.

The variables used are summarized in the following Table 13, by distinguishing the outputs, the inputs, the dummy environmental variable and the fixed factor.

Table 13. The variables.

<table>
<tr><th colspan="4">Variables</th></tr>
<tr><th>Outputs</th><th>Inputs</th><th>Fixed factor</th><th>Dummy variables</th></tr>
<tr><td>Users (yut)</td><td>Price of labour (pw)</td><td rowspan="5">Technical assets (k)</td><td>Index of commerce of water between areas (ydisp)</td></tr>
<tr><td rowspan="4">Mc of water treated (ydep)</td><td rowspan="4">Price of raw materials and service (pms)</td><td>Geographical collocation (ylocu e ylocd)</td></tr>
<tr><td>Water losses (yper)</td></tr>
<tr><td>Area population density (ydens)</td></tr>
<tr></tr>
</table>

Table 14 shows the descriptive statistics for the environmental dummy variables.

Table 14. The SUR estimate of the cost function.

Variables	Variables descriptions	N	Min	Max
Index of commerce of water between areas (ydisp)	ydisp = 0 (no water commerce), ydisp=1 otherwise.	22	0	1
Geographical collocation (ylocu)	ylocu = 1 (water company is in the North of Italy), ylocu = 0 otherwise.	22	0	1
Geographical collocation (ylocd)	ylocd= 1 (water company is in the Center of Italy), ylocd = 0 otherwise.	22	0	1
Water losses (yper)	yper = 0 (low water losses), yper = 1 otherwise.	22	0	1
Area population density (ydens)	ydens = 0 (high area population density), ydens = 1 otherwise.	22	0	1

The short-term total variable cost is the sum of labour costs and the ones of raw materials and services.

The price of labour was calculated as of the ratio between the cost of labour and the number of employees.

The price of raw materials and services is given by the division between the respective variable costs and the volume of water injected into the network.

The fixed factor concerns the technique assets including the assets fund.

The short period total variable cost function is constructed using the linear logarithmic terms of output and logarithmic interactions between the price of inputs and outputs.

The cost function to estimate is as follows:

$$
\begin{aligned}
ln\_ctv = \; & \beta_0 + \beta_{ydep}\, ln\_ydep + \beta_{yut}\, ln\_yut + \beta_{pms}\, ln\_pms + \beta_k\, ln\_k \\
& + \beta_{ydep\ pms}\, ln\_ydep\_pms + \beta_{yut\ pms}\, ln\_yut\_pms + \beta_{k\ pms}\, ln\_k\_pms \\
& + \beta_{yut\ dep}\, ln\_yut\_ydep + \beta_{ydep\ k}\, ln\_ydep\_k + \beta_{yut\ k}\, ln\_yut\_k \\
& + 1/2\ \beta_{yut\ yut}\, (ln\_yut)^2 + 1/2\ \beta_{ydep\ ydep}\, (ln\_ydep)^2 + 1/2\ \beta_{k\ k}\, (ln\_k)^2 \\
& + 1/2\ \beta_{pms\ pms}\, (ln\_pms)^2 + \beta_{ydisp}\, ydisp + \beta_{yper}\, yper + \beta_{ylocu}\, ylocu + \\
& + \beta_{ylocd}\, ylocd + \beta_{ydens}\, ydens.
\end{aligned}
$$

where:

ctv = variable total cost being standardized to the price of labour;
ydep = Mc of treated water;
yut = users of the distribution water service;
pms = price of raw materials and services being standardized to the price of labour;
k = technique fixed assets;
ydisp = index of commerce of water between areas (0 = no water commerce; 1 otherwise);
ylocu = geographical collocation (1 = water company is in the North of Italy; 0 otherwise);
ylocd = geographical collocation (1 = water company is in the Center of Italy; 0 otherwise);
yper = water losses (0 = low water losses; 1 otherwise);
ydens = (0 = high area population density; 1 otherwise);

The estimate of the cost function has been realized through the software econometric STATA using the iterated SUR method (Seemingly Unrelated Regression), where the system is composed of cost equation and cost share equation (cost-share) of the raw materials and service factor, obtained by applying "Shephard's Lemma[19]" to the variable total cost function.

$$\frac{\partial \ln\_ctv}{\partial \ln\_pms} = \frac{\partial cvt}{\partial pms}\frac{pms}{ctv} = \frac{MS(pms)}{ctv}$$

Share MS=β_{pms}+ $\beta_{ydep\ pms}$ ln_ydep+$\beta_{yut\ pms}$ ln_yut +$\beta_{yut\ k}$ ln_k + $\beta_{pms\ pms}$ ln_pms

The results of the SUR estimate of the cost function are shown in Table 15.

Table 15. The SUR estimate of the cost function.

Seemingly unrelated regression

Equation	Obs	Parms	RMSE	"R-sq"	chi2	P
ln_ctv	180	19	.3218122	0.9275	8196.24	0.0000
share	180	4	.0781646	0.3313	69.93	0.0000

```
( 1)  [ln_ctv]ln_pms - [share]_cons = 0
( 2)  [ln_ctv]ln_yut_pms - [share]ln_yut = 0
( 3)  [ln_ctv]ln_ydep_pms - [share]ln_ydep = 0
( 4)  [ln_ctv]ln_k_pms - [share]ln_k = 0
( 5)  [ln_ctv]ln_pms_2 - [share]ln_pms = 0
```

[19] Fabbri, Fraquelli (1997), "According to "Shephard's Lemma" the derivative of the cost function with respect to factor price yieldthe demand for input.".

	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
ln_ctv						
ln_yut	.6468477	.0533608	12.12	0.000	.5422623	.751433
ln_ydep	.081034	.0399256	2.03	0.042	.0027813	.1592866
ln_pms	.6490643	.0090572	71.66	0.000	.6313125	.666816
ln_k	.0521335	.0307415	1.70	0.090	-.0081187	.1123857
ln_yut_2	.5529391	.0769729	7.18	0.000	.4020749	.7038032
ln_ydep_2	.3441989	.0400992	8.58	0.000	.265606	.4227919
ln_pms_2	.074158	.0113289	6.55	0.000	.0519538	.0963622
ln_k_2	-.008225	.0268804	-0.31	0.760	-.0609096	.0444595
ln_yut_pms	.0575214	.0130687	4.40	0.000	.0319072	.0831356
ln_ydep_pms	-.0440927	.0110029	-4.01	0.000	-.0656579	-.0225274
ln_k_pms	-.0021141	.0067257	-0.31	0.753	-.0152963	.0110681
ln_yut_k	-.0701714	.0362316	-1.94	0.053	-.141184	.0008412
ln_ydep_k	.1115167	.0218339	5.11	0.000	.0687229	.1543104
ln_yut_ydep	-.456645	.0466405	-9.79	0.000	-.5480588	-.3652313
ydisp	-.5526059	.0931795	-5.93	0.000	-.7352344	-.3699774
yper	.0917459	.0568514	1.61	0.107	-.0196808	.2031727
ylocu	.2105514	.0823198	2.56	0.011	.0492076	.3718951
ylocd	-.0073643	.0738908	-0.10	0.921	-.1521875	.137459
ydens	.1534404	.0727131	2.11	0.035	.0109253	.2959555
_cons	-.005725	.1658219	-0.03	0.972	-.3307299	.31928
share						
ln_pms	.074158	.0113289	6.55	0.000	.0519538	.0963622
ln_k	-.0021141	.0067257	-0.31	0.753	-.0152963	.0110681
ln_yut	.0575214	.0130687	4.40	0.000	.0319072	.0831356
ln_ydep	-.0440927	.0110029	-4.01	0.000	-.0656579	-.0225274
_cons	.6490643	.0090572	71.66	0.000	.6313125	.666816

R^2 is 0.9275. This means that 92.8% of the variation of the dependent variable is explained by the regressors variability.

