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Essays on Water Economics

Phd Thesis

Academic Year 2012 - 2013

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Table of Contents

1 Introduction

Water is an indispensable resource for the survival and growth of every community. Its economic, ecological and welfare contributions are obviously many and varied. Throughout the millennia, mankind has developed new ways and technologies in order to improve water usage and management.

In the past 60 years, the demand for water has increased substantially, due to population growth and increased water use for industrial and energy purposes (Brown Weiss et al., 2005; Griffin, 2006). This unprecedented pressure on water has dramatically shown that, under certain circumstances, not only water is scarce, but it can sometimes be considered more as an exhaustible resource than a renewable one (Savenije, 2002). For instance, the extraction rate of water from aquifers is often higher than their filtration rate: this means that drinkable water from aquifers can sometimes be considered as an exhaustible resource.

Its indispensable nature, its role as a production factor and its scarcity have drawn economists' attention to water management. To this respect, the Dublin Conference on Water and the Environment, held in 1992, has indeed declared that water is an economic good, which implies that economic reasoning should apply both in its allocation and in its management decisions. For some (Briscoe, 1996), this definition entails that water should be priced at its economic value and that the markets should drive its allocation. For others, being an economic good just means that water allocation should be done on the basis of an integrated, multi-sectoral and multi-interest cost-benefit analysis (Green, 2000).

Irrespective of the school of thought, nowadays there is a widespread recognition that access to water and water management are among the major challenges of this Century (Hanemann, 2006). Since 2000, the UN started a flagship program on water, named the World Water Assessment Program (WWAP), whose main objective is to report on the status of global freshwater resources and the progress achieved in reaching the Millennium Development Goal related to water, that is halve, by 2015, the proportion of the global population that has no access to drinking water and basic sanitation.

The WWAP, as well as other global initiatives, is aware that access to water and water management intrinsically entail trade-offs among several factors, such as food, energy and the environment. Here again, irrespective of the school of thought, it is fair enough to say that economics is the subject more accustomed to addressing trade-offs.

And it was precisely a trade-off that got me into this field of research: I came across water while researching on another topic, that is renewable energies. This explains why three out of four papers study the interaction between energy production, water and the environment. More, the integrated water services that I have analyzed in the fourth paper share some basic characteristics of energy distribution, whose regulation and performance are much more advanced. Consequently, even though this thesis is about water economics, it is easy to spot my background in energy economics.

The thesis is structured as a collection of four papers and it is ideally divided into two parts: the first one, composed of just one paper, is an efficiency analysis of the Italian integrated water sector; the second part, made of the other three papers, is thematic and studies hydropower production in terms of rent generation and environmental impacts.

1.1 The first part: the Italian integrated water sector

The first paper – *What determines efficiency? An analysis of the Italian water sector* – offers an original evaluation of the efficiency of the biggest sample ever gathered of Italian water companies over a period of four years. The rationale for this paper comes from the recent reform that has empowered the Authority for Electricity and Gas (AEEG) to regulate also the water sector. The AAEG is about to reform the whole tariff system. Consequently, it is important to study firms' efficiency and its evolution over time. More, I have investigated the determinants of the efficiency scores.

The paper shows that despite a satisfactory mean level of efficiency, in the period under investigation, performance improvements have been limited. This urges the need to introduce a more stringent efficiency-enhancing regulation, by means of some performance-based regulation. Moreover, the results demonstrate that both the ownership structure and politics do have an impact on the efficiency of the firms: in particular, public shareholding and center-right local governments negatively affects firms' performances. This is another supporting argument for a more effective regulation that would ease political pressure over tariff decision making.

From the methodological viewpoint, I have opted for a two-step approach: I have used the non-parametric linear-programming technique of Data Envelopment Analysis (DEA), to estimate the efficiency score of the water companies in the sample and I have later used these scores as dependent variables in different regression analyses.

1.2 The second part: hydropower

The second part is devoted to analyze the interaction between hydropower production, the electricity market and the fluvial ecosystem. The rationale for this thematic part stems from the concession renewal of several hydropower schemes that is about to take place in Italy and in France, which has highlighted the trade-off between profitability and environmental sustainability. Both in Italy and in France, the renewal procedure has been structured as a beauty contest, where bidders have to present offers for technical and environmental improvement, as well as a revenue sharing percentage for Local Authorities. At present, both Countries have not yet issued technical details of their beauty contest procedures; still, it is easy to imagine that they will have to be shaped in order to comply with the requirements of the Water Framework Directive (WFD, 2000/60/EC). The WFD, among other things, requires that any user should pay the full cost of the water he is withdrawing. In particular, article 9.1 specifies that the costs of water have to include environmental and resource costs, in accordance with the polluter/user pays principle. Moreover, article 9 requires that the water pricing policy has to be derived from economic analysis, which will translate into a pricing scheme able to guarantee adequate incentives for users to use water resources efficiently and thereby contribute to the environmental objective of the Directive, that is the attainment of a good ecological status by 2015 for all European water bodies.

The first paper of the thematic part – *Hydropower rent in Northern Italy: economic and environmental concerns in the renewal procedure* – has two objectives: the first one is to estimate the hydropower rent in Italy, which has never been done before; the second one is to investigate the trade-off between rent seizing and environmental improvements. Due to budgetary constraints, in fact, Local Authorities consider the renewal procedure a good opportunity to increase their share in the hydropower business, by means of a 30% fee on revenues. This high fee, though, might reduce the commitment in asking stricter environmental requirements, as operators would lack the money to invest in mitigation measures.

As expected, results show very high estimates for the hydropower rent, averaging from 42.3 €/MWh to 70.8 €/MWh. These high values explain why the current rent sharing mechanism is considered unsatisfactory by Local and Central Authorities, as they keep less than 50% of the rent; instead, the introduction of the proposed 30% revenue sharing fee would increase the overall percentage accruing to them up to 90% of the rent. At the same time, the paper shows that this revenue sharing fee would hinder operators in implementing mitigation measures, which would significantly reduce flow alterations and improve ecosystem integrity. These measures, in fact, entail significant investments, consequently increasing capital costs and reducing the possibility to pay such a high revenue sharing percentage.

As a policy recommendation, I show that instead of the proposed 30% revenue sharing mechanism, a resource rent tax would reduce the trade-off between rent seizing and environmental protection, as it would guarantee cost recovery to operators and a satisfactory percentage to Local and Central Authorities.

The second thematic paper – *Estimating a performance-based environmental fee for hydropower production: a choice experiment approach* – develops a performance-based environmental fee able not only to internalize the environmental costs that hydropower causes, but also to stimulate producers to outperform existing environmental regulation: the more they outperform, the less they pay. The rationale of this paper stems from the WFD, which suggests the adoption of economic instruments to attain the environmental targets. An environmental fee (or tax) is a fee designed to achieve a well-defined environmental effect, at a minimum of excess burden. Contrary to other forms of taxation, if the environmental fee is optimally designed, then its revenue should be zero, as it would make more economic sense to meet the environmental objective than to pay the tax. In general, the application of an environmental fee requires the monetization of the environmental damage, in order to compare the cost of the tax and the monetary benefit of not incurring in that damage. With a performance-based environmental fee, the monetization is even more decisive, as the value of the fee is directly related to the environmental performance. Moreover, this type of fee requires a clear definition of the cause-effect relationship among different ways of managing hydropower production and their impact on different characteristics of the fluvial ecosystem.

After the theoretical design of the fee, the paper proposes a practical application in the Province of Sondrio, in Northern Italy. In this case, the value of the local fluvial ecosystem has been estimated with a discrete choice experiment (DCE). Given its characteristics, the DCE offers the possibility to estimate the total value of improvements to the environmental good under study as a consequence of the foreseen performances.

Results show that people are willing to pay to increase the ecological status of regulated rivers; in particular, the highest total willingness to pay (WTP) is above € 122 per household and per year. The values derived from the DCE have then been used to simulate the effects of the performance-based environmental fee: calculation shows that the fee does not hinder operators' profitability, but it does reduce the rent generated by hydropower production.

Finally, the third thematic paper – *Cheaper electricity or a better river? Estimating fluvial ecosystem value in Southern France* – applies the DCE approach to study the potential trade-off between revenue-sharing and environmental improvements in the Aspe valley, located in the French Pyrenees, where more than 100 MW of hydropower capacity are installed. As anticipated before, the renewal of hydropower concession have been designed as beauty contests, where bidders have to present offers for technical and environmental improvement, as well as a revenue sharing percentage for Local Authorities. The underlying hypothesis of the paper is that the higher the offer for environmental improvements, the lower the offer for revenue sharing. Accordingly, I study the emerging trade-off between a better environment and a higher percentage of money handed down to Local Authorities by estimating people's preferences. Therefore, I have conceived a DCE where I translate the revenue sharing in an immediate rebate in the electricity bill. Respondents could opt for a higher rebate, with the consequence that the fluvial ecosystem remains at its current status (that is, operators cannot perform worse than the incumbent from an environmental point of view), or for a lower (or even no) rebate for (substantial) fluvial ecosystem improvements. Of course, in real life, there will be no rebate; still, an increased amount of money for Local Authorities should mean either less local taxes or better local services. This justifies also why I targeted only people leaving in the Aspe region.

It is important to bear in mind that, even if I use a rebate as a bidding vehicle, the results return a willingness to pay and not a willingness to accept. The rebates, in fact, are not associated to ecosystem degradation, as at the highest level of rebate is associated the status quo. As a consequence, the experiment has a willingness to pay approach: I ask people whether they are ready to renounce to money they could spend on something else in order to have a better fluvial ecosystem.

Results show that people are willing to pay to increase the ecological status of the Aspe river; in particular, the highest total willingness to pay (WTP) is above € 96 per household and per year, which is considerable and comparable to what I have estimated for the Italian case.

In the end, I can say that the thematic part returns a convincing result: people do value considerably the improvement of the fluvial ecosystem they live close to and they are willing to pay to increase its ecological status. This is something that operators and Public Authorities have definitely to take into account if they want to have public acceptance and support in the renewal procedure.

1.3 References

Briscoe, J., 1996. Water as an economic good: the idea and what it means in practice. Proceedings of the World Congress of the International Commission on Irrigation and Drainage, September 1996, Cairo.

Brown Weiss, E., Boisson de Chazournes, L., Bernasconi-Osterwalder, N., eds., 2005. *Fresh Water and International Economic Law*. Oxford: Oxford University Press.

Green, C., 2000. If only life were that simple: optimisim and pessimism in economics. *Physics and Chemistry of the Earth*, 25, 205–212.

Griffin, R.C., 2006. *Water Resource Economics*. Cambridge: MIT Press.

Hanemann, W.H., 2006. The economic conception of water, in Rogers, P.P., Llamas, M.R., Martinez-Cortina, L., eds., *Water Crisis: myth or reality?,* London: Taylor & Francis plc.

Savenije, H.H.G, 2002. Why water is not an ordinary economic good, or why the girl is special. *Physics and Chemistry of the Earth*, 27, 741–744.

2 What determines efficiency? An analysis of the Italian Water Sector

Abstract

The Italian water sector has encompassed major changes since mid-90s when law 96/94 has entered into force. Next to private participation, integration of services and growth in production scales, the reform was intended to revolutionize the traditional financial model almost fully based on public funds. Although citizens, politicians and experts on water services have been debating for a long time on the impact of the reform on the industry, as well as on the fairness of a tariff system inspired by the concept of full cost recovery, we are still on a state of uncertainty. The final purpose of this paper is to provide regulators with guidelines that could be used to revise water tariffs in a way that may be cost-efficient, sustainable and fair to the most. According to the analyses, which rely on firm-specific *X-inefficiency* scores, despite a satisfactory mean level of performance, in the period under investigation, efficiency improvements have been limited. Moreover, the results demonstrate that both the ownership structure and politics do have an impact on the efficiency of the firms: in particular, public shareholding and centre-right local governments negatively affects firms' performances. To this respect, I think that a more effective regulation would also have the side effect of loosening the ties between politicians and managers.

Keywords: Water Policy, Water Distribution, Water Pricing, Efficiency.

JEL Classification: H44, L95

2.1 Introduction

Water supply industries around the world have been radically transformed in the last two decades due to liberalization, privatization and implementation of new regulatory design. These reforms were intended to enhance efficiency, productivity and quality of services provided. Italy has followed a similar path since 1994, when the so called Galli Law (l. 36/94) entered into force. Alongside with statutory efficiency and minimum quality standards, the law (and its subsequent amendments) set rules for delegation and private-public participation. This led to a final puzzle where fully public, mixed and listed water companies coexist. Albeit Italian water utilities distinguish from each other for other dimensions than ownership, this characteristic is the one that has been mostly debated. On the wave of rising prices for water services, some local representative started complaining that privatization was causing more damages than it was supposed to cure, due to the gambling of privates upon basic public needs (Massarutto,2009). The partial failure of the liberalization process and the growing concerns on private participation paved the way to a referendum in 2011. This latter has resulted in a break of the legislative framework, thus leaving a urge for supplementary reforms. As a consequence, there is a clear need for more information about the performance of the Italian water companies (Walter *et al*., 2009). Performance analyses do exist (Romano and Guerrini, 2011; Caliman and Nardi, 2010; Benvenuti and Gennari, 2008; Antonioli and Filippini, 2001); however, to date, there are no studies that investigate efficiency in Italy over several years nor studies on all the water services, namely distribution, sewerage and treatment. These analyses have been performed for several countries (Abbott and Cohen, 2009; Coelli and Walding, 2005). Establishing a more robust regulatory benchmark has become more and more urgent given that law 214/11 has empowered the Italian Regulatory Authority for Electricity and Gas to define, in a couple of years, tariff schemes to be implemented by water utilities.