Where

a) in the function *ln_ctv* the coefficients:

   a. *ln_yut*, *ln_pms*, , *ln_yut_2*, *ln_ydep_2*, *ln_pms_2*, *ln_yut_pms*, *_pms*, *ln_ydep_k*, *ln_yut_ydep*, *_cons* are significant at the 1% level.

   b. *ln_ydep*, *ydens* are significant at the 5% level

   c. *ln_k*, *ln_k_2*, *ln_k_pms*, *ln_yut_k*, *yper*, *ylocu*, *ylocd* are not significant

b) in the share function the coefficients:

- *ln_pms*, *ln_yut*, *ln_ydep*, *_cons* are significant at the 1% level

- *ln_k* is not significant

With regard to:

- **Outputs:**

β_{yut} = 0.65: an increase of 10% of users means an increase of 6.5% of total costs.

β_{ydep} = 0.08: an increase of 10% of Mc of treated water means an increase of 0.8% of variable total costs.

Cleaning the output parameters from the environmental factors has a positive impact: there is a lowest increase of total costs following to the outputs growth.

- **Prices**

β_{pms} = 0.65: an increase of 10% of raw materials and service price means an increase of 6.5% of total costs.

β_{k} = 0.05 : an increase of 10% of technical assets means a decrease of 0.5% of total costs.

Cleaning the fixed output parameter from the environmental factors has a positive impact: there is a lowest increase of total costs following to the capital growth.

- **Evironmental variables:**

β_{ydisp} = - 0.55: an increase of the index commerce of water of 10% means a decrease of 5.5% of total costs.

B_{per} = 0.09: an increase of 10% of high water losses means an increase of 0.9% of variable total costs.

β_{ylocu} = - 0.21: an increase of 10% of operating in the North means a decrease of 2.1% of total costs.

B_{ylocd} = - 0.01: an increase of 10% of operating in the Center means an decrease of 0.1% of variable total costs.

B_{ydens} = 0.15: an increase of 10% of low area population density means an increase of 0.1% of variable total costs.

In particular a water utility operating in an area with external water exchanges means a decrease of variable costs (major possibility of optimizing between the decision of a potable own water or buying water from other country areas).
A high level of water losses increases the variable costs: with the same conditions the companies treats a major quantity of water.

All variables, expressed under logarithmic form, have been normalized with respect to their geometric means. This operation allows to interpret the coefficients of first order of the cost function estimate as the elasticity of the total cost calculated at the midpoint of the sample. Through the inverse of the sum of these elasticities the economies of scale are finally calculated.

The values of the economies of scale on the short and long-run at the midpoint of the sample are shown in the following Table 16:

Table 16. The economies of scale.

Short run		**Long run**	
ESBP	1.39	**ESLP**	1.32

Where:

ESBP = economies of scale of short-run

ESLP= economies of scale of long-run

The values of the short period economies of scale are higher than those of long period.

The average short period economies of scale are estimated to 1.39. This value indicates the existence of economies of scale: the operator, by proportionally increasing the output, encounters a saving in the average cost of production.

Also the long run shows economies of scale (1.32).

If the manager varies, in the same proportional measure, the Mc of water supplied, the users and the Kilometers of network, the total average unit costs of production decrease.

The results show the presence of relevant scale economies.

Table 17 show the economies of scale taking into account or not the environmental variables in the econometric model.

Table 17. The difference between the economies of scale with and without the inclusion in the econometric model of the environmental variables.

Model including environmental variables		**Model not including environmental variables**	
Short run		**Long run**	
ESBP	1.39	**ESBP**	1.15
ESLP	1.32	**ESLP**	1.25

As shown in Table 17, cleaning the parameters form the environmental variables effects give better results for the economies of scale.

PART 4

The second empirical work: the effects of merging Italian water companies on efficiency

1. Introduction

This chapter will investigate how Italian water companies change their efficiency when they potentially merge and how these potential gains or losses could be decomposed in terms of technical, scope and scale effects.

In other words the potential effects of costs, size, and technology on efficiency are examined from merging in a different contiguous way Italian water companies belonging to the same Region.

The meaning of "economic efficiency" is introduced.

A situation can be called economically efficient if no one can improve its own welfare without making the situation of anybody else worse (Pareto efficiency), if no additional units of output can be obtained without increasing the inputs units (technical efficiency), if there is an optimal proportional choice of inputs given the prices and production technology (allocative efficiency). Finally, if both allocative and technical efficiency is considered, the result is the productive efficiency.

The reasons to be interested in the industrial efficiency might concern the inadequate allocation of inputs, which may be costly and sub-optimal in order to reach the best practise.

Moreover, the efficiency is an important issue in antitrust analysis because it can be modified by merging decision making units.

There are different possibilities of merging, but the empirical analysis of this work considers potential horizontal merger, only when two companies operate at the same level in the production chain.

By merging, the companies wish to benefit from economies of scale, the ones of scope[20], risk sharing, reduction in transaction costs, acquisition of new technology.

On the other hand, there are also many obstacles to mergers, including the possible conflicts between different business styles and a series of public policies aimed at sustaining competition.

It seems that mergers play an important role in the restructuring of many sectors.

A considerable literature tries to ex post assess the impact on efficiency of existing mergers.

Efficiency and supply structure are two extremely updated issues in the Italian water sector.

In this work the aim of the empirical study is to test the potential gains from merging water suppliers, on a sample of 37 Italian water companies

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[20] Economies of scope prevail, if joint production is cheaper than separate production. With two products, this means that $C(y1, y2) < C(y1, 0) + C(0, y2)$, where $C(y1, y2)$ is the minimal costs of producing products 1 and 2 in the amounts y1 and y2.

(data refers to as 2009) and to decompose the potential gains or losses into technical efficiency (improvement of efficiency in individual firms), harmony effects (remix of inputs and outputs in inter-firms markets) and scale effects (increase of the production scale).

The Data Envelopment approach (DEA) in Bogetoft and Wang (2005), is followed.

In order to define new policies to be applied in the Italian water sector, it is necessary to perform some empirical studies on efficiency enlarging the existing research. In Italy, there are applications aimed at finding the lowest efficient size but at the same time nobody in Italy has analyzed the issue of efficiency associated to merging ex ante water companies.

2. Bogetoft and Wang's DEA approach: estimating the potential gains from merging

The efficiency of a single DMU, says DMU_i, is measured by the so-called "input-based Farrell measure" (1957):

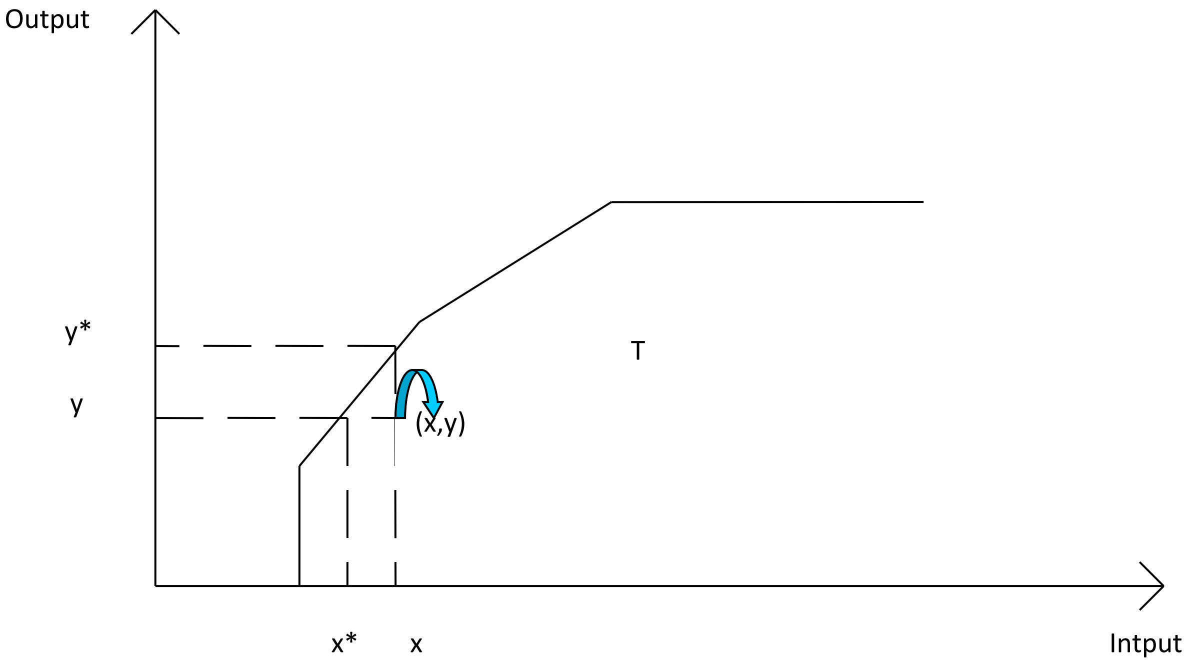
$$E^i = \text{Min}\ \{E \in \Re_o \mid (Ex^i, y^i) \in T\}$$

i= number of observations.

, where E^i is the maximum proportional input reduction allowing to produce output (input-output oriented).

Example 1. Farrell efficiency on one input-one output example (see Figure 7).

Figure 7. Farrell efficiency on one input-one output.



Input x can be reduced to x^* without losing output; output y can be increased to y^* without using more resources.

As the underlying production set T is not often known, it can be estimated by means of the Data Envelopment Analysis (DEA) approach.

In the case examined here, called "input-oriented" it is said that the unit is operating at its maximum efficiency when it is not possible to contract proportionally the input given the output. In such conditions, the DMU operates under optimal conditions and could not improve his position.

An efficiency score value $E^i = 1$ shows that the DMU could not proportionally reduce its input without violating the condition of belonging to T. This means that the observed unit is fully efficient. Instead, when $E^i < 1$, it is possible a reduction of the input and the unit should use a percentage of its inputs, for the same output, in order to reach full efficiency.

DMU_J is the merged unit. There is a number of possible mergers.

The potential overall gains associated to merging the J-DMUs are as follows:

$$E^J = \text{Min}\ \{E \in \Re_o \mid (E[\textstyle\sum_{j \in J} x^j], \sum_{j \in J} y^j) \in T\}$$

where J= number of mergers.

such that E^J is the maximal proportional reduction on the aggregated inputs $\sum_{j \in J} x^j$ allowing the production of the aggregated outputs $\sum_{j \in J} y^j$.

If $E^J < 1$, the merger produces savings, if $E^J > 1$, the merger is not beneficial.

If a DEA estimate for the unknown production possibility set T is imposed, the following measures of the potential merger gains are got.

$$\min_{E^J,\ \lambda} E^J$$

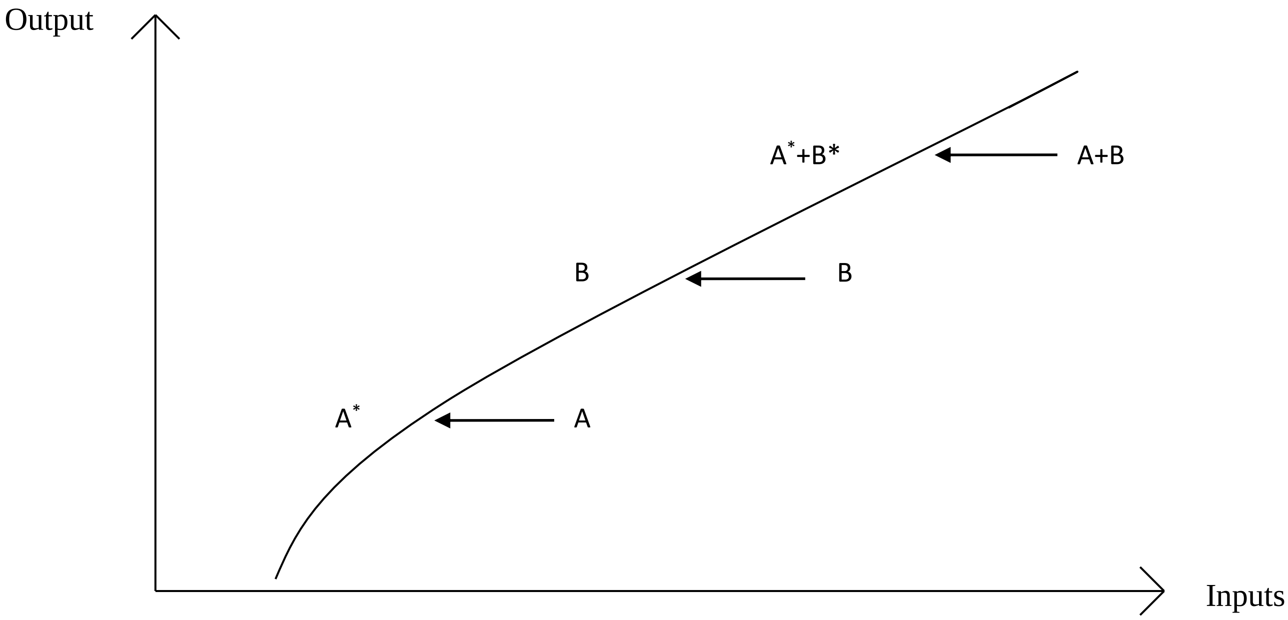
$$\text{s.t. } E^J\left[\sum_{j \in J} x^j\right] \geq \sum_{i \in I} \lambda^i x^i$$

$$\left[\sum_{j \in J} x^j\right] \leq \sum_{i \in I} \lambda^i y^i$$

$$\lambda \in \Lambda\,(k)$$

Technical efficiency effect (see Figure 8)

Figure 8. Technical efficiency example.



If the organizations merge and operate as in the past (A and B dots) there are considerable potential savings, as shown by the “A+B” distance according to the production possibility set. If optimized businesses A* and B* is integrated, this would lead to the aggregate dot “A*+B*” where the potential savings are considerably less than in “A+B”. This aspect is called learning or technical efficiency effect.

The potential overall gains from merging still include inefficiencies of the individual firms from merging that cannot be attributed to a merger.
According to Bogetoft and Wang’s approach, in order to adjust the overall merger gains for the technical efficiency effect, the original units are projected to the production possibility frontier and the projected plans are

used as a basis for evaluating the remaining gains from the merger. This result is labelled as the adjusted overall gains from the merger.

$E^{*J} = \text{Min}\ \{E \in \Re_o \mid (E[\sum_{j \in J} E^j x^j], \sum_{j \in J} y^j) \in T\}$

For $E^{*J} < 1$ a merger is beneficial, otherwise costly.

Using DEA estimate for T, the following potential measure of adjusted overall gains is obtained:

$$\begin{aligned} & \text{Min } E \\ & E, \lambda \\ & \text{s.t. } E^J[\textstyle\sum_{j \in J} E^j x^j] \geq \sum_{i \in I} \lambda^i x^i \\ & \qquad [\textstyle\sum_{j \in J} y^j] \leq \sum_{i \in I} \lambda^i y^i \\ & \qquad \lambda \in \Lambda\,(k) \end{aligned}$$

By means of this $T^j = E^J / E^{*J}$ it's got $E^J = T^J * E^{*J}$

where $T^J[0,1]$ is the technical index stressing what can be gained by making all companies efficient. In other words, it represents efficiency improvement potentials resulting from individual inefficiencies.

The technical effect is always positive ($T^J \leq 1$), since $E^J < E^{*J}$.