The novelty of the study is threefold. First, I offer an original evaluation of the efficiency of the biggest sample ever gathered of Italian water companies over a period of four years. Second, I contribute to the debate on the likely impact of ownership upon the relative efficiency and the productivity of water companies. Third, I provide some guidelines for the future regulatory reform of the sector. From the methodological viewpoint I use non-parametric linear-programming technique of Data Envelopment Analysis (DEA), which has been suggested by several scholars for the water sector (Thanassoulis, 2000a&b). The orientation is to opt for an input minimization DEA, as the main objective for each water utility is to minimize costs rather than maximizing their output. Both constant and variable returns to scale are considered to test the role of both technical and allocative efficiency. I then investigate the determinants of the efficiency by performing different regression analyses.

The study shows that, despite a satisfactory mean level of efficiency, in the period under investigation, performance improvements have been limited, suggesting the need to introduce a more stringent efficiency-enhancing regulation. Moreover, the results demonstrate that both the ownership structure and politics do have an impact on the efficiency of the firms: in particular, public shareholding and center-right local governments negatively affects firms' performances.

The paper unfolds as follows: Section 2 briefly describes the Italian water distribution sector. Data and methodology used are described in Section 3, while Section 4 discusses the main findings. In Section 5, I perform some econometric estimates to explain the efficiency scores obtained with the DEA analysis. Finally, in Section 6 I draw some policy recommendations.

2.2 The Italian water distribution sector: a short description

Until the first half of the 90's, the management of water utilities was entrusted exclusively to municipalities and was performed *in-house*, i.e. performed directly from the local municipality, or thru a public grant. The result was a high number of firms, almost one for each municipality, with a subsequent low level of production efficiency together with poor quality of service provided[1].

Such scenery was completely reformed in 1994 by the Galli Law (law 36/1994). Its main objective was to enhance the efficiency of water resources by applying an "industrial" regime to the sector. The founding principles of such a measure were:

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[1] According to ISTAT, in 1999, five years after the Galli reform, the number of firms was still very high: 7,822.

1. The identification, delegated to the Regions, of hydrographic basins (*bacini idrografici*), i.e. of optimal license areas (*Ambito Territoriale Ottimale, ATO*), that could promote a corporate management of the process;
2. The separation of the control and auditing activites, through the creation of an authority for each optimal license area (Autorità d'Ambito Territoriale Ottimale), from the managerial activities, with the commitment of a single supervisor for the whole water integrated system (*Sistema Idrico Integrato, SII*, hereinafter) for each ATO;
3. A tariff regime with a full coverage of costs, both fixed and variable.

In other words, the goal was to realize both a vertical integration within the heterogeneous activities of distribution, treatment and sewage and a horizontal integration on a sufficiently big area for attaining economies of scale (Parisio, 2013).

In the end, the identification of the ATOs has been quite heterogeneous:

- 5 Regions (Val d'Aosta, Molise, Basilicata, Puglia and Sardegna) opted for unique regional ATOs;
- Calabria, Emilia Romagna, Liguria, Lombardia, and Sicilia defined the ATOs by the province boundaries, with the exception of the city of Milan, which alone constitutes an ATO;
- All other Regions (Abruzzo, Campania, Friuli-Venezia-Giulia, Marche, Piemonte, Toscana, Umbria, Veneto) opted for mixed ATOs, which can either be defined by single provinces or by the aggregation of more than one.

In the end, all Italian Regions, with the exception of Trentino-Alto-Adige (being a Region with a special statute), implemented the SII between 1994 and 2002, for a total of 91 ATOs.

The Galli law contemplated also the existence of CoNViRI (*Comitato Nazionale per la Vigilanza sull'uso delle risorse idriche*), a National Committee whose duty was to protect the interests of consumers and ensure a fair adjustment of water tariffs. Nevertheless, the whole system was centered on the AATOs. In fact, the newly defined Area authorities were required first to conduct a survey of the water system and then to set up a 20-year management and investment plan indicating the situation of the existing infrastructure, the quality of the service to attain, the expected future investments and the tariff to be applied. This plan represented the basis for the assignment procedure, defined with the financial law of 2002, which introduced three delegation procedures, namely: public tender, *in house* entrustment, direct grant to a mixed society where the private partner is chosen thru a tender.

The 2009 amendment of the Galli law (l. 166/2009) reduced the possibility for direct assignments, pushing the sector towards public tenders. In particular, all existing delegations granted through direct assignments were to be reassigned with public tenders. Moreover, the 2009 amendment introduced a safe return on investments equal at a national level (as before it was set by each AATO).

In June 2011, a referendum repealed both amendments, creating a legislative vacuum, only partially solved by the 214/11 legislative decree. As for the delegation procedure, Italy is back to the system that imposes public tenders only when the grantee is a private firm, letting again direct entrusting to public firms, under the supervision of local authorities. As for the return on investments in particular, and the tariff scheme more in general, the decree has devolved to the Regulatory Authority for electricity and gas (AEEG) the powers that had initially been exercised by AATOs and CoNViRI, which has been abolished. AEEG therefore has the function of defining and maintaining a reliable and transparent tariff system, reconciling the economic goals of operators with general social objective, and promoting environmental protection and the efficient use of energy.

2.2.1 The old tariff scheme

Until the referendum, the tariff system was designed as a *revenue cap*, but it was, *de facto*, a cost of service regulation. AATO had to determine the reference tariff on the basis of the 20-year investment and management plan. The basic revenue scheme was the following:

Equation 2-1

$$R_n = (C + A + R)_{n-1} \times (1 + RPI - X)$$

Where the revenues for year n (R_n) were equal to the sum of the allowed operative expenditures (OPEX), or variable costs, (C), the amortization (A) and the return on capital (R) for year *n-1*, multiplied by the inflation (RPI) and capped by the *X-efficiency term*. The peculiarity is that the revenues and the tariffs where not set on actual costs but on those foresaw in the plan. Every three years, if costs were higher than those modeled, operators could ask for the revision of the plan; only for differences bigger than 30%, then the AATO could ask for efficiency improvements. Till the referendum, the average tariff was about 1.2 Euros per cubic meter[2].

As we have seen, AEEG is now responsible for tariff setting. To this day, the authority has arranged the hearings of the interested parties with the aim to set the adequate standards apt to guarantee the quality of the service, intended as technical, environmental and commercial quality. We do believe that, in this context, an efficiency analysis of the sector is of extreme importance.

2.3 Efficiency in the Italian water distribution sector

2.3.1 Efficiency analysis: preliminary considerations

The performance of a firm is a measure of "how well" the firm converts inputs into outputs. Inputs and outputs can be measured as quantities or in monetary terms. In the first case, the focus will be on technical efficiency, that is how well a firm combines inputs to produce outputs; in the latter, instead, the focus will be on allocative efficiency, that is the ability of the firm to use the inputs according to their costs. Technical and allocative efficiency combined give an overall economic efficiency measure. Finally, as performance is a relative concept, it is necessary to compare the firm under study with a peer.

As stated in Coelli et al. (2005), there are basically four major methodologies to analyze firms' efficiency:

- Total factor productivity indeces;
- Least-squares econometric production models;
- Non parametric analysis, such as data envelopment analysis (DEA);

[2] Data from Utilitatis database, 2008

- Stochastic frontiers.

The first two methods are generally used to compare the evolution of the efficiency of a firm over time. They are the simplest methods as they assume that all firms under study are technically efficient. On the other hand, the last two methods do not assume that all firms are efficient and they are used to compare the relative efficiency of *n* peers. The main difference between the two methods is that DEA, being non-parametric, does not assume any specific production or cost function; stochastic frontier, instead, does require a functional form.

Given its flexibility, I have opted for the DEA. DEA is a multi-factor productivity analysis model, based on a non-parametric approach that measures the relative efficiency of the so-called Decision Making Units (DMU). Charnes et al. firstly introduced this analysis in 1978, as a tool that could extensively be applied in benchmarking and performance evaluation of various public institutions such as schools, libraries, hospitals, but also of private entities such as banks and production plants. It was later extended by other authors such as Banker, Charnes, and Cooper (2000) and extensively developed in the last two decades thanks to its versatility and loose assumptions.

The basic idea underlying this methodology is to envelop observed input-output linear combinations in order to retrieve an estimate of the best practice frontier for the decision making units, by solving a linear programming model. Units achieving the highest level of efficiency within the dataset will form the *best practice frontier* and will score 1 in the efficiency index. The remaining DMUs will reach an index lying between O and 1, which is inversely proportional to their distance from their virtual best. This score thus measures the potential reduction in the quantity (or costs) of inputs necessary to reduce the inefficiency (or *X-inefficiency*, under the cost case) of the firm, in relation to the optimal frontier. In this framework, efficiency is defined as the ratio of a linear combination of outputs over a linear combination of inputs (or input-costs). In other words, DEA methodology aims at reducing the ratio multi-input/multi-output towards a single virtual input and a single virtual output.

Clearly there are two ways to accomplish this. One is by maximizing the numerator, i.e. the outputs, keeping inputs constant. This is the so-called *output-oriented model.* Vice versa, when we keep output constant and we minimize the denominator, i.e. the inputs, we obtain an *input oriented model*.

DEA approach has been widely extended thanks to its various advantages. First of all, being a non-parametric model, no assumptions on input or output functional forms are required, apart from a general convexity presumption. This feature also avoids in misidentifying the effect of erroneous specifications in the functional form of technology and inefficiency with those of inefficiency. Secondly, it can be applied also in small datasets, even thou its discriminatory power would be less effective in small samples. Also, by increasing sample size it is more likely to have a higher number of efficient combinations of inputs and outputs, since there can be significant gaps between observations, being the frontier determined by a piecewise linear function. It is thus important to check for robustness of results. Being n and m respectively the number of inputs and of outputs, according to Cooper et al. (2000) the minimum number of observations should be given by the maximum between $3 \times (m + n)$ and$(m \times n)$.

Moreover, firms are not compared to statistical measures, but they are put in comparison directly against a peer or a combination of peers. Consequently, DEA can be easily applied to any regulated firm and it allows for control of other exogenous variables that might affect efficiency through a two step approach or also by adding them as non-controllable inputs or outputs in the linear programming. As a drawback, when adding these non-controllable variables, it is compulsory to know their classification as inputs or outputs a priori before the analysis is computed, in order to set the correct inequality in linear programming problem.

The main drawback of DEA is the absence of a random error. Any measurement error, noise or outlier can cause significant problem, being DEA an extreme point technique, and will be automatically interpreted as inefficiencies. The choice of outputs and inputs is thus very sensible, as it influences directly the scores. Also, being DEA a non-parametric technique, it does not permit for statistical hypothesis tests. Hence, it is not possible to test neither for the significance of the main variables included in the model nor for the significance of differentials in efficiency.

2.3.1.1 Statistical properties

As already seen, DEA estimators measure the level of efficiency relative to an estimate of an unobserved true frontier, conditional on observed data resulting from an underlying data generating process (DGP). The properties of the DEA estimators depend thus on this DGP which created the data sample. Simar and Wilson (2008) list several assumptions for the DGP:

- observations on inputs (*x*) and outputs (*y*) are realizations of *i.i.d.* random variables (*X,Y*) with density function *f(x, y);*
- The probability of observing and efficient unit approaches unity as the size grows;
- For all (*x, y*) belonging to the feasible production set, DEA estimators *ϑ(x,y)* are differentiable in (*x, y*);
- Convexity and closeness of the feasible production set;
- Free disposability of inputs and outputs;
- All outputs require the use of some inputs, that is no *free lunch hypothesis* (Bottasso et al., 2013).

Under these assumptions, the authors show that DEA efficiency estimator is consistent and has a known rate of convergence. (Simar and Wilson 2000). But still a closed form for the density function is yet to be derived. The authors propose a means for inferences about the efficiency of this estimator in a multivariate framework, through a methodology called Bootstrap DEA. The aim of this approach is to approximate the sampling distribution by simulating the DGP and to capture the sampling variation of the DEA estimator from the true estimator *[ϑDEA(x,y) -ϑ(x,y)].* Bootstrap DEA, thus, improves statistical efficiency in the second stage regression as it corrects from serial autocorrelation (Simar and Wilson, 2007).

2.3.1.2 Constant and variable return to scale

Return to scale describe what happens as the scale of production increases in the long run, when all input levels, including physical capital usage are variable i.e. chosen by the firm. Constant return to scale (CRS) apply when the change in output resulting from the change in all inputs is proportional. On the other hand, if the changes in output are not proportional, i.e. output either outperforms or underperforms in relation to inputs, then variable return to scale (VRS) apply. In other words, VRS index measures the real capability of a company to purchase, mix and consume inputs i.e the *allocative efficiency*, while CRS represents the productive efficiency of a DMU, given by the product of pure efficiency and scale, i.e. the *technical efficiency.*

2.3.2 Literature review

Investigations on efficiency of the Italian water sector do exist but are mostly small sampled and are limited in the time dimension. Since data collection is not entrusted to a public central administration, the lack of reliable and complete database is an issue and has limited the analysis so far. Romano and Guerrini (2011) provide an analysis of 43 Italian water mono-utilities to determine what affects their efficiency, using the DEA. They find that public owned companies are more efficient and thus better able to purchase and employ inputs when compared to mixed owned companies. Surprisingly, they also find that Southern and Central firms are more efficient compared to Northern firms, but they explain this unexpected result by proposing that it could be due to the higher rate of sanitation treatment per cubic meter shown by northern companies as well as to the size of firms, since companies in central-southern Italy are mostly large, and large companies typically have high scale efficiency.

Giolitti (2010) investigates the presence of economy of scale and density on a sample of 30 water firms in the years 2005-2007, using a translog variable cost function. She finds evidence for both economies of scale and density until a served population of 500,000 inhabitants.