The authors propose a way to decompose the adjusted overall gain. A first step will consider that the merger units will operate with somehow different input and output mixes, which can be more or less powerful. In order to capture the mix (harmony or scope effect) gains we have to determine how much of the average input could be saved in the production of the average output, i.e. by the measure H^J. So the harmony effect aims to represent the potential efficiency gains from a reallocation in the mixture of inputs and outputs within a merged company as compared to the pre-merger firms.

$$H^J = \text{Min } \{H \in \Re_o \mid (H[|J|^{-1} \sum_{j \in J} E^j x^j], |J|^{-1} \sum_{j \in J} y^j) \in T \}$$

We look at the average input and output as we do not want the expansion of size to come into play. Using the average, it's most relevant if the firms in "H" are not too different in size to start with.

To be noted that if $H^J<1$, all this could be advantageous.

If a DEA estimate of T is performed, the following operational measure of potential harmony gains is got:

$$\min_{H, \lambda} H$$

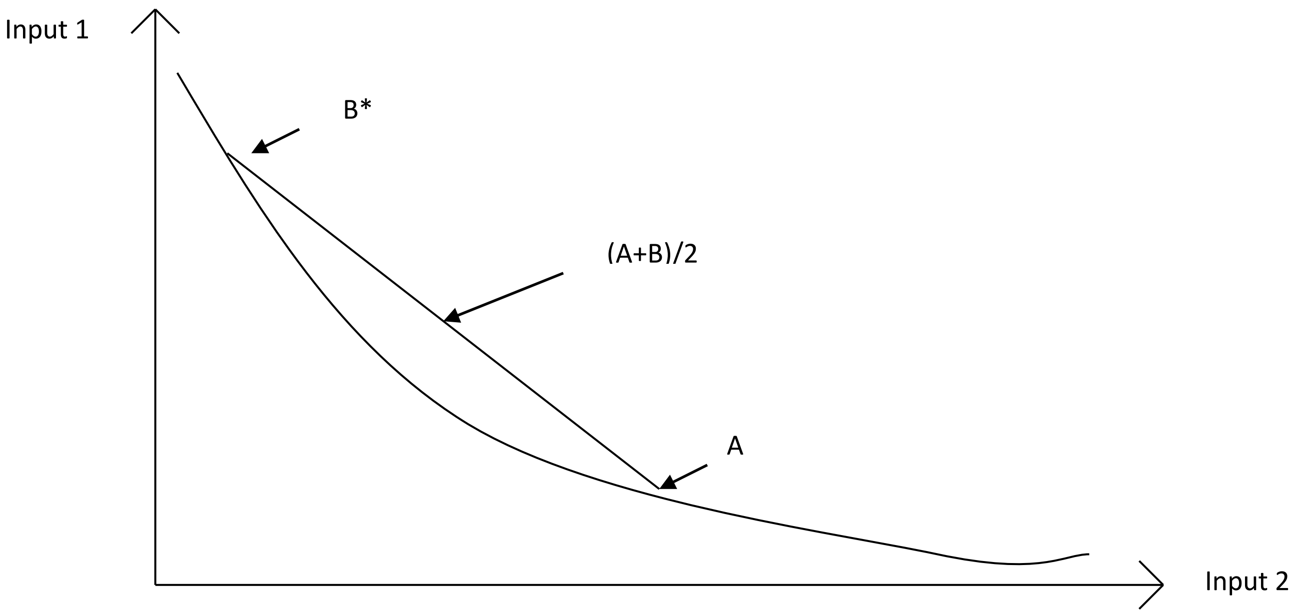
$$\text{s.t. } H[|J|^{-1} \sum_{j \in J} E^j x^j] \geq \sum_{i \in I} \lambda^i x^i$$

$$[|J|^{-1} \sum_{j \in J} y^j] \leq \sum_{i \in I} \lambda^i y^i$$

$$\lambda \in \Lambda (k)$$

Harmony or scope effect (see Figure 9).

Figure 9. Harmony or scope effect example



From the graph it is seen that A is quite Input 1 intensive while B is Input 2 intensive. The rate of substitution between Input 1 and 2 is different in the two firms. If the factors are moved as indicated in the graph, both firms end-up at (A+B)/2, where there are opportunities for savings. We talk about this effect as of harmony or scope effect.

In addition to these effects, a merger will have an impact on the scale of operation. The last one is called scale or size effect. In particular, size gains are assessed by asking how much can be saved increasing the production size by operating on a full scale:

$$S^J = \text{Min } \{S \in \Re_o \,|\, (S[H^J \textstyle\sum_{j \in J} E^j x^j], \textstyle\sum_{j \in J} y^j) \in T \}$$

S^J <1 means that there are potential economies by operating on a full scale; S^J>1 shows the opposite.

The DEA measure of T for potential size gains as follows:

$$\min_{S,\ \lambda} S$$

$$\text{s.t. } S[H^J | \textstyle\sum_{j\in J} E^j x^j] \geq \sum_{i\in I} \lambda^i x^i$$

$$\textstyle\sum_{j\in J} y^j \leq \sum_{i\in I} \lambda^i y^i$$

$$\lambda \in \Lambda\ (k)$$

Synthetically the decomposition of the overall potential gains from merging is written as follows:

$$E^J = T^J * H^J * S^J$$

where E^J is decomposed into a technical efficiency index "T^J", a harmony index "H^J" and a size index "S^J".

3. The empirical application

3.1 The sample

The analysis is based on data from different sources: water companies web-sites, interview. The aim of this analysis is to test the potential gains associated to merging Italian water companies (as it is said 22 possible mergers are considered). The sample contains both small and large water firms.

Following Bogetoft and Wang's approach in our analysis, we will consider as Decision Making Units (DMUs) 37 companies over the year 2009 performing the input into output and the possibility set "T" under given assumptions of convexity, variable returns to scale[21], additivity.

The DMUs sample used was already described in the previous chapter 3.

One input and two outputs used are shown in the following Table 18.

[21] Variable return to scale is used as no assumptions are made on the size effect (by crs, size effect is equal to 1).

Table 18. The variables.

Variables	
Inputs	**Outputs**
Tcost	Users
	Ydep

Where:

Tcost = total production costs (000 €) ;

Users = number of users as for water distribution sector;

ydep = Mc (000000) of treated water;

For the representation of the main activities of water utilities, the output measures in our model are the number of users to the water supplied and the quantity (Mc) of treated water. Total costs as inputs concern the cost of raw materials and service and the cost of labour

22 mergers are simulated, whose features are shown through the descriptive statistics as follows (Table 19). Each mergers involves contiguous units belonging to the same region.

Table 19. Descriptive statistics

22 mergers

Statistics	Tcost (000 €)	Users	ydep (Mc(000000))
Min	19.775	45.930	8
Max	324.182	940.026	236
Average	163.784	489.239	74

37 decision making units

Statistics	Tcost (000 €)	Users	ydep (Mc(000000))
Min	2325	5184	0
Max	371567	1231459	352
Average	72290	214563	42.24

3.2 The results

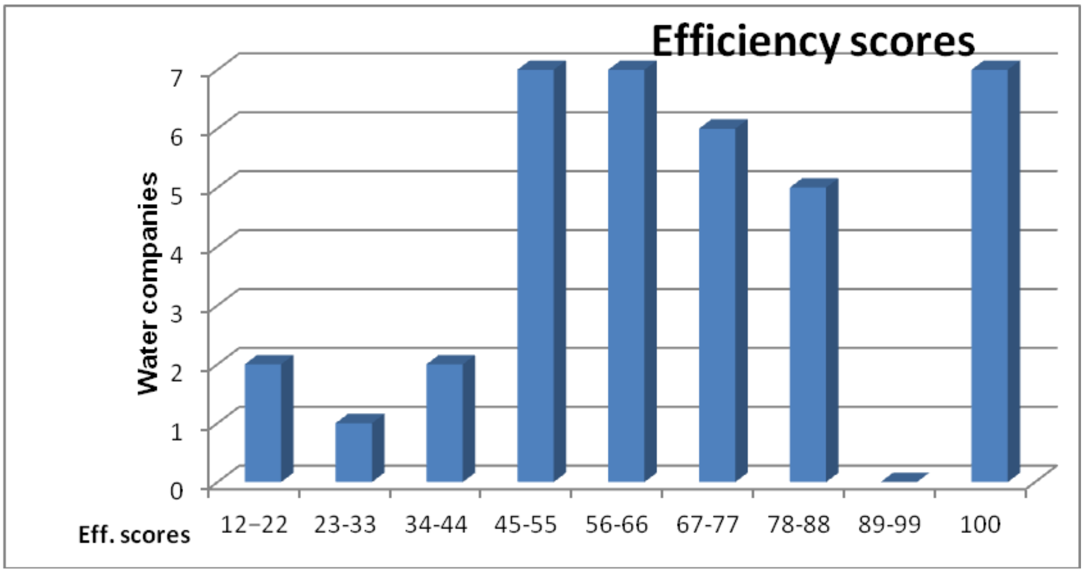
We consider mergers of 37 Italian water utilities into 22 hypothetical new companies (mergers).

We assume an input orientation in the DEA to analyze the possible reduction of input with outputs assumed to remain constant since the demand for water can be regarded as being exogenously given, not influenced by the water utilities.

Furthermore we assume variable return to scale (VRS).

In order to investigate the efficiency for each of the 37 individual companies, input based DEA scores are calculated for each of them. The efficiency distribution with variable return to scale (VRS) technology is shown in Figure 10.

Figure 10. E[J] Efficiency distribution of 37 Italian water companies in VRS Technologies (means 67.08 %).



If the technology is modelled using a variable return to scale DEA model, the estimated average losses of efficiency are 32.92%.

We have examined how much potentially could be saved by merging, by combining units belonging to the same Region in several ways. This leads to a total of 22 contiguous mergers involving two or three companies (Table 20).

Table 20. The mergers and their outputs.

Mergers (n. of companies)	Users	ydep (Mc(000000))
A1 (2)	228080	23
A2 (7)	351974	46
A3 (2)	127939	15
A4 (2)	45930	8
A5 (3)	156916	28
A6 (2)	126822	22
A7 (3)	762938	101
A8 (4)	922305	122
A9 (3)	818795	102
A10 (4)	779305	93
A11 (3)	734514	83
A12 (3)	810495	103
A13 (3)	911143	114
A14 (3)	575147	62
A15 (2)	353352	27
A16 (2)	106165	27
A17 (2)	121136	69
A18 (2)	111784	113
A19 (2)	87182	12
A20 (2)	430000	43
A21 (2)	828242	123
A22 (2)	940026	236

Where:

Users = number of users as for water distribution sector;

ydep = Mc (0000000) of treated water.

We’ll test the merger gains from all these combinations using variable return to scale DEA-models. The distribution of merger gains is shown in Table 21, where some cases with no potential gains are also indicated. Table 22 summarize the results in Table 21 by using descriptive statistics.

Table 21. The distribution of merger gains.

Mergers (n. of companies)	E^J (%)	T^J (%)	E^{*J} (%)	H^J (%)	S^J
A1 (2)	67.83	65.95	102.85	99.75	1.03
A2 (7)	68.43	50.67	135.06	96.54	1.40
A3 (2)	76.16	76.29	99.83	99.17	1.01
A4 (2)	15.94	19.56	81.50	83.73	0.97
A5 (3)	34.03	36.19	94.04	93.23	1.01
A6 (2)	62.93	63.72	98.76	98.08	1.01
A7 (3)	86.05	57.13	150.62	100.00	1.51
A8 (4)	81.09	57.31	141.49	100.00	1.41
A9 (3)	77.38	52.44	147.56	100.00	1.48
A10 (4)	90.36	58.05	155.66	100.00	1.56
A11 (3)	77.31	53.27	145.14	100.00	1.45
A12 (3)	77.52	57.70	134.35	100.00	1.34
A13 (3)	80.62	57.14	141.08	100.00	1.41
A14 (3)	82.36	51.22	160,81	100.00	1,61
A15 (2)	71.55	51.90	137.85	99.87	1.38
A16 (2)	51.40	51.69	99.44	99.26	1.00
A17 (2)	22.05	23.62	93.37	92.56	1.00
A18 (2)	146.94	100.00	146.94	100.00	1.47
A19 (2)	68.25	72.13	94.62	95.33	0.99
A20 (2)	73.82	52.81	139.78	92.81	1.51
A21 (2)	90.46	79.34	114.02	96.80	1.18
A22 (2)	112.60	81.00	139.02	100.00	1.39

Table 22. Descriptive statistics.

Statistics	E^J (%)	T^J (%)	E^{*J}(%)	H^J (%)	S^J
Min	15.94	19.56	81.50	83,73	1.61
Max	146.94	100.00	160.81	100.00	0.97
Average	73.41	57.69	125.17	97.60	1.28

The merger "A1", for example, suggests a potential efficiency gain of 32.17%. The underlying units are technically inefficient. The technical efficiency measure captures what can be gained by making the individual firms efficient (34.1% of potential savings). There is a small potential harmony effect. There is no evidence of economies of scale; the size effect may not favour a merger. In this case it will be more costly to operate the companies jointly than individually.

In 20 out of the 22 cases a merger would be beneficial when looking at the potential overall gains (E^J).

Since those results still include the individual inefficiencies within water companies before merging, we calculate the corrected potential gains (E^{*J}). In 15 merger cases we find potential losses from a merger. At the mean we find potential merger losses of 25.17% (E^{*J}).

After calculating overall gains from merging, we provide the decomposition into the technical effect, the harmony effect and the scale effect.

At the mean, around 42% of the overall merger gains E^J could be realized by improving efficiency within the individual water utilities (the technical effect).

The harmony effect show significant potential gains in 12 cases. At the mean, less than 3% of the inputs could be saved by reallocating the outputs in the integrated companies.

Only two potential merger suggest positive scale effect. At the mean, there is no evidence of efficiency gains from an increase in firm size.

4. Bias-corrections by means of bootstrapping

4.1 Introduction

Our empirical analysis on the effect of merging contiguous Italian water company is based on the same Bogetofts's nonparametric Data Envelopment Analysis (DEA) but with bias corrections through bootstrapping (Chapter 3). The robustness of results is checked and guaranteed by means of bootstrapping bias correction.

Bootstrapping is a not parametric method which allow compute estimated standard errors, confidence intervals and hypothesis testing.

DEA and similar not-parametric estimators, offer numerous advantages, such as the flexibility advantage that one need not specify a (potentially erroneous) functional relationship between production inputs and outputs (no particular form is assumed for the frontier model).

However, the two major drawbacks are the sensitivity to outliers and extreme values, and the noise disallowance on the data (Simar and Wilson (2000, 2007)).

Indeed, in this chapter statistical inference is conducted using bootstrapping to correct for the bias in the simple empirical deterministic efficiency estimates. Simar and Wilson (2000, 2007) offer a detailed discussion about statistical inference through the use of bootstrapping.
When there are large inputs and outputs numbers, the imprecision of the results will be reflected on large biases, large variances, and wide confidence intervals (Simar and Wilson, 2007). In fact, in our analysis the problem arises from the fact that we have few observations with big output (as big as the simulated mergers). As we compare these last ones with a border that in that stretch is not well defined, the bias is large.

The next section show the basic steps of the bootstrap procedure we will follow in our application.