Abrate *et al.* (2008) analyze the relationship between heterogeneity and inefficiency on 46 regulatory plans drafted by ATOs by means of cost frontier models on a 20-year period. Results show that part of the managerial inefficiency is due to structural nature. Operating costs are found to depend positively and significantly upon the extension of the service area and the number of municipalities. “The percentage of highlands influences costs negatively and significantly, thus indicating that higher expected costs for maintenance in highland areas are probably offset by the proximity to the water sources. Likewise, the geographical dummy shows a negative and statistically significant sign, thus denoting a structural shortfall in southern Italy, with respect to northern Italy, which might be attributed to the different status of the network and other capital facilities. This highlights the high penalization suffered by the southern area in terms of major maintenance and intervention costs" (Abrate *et al.*, 2008). Moreover, the authors assess that local authorities do not include in the regulatory long-term plans incentives to improve efficiency with respect to operative costs, which is in contrast with what suggested by the water reform. Hence, as policy implication they suggest that a benchmarking activity at a national level is necessary in order to provide the right incentives to improve efficiency.

Antonioli and Filippini in 2001 estimate a variable cost function using a sample of 32 water distribution firms operating at the provincial level over the period 1991-1995. They find that several explanatory variables such as price of labor, water loss and service area characteristics are significant in explaining efficiency. In particular the coefficient of chemical treatment is significant, confirming the relevance of geographical and morphological variables in water cost estimation. Nevertheless, the authors find no evidence that larger areas result in any economies in water distribution, imputing that a merger between two companies with adjacent service areas does not significantly decrease average cost.

Concluding, the datasets and the time dimensions of the studies already conducted in Italy are quite limited and neglect to investigate several variables, such as the political stability of the municipality of the firm, or the quality of water delivered.

2.3.3 The water companies in the sample

The sample consists of 54 companies that operate as regulated monopolist in the provision of water and wastewater services (SII, hereinafter) in specific areas of Italy. These utilities have been selected among the extensive list of companies to which the Italian local regulatory authorities (AATOs) entrusted the SII no later than 2007 (CoNViRI, 2009). Due to delays in the implementation of law 36/94, most of the companies have been entrusted between 2003 and 2007. Given the time perspective of the study and the need to collect data for the same companies over a 4 year period (2007-2010), those players that were inactive in 2007 or that have become so later on -

due to merges or changes in the local framework - have been excluded from the analysis. Table 2-1 describes the main features of the utilities in the sample as compared to the full list of Italian operators, as reported by CoNViRI (2009). Notwithstanding the partial coverage, the selected companies are representative of the Italian water industry as for geographical location, size, ownership structure, type of business and clients served.

Geographical location is crucial in that while in Northern and Central Italy there is abundance of rivers and lakes, in Southern regions (islands included) the water is scarcer and irregularities are more likely. Indeed, according to the most recent assessments by ISTAT (the Italian statistic Bureau), while less than 6% of clients suffers from irregularities in water distribution in the Northern regions, one out of three clients experiences severe service irregularities (with likely rationing of water especially in the summer) in the Southern regions. The sample encompasses firms located in any geographic area of the Country, with some 26% of the companies in the Northwest, 26% in the Northeast, 28% in the Centre and 20% in the South (including islands).

Regarding ownership, I have distinguished among publicly owned, mixed and privately owned companies. The former class includes utilities that are fully under the control of local entities, the latter those that are completely managed and operated by private parties, while the second group considers firms where private and public parties coexist due to the joining of private shareholders to traditional public ones. Concerning ownership, 56% of the selected companies are public, 24% are mixed and the remaining 20% is private. These figures match the Italian structure of the water sector where few less than 60% of the utilities are currently managed and operated by local authorities. Data on the shares held by the main shareholder have been collected as well to investigate, beside the effect of private participation on companies' relative efficiency, the impact of fragmentation in shareholding on cost-efficiency, an issue never taken into account in so far.

As in past assessments (Romano and Guerrini, 2011; Antonioli and Filippini, 2001), I have classified firms based on the number of residential consumers served. A water company will thus be defined as large, medium or small if it has respectively more than 250.000, between 50.000 and 250.000, or less than 50.000 customers, respectively.

Large companies prevail, both in the sample (60%) and in Italy. Medium (30%) and small (10%) follow. Although one can see a bias in the sample which takes in some 76% of the large companies listed by CoNViRI (2009), while leaving aside some 80% of the small ones, the distribution of clients served confirms that the data are representative and fully consistent with national paths. In fact, according to CoNViRI (2009), while 42 large companies are responsible for the provision of SII to some 87% of customers, 32 small firms do supply water to some 1% of users.

	Sample			CoNViRI, 2009		
Geographical location	n. of firms	% of firms	% of clients	n. of firms	% of firms	% of clients
North-East	14	25.93%	17.21%	28	26.42%	23.92%
North-West	14	25.93%	14.01%	39	36.79%	19.34%
Central	15	27.78%	37.59%	19	17.92%	29.69%
South	9	16.67%	29.11%	14	13.21%	24.08%
Island	2	3.70%	2.08%	6	5.66%	2.97%
Size						
Small	6	11.11%	0.58%	32	30.19%	1.28%
Medium	16	29.63%	8.27%	32	30.19%	11.85%
Large	32	59.26%	91.15%	42	39.62%	86.88%
Ownership structure						
Public	30	55.56%	43.63%	63	59.43%	50.58%
Private	11	20.37%	19.68%	17	16.04%	16.21%
Mixed	13	24.07%	36.69%	26	24.53%	86.88%
Type of business						
Mono-utility	37	68.52%	79.69%	72	67.92%	74.71%
Multi-utility	17	31.48%	20.31%	34	32.08%	25.29%

Table 2-1. The main features of the companies in the sample as compared to the extensive list of Italian operators as reported by CoNViRI. Source: authors' elaborations.

Concerning the type of service to be taken into account, I have opted for the inclusion of both firms that are active in the SII sector exclusively (*mono-utility*, 69%) and utilities that are active in related sectors (*multi-utility*, 31%) such as energy and waste, to see if there are scope economies.

2.3.4 Designing the DEA for the efficiency analysis of the water sector

As specified before, the linear programming problem that could be run with DEA may be defined in several ways. It is possible to opt for: input or output orientation; constant or variable returns to scale; one, two or multi-stage models. Consistently with the most recent analyses (e.g. Romano and Guerrini, 2011), I decided for input orientation and run both constant and variable returns to scale in a multi-stage framework. The rationale for these choices is as follows.

Input oriented models aim at minimizing the cost of producing a fixed (predetermined) level of output. Efficiency within this context is measured as the proportional reduction in inputs to get the actual level of output. By converse, output oriented models aim at maximizing output given input availability. Here, efficiency is computed as the increase in output that could be achieved by optimally using available inputs. Depending on whether it is more suitable to consider the sector as input or output constrained, the latter or the former approach must be set. In the case of water utilities, where output - as measured by the water delivered or by the inhabitants served – is price-inelastic and inputs (labour costs, material costs, etc.) may be adjusted accordingly, input-orientation is more suitable.

Return to scale concerns the effects on output of a proportional rise in all inputs. In particular, if the rise in output is proportional to those in inputs constant return to scale holds, which means that there is no-size performing better than others. The other way round, if the rise in output outperforms (underperforms) those in inputs, increasing (decreasing) return to scale applies, thus indicating that large (small) companies do perform better. I have considered both CRS and VRS to investigate both technical and allocative efficiency, a crucial issue in the context. CRS efficiency scores rank DMUs according to their technical efficiency *id est* the suitability of the production process used. VRS efficiency scores rank DMUs with respect to their purchase, mix and usage of inputs in the production process.

Finally, the run of multi-stage DEA is intended to reduce the inefficiency caused by the likely occurrence of input/output slacks, *id est* to situations where the efficient projected points of a decision making unit belong to the perfectly elastic or inelastic portion of the frontier. Since slacks do not represent Pareto-efficient projections of DMUs, efficiency indexes relying on slacks would provide misleading information. To overcome this issue, I carry out two or multi-stage DEA as suggested by Coelli *et al.* (2005).[3]

2.3.4.1 Input and output data

Studies applying DEA on water utilities present several similarities in input and output selection to which I conform. Materials, labour, services and capital (amortization and depreciation), measured either in term of unit consumed or of cost incurred, are traditional inputs.

The water delivered and treated (or the population served, using both would be misleading given the high correlation shown by the two variables) and the length of water and sewerage mains[4] are used as traditional outputs. Since data on the water delivered provided by CoNViRI were available only for 2008 and given the regulated structure of the sector with predetermined tariffs, I opted for water revenues and water mains as outputs. I collected financial data on relevant inputs – cost of material, labour and services (OPEX) and other indirect costs - from Bureau Van Dijk's AIDA database. Depreciation, amortization and interests have been excluded because of the limited time span of the assessment and because these items are often affected by earnings management policies, such as fiscal optimization. This exclusion means that I clearly focus on operative efficiency; one could question that water services are capital intensive and measuring the efficiency without taking into account capital costs could be misleading. Although I am aware that investments are relevant, considering their extremely long expected lifetime and amortization period, CNEL (2010) shows that operative costs account for more than 75% of the tariff structure, while capital remuneration and amortization the remaining part. As for outputs, revenues have been collected from Bureau Van Dijk's AIDA database, while corporate web sites were used for data concerning assets and network length.

Finally, to reduce the heterogeneity in the sample due to the number of residential served, all variables are expressed in per-capita terms by dividing the overall figures for

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[3] For more details on slacks and multi-stage DEA, see Coelli *et al*. (2005).

[4] Water mains are used as a proxy to measure economies of density (Thanassoulis, 2000a&b; Garcia-Valinas e al, 2007).

the number of residential served. Table 2-2 displays the correlation matrix for the variables collected.

	Mains length per capita	Revenues per capita	Cost of materials per capita	Operative costs per capita	Indirect costs per capita
Mains length per capita	1				
Revenues per capita	-0.02	1			
Cost of materials per capita	0.03	0.18	1		
Operative costs per capita	-0.02	0.90	0.10	1	
Indirect costs per capita	0.03	0.21	0.00	0.06	1

Table 2-2. The correlation matrix of inputs and outputs.

The positive correlation between revenues and costs confirms the cost of service structure of the tariff, while the negative effect of mains over revenue suggests likely economies of density.

2.4 Efficiency scores: results and discussion

Table 3 shows the minimum, mean, median and standard deviation values for technical (CRS), allocative (VRS) and cost-efficiency (S) scores for the utilities in the sample over the relevant time period (2007-2010). Following Coelli (1998), cost-efficiency (S) is the ratio between CRS and VRS: if its value is one, than the DMU is operating at its optimal scale; if the value is lower than one, than the DMU is not at its optimal scale, but the index does not say whether the DMU should increase or decrease it.

The mean and median level of CRS and VRS are close and relatively high, indicating a good level of efficiency among water utilities. Allocative efficiency is significantly higher than technical efficiency: this is not surprising since, at least in the short term, it is impossible to adjust significantly the production process, which is linked to mains and other long term assets. Therefore, notwithstanding complaints and oppositions, which have contributed in smoothing down the implementation of the water reform, the performance of the sector twenty years after the Galli law could be regarded as quite satisfactory.

	Obs.	Min.	Mean	Median	N. of frontier DMUs	Std. Dev.
CRS 2007	54	0.44	0.81	0.83	10	0.15
CRS 2008	54	0.48	0.82	0.83	10	0.14
CRS 2009	54	0.40	0.81	0.84	11	0.16
CRS 2010	54	0.42	0.80	0.81	12	0.17
VRS 2007	54	0.46	0.87	0.94	20	0.15
VRS 2008	54	0.48	0.87	0.91	19	0.14
VRS 2009	54	0.40	0.85	0.89	17	0.16
VRS 2010	54	0.42	0.83	0.86	15	0.17
S 2007	54	0.69	0.94	0.98	10	0.08
S 2008	54	0.64	0.95	0.97	10	0.07
S 2009	54	0.66	0.95	0.99	11	0.07
S 2010	54	0.65	0.96	0.99	12	0.06

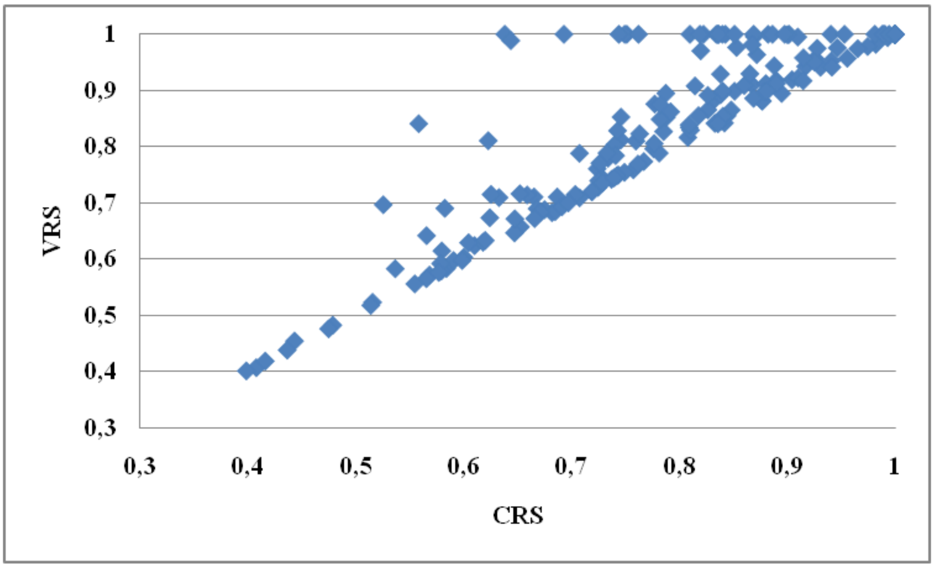
Table 2-3: DEA efficiency scores.

Both CRS and VRS have decreased between 2009 and 2010: this might be a symptom of the economic crisis, which has affected the efficiency of the utilities, in particular their capabilities in purchasing, mixing and using inputs in the production process.