4.2 Bootstrapping in DEA (*Bogetoft and Otto (2011*))

This following application will implement the bootstrap algorithm of Simar and Wilson (1998), known as the smoothed homogeneous bootstrap to conduct bias correction in each step of the different linear programming problems of merger gains decomposition.
DEA estimators are biased by construction as follows:
$BIAS(\theta\ (x, y)) = E(\theta\ (x, y)) - \theta\ (x, y)$,

where:

x= input

y=output

θ =estimator

E = expected value

After downloading and installing R software, FEAR 1.15
package can be downloaded from
http://www.economics.clemson.edu/faculty/wilson/Software/FEAR
FEAR 1.15 consists of a software library that can be linked to the general-purpose statistical package R.
The routines included in FEAR 1.15 allow the user to compute DEA estimates of technical, allocative, and overall efficiency while assuming either variable, not-increasing, or constant returns to scale.

Description of simplified version of **boot.sw98**

In what follows we shall use the following terms:

$(x^1, \dots, , y^{\dagger}1), \dots, (x^{\dagger}k, \dots, y^{\dagger}k)$ The observations.

θ^k The true efficiency based on the true but unknown technology T

$\hat{\theta}^K$ DEA-estimated efficiency and $\hat{T}$ the estimated DEA technology.

θ^{kb} The bootstrap replica b estimate based on the replica technology T^b

$\theta^{k\bullet}$ The bootstrap estimate of θ^k

$\tilde{\theta}^k$ The bias-corrected estimate of θ^k

Description of the boot.sw98 version.

(1) Compute $\hat{\theta}^k$ as solution to min $\{\theta \mid \theta x^k, y^k) \in T\}$ for $k = 1,\ldots,n$.

(2) Use bootstrap via smooth sampling from $\hat{\theta}^1, \ldots, \hat{\theta}^K$ to obtain a bootstrap replica $\hat{\theta}^{1*}, \ldots, \hat{\theta}^{K*}$. This is done as follows

(2.1) Bootstrap sample with replacement from $\hat{\theta}^1, \ldots, \hat{\theta}^K$, and call the results $\beta^1, \ldots, \beta^K$.

(2.2) Simulate standard normal independent random variables $\epsilon^1, \ldots, \epsilon^K$.

(2.3) Calculate

$$\tilde{\theta}^k = \begin{cases} \beta^k + \mathbf{h}\,\epsilon^k & if\ \beta^k + \mathbf{h}\,\epsilon^k \leq \mathbf{1} \\ \mathbf{2} - \beta^k + \mathbf{h}\,\epsilon^k & otherwise \end{cases}$$

Note that $\tilde{\theta}^k \leq 1$.

(2.4) Adjust $\tilde{\theta}^k$ to obtain parameters with asymptotically correct variance, and then estimate the variance

$$\hat{\sigma}^k = \frac{1}{n}\sum_{k=1}^{K} (\hat{\theta}^K - \bar{\hat{\theta}})^2$$

and calculate

$$\theta^{k*} = \bar{\beta} + \frac{1}{\sqrt{1 + \frac{\mathbf{h}^2}{\hat{\sigma}^2}}}(\tilde{\theta}^k - \bar{\beta})$$

where $\bar{\beta} = \frac{1}{n}\sum_{k=1}^{K} \hat{\beta}^k$

(3) Calculate bootstrapped input based on bootstrap efficiency $x^{kb} = \frac{\hat{\theta}^{k}}{\theta^{k*}} x^{k}$

(4) Solve the DEA program to estimate θ^{kb} as

$$\theta^{kb} = \min\{\theta \geq 0 \,|y^{k} \leq \sum_{j=1}^{K} \lambda_j y_j, \theta x^{k} \geq \sum_{j=1}^{K} \lambda_j x^{kb}{}_j,$$

$$\lambda_j \geq 0, \sum_{j=1}^{K} \lambda_j = 1 \} \qquad (k = 1, \dots, n)$$

(5) Repeat the steps from (2.1) to obtain the bootstrap estimates

$$(\theta^{*}1b, \dots, \theta^{*}Kb) \qquad (b = 1, \dots, B)$$

(6) Calculate the mean and the variance of $(\theta^{1b}, \dots, \theta^{Kb})$ to get the bootstrap estimate $\tilde{\theta}^{k*}$, and the variance.

4.3 The application

The aim of this analysis is to test the potential gains associated to merging Italian water companies (as it is said 22 possible mergers are considered).

Following Bogetoft and Wang's approach in our analysis, we will consider as Decision Making Units (DMUs) 37 companies over the year 2009 performing the input into output and the possibility set “T” under given assumptions of convexity, variable returns to scale[22], additivity.

The DMUs sample used was already described in the previous applications.

One input and two outputs used are shown in Table 13.

A subsample of 22 contiguous mergers is selected belonging to the same Italian Region, whose features are shown through the descriptive statistics as follows (Table 14).

Bias-corrected efficiency scores of 37 unmerged Italian water companies for variable returns to scale

The data contain observations on p = 1 inputs and q = 2 outputs for n = 37 Italian unmerged water companies.
Variable return to scale are assumed.
The results from the dea and boot.sw98 commands can be manipulated to produce LaTeX code for a table:
At this point, table.in (Table 18) is a (37 × 7) matrix, with each row corresponding to an observation in the data. The first column contains the observation number (1–37); the second column contains the DEA estimates of the Shephard input distance function for each observation; columns 3 contains a bias-corrected estimates of the Shephard input distance function, obtained by subtracting the bootstrap bias estimate from the original

[22] Variable return to scale is used as no assumptions are made on the size effect (by crs, size effect is equal to 1).

distance function estimates in dhat; columns 4–5 contain the bootstrap bias and variance estimates, respectively; and columns 6–7 contain estimated upper and lower bounds for 95-percent confidence intervals obtained by bootstrapping.

The LaTeX code in table.in can be written to a file named table in.tex using the command write (table.in,file="table in.tex").
Inserting the code into a LaTeX document, a table of results in Table 23 is produced.

Table 23. The average efficiencies for the unmerged Italian water companies.

Units	Eff. Scores (VRS)	Eff. Bias-Corrected	Bias	Var	Lower Bound	Upper Bound
1	2.0389	2.3533	-0.3144	0.0241	2.0699	2.6516
2	1.0000	1.3623	-0.3623	0.0457	1.0263	1.9033
3	2.2691	2.4598	-0.1907	0.0093	2.3061	2.6806
4	1.5681	1.7244	-0.1563	0.0096	1.5859	1.9465
5	1.2219	1.3254	-0.1035	0.0029	1.2400	1.4520
6	1.2917	1.6210	-0.3293	0.0357	1.3151	1.9977
7	1.9893	2.2426	-0.2533	0.0148	2.0299	2.4985
8	2.1181	2.3540	-0.2359	0.0135	2.1583	2.6077
9	1.1950	1.3321	-0.1371	0.0048	1.2189	1.4936
10	1.0000	1.0868	-0.0868	0.0018	1.0191	1.1851
11	1.6490	1.9093	-0.2603	0.0180	1.6812	2.1858
12	1.3174	1.4303	-0.1129	0.0031	1.3429	1.5557
13	5.6941	6.2441	-0.5500	0.0777	5.7878	6.8560
14	3.6161	4.3172	-0.7011	0.1500	3.6905	5.1391
15	1.5218	1.7046	-0.1828	0.0094	1.5522	1.9291
16	1.5061	1.6479	-0.1418	0.0055	1.5317	1.8093
17	1.5602	1.8766	-0.3164	0.0268	1.5881	2.1999
18	1.9021	2.0900	-0.1879	0.0092	1.9381	2.3008
19	1.9279	2.1956	-0.2677	0.0211	1.9579	2.4837
20	1.4616	1.5894	-0.1278	0.0040	1.4888	1.7399
21	1.1536	1.3445	-0.1909	0.0118	1.1772	1.5738
22	1.5709	1.7234	-0.1525	0.0063	1.6018	1.9045
23	1.5857	1.8093	-0.2236	0.0131	1.6182	2.0438
24	1.4215	1.6368	-0.2153	0.0118	1.4552	1.8855
25	1.0000	1.2129	-0.2129	0.0101	1.0265	1.4096