The frontier is extremely stable, as well as the distribution of DMUs among different years. For CRS efficiency, 6 companies rank first for all four years; 3 for three years; 3 ad 4 DMUs rank first for two years and one year respectively. For VRS, there are 11 units raking first for all 4 years and 5 for three years; 4 companies rank first for two years and 4 for just one year.

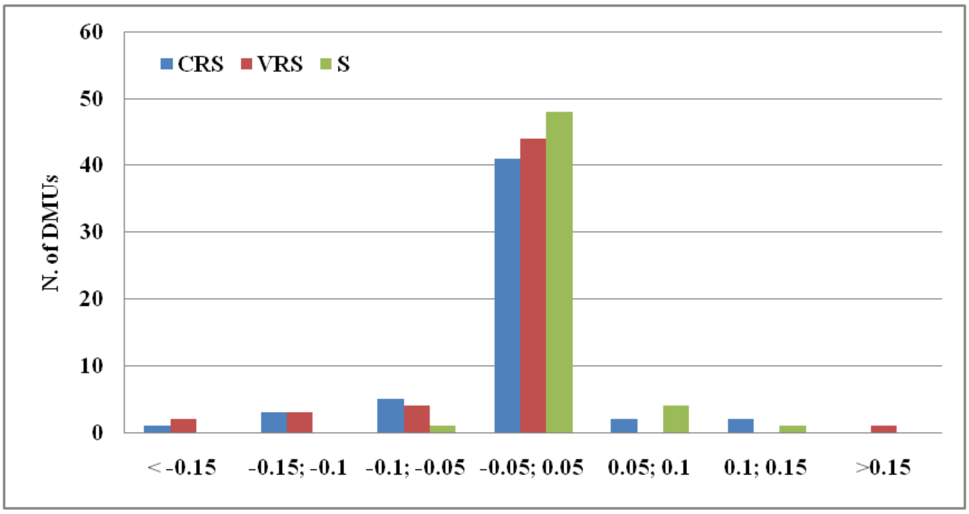
Cost-efficiency scores indicate that water utilities are operating extremely close to their efficient scale. The median operator has a value ranging from 0.97 to 0.99: this might indicate that the conceived licence areas are indeed optimal. Figure 2-1 shows a scatter plot of DMUs with respect to CRS and VRS: the relationship is linear and the correlation is high (0.90); the deviation from the linear correlation is always in favour of allocative efficiency, which of course is easier to improve than technical efficiency in the short term.

Figure 2-1: Correlation between VRS and CRS of Italian water utilities: 2007-2010.



Most utilities have not improved their efficiency over time either in technical or in allocative terms. At this purpose, data illustrate that several distributors – nine out of ten in global terms, three out of four in CRS and four out of five in VRS - have experienced a change in their efficiency paths in the zero range.

Figure 2-2: Mean efficiency score changes of Italian water utilities: 2007-2010.



Stable efficiency frontiers may have a twofold rationale. On the one hand, utilities in the sample may have just attained maximum efficiency levels (i.e. Pareto-efficiency), so that further improvements are not possible, at least in the time span under investigation in the study. On the other hand, water suppliers have not enough incentives toward better performance. Indeed in the former case, it is possible to consider that the reform initiated by the Galli Law has attained a fair efficiency objective; while in the latter, a break with the past is necessary to prompt the cost-efficient evolution of the sector.

Notwithstanding the relatively high levels of efficiency shown above, there are companies whose score is particularly low. What could explain the coexistence of such heterogeneous levels? May regulators affect the ability of water distributors to deal with risks? Is yardstick-based regulation optimal on benchmarking? To tackle these issues I econometrically explore some factors that, according to scholars (Massarutto et al. 2009), can interfere with efficiency. Both endogenous and exogenous variables are considered to effectively identify the areas for future policy interventions.

2.5 The determinants of efficiency

The second stage of the analysis aims at investigating what determines the efficiency scores calculated above. There is an ample debate on which regression technique performs better in the second stage, given a first stage based on DEA. According to several scholars (Dusansky and Wilson, 1994; Hoff, 2007), the DEA approach introduces a censoring problem in the upper tail of the distribution as most efficient units cluster at a limiting value. Consequently, the appropriate econometric treatment to avoid inconsistent estimates can be a tobit model, as it assumes that the dependent variable has a number of its values clustered at a limiting value and, as such, it can give unbiased results even if observations are clustered at that limiting value (McDonald and Moffit, 1980); however, estimates may be inconsistent if errors are not normally distributed or if they are heteroskedastic (Carson and Sun, 2007).

On the other hand, McDonald (2009) contends that DEA does not have a censoring data generating process (DGP), as its results are a kind of fractional or proportional data. Moreover, by the very nature of DEA, a second stage analysis performed with a tobit model will result in an error term being heteroskedastic, thus resulting in inconsistent estimates. As a consequence, McDonald suggests the adoption of OLS, as its estimates of β are "consistent and asymptotically normal under general conditions, and hypothesis tests can be validly carried out if allowance is made for heteroskedasticity" (McDonald, 2009, p. 794) .

Notwithstanding the regression methods used, Simar and Wilson (2007) shows that DEA scores might suffer from serial autocorrelation, which can be corrected only with a bootstrap procedure, as it improves statistical efficiency in the second-stage regression. As for the second stage of the analysis, the final option is to opt for both bootstrapped OLS and tobit models[5].

To perform such econometric analyses, first I have looked at variables that may be related with the governance: ownership (*PP*, which measures the percentage of shares owned by the public, and *SH*, which measures the percentage of shares hold by the main shareholder of the utility) and the type of business (*Mono*, which takes value 1 if the company is a *mono-utility* and 0 otherwise). Second, I have taken into account two managerial parameters: concentration (n. of clients served by the utility expressed as a share of the population in the ATO, *HHI*) and interruptions (*Inter*, measuring the frequency of interruptions in water distribution). Finally, I have considered environmental variables, related to the area where the unit is active: geographic location (two dummies *North* and *South*), incidence of metropolitan areas (daily in/outflows of people, *D flex*), incidence of touristic areas (seasonal in/outflows of people, *S flex*) and the coalition in charge in the municipality granting the concession[6] and nominating AATO's governing body (*DX*, which takes value 1 if a center-right coalition has the majority and 0 otherwise).

Indeed, the company and shareholders have (almost) direct control over the variables in the first and second classes, while in the last set are reported indexes, which are almost beyond the control of the persons in charge of managing, operating, controlling and sanctioning the activity. Summary statistics and correlation matrices for the variables to be included in the regressions are reported in App. I (Tab. A1-A2).

Table A2 shows that the explanatory variables are not particularly correlated among each other, with the notable exception of *Inter* with the geographical dummies, with

[5] I have also considered the possibility of a panel data analysis, but tests have rejected this possibility. This may be due to the short time span of the sample; still, I have introduced a time dimension in the analysis (discussed later).
[6] In case of multiple municipalities, I have considered the coalition governing the most important one; in case of regional ATOs, I have considered the regional government.

opposite signs (positive with *South* and negative with *North*). This high correlation recommends the exclusion of one of the two variables to avoid collinearity concerns.

I perform four bootstrapped regressions to test what affects both CRS and VRS (one OLS and one tobit each). Preliminary results have shown the presence of heteroskedasticity, which has obliged us to opt for White's method (1980) for calculating standard errors in the OLS regressions. At the same time, I have kept also tobit results, as a comparison. I have also introduced time dummies; results are not shown, as they were never significant in any of the different regressions performed.

Variable	**Category**	**Dependent Variable CRS**		**Dependent Variable VRS**	
		OLS	tobit	OLS	tobit
Constant		0.8190 (24.94)***	0.8283 (18.32)***	0.9060 (27.59)***	0.9711 (16.43)***
PP	Governance	-0.011 (-4.55)***	-0.0014 (-4.31)***	-0.0010 (-2.89)***	-0.0017 (-4.16)***
Mono	Governance	-0.0265 (-1.38)	-0.0333 (-1.47)	-0.0537 (-3.17)***	-0.0749 (-2.70)***
SH	Governance	-0.0002 (-0.01)	-0.0028 (-0.12)	-0.0239 (-1.03)	-0.0336 (-1.00)
HHI	Governance	0.0001 (0.38)	0.0002 (0.58)	0.0004 (1.26)	0.0007 (1.39)
Inter	Managerial	0.0022 (1.20)	0.0023 (1.10)	0.0039 (2.35)**	0.0041 (1.75)*
South	Exogenous	-0.0724 (-2.74)***	-0.0825 (-4.39)***	-0.1034 (-4.12)***	-0.1300 (-3.92)***
D flex	Exogenous	2.2890 (4.97)***	3.0008 (4.70)***	1.7715 (3.71)***	3.1194 (3.59)***
S flex	Exogenous	0.07311 (0.61)	0.0971 (0.64)	-0.0711 (-0.57)	-0.1064 (-0.59)
DX	Exogenous	-0.0416 (-2.17)**	-0.0429 (-1.99)**	-0.0360 (-1.83)*	-0.0426 (-1.60)
	<u>Summary Stats</u> Adj R2 chi2 Prob>chi2	 0.23 121.08 0.000	 97.25 0.000	 0.24 184.03 0.000	 137.63 0.000

***z-ratios significant at 1% level; ** 5% level; * 10% level.

Table 2-4: Regressions results.

According to the study, the higher the share of the public, the lower the performance. This result is in contrast with the rising distrust on private participation in water services, at least in Italy (Romano and Guerrini, 2011). Moreover, it has to be highlighted that PP is a continuous variable, ranging from 0% to 100%. This means that every percentage point increase in public participation reduces, although very little, the dynamic efficiency of the firm. In the literature, there is no clear evidence that private companies perform better: very recent studies on Spain (Garcia-Sanchez, 2006) and the UK (Saal et al., 2007) cannot find any efficiency differences between private and public companies. Since the sector is extremely country specific, I think that findings for a country might not work for another. As for the results, given that the timeframe of the analysis encompasses a period of economic downturn, I can explain them by saying that private and mixed companies were able to better respond to the crisis than their public counterpart. There are two major *caveat* to this: first, as stated in Massarutto (2009), public-owned utilities tend to serve also unattractive municipalities (for instance, those with a scattered population far from big cities); second, the analysis does not take into account service quality. The latter is an issue that must be checked and that is left for future researches. Quality standards, in fact, are tying and a slowdown in the performance such as the one envisaged by public utilities may reflect a more timely accomplishment of new requests. If this would be the case, the primacy held by privates would be nothing but a worthless success.

Consistently with expectations, the possibility to purchase, mix and combine inputs for water and other services, increase the allocative efficiency of a DMU while leaving its technical counterpart unaffected, thus explaining why *Mono* is significant only when the dependent variable is *VRS*. Indeed network services are characterized by scope economies that, however, do not span to technological assets given their sector-specific value. Also this result is consistent with previous literature, in particular with Piacenza and Vannoni (2004), which show the presence of scope economies for Italian multi-utilities.

With respect to size, the findings support the existence of constant return to scale. The variable HHI is not statistically significant, thus indicating that there is not a specific firm-size performing better than others. Fabbri and Fraquelli (2000) have found weak economies of scale in the Italian water industry, suggesting that efficiency drivers have to be found somewhere else. Also SH is not statistically significant, thus indicating that breaks-up in the shareholding does not appear to reduce firm's ability to optimally allocate resources. In particular, the participation of many municipalities in the governance does not seem to influence efficiency.

From a pure managerial perspective, I find that interruptions have a positive impact on (allocative) efficiency. Indeed, interruptions are commonly used in southern region (and islands) to optimally deal with shortages. Data confirms that this strategy raises the efficiency of the system. To myknowledge, this is the first time that this result has been proved.

While seasonal in/outflows of people do not statistically contribute to efficiency, daily in/outflows do matter, indicating that urban density is one important determinant of efficiency. To this respect, the result is consistent with previous findings (Garcia-Sanchez, 2006; Renzetti and Dupont, 2008).

Finally, I find negative and statistically significant figures for the variable proxying the center-right coalition on the efficiency of water utilities. As shown in table A2, *DX* is not correlated to geographical variables nor to the public participation in the company. On the one hand, this rules out the possibility that conservatives' local governments are concentrated where there are the less efficient operators or the worst conditions; on the other hand, there is no evidence that center-right coalitions are more present in municipalities with higher stakes in water utilities. Consequently, I can imagine that conservatives are less experienced or less interested in efficient local public service provisions.

2.6 Conclusions and policy recommendations

The present paper is the first attempt to measure and explain efficiency in the Italian water distribution sector over four years. The analysis clearly adds to the existing literature on water distribution as it stresses the importance of the dynamic aspects of firm's efficiency. In particular, the dynamic analysis showed that only a third of the sample was able to improve its efficiency scores, thus suggesting the idea that a more efficiency-based regulation could prove to be beneficial. At the same time, the paper shows that the Italian water companies perform well both in relation to technical efficiency (CRS) and inputs purchase (VRS). In fact, more than 78% of the suppliers in the dataset are characterized by CRS's figures in the upper range (70-100%). Results are even stronger when VRS is taken into account since other units join the upper range.

The econometric estimates are highly significant too. In particular, they reverse some previous findings on the Italian water distribution, which were either claiming higher efficiency scores for public firms (Romano and Guerrini, 2011) or that ownership was not influencing efficiency (Caliman and Nardi, 2010). Looking at the efficiency from a dynamic perspective shows that public companies perform slightly worse than mixed and privately owned counterparts, at least in time of economic slowdowns. At the same time, the analysis confirms the importance of some exogenous variables, namely the geographical location and population density.

Therefore, I think that the new tariff structure, which will introduce some efficiency mechanisms, has to be properly designed. In particular, I think that it would be appropriate to introduce a differentiated performance-based mechanism, in order to take into account different quality levels and the geographical location of the utilities.

Finally, the new tariff structure, together with a more effective regulation, would ease the impact of both the shareholding structure and the political parties on firms' efficiency, which at present is relevant. In particular, I show how public-owned utilities tend to underperform and how conservatives' local governments have a negative impact on firms' efficiency.

Further studies are needed in order to better assess the performance of water utilities. First, it would be important to extend the timeframe taken into account, to study the dynamic efficiency over a longer period. Moreover, as already stated above, it would be interesting to consider the availability and quality of water for each company in the area where they operate.

2.7 References

Abbott M. and Cohen B., 2009. *Productivity and efficiency in the water industry*. Utilities Policy. 17(3-4):233-244.

Aida, K., Cooper, W.W., Pastor, J.T., Sueyoshi, T., 1998. *Evaluating water supply services in Japan with RAM: a range-adjusted measure of inefficiency*. OMEGA. The International Journal of Management Science 26 (2): 207-232.

Antonioli B., Filippini M., 2001. *The use of a variable cost function in the regulation of the Italian water industry*. Utilities Policy 10(3-4):181-187.

Beaver, W.H., 1968. *Market prices, financial ratios, and the prediction of failure*. Journal of Accounting Research, 32: 30-44.

Benvenuti M., Gennari E.,2008. *Il servizio idrico in Italia: stato di attuazione della legge Galli ed efficienza delle gestioni*. Banca d'Italia – Questioni di Economia e Finanza, 23.

Byrnes, P., Grosskopf, S., Hayes, K., 1986. *Efficiency and ownership: further evidence*. Review of Economics and Statistics 668:337-341.

Byrnes, J., Crase, L., Dollery, B., Villano, R., 2010. *The relative economic efficiency of urban water utilities in regional New South Wales and Victoria*. Resource and Energy Economics, 32 (3): 439-455

Caliman T., Nardi P., 2010. *Technical efficiency drivers for the Italian water industry*. Economia delle Fonti di Energia e dell'Ambiente, 1:87-103

Carson, R.T., Sun, Y., 2007, *The tobit model with a non-zero threshold*. Journal of Econometrics, 10(3): 488-502.

Charnes, A., Cooper, W.W., Rhodes, E., 1978. *Measuring the efficiency of decision making units*. European Journal Operational Research, 2: 429–444.

CNEL, 2010. *Organizzazione industriale del servizio idrico integrato: stato dell'arte e criticità emergenti*. Rapporto di ricerca, Marzo 2010.

Coelli T., Walding, S., 2005. *Performance Measurement in the Australian Water Supply Industry*, CEPA Working Paper Series, WP012005

Coelli, T., Rao, D.S.P., O'Donnel, J.C., and Battese, G.E., 2005. *An Introduction to Efficiency and Productivity Analysis*. Springer, New York.

CoNViRI, (2009). *Relazione annuale al Parlamento sullo stato dei sevizi idrici*. Anno 2009, Roma, 22 Luglio 2010.

Cooper, W.W., Seiford, L.N., Tone, K., 2000. *Data Envelopment Analysis: a Comprehensive Text with Models, Applications, References and DEA-Solver Software*. Kluwer Academic Publisher, Boston.

Davis, H., Pele, Y., 1993. *Measuring equilibrating forces of financial ratios. The Accounting review*, 65: 725-747.

Dusansky, R., Wilson, P.W., 1994. *Technical efficiency in the decentralized care of developmental disabled*. Review of Economics and Statistics 76: 340–345

Fabbri P., Fraquelli, G., 2000. *Cost and structure of technology in the Italian water industry.* Empirica, 27: 65-82.

Fraquelli, G., Giandrone, R., 2003. *Reforming the wastewater treatment sector in Italy: implications of plant size, structure and scale economies*. Water Resources Research, 39(10): 1293-1299.

García-Sánchez, I., 2006. *Efficiency measurement in Spanish local government: the case of municipal water services*. Review of Policy Research 23 (2), 355-371.

Garcia-Valiñas, M.A., Muñiz, M.A., 2007. *Is DEA useful in the regulation of water utilities? a dynamic efficiency evaluation (a dynamic efficiency evaluation of water utilities).* Applied Economics 39:245-252.

Hoff, Q., 2007. *Second stage DEA: Comparison of approaches for modelling the DEA score*. European Journal of Operational Research, 181: 425-435.

MacDonald, J.F., Moffit, R.A.,1980. *The Uses of Tobit Analysis*. The Review of Economics and Statistics, 62(2): 318-321.

McDonald, J.F., 2009. *Using least squares and tobit in second stage DEA efficiency analyses*, European Journal of Operational Research, 197: 792-798.

Massarutto, A., 2009. *La regolazione economica dei servizi idrici*, IEFE Research Report, 1.

Paraiso, V. (ed), 2013. *The water supply service in Europe: Austrian, British, Dutch, Finnish, German, Italian and Romanian experiences*. Giuffrè Editore, Milano.

Piacenza, M., Vannoni, D., 2004. *Choosing among alternative cost function specifications: an application to Italian multi-utilities*, Economics Letters 82 (3): 415–422.

Renzetti, S., Dupont, D., 2008. *Measuring the technical efficiency of municipal water suppliers: the role of environmental factors*, In: Working Papers 0802, Brock University, Department of Economics.

Romano, G., Guerrini, A., 2011. *Measuring and comparing the efficiency of water utility companies: a data envelopment analysis approach*, Utilities Policy, 19: 202-209.

Saal, D.S., Parker, D., Weyman-Jones, T., 2007. *Determining the contribution of technical change, efficiency change and scale change to productivity growth in the privatized English and Welsh water and sewerage industry: 1985–2000*, Journal of Productivity Analysis 28(1): 127–139.

Seroa da Motta, R., Moreira, A., 2006. *Efficiency and regulation in the sanitation sector in Brazil*. Utilities Policy 14:185-195.

Shih, J., Harrington, W., Pizer,W., Gillington, K., 2006. *Economies of scale in community water systems*. Journal of American Water Works Association. 98: 100-108.

Simar, L., Wilson, P.W., 2007. *Estimation and inference in two-stage, semi-parametric models of production processes*. Journal of Econometrics, 136: 31-64.

Thanassoulis E., 2000a. *The use of Data Envelopment Analysis in the regulation of UK water utilities: Water distribution*, European Journal of Operational Research, 126:436-453.

Thanassoulis E, 2000b. *DEA and its use in the regulation of water companies*, European Journal of Operational Research, 127:1-13.

Walter M., Cullmann A., von Hirschhausen C., Wand R., Zschille, M., 2009. *Quo vadis efficiency analysis in water distribution? A comparative literature review*, Utilities Policy, 17:225-232.

2.8 Appendix

Table A1. Summary stats of independent variables

Variable	Obs.	Mean	Std. Dev.	Skewness	Kurtosis
PP	216	71.99	37.37	-0.98	2.48
SH	216	41.42	29.03	0.69	2.56
HHI	216	0.77	0.40	-0.18	2.67
Inter	216	10.73	7.31	1.81	6.10
D flex	216	0.03	0.02	2.87	15.21
S flex	216	0.07	0.07	1.98	6.79

Table A2. Correlation matrix of independent variables

	PP	Mono	SH	HHI	Inter	South	North	D flex	S flex	DX
PP	1.00									
Mono	0.02	1.00								
SH	-0.40	0.05	1.00							
HHI	-0.09	0.12	0.01	1.00						
Inter	-0.27	0.28	0.16	0.23	1.00					
South	-0.11	0.24	0.13	0.19	0.77	1.00				
North	0.11	-0.24	-0.13	-0.19	-0.77	-1.00	1.00			
D flex	0.03	0.01	0.30	0.05	-0.11	-0.13	0.13	1.00		
S flex	0.17	-0.01	-0.21	0.22	-0.04	-0.15	0.15	-0.03	1.00	
DX	0.09	-0.02	-0.05	-0.06	-0.06	-0.04	0.04	0.08	0.02	1.00

3 Hydropower rent in Northern Italy: economic and environmental concerns in the renewal procedure

Abstract

Local governments in Italy are about to renew some of their hydropower concessions. Due to fiscal and budgetary constraints, they are willing to capture a higher part of the rent, which has never been estimated. At the same time, the renewal procedures are a good opportunity to force operators in implementing mitigation measures to attain the requirements set forth in the water framework directive. Rent seizing and environmental improvements might consequently generate a significant trade-off. This paper investigates this potential conflict. Above all, it is the first attempt to estimate the hydropower rent in Italy. To do so I focus on the Province of Sondrio, which is home to 18% of the Italian hydropower capacity, as it is the first place where concession renewals will take place. I find very high estimates for the hydropower rent, averaging from 42.3 €/MWh to 70.8 €/MWh. These high values explain why the current rent sharing mechanism is not satisfactory for local and central authorities, as they keep less than 50% of the rent; with the introduction of the proposed 30% revenue sharing fee, instead, they would seize almost 90% of the rent. At the same time, I show that this revenue sharing fee would hinder operators in implementing mitigation measures, which would significantly reduce flow alterations and improve ecosystem integrity. These measures, in fact, entail significant investments, consequently increasing capital costs and reducing the possibility to pay such a high revenue sharing percentage. Finally, I show that a resource rent tax would reduce the trade-off between rent seizing and environmental protection.

Keywords: Hydropower; economic rent; concession fees.

JEL Classification: H27, K23, Q25, Q48.

3.1 Introduction

Hydroelectricity has been one of the most important water-related technological breakthroughs. Power is generated through the use of the gravitational force of water that activates power turbines. Hydropower can be generated with run-of-the-river plants or with dams. A particular and very lucrative type of hydropower production is represented by pumped storage, which implies the use of water reservoirs at different heights.

Hydroelectric generation is still the most widespread renewable energy source; this depends on three main characteristics: first, hydroelectricity is cheap, in particular from infrastructures whose investment costs have already been recovered; secondly, hydropower is the only renewable source that guarantees reliability to the whole power system, as it can be used to meet different load profiles; finally, reservoirs are the only economically viable way to "store power".

Hydropower has another peculiarity, compared to other renewable energy sources: contrary to wind and sunlight, it is economically feasible to prevent (at least partially) others from using water (especially in the case of reservoirs), thus generating exclusive rights. As such, water exploitation for electricity production can generate a rent (Amundsen & Andersen, 1992). Economic rent refers to the surplus value accruing to the owner of a resource, when the total market value of the resource exceeds the long-run total costs of supplying it. Since States tend to licence hydropower production to third parties, they have to set up mechanisms to seize the rent which otherwise would accrue to someone else. A very simple and common mechanism has been charging the producer with a fixed amount based on the nominal capacity (that is the capacity stated in the concession agreement). For instance, this is the system currently used in Italy. As I will discuss below, this fee is very inefficient because, on the one hand, it does not reflect the value of the rent, on the other, it might engender distortions.

This situation, though, is rapidly and dramatically changing for three reasons:

- In Italy and in other EU Countries, several hydropower concessions are about to expire in the next years;

- Due to fiscal and budgetary constraints, Local Governments in Italy are willing to capture a higher part of the rent, by means of a revenue sharing mechanism;
- Even though hydropower is an emission free technology, it impacts the environment in several other ways (for instance it negatively affects biodiversity) and the renewal procedures are considered a good opportunity for introducing mitigation measures, foreseen by the water framework directive (WFD).

These three points are the pillars on which this paper is built upon. Foremost, the study is the first attempt to estimate the hydropower rent in Italy, focusing on hydropower rent sharing procedures in the Province of Sondrio, which has the highest concentration in Italy of installed capacity per km^2, roughly 680 kW[7], and where the first tender procedures will take place. Secondly, I study the effects of the revenue sharing mechanism on the environmental mitigation measures that the new operator should put in place so that the rivers in the Province of Sondrio attain the good ecological status as required by the WFD; as means of comparison, I will compare these effects with the ones that would be generated by a resource rent tax (RTT), similar to the one currently adopted in Norway.

The study shows that hydropower generates a significant rent, which averages from 42.3 €/MWh to 70.8 €/MWh. These are the highest values ever estimated for the hydropower rent (estimation have been performed for Canada, Norway and Switzerland): the Italian generation mix, which relies on very costly technologies, can explain them. Moreover, the current fee system allows the State to seize less than a half of the rent. By contrast, the proportional system and the RTT would increase the slice to 90% and 75% respectively. Finally, the paper demonstrates how the proportional system would dramatically reduce the rentability of investing in environmental mitigation measures, thus creating a permanent trade-off between environmental sustainability and rent extraction, unless an RTT scheme is introduced.

The paper unfolds as follows: section 2 is devoted to the discussion of some preliminary aspects of the hydropower rent and to the review the relevant literature; section 3,

[7] The second highest is the Province of Brescia with some 450 kW/ km^2

instead, describes the hydropower sector in Italy and in the Province of Sondrio; in section 4 I estimate the rent and I see the effects of the three different rent sharing mechanisms; section 5 discusses the interaction among the different mechanisms and the environmental mitigation measures; finally, section 6 concludes.