26	1.0000	1.2446	-0.2446	0.0126	1.0261	1.4664
27	1.8902	2.1165	-0.2263	0.0159	1.9164	2.3805
28	1.4745	1.6487	-0.1742	0.0074	1.5048	1.8418
29	1.8596	2.1247	-0.2651	0.0189	1.8924	2.4330
30	1.1387	1.2355	-0.0968	0.0024	1.1562	1.3438
31	1.0000	1.1609	-0.1609	0.0056	1.0225	1.3060
32	1.9246	2.0989	-0.1743	0.0106	1.9558	2.3475
33	2.5649	2.8315	-0.2666	0.0276	2.5984	3.2049
34	1.0000	1.3693	-0.3693	0.0455	1.0274	1.9046
35	1.1390	1.3731	-0.2341	0.0185	1.1610	1.6625
36	1.0000	1.3613	-0.3613	0.0437	1.0237	1.8343
37	10.949	13.554	-2.6055	2.4799	11.144	16.724

Interpretation of results

Individual efficiencies of the firms relative to the boundary of the convex hull of the input output (Simar and Wilson 2007) are calculated by means of DEA. This one evaluate by how much of the input may be proportionally contracted with the output held fixed.

Table 18 shows the bias-corrected individual efficiencies for the Italian water unmerged companies, under variable returns to scale. Results were produced using 2000 bootstrap replications for each observation. Of 37 observation in the data, 7 appear efficient as indicated by distance function estimates equal to 1, in the second column of Table 23. The remaining 30 Italian water unmerged companies have distance functions values higher than 1. Table 23 shows that the estimated biases are negative, as expected, and in many cases large, while the estimated variances are quite small.

For example, observation 2, which appear efficient for the only original distance function estimate, has a bias corrected distance function of 1.3623, suggesting that the same outputs could have been produced while scaling inputs by more than 36%. The estimated 95% confidence interval for this observation indicates that inputs could have been reduced by between 2.63 % and 90.33 %.

Bogetoft and Wang's paper expresses the efficiency scores "in the Farrell way", i.e. from 0 to 1, while the R software calculate them "in the Shephard way", i.e. from 1 to ∞. So the bias-corrected results just obtained with R can be manipulated to convert them in the Farrell way (Table 24).

Table 24. Bias-corrected efficiency scores for the unmerged Italian water companies.

Units	Bias-corrected efficiency scores (%)
1	42.49
2	73.41
3	40.65
4	57.99
5	75.45
6	61.69
7	44.59
8	42.81
9	75.07
10	92.01
11	52.38
12	69.92
13	16.02
14	23.16
15	58.66
16	60.68
17	53.29
18	47.85
19	45.55
20	62.92
21	74.38
22	58.02
23	55.27
24	61.05
25	82.45
26	80.35

27	47.25
28	60.65
29	47.07
30	80.94
31	86.14
32	47.64
33	35.32
34	73.03
35	72.83
36	73.46
37	7.38

If the technology is modelled using a variable return to scale DEA model, the estimated average losses of efficiency are 42.17 %. This last value is bigger than the value obtained in the last chapter (32.92%). Thus this difference shows the importance to correct for the bias.

Decomposition of bias-corrected potential merger effects for variable returns to scale. The results.

We calculate the overall potential merger effects for variable return to scale, based on the bias-corrected efficiency estimates. We decompose these overall effects into real merger effects (synergy and size effect together) and technical efficiency effects. Table 25 presents results for 23 hypothetical Italian water companies mergers. Table 26 instead summarize the results in Table 25 by using descriptive statistics.

Table 25. The distribution of merger gains.

Mergers (n. of companies)	**E^J (%)**	**T^J (%)**[23]	**E^{*J} (%)**	**H^J (%)**[24]	**S^J**
A1 (2)	59.66	69.60	85.71	92.28	0.93
A2 (7)	60.21	55.92	107.68	86.93	1.23
A3 (2)	69.81	76.14	91.69	91.89	0.99
A4 (2)	14.54	19.56	74.35	72.39	1.03
A5 (3)	30.45	36.16	84.22	85.59	0.98
A6 (2)	57.16	63.74	89.67	89.94	0.99
A7 (3)	69.90	53.58	130.46	100	1.30
A8 (4)	63.27	51.21	123.56	100	1.24
A9 (3)	62.50	48.77	128.16	100	1.28
A10 (4)	73.62	54.85	134.23	100	1.34
A11 (3)	63.88	50.57	126.33	100	1.26
A12 (3)	62.62	53.03	118.08	100	1.18
A13 (3)	63.19	51.27	123.24	100	1.23
A14 (3)	69.33	50.22	138.05	100	1.38
A15 (2)	62.36	51.64	120.77	91.02	1.33
A16 (2)	46.10	51.66	89.24	89.72	0.99
A17 (2)	17.84	23.58	75.65	78.83	0.96
A18 (2)	146.95	136.85	107.38	84.15	1.28
A19 (2)	63.08	72.25	87.31	87.25	1.00
A20 (2)	63.58	51.11	124.41	82.14	1.51
A21 (2)	72.18	69.69	103.58	83.45	1.24
A22 (2)	146.95	118.69	123.81	97.51	1.27

[23] With bootstrapping $\mathbf{T^J}$ is not always <1.

[24] We assume a convex technology, thus each linear combination of feasible observations must result feasible. For this purpose we decide to fix the superior limit of $\mathbf{H^J}$ to 100%. $\mathbf{S^J}$ in bootstrapping is calculated in a residual way ($\mathbf{E^{*J}/ H^J}$).

Table 26. Descriptive statistics.

Statistics	E^J (%)	T^J (%)	E^{*J}(%)	H^J (%)	S^J
Min	17.84	19.56	74.35	72.39	1.51
Max	146.95	136.85	138.05	100.00	0.93
Average	65.41	59.55	108.53	91.50	1.18

In 20 out of the 22 cases a merger would be beneficial when looking at the potential overall gains (E^J).

Since those results still include the individual inefficiencies within water companies before merging, we calculate the corrected potential gains (E^{*J}). In 14 merger cases we find potential losses from a merger. At the mean we find potential merger losses of 8.53% (E^{*J}).

After calculating overall gains from merging, we provide the decomposition into the technical effect, the harmony effect and the scale effect.

At the mean, around 40.45% of the overall merger gains E^J could be realized by improving efficiency within the individual water utilities (the technical effect).

The harmony effect show significant potential gains in 14 cases. At the mean, more than 8% of the inputs could be saved by reallocating the inputs in the integrated companies.

Only 6 potential merger suggest positive scale effect. At the mean, there is no evidence of efficiency gains from an increase in firm size.

Discussion

Using bias corrections, the overall merger gains E^J indicate greater efficiency improvement potentials as compared to the results without bias corrections (Table 27). At the mean the harmony effect and the scale effect bias-corrected results are better for an hypothetical merger.

Table 27. Descriptive statistics.

Statistics	**E^J (%)**	**T^J (%)**	**E^{*J}(%)**	**H^J (%)**	**S^J**
DEA-VRS					
Min	15.94	19.56	81.50	83,73	1.61
Max	146.94	100.00	160.81	100.00	0.97
Average	73.41	57.69	125.17	97.60	1.28
DEA-VRS with bias-correction					
Min	17.84	19.56	74.35	72.39	1.51
Max	146.95	136.85	138.05	100.00	0.93
Average	65.41	59.55	108.53	91.50	1.18

Using bias corrections based on bootstrap methods proposed by Simar and Wilson (2007) we find that substantial merger gains are not expected for all the Italian water companies. At the mean the decomposition of these ones report positive technical and harmony effect, while only the bias-corrected scale index in 16 cases is not sufficient to make convenient merging. Law scale effects in the sample could still depend on the low number of observation of large-scale in the dataset, even if bias correction partially overcomes this issue.