3.2 The hydropower rent and its capture

3.2.1 Preliminary aspects

The economic rent can be defined as the surplus value, that is the difference between the price and the average production cost of a good. This surplus value can accrue to producers even in perfectly competitive markets, as there can be intrinsically different production costs. This inherent difference generates a long-run equilibrium where those with lower costs gain a rent. For instance, let us consider a competitive market for electricity, where $D(p)$ is the demand function and $S(p)$ the aggregate supply function, which is the sum of $S_i(p)$ single supplier functions; then at point P the sum of the suppliers' rent and the consumers' surplus will be given by:

Equation 3-1

$$R = \int_{P}^{\infty} D(p)dp + \int_{0}^{P} S(p)dp$$

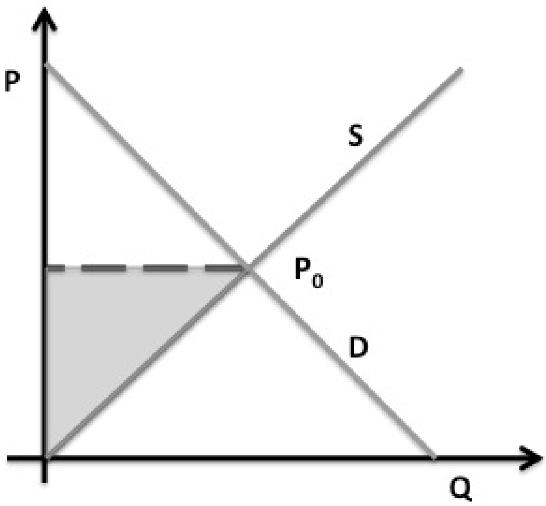
For normally shaped supply and demand functions, such those depicted in figure 1, the integral [1] defines R as a U-shaped function, which therefore has a minimum P_0:

Equation 3-2

$$\frac{dR}{dP} = -D(P) + S(P) = 0$$

Precisely where the supply meets the demand. As a consequence, all suppliers with a marginal cost lower than P_0 earn a rent (indicated by the shadowed area).

Figure 3-1: Graphic representation of the rent.



A rent can stem from differences in quality of factors of production or from scarcity. In the hydropower case, the total rent is normally given by the sum of three different types of rent (see Rothman, 2000, for a more thorough discussion):

- Differential rent among hydropower sites;
- Scarcity rent, as the restricted availability of water makes it impossible to produce electricity only with hydropower;
- Technological rent, as it is cheaper than other production technologies.

As already stated above, even though States retain the ownership of waterbeds, they are not willing (or able) to entirely capture it. There are several rent extraction mechanisms and not all are conceived as taxes (for instance, operators might be forced to sell a percentage of their production at its cost). Watkins (2001) and Rothman (2000) give a complete overview of these mechanisms, which are not peculiar to the hydropower sector. Here, I will briefly discuss three extraction mechanisms: concession fee; revenue sharing and resource rent tax. All these extraction mechanisms are something that is added on top of "standard" taxation, that is taxes that all businesses have to pay, such as corporate income tax or property taxes.

The simplest and most common extraction mechanism is the *concession fee*, currently used in Italy. This is a fixed yearly payment that the licensee has to pay to the licensor, based on the nominal capacity (that is the gravitational potential energy resulting from the quantity of water that the operator is allowed to withdraw and the head of the plant). This type of fee is easy to compute and has almost no monitoring costs. At the same time, though, it has several drawbacks (Banfi et al., 2005): it is inflexible to price changes (meaning that if it is set too high it might paradoxically rule out hydropower production); it does not take into account differences in production sites; it is not neutral to investment decisions, as it does not tax pure economic profits (see for instance, Samuelson, 1964).

Licensors might opt for a *revenue sharing mechanism*, which is simply a percentage of gross revenues. It is almost as easy to compute as the concession fee, but contrary to it, the revenue sharing mechanism internalizes price changes. On the other hand, it does not take into account differences in production sites and it is not neutral to investment decisions.

A *RRT*, instead, is a tax levied on "extra profits", that is profits that are above an "adequate" return on production factors, which is the return expected by investors to engage in hydropower production. A concession scheme based on RRT is, from an economic point of view, the most efficient one, because it is connected directly to the economic value of the resource and is neutral to investment decisions.

3.2.2 Literature review

Estimations of the economic rent of hydropower plants have already been performed, for instance for different Canadian provinces, for Norway and for Switzerland (Zucker and Jenkins, 1984; Amudsen and Tjotta, 1993; Banfi *et al.*, 2005). All these studies have found that hydropower generate a significant rent (see table 3-1). This is quite remarkable, given that all these Countries have a very cost effective generation mix: in Canada, 60% of the electricity is produced with hydro, another 30% with nuclear and coal; in Norway almost 99% of the electricity is produced with hydro; in Switzerland, hydropower accounts for 58% and nuclear for almost 40%. As I show later on, Italy has a generation mix that relies a lot on combined-cycle gas turbines plants, which have very high variable costs.

Author (year)	Sample	Results (€(MWh)
Bernard et al. (1982)	Canada	6.8 – 16.4 (1989)
Zucker and Jenkins (1984)	Canada	27.3 (1989)
Gillen and Wen (2000)	Ontario	25.3 (1995)
Amudsen and Tjotta (1993)	Norway	9.5 – 17 (1988)
Banfi et al. (2005)	Switzerland	10.7 – 22.8 (2001)

Table 3-1: Comparison of different estimates of the hydropower rent in €/MWh.

Source: Adapted from Banfi et al. 2005.

Estimating the rent means estimating total costs and total revenues and it can be done on past production or on future forecasts. Costs can either come from annual reports (Gillen and Wen, 2000; Banfi *et al*., 2005) or they can be estimated (Amudsen and Tjotta, 1993). Total revenues, instead, should consider the real competitive price for electricity (Banfi *et al*., 2005). Clearly if no such a market exists, then alternative options should be used: taking into account long-run backstop technologies (Amudsen and Tjotta, 1993) or bilateral long-term prices (Gillen and Wen, 2000).

Each methodology has its advantages and disadvantages. On the cost side, the problems on relying on annual reports come from possible accounting strategies put in place by operators (from accelerated depreciation to intra-group operations). At the same time, given that hydropower is site-specific, cost estimation might return poor results. On the revenue side, instead, power exchanges might not be perfectly competitive (which means that operators act strategically); on the other hand, the validity of backstop technologies or bilateral contracts as good indicators is at least dubious: backstop technologies and their costs vary significantly over time; as for bilateral contracts, instead, there is the need to collect a significant sample in order to have a representative price, but given their confidentiality, it is not an easy task.

As for rent extraction in the hydropower sector, given the difficulties explained above, there are just few papers that estimate the impact of different taxation mechanisms. Despite being few, these studies have had significant impact. The most notable one is the paper written by Amundsen & Andersen (1992): the authors simulate the impact of different taxation mechanisms on new hydro investments in Norway, showing that an RTT is the only extraction scheme to be neutral to investment decisions and the most appropriate in capturing the rent. Following their findings, in 1997 the Norwegian government has introduced a RRT on top of the other fees and extraction mechanisms.

At present, the Norwegian system encompasses a plurality of mechanisms, each of which accrues to different authorities. Local governments and municipalities are entitled of a property tax and a natural resource tax (which is a fixed unitary amount multiplied by the withdrawn water); moreover, they receive up to 10% of the electricity produced at its cost. The central government, instead, on top of the standard taxation, levies an RRT, whose rate is 30%.

Banfi *et al.* (2010) build on the RTT scheme by addressing its main drawback: if not properly designed, a RTT does not promote efficiency. To this respect, the authors have set forth a RRT scheme that introduces elements derived from the yardstick competition framework. The authors propose: "*to estimate for each hydropower plant a cost inefficiency indicator based on the estimation of a frontier variable cost function that should be considered in the computation of the RRT*". The application of this inefficiency indicator into the RTT formula would guarantee that more efficient generators would pay less than inefficient ones. Moreover, it allows differentiating among different technologies and different locations, as it possible to build different inefficiency indicators for different types of power plants. In the paper, no practical example is given on how this would change the rent extraction. In this case, the Swiss government has opted not to introduce the RTT; still, Banfi *et al.* estimates have been used to revise upwards the concession fees.

In the end, notwithstanding the methodologies used for its estimation, it is possible to say that hydropower generates a noteworthy rent. As a consequence, one would expect more refined rent-sharing mechanisms, for instance the ones normally adopted in the oil industry. That is why I think that the adoption of an RRT should be promoted: this would permit to:

- Impose a tax directly connected to the economic value of the resource and is neutral to investment decisions;
- Attach a precise monetary value to the resource;
- Promote, or at least not hinder, environmental-related investments, in order to comply with the WFD.

3.3 A brief description of the Italian hydropower sector

In Italy, hydropower accounts, on average, for 15% of total electricity production. In 2011, the production stood at 45.8 TWh (47.7 TWh with pumping). It is by far the most important renewable energy resource (RES), accounting for 59% of RES installed capacity and 55% of energy produced. Hydropower is a mature sector in which further developments are hardly achievable. In recent years, due to European and National policies aimed at incentivizing renewable generation[8], there has been a significant increase in mini and micro hydro-plants, which, anyway, can provide nothing more than a marginal amount of electricity.

Hydropower installations are unevenly distributed: 74% of the installed capacity resides in the Alpine region. The abundance of favourable sites results in lower costs and higher profitability for plants set in the North. As for the ownership, all the most important players have hydropower plants in their generation portfolio, as it is possible to see in the sample below.

The Italian electricity market has been liberalized 14 years ago and, since 2004, there is a power exchange that is very liquid and whose price is highly representative: consequently, it is possible to use the average power exchange prices within the rent estimation procedure.

3.3.1 Hydroelectricity in the Province of Sondrio

The Province of Sondrio is geographically located in northern Lombardy, close to Switzerland. It is home of some 2.2 GW of hydropower plants, roughly 18% of the overall Italian hydropower capacity. Of this, 2.16 GW are big hydro schemes, owned by four companies, A2A, Edipower, Edison and Enel. In the next four years all A2A and Edison concessions will expire; by contrast, Edison and Enel concessions will expire only in 2029. The oldest plants date back to the beginning of the 20th century, the most recent ones where built in the fifties. Major refurbishments (mainly for the powerhouse) took place in the ‘80s for Edipower, in the ‘90s for Edison and Enel and in the early 2000s for A2A.

[8] Starting from the legislative decree of December 29, 2003 n. 387, which has implemented the first European directive, 2001/77/EC on the promotion of renewable energies.

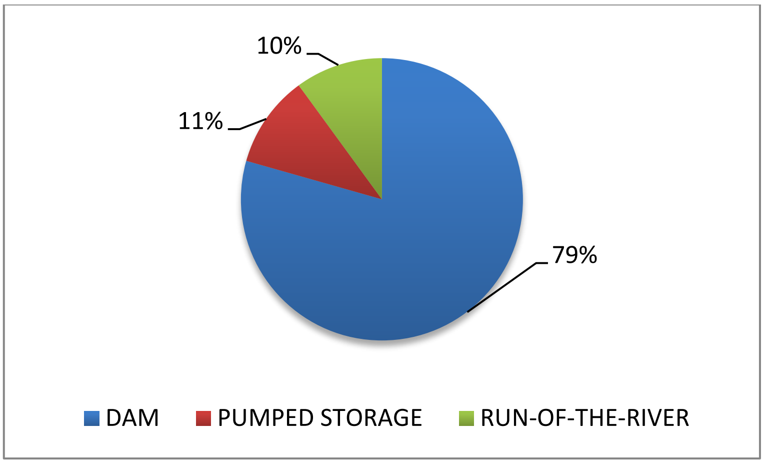
Operator	Nominal capacity (MW)	Installed Capacity (MW)	Average (MW)	Min (MW)	Max (MW)	Number of plants	Average prod. (GWh)
A2A	226	765	109	3.3	428	9	1,733
Edipower	128	376	47	2.8	157	8	816
Edison	127	322	46	2.1	150	7	635
Enel	235	697	51	10.4	225	12	871
TOTAL	715	2.160	61	2.1	428	36	4,096

Table 3-2: Structure of the sample.

Source: Province of Sondrio and Operators' data.

A2A manages both the biggest plant and the second biggest one (which is 226 MW). As the data suggest, all operators manage hydropower schemes relying on one big plant to which smaller ones depend. In fact, as the figure below shows, the overwhelming majority of the installed capacity are dams. Moreover, all run-of-the-river plants depend on the waters that are released from dams. In fact, all the plants are conceived as schemes as the released waters are turbinated more than once; as such, it is better to estimate the rent for each scheme and not for single plants.

Figure 3-2: Composition of hydropower plants in the Province of Sondrio.



3.3.2 Concessions: fees and renewals

In Italy, water and waterbeds are public goods owned by the State. As a consequence, the use of the resource is subject to a concession agreement. The use of water for hydropower production is regulated by the Royal Decree n. 1775 of 1933, which foresees that the exploitation of public waters for power generation is subject to a concession granted by the competent public authority. The licensee has to pay a fixed annual fee calculated on the basis of the nominal power capacity. Initially, the Royal Decree stated that the State was directly in charge of the concession procedure. In 1999, following the devolution of the administrative powers to local authorities, Regions have become responsible for the whole procedure; moreover, they can even set an additional fee on top of the one set by the State and they can differentiate it according to the nominal capacity. This situation causes a strong local variability on the amount of royalties collected. At present, the range varies from a maximum of 35.05 €/kW of nominal power capacity in Molise to a minimum of 13.32 €/kW in Emilia Romagna. In Lombardy is equal to 14.9 €/kW (APER, 2012).

The Royal Decree also sets a specific fee in favour of those local authorities (municipalities and provinces), whose territory power plants and derivations are built on. In 2012, this specific fee is fixed at 7.00 €/kW of nominal capacity for all the plants that exceeded 220 kW.

Finally, there exists a third fee in favour of consortia of municipalities located in mountainous areas. Such fee is due by all plants built above 500 meters, whose capacity exceeds 220 kW. This fee was conceived as a means of redistribution to communities in mountain areas, which are usually depopulated and impoverished. In 2012, this fee stood at 28.00 €/kW.

Clearly, Italy has opted for a simple fee mechanism, based on the nominal capacity. This system is predictable and guarantees a fixed flow of income for public authorities; on the other hand, it is not at all related to the rent.

To sum up, the overall amount paid by the operators in the Province of Sondrio is 49.9 €/kW, which is the sum of the State concession fee, the Regional fee and the fee in favour of the consortia (APER, 2012).

As for the renewal procedure, the law-decree of June 22, 2012, n. 83 introduces publicity and competition requirements in the tender process. The decree foresees that the new concession will last 20 years. More, the tender procedure is structured as a beauty contest, where petitioners will have to present:

1. A technical offer, which means that candidates are expected to significantly ameliorate the existing infrastructures in order to increase (if possible) the production;
2. An environmental offer, within each project, petitioners have to show their actions to reduce their environmental impact;
3. An economic offer, candidates are expected to present a financial business plan in which they will show the expected revenues and a revenue sharing percentage.

As set forth in the decree, the economic offer is more important than the two other offers. As France, Italy has decided to introduce, on top of the concession fees, a revenue sharing mechanism, commonly adopted in different Public-Private Partnerships (PPP). As stated before, its main advantage is its simplicity, as grantors do not have to perform due diligences on operators' accounts. On the other hand, though, it shows that governments are more interested in increasing the rent extraction, rather than improving the management of the resource, as shown in the next paragraphs.

3.4 Rent Estimation

3.4.1 Estimating production costs

Operators in the Province of Sondrio did not release any information on costs. Still, I was able to construct a dataset on technical and concession-related variables for all hydropower plants currently operating in the Province of Sondrio, combining the hydropower register held by the Province and the data present in the concession agreements. The newly built dataset includes information on the location, the year of construction, the year of refurbishment, the average water flow, the net head, the nominal capacity, the installed capacity, the company that operates the plant and the yearly hydroelectric production of each plant.

To estimate both investment costs and operative costs, I opted for parametric approaches. I estimated capital expenditure (CAPEX) as overnight investment costs for a greenfield project. This gives the possibility to take into account in the rent estimation the long-run capital costs. In the parametric formulas, all the components needed to set up a hydropower scheme are included, namely:

- Project and licensing;

- Dams or reservoirs (even the run-of-the-river plants in Sondrio Province have at least a daily storage capacity);
- Intakes, penstocks, surge chambers and outflow systems;
- Turbines, generators, transformers and related powerhouse civil works.

CAPEX were computed with using to different parametric estimations to see if I would get similar results. The first parametric equation comes from Kaldellis (2007), whose sample consisted of 50 small and medium Greek hydropower plants. Kaldellis' equation relates CAPEX with the net head and the installed power:

Equation 3-3

$$C = (1 + \xi) \times 3{,}300 \times (P^{-0.122} \times H^{-0.107})$$

where ξ is a value that has to be calibrated and that internalizes intangible expenses and specific market conditions; P is the installed power capacity in kW and H is the net head. For the calibration of ξ I used the only publicly available information on hydropower investment costs given by GSE, the State-owned company that manages all the incentive programs for renewable energies. According to GSE (2010), the average CAPEX for dams bigger than 100 MW are 2,244 €/kW (real 2012 value); for small dams, instead, 2,459 €/kW; finally CAPEX for small run-of-the-river plants (less than 20 MW) they sum up to 1,924 €/kW. Consequently, in order to have the same weighted average value from the sample, I have iteratively estimated the value of ξ and found it to be equal to 4.06.

The second parametric equation, instead, has been estimated by Hall *et al.* (2003) from a sample of 267 US plants. It is simpler than the first one has it relates CAPEX just to the installed capacity:

Equation 3-4

$$C = 3{,}300{,}000 \times P^{0.9} + 610{,}000 \times P^{0.70}$$

Where P is clearly the installed capacity in MW. Hall *et al.* developed also a parametric approach to estimate also the refurbishment costs for the powerhouse equipment:

Equation 3-5

$$C_{phouse} = 4{,}000{,}000 \times P^{0.72} \times H^{-0.38} + 3{,}000{,}000 \times P^{0.86} \times R^{-0.38}$$

Where R are the rotations per minute of the generator. Equation [3-3], [3-4] and [3-5] were adjusted for inflation and converted in real euro values with base 2012. In the table below, I show the results for total CAPEX and I compare them with the values published in the survey conducted by IRENA (2012), the International Renewable Energy Agency.

As shown in the table below, both computations return similar results for average CAPEX (with a 19% difference) and the highest observation (8% difference). Both average values do not differ significantly from those reported by IRENA for small and medium hydro plants built in the EU (taking into account that, in the dataset under study, only 6 out of 36 plants are bigger than 100 MW).

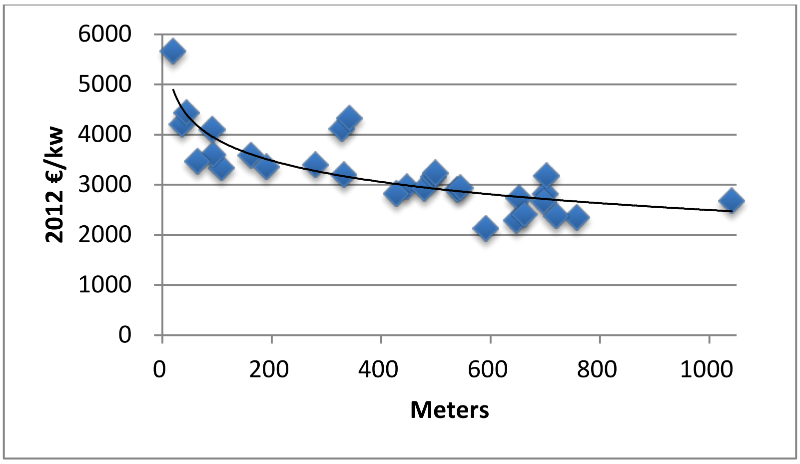
More striking differences are found when comparing extreme values: this is due to the difference in the sample and to the fact that in the IRENA report some of the investments were, in fact, major refurbishments, which cost less than greenfield ones.

Estimation (2012€/kW)	Weighted average	Min	Max	Std. Dev.
Kaldellis approach	2,395	1,964	5,223	668
Hall approach	2,960	2,545	4,760	515
IRENA big hydro EU (>100 MW)	1,879	918	2,923	N.A.
IRENA small and medium hydro EU (<100 MW)	2,274	1,086	6,681	N.A.

Table 3-3: total CAPEX. Results from the sample compared to IRENA data.

Still, Kaldellis' approach performs better for high CAPEX: this is so because it internalizes the head in its equation and there are significant economies of scale for heads above 50 meters, as both suggested by Kaldellis *et al.* (2005) and shown in the graph below. As a consequence, I have opted to keep the values found with Kaldellis' approach.

Figure 3-3: Relation between net head and CAPEX in the data sample.



As for the powerhouse, Hall *et al.* estimation procedure gave consistent estimates with the survey performed by Alvarado-Ancieta (2009). Moreover, the average value weighs from 16% to 19% of the overall investment costs presented above, which is precisely the range reported by IRENA (2012).

Estimation (2012€/kW)	Weighted average	Min	Max	Std. Dev
Hall approach	409	137	1,252	233

Table 3-4: Powerhouse equipment CAPEX. Results from the sample.

As for operative expenditures (OPEX), I have compared three different approaches. The first one being a parametric estimation, again from Hall *et al.*, the other two being the above-mentioned surveys from GSE (2010) and IRENA (2012). Hall's formula relates fixed and variable OPEX to the installed capacity once the average production is known. IRENA, instead, estimates OPEX as a percentage of CAPEX again once the average load factor has been defined. GSE, finally, gives just a punctual value, estimated in 2010 on newly operating hydropower plants.

Estimation (2012€/MWh)	Average	Min	Max
Hall approach	18.5	12.4	33.7
IRENA	20.1	13.6	61.5
GSE	28	-	-

Table 3-5: OPEX. Results from the sample compared to IRENA and GSE data.

The table above shows that Hall's approach returns average OPEX 9% lower than the ones surveyed by IRENA. The punctual value found in the GSE report seems too high to be trustworthy.

Once I have computed CAPEX and OPEX, I have to set the invested capital as well as an "adequate return". As shown in Newbery (1997), the theory of accounting states that an asset, costing K at date n=0 that produces a flow of gross returns g_n ceasing at date N, at any date n has a present value equal to the discounted sum (at a rate r) of its remaining returns so that:

Equation 3-6

$$V_n = \int_{s=n}^{N} g_s e^{-r(s-n)} ds = e^{rn} \int_{s=n}^{N} g_s e^{-rs} ds.$$

The amortization of an asset is simply its fall in value over its lifetime; differentiating [3-6], I obtain the instantaneous rate of amortization (A_n):

Equation 3-7

$$A_n = -\frac{dV}{dn} = -rV_n + g_n.$$

From equation [3-7] it can be derived that:

Equation 3-8

$$g_n = rV_n + A_n$$

Which means that the gross return is made up of the return on the capital value at the beginning of each period, rV_n, plus the amortization A_n. The amortization period has been set at 60 years for all civil works and at 40 years for the powerhouse equipment, consistent with the Italian accounting standards (Ministerial Decree December 31, 1988 and subsequent amendments). The rate of return, instead, has been set at 7.6%, equal to the remuneration set by the Italian Authority on Electricity and Gas for all regulated activities (AEEG, 2011).

3.4.2 Results

The total rent generated, of course, is given by total revenues net of total costs, including the cost of capital. Unfortunately, I have only yearly production data, which have not enabled us to better estimate companies' revenues. As a consequence, I have made two extreme estimates: in the first, revenues have been calculated by multiplying the quantity produced by the average zonal price; in the second one, instead, I have multiplied the quantity by the average peak zonal price of the power exchange.[9] Rent calculations have been performed from 2004, the first year of operation of the power exchange, to 2011, the last year of available production data. The yearly prices have been all converted into 2012 values using the electricity deflator of the harmonized index of consumer products (Eurostat database).

Values in 2012€	A2A	Edipower	Edison	Enel	Total
Revenues (in million €)	142.1	64.7	50.8	69.9	327.4
Revenues (in €/MWh)	79.9	79.9	79.9	79.9	79.9
OPEX and amortization (in million €)	57.2	15.8	13.6	28.8	115.3
OPEX and amortization (in €/MWh)	33.2	20.3	22.4	34.2	28.2
Cost of capital (in million €)	27.5	3.5	3.6	7.3	42.1
Cost of capital (in €/MWh)	16.4	4.6	6.0	8.9	10.3
Rent (in million €)	57.3	45.3	33.6	33.7	169.9
Rent (in €/MWh)	31.2	55.9	52.4	37.7	41.5
Cumulated rent 2004-2011 (in million €)	458.1	362.6	268.7	269.6	1,359.4

Table 3-6: Average revenues, costs and rent in the period 2004 – 2011 with average prices.

Table 3-6 shows the result obtained with the average yearly zonal prices. The value of the rent is considerable and much higher than those found in previous studies (Zucker and Jenkins, 1984; Amudsen and Tjotta, 1993; Banfi *et al*., 2005). In fact, even if I value hydropower production at the average price, the rent is comprised between 31.2 €/MWh and 55.9 €/MWh, for a total amount of almost 170 million € per year. If I consider that the Province of Sondrio represents a bit less than 20% of the Italian

[9] The Italian power market is divided in market zones, due to transmission constraints.

hydropower production, "back-of-the-envelope" calculations show us that the overall Italian rent should not be far from at least 1 billion € per year.

These simple calculations show how hydropower benefits from a generation mix totally relying on natural gas, which is the marginal technology in the power exchange almost 50% of the hours every year (GME, 2012).

A2A has a much higher cost of capital because it performed major refurbishments less than 10 years ago; moreover, some of the original assets have not been totally amortized yet.

Values in 2012€	A2A	Edipower	Edison	Enel	Total
Revenues (in million €)	190.6	87.3	68.1	93.6	439.5
Revenues (in €/MWh)	107.3	107.3	107.3	107.3	107.3
Rent (in million €)	105.9	67.9	50.8	57.3	282.0
Rent (in €/MWh)	60.2	84.9	81.4	66.7	70.0
Cumulated rent 2004 – 2011 (in million €)	847.2	543.4	406.7	458.9	2,256.3

Table 3-7: Average revenues and rent in the period 2004 – 2011 with peak prices.

In Table 3-7 I show that if operators are able to sell their production at peak prices, then the amount of the rent increases significantly, as the average peak price is almost 34% higher than the average one. Given that almost all hydropower production in the Province is programmable and that I expect operators to be profit maximizers, then it is likely that the overall rent is closer to the second estimate than to the first one.

3.4.3 Taxing the rent: comparing the three different mechanisms

In this paragraph I compare the actual Italian fee system with the other two different extraction mechanisms described above, in order to show how this could affect the rentability for private operators, a major issue in the renewal procedure. In the table below I show how, in practice, the rent would be split between the State and the operators, according to three rent extraction system. In the proportional system, on top of the concession fee I have added a revenue sharing percentage equal to 30% (as it has been already set in France in the Rhone Concession); in the RTT system, on top of the concession fee, I have added an RTT whose rate is 30% as well, which is the same percentage used in Norway. Finally, it is important to bear in mind that in Italy, overall corporate taxation is equal to 31.4% of the taxable income.

In million 2012€ for the whole Province	Actual system	Proportional system	RTT
Revenues	327.4	327.4	327.4
Average price (€/MWh)	*80.1*	*80.1*	*80.1*
(-) OPEX and Amortization	115.3	115.3	115.3
(-) Concession fees (A)	30.4	30.4	30.4
(-) Revenue sharing (B)	-	98.2	-
Taxable basis (C)	181.6	83.3	181.6
(-) Corporate tax (D)	57.0	26.2	57.0
Net Income (E)	124.5	57.2	124.5
(-) Cost of capital (F)	42.1	42.1	42.1
Taxable basis for rent tax (G=C-F)	-	-	139.4
(-) Rent tax (H)	-	-	41.8
Net Rent for operators (E-F-H)	82.5	15.1	40.6
Rent for the State (A+B+D+H)	87.4	154.8	129.3
Rent sharing (Operators:State)	*49:51*	*9:91*	*24:76*

Table 3-8: Rent sharing with average prices.