Table 28 order the levels of output for two different groups of bias-corrected scale economies (bias-corrected S^J<1 and bias-corrected S^J>1).

Table 28. A further comparison.

Statistics	Mergers	Users	ydep (Mc(000000))
Bias-corrected S^J<1	22	144510	30.67
Bias-corrected S^J>1	22	591446	86.75

Economies of scale are present for a maximum of 127939 users and for a maximum of 69000000 Mc of treated water.

The lowest size to have diseconomies of scale correspond to 45930 users.

For medium-big mergers potential scale effects could be substituted for example by a cooperation between different firms.

As compared to the results of economies of scale in the estimate of the Translog cost function for 37 Italian water companies, the lowest size to have diseconomies of scale is similar (45930 users for DEA-VRS bias-corrected model vrs 37000 users for the estimate of the Translog cost function for 37 Italian water companies). Indeed results are quite consistent when relating on a cost model (estimate of the Translog cost function) rather than on a non-parametric efficiency model (DEA-VRS bias-corrected model).

Small Italian water utilities and small hypothetical mergers between them present economies of scale, i.e. of significant potentials for efficiency increases arising from an increase in firm size. These results are in line with the empirical evidence in the literature indicating diseconomies of scale for big operators see Fraquelli and Giandrone (2003).

4.4 Accounting for the operating environment

In the previous analysis we calculate standard DEA efficiency scores to evaluate the performance of the water utilities in a given data sample. After calculating overall gains from merging, we provide the decomposition into the learning effect, the harmony effect and the scale effect.

One important factor is that the operating environment effect may impact on the potential of consolidation.

Now we'll analyze how the environmental variables are significant or not-significant on the decomposition of the potential efficiency gains. We'll use the not-parametric Kruskal-Wallis test to test the statistical differences among subsamples.

We have data on the 22 hypothetical mergers. The data and the mergers are those described previously. The data contain the potential overall gains, decomposed into technical gains, harmony gains and scale gains for each merger, as resulted in the analysis reported in Chapter 2.4 of the PART 3 of this work. But now we also consider two environmental dummy data, the water losses and the population density already described previously. In table 29 we report all these considered data.

Table 29. Data

Mergers (n. of companies)	MO (%)	T (%)	MA (%)	H(%)	S	PER	DENS
A1 (2)	59.66	69.60	85.71	92.28	0.93	1	1
A2 (7)	60.21	55.92	107.68	86.93	1.23	0	0
A3 (2)	69.81	76.14	91.69	91.89	0.99	1	1
A4 (2)	14.54	19.56	74.35	72.39	1.03	1	0
A5 (3)	30.45	36.16	84.22	85.59	0.98	0	0
A6 (2)	57.16	63.74	89.67	89.94	0.99	1	1
A7 (3)	69.90	53.58	130.46	100	1.30	1	1
A8 (4)	63.27	51.21	123.56	100	1.24	1	1
A9 (3)	62.50	48.77	128.16	100	1.28	1	1
A10 (4)	73.62	54.85	134.23	100	1.34	1	1
A11 (3)	63.88	50.57	126.33	100	1.26	0	1
A12 (3)	62.62	53.03	118.08	100	1.18	0	1
A13 (3)	63.19	51.27	123.24	100	1.23	0	1
A14 (3)	69.33	50.22	138.05	100	1.38	0	1
A15 (2)	62.36	51.64	120.77	91.02	1.33	0	1
A16 (2)	46.10	51.66	89.24	89.72	0.99	0	0
A17 (2)	17.84	23.58	75.65	78.83	0.96	0	0
A18 (2)	146.95	136.85	107.38	84.15	1.28	1	1
A19 (2)	63.08	72.25	87.31	87.25	1.00	0	1
A20 (2)	63.58	51.11	124.41	82.14	1.51	1	0
A21 (2)	72.18	69.69	103.58	83.45	1.24	1	0
A22 (2)	146.95	118.69	123.81	97.51	1.27	1	0

Where:

PER = hypothetical dummy values of water losses (0 = low water losses; 1 otherwise);
DENS = hypothetical dummy values of merger population density. (0 = high area population density; 1 otherwise);

For Kruskal-Wallis, the hypotheses are:
H_0: the distributions of the efficiency scores are the same in the two groups (density below the mean).
H_1: the distributions are not the same.

Table 30 reports more significant results of the Kruskal-Wallis test for the sample. All calculations are conducted using the statistical software STATA.

Table 30. Kruskal-Wallis results.

PER statistics	**Ej (mean)**	**Ej*(mean)**	**Tj*(mean)**	**Hj*(mean)**	**Sj*(mean)**
Low losses	53.906	107.057	49.63	91.93	1.15
High losses	75.01	109.75	67.82	91.15	1.2
p-value	0.0131	0.2917	0.2643	0.8351	0.1824
DENS statistics	**Ej (mean)**	**Ej*(mean)**	**Tj*(mean)**	**Hj*(mean)**	**Sj*(mean)**
Low dens	70.52	114.62	63.12	95.46	1.195
High dens	56.48	97.87	53.3	84.57	1.15
p-value	0.1652	0.0454	0.3662	0.0016	13.662

The results show:

- **PER variable:** there are not significant differences between the scores for the decomposition of the potential overall merger gains.
- **DENS variable:** the component T^J of inefficiency (and so the variable MO) is not significantly affected from the effect of DENS. This last one prevalently focuses on technological characteristics impacting on MA, in particular on the harmony H. One explanation might be our focus on highly densely populated territories which allow to be served by operators more specialized. Thus they might benefit of consolidation because they have a more balanced mix of output.

  Furthermore the results show that when there is much difference of density between the hypothetical merged units the harmony is lower, otherwise the harmony is higher.

Concluding remarks

Empirical efficiency is tested in different samples and approaches, in order to read the presence or absence of economies of scale. Firstly, in a sample of 37 Italian water firms, by using the Translog total variable cost function, a parametric methodology, efficiency is estimated with two outputs (Mc of treated water and the number of users as for service water distribution), two variable inputs (price of work and price of raw materials and services) and a fixed factor (technical assets).

The economies of scale for Mc of treated water and number of users at the midpoint and for others levels of outputs are evident (1.15 in the short run and 1.25 in the long period).

We have compared the results obtained with this empirical work with the scale effects results for a sample of 23 selected mergers, by using a not-parametric approach, the Bogetoft and Wang's (2005) DEA method with a bias-correction through bootstrapping, and by performing the same inputs and outputs. This last investigation has studied the potential change in the efficiency from merging in a different contiguous way the Italian water companies belonging to the same Region and how these potential gains or losses of efficiency could be potentially decomposed in terms of technical, scope and scale effects.

Using bias corrections based on bootstrap methods proposed by Simar and Wilson (2007) we find that substantial merger gains are not expected for all the Italian water companies. At the mean the decomposition of these ones reports positive technical and harmony effect, while only the bias-corrected scale index in 17 cases is not sufficient to make convenient merging. However, we point out that the law scale effects in the sample might be partially influenced by the low number of observation of large-scale in the dataset.

As compared to the economies of scale results in the estimate of the Translog cost function for 37 Italian water companies, the lowest size to have diseconomies of scale is similar (45930 users for DEA-VRS bias-corrected model 37000 users for the Translog cost function estimate for 37 Italian water companies. Indeed results are quite consistent when relating on a cost model (estimate of the Translog cost function) rather than on a production model (DEA-VRS bias-corrected model).

Finally, further extension of our analysis might accounting for the operating environment. In particular, similar to the other network industries, operations of merging water utilities hightly depend on the operating environment and on the different features of a service area.

Thus the last step of the analysis by using the not-parametric Kruskal-Wallis test shows that more densely populated territories of benefit of merging allowing to be served by operators more specialized.

Finally economies of scale are evident for small-sized mergers. For the other hypothetically consolidated operators the sizing is not wrong.

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