The current system has left a significant amount of the rent to private operators. On the other hand, all other things being equal, with the proportional system on top of the current one, the State would have seized almost all the rent. To be fair, also the RTT, coupled with the current fees, would have granted the State a significant amount of the rent, while leaving a not marginal slice to producers. This table shows why, on the one hand, the current system alone is not satisfactory for public bodies; on the other, it reveals why a proportional fee has been suggested. A system based just on concession fees does not fit a complex and liberalized electricity market, in which the price varies significantly, on an hourly basis. Clearly, a proportional system guarantees that also the State benefits from such price movements. The crucial point, of course, is to set a percentage that is unlikely to hinder the returns for private operators.

The table also shows that, given the structure of the current system and the fixed percentages of both the proportional system and the RTT, as revenues increase, operators get a higher share of the rent; more, all three systems generate a threshold below which operators face a loss. For instance, with an average price lower than 77.6 €/MWh operators would lose money with the proportional revenue sharing mechanism; 58.9 €/MWh is the lowest threshold with a RTT; 54.3 €/MWh with the current system.

Considering that producers should be able to sell in peak hours, at first sight all these threshold prices seem unlikely, also taking into account the unbalanced Italian generation mix. At the same time, in the renewal procedure, operators are expected to invest, in particular in environmental mitigation measures. Below, I show how the three different systems would affect such investment decisions.

Finally it is important to bear in mind that I are not considering an overall reform of the system; both the proportional system and the RTT are introduced on top of the concession fees, as it has been done in other countries. As a consequence, it is not possible to set an "optimal" tax rate, nor an optimal percentage. At the same time, given its structure, no matter the percentage, the RTT scheme is the only one where it is possible to introduce a tax refund if the rent is found to be negative, as it is the only sharing mechanism that explicitly takes into account capital costs.

3.5 The impact on environmental mitigation measures

Hydropower is an emission free technology, but it impacts the environment in several other ways. For instance, there is a wide literature on the impacts of hydropower production on biodiversity and ecosystem services (among others, Céréghino *et al.*, 2002; Brown *et al.*, 2009 and Renofalt *et al.*, 2010). Those studies have a clear biological perspective: they study the impact of hydropower production management (in terms of, among others, minimal vital flows, hydro-peaking and sediment releases) on several biological indicators. All studies demonstrate that hydropower production significantly impacts both biodiversity and ecosystem services and, what is more important, they show that mitigation measures and a change in production management strategies can dramatically improve the quality of the surrounding environment. Mitigation measures vary from simple fish-passages to complex outflow reservoirs aimed at minimizing flow changes generated by hydro-peaking. Changes in production strategies normally mean to reduce flow alterations by means of re-naturalisation (Nilsson, 1996). This is in sharp contrast with the functioning of electricity markets, as intraday price volatility clearly implicates intraday production volatility.

It is beyond the scope of this paper to assess and to monetize the environmental impacts of hydropower production in the Province of Sondrio. Here I just want to show how the proposed proportional system might reduce the scope for environmental investments.

At present, operators in the Province of Sondrio have not undertaken major mitigation measures. The Province itself performs monitoring activities for the minimal vital flow requirement that has been introduced two years ago. As a consequence, in the renewal procedure bidders might commit themselves to significant environmental investments. The study by Hall et al. (2003) has estimated a parametric equation that relates mitigation costs and installed capacity. This is not surprising, as bigger plants require bigger civil works and use more water; both issues have higher impacts on the environment, requiring more extensive mitigation measures. Consequently, using the equation by Hall *et al.* (2003), I have been able to estimate the costs of fish and wildlife mitigation investments and water quality monitoring equipment for all A2A and Edison plants, which will be subject to the tender procedure in the next four years:

Equation 3-9

$$C_{environ} = 310{,}000 \times P^{0.96} + 400{,}000 \times P^{0.44},$$

where P is the installed capacity.

Estimation (2012€/kW)	Average	Min	Max
A2A	150	138	156.6
Edsion	154	144	171

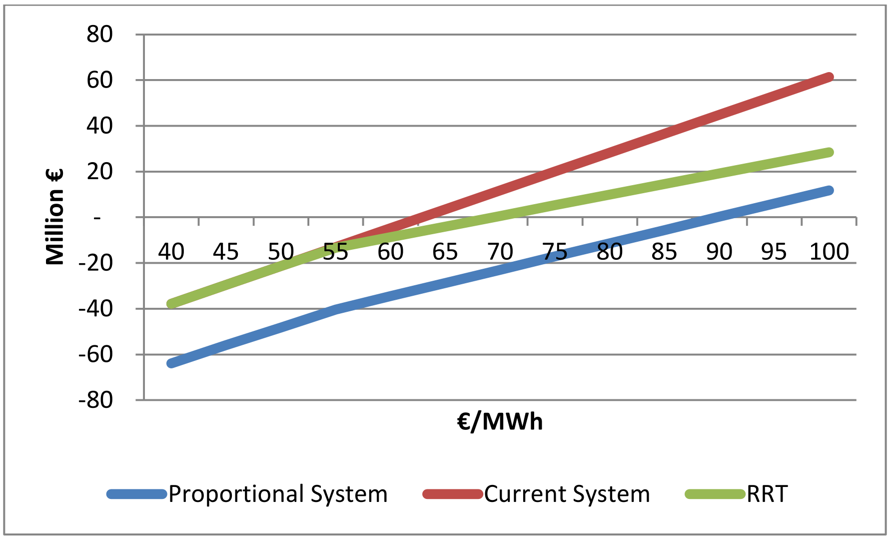
Table 3-9: Fish, wildlife and quality related CAPEX.

The table above shows that environmental investments are not negligible. For the plants managed by A2A, this would mean an overall investment of almost 108 million €; for those managed by Edison, instead, 48 million €. Consequently, this would increase capital costs, in the short run, from 31.1 million to 43 million, dramatically changing all minimum thresholds. Figure 4 below shows that, under the current system, 61.6 €/MWh is the minimum average price that would guarantee the full repayment of all costs under the current fee system; with the RTT system, instead, the threshold would increase to 67.9 €/MWh; finally, with the proportional system, it would rise to 87.9 €/MWh. This result means that with the historical average price of 80.1 €/MWh, operators under the proportional system would not be able to repay their capital costs, unless they reduce by 7% the revenue sharing percentage, which would translate in -9 million € for the State.

The sensitivity analysis in figure 4 was performed by varying the price and keeping constant all other variables, namely production costs and the quantity produced.

This simple simulation shows the perverse effect of the proportional system on investment decisions in general and on environmental ones in particular. In fact, for a more environmentally friendly hydropower production, not only investments are needed, but operators should also opt for production patterns that minimize their impact on the flow. This reduces the scope for production in peak hours only, consequently reducing unitary revenue.

Figure 3-4: Sensitivity analysis of the net rent to the electricity price.



Clearly, these are simplistic estimations that do not take into account variations in production nor a long run perspective. For instance, in the 8 years under study and for the two operators under consideration, production has varied from -24% to +26% from the average. With the highest levels of production, which would mean working for 2,670 hours instead of the average 2,178 hours used for the estimations, the thresholds would become: for the current system, 48.9 €/MWh; for the RTT system, 54.0 €/MWh; finally, for the proportional system, 69.9 €/MWh. Of course, production relies on precipitations, which would complicate further the simple estimations.

3.6 Conclusions

The paper is the first attempt to estimate the hydropower rent in Italy. The results show that Italian hydropower production generates the highest rent ever estimated, averaging from 41.5 €/MWh to 70 €/MWh. The generation portfolio relying heavily on natural gas is the main source of such a rent. These high values explain why, in the light of the renewal procedure, the current rent sharing mechanism is not satisfactory for the local authorities, which keep less than 50% of the rent: the suggested proportional fee would guarantee almost 91% of the rent.

At the same time, though, the renewal procedure represents an opportunity for the introduction of environmental mitigation measures, which would significantly reduce flow alterations and would improve ecosystem integrity, as required by the WFD. These measures entail significant investments, consequently increasing capital costs and reducing the possibility to offer high revenue sharing percentages. A RRT, instead, would reduce the trade-off between rent maximization and environmental protection.

Of course, the results are based on important assumptions with regard to CAPEX, OPEX and revenues. Hence, the results are a first approximation Future lines of research should go towards a more precise estimation of the hydropower rent both in the Province and in Italy, by using hourly production data and real costs. Moreover, it would be necessary to better frame the trade-off between rent maximization and environmental protection by estimating the monetary value of environmental damages and internalizing it in each operator's cost function, by means of an *ad hoc* environmental fee.

3.7 Acknowledgments

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3.8 References

Alvarado-Ancieta, C.A., 2009. Estimating E&M powerhouse costs, *International Water Power and Dam Construction*, 17 February 2009, 21-25.

Amundsen, E. S., Andersen, C., 1992. Rent Taxes on Norwegian hydropower generation. *Energy Journal*, *13* (1), 97-116.

Amundsen, E. S., Tjøtta, S., 1993. Hydroelectric rent and precipitation variability: The case of Norway. *Energy Economics*, *15* (2), 81-91.

APER - Associazione Produttori Energia da Fonti Rinnovabili, 2012. *Canoni e sovracanoni idroelettrico per l'anno 2012*. Milano

Autorità per l'Energia Elettrica e il Gas - AEEG, 2011. Decision Arg/elt 199/11. *Disposizioni per l'energia elettrica e il gas per l'erogazione dei servizi di trasmissione, distribuzione e misura dell'energia elettrica per il periodo di regolazione 2012-2015 e disposizioni in materia di condizioni economiche per l'erogazione del servizio di connessione*.

Banfi, S., Filippini, M., 2010. Resource rent taxation and benchmarking—A new perspective for the Swiss hydropower sector. *Energy Policy*, *38* (5), 2302-2308.

Banfi, S., Filippini, M., Mueller, A., 2005. An estimation of the Swiss hydropower rent. *Energy Policy*, *33*, 927-937.

Brown, L.E., Hannah, D.M., Milner, A.M., 2007. Vulnerability of alpine stream biodiversity to shrinking glaciers and snow-packs. *Global Change Biology*, *13*, 958–966.

Céréghino, R., Cugny, P., Lavandier, P., 2002. Influence of intermittent hydro-peaking on the longitudinal zonation patterns of benthic invertebrates in a mountain stream. *International Review of Hydrobiology*, *87*, 47–60.

IRENA, 2012. Hydropower. *Renewable Energy Technologies: Cost Analysis Series*, *1* (3).

Gillen, D., & Wen, J. F., 2000. Taxing Hydroelectricity in Ontario. *Canadian Public Policy / Analyse de Politiques*, *26* (1), 35–49.

GME, 2012. *Annual Report*, Rome.

GSE, 2010. Produzione di energia da fonti rinnovabili. Costi di produzione e analisi degli investimenti. Unità Studi, Rome.

Hall, D.G. Hunt, R.T., Reeves K. S. Carroll, G.R., 2003. *Estimation of Economic Parameters of U.S. Hydropower Resources*, Idaho National Engineering and Environmental Laboratory, Idaho Falls, Idaho.

Kaldellis, J.K., Vlachou, D.S., Korbakis, G., 2005. Techno-economic evaluation of small hydro power plants in Greece: A complete sensitivity analysis. *Energy Policy*, *33* (15), 1969–1985.

Kaldellis, J.K, 2007. The contribution of small hydro power stations to the electricity generation in Greece: Technical and economic considerations. *Energy Policy*, *35* (4), 2187–2196.

Newbery, D., 1997. Determining the regulatory asset base for utility price regulation. *Utilities Policy, 6* (1), 1–8.

Nilsson C., 1996. Remediating river margin vegetation along fragmented and regulated rivers in the north: what is possible? *Regulated Rivers: Research and Management*, 12, 415–431.

Renofalt, B. M., Jansson, R., Nilsson, C. 2010. Effects of hydropower generation and opportunities for environmental flow management in Swedish riverine ecosystems. *Freshwater Biology*, *55* (1), 49-67.

Rothman, M., 2000. Measuring and apportioning rents from hydroelectric power developments. World Bank Discussion Paper 419.

Samuelson, P. A., 1964. Tax Deductibility of Economic Depreciation to Insure Invariant Valuations. *Journal of Political Economy*, 72, 604-606.

Watkins, G. C., 2001. Atlantic petroleum royalties: fair deal of raw deal? The AIMS (Atlantic Institute for Market Studies) Oil and Gas Papers, Paper No. 2.

Zuker, R.C., Jenkins, G.P. 1984. Blue Gold: Hydroelectric Rent in Canada. Economic Council of Canada, Ottawa.

4 Estimating a performance-based environmental fee for hydropower production: a choice experiment approach

Abstract

Hydropower is an emission free technology, but it impacts both biodiversity and ecosystem services. Mitigation measures and a change in production management strategies can reduce this impact. This paper proposes a performance-based environmental fee able to stimulate producers to outperform existing environmental requirements: the more they outperform with respect to the environmental target, the less they pay. To test the validity of the fee and to obtain a consistent monetary value of the fluvial ecosystem to be used as the monetary input for the performance-based environmental fee, I have conducted a discrete choice experiment (DCE) in the Province of Sondrio. DCE results show that people are willing to pay more than € 122 per household and per year (which is more than 20% of the average electricity bill) to increase the ecological status of regulated rivers. Moreover, the simulation of the performance-based environmental fee shows that its adoption would not hinder hydropower's profitability.

JEL Classification: H23, Q2, Q4, Q5

Keywords: Environmental Fee, Water Framework Directive, Choice Experiment, Hydropower.

4.1 Introduction

Hydropower is an emission free technology, but it impacts the environment in several other ways. For instance, there is a wide literature on the impacts of hydropower production on biodiversity and ecosystem services (among others, Céréghino *et al.*, 2002; Brown *et al.*, 2009 and Renofalt *et al.*, 2010). Those studies have a clear biological perspective: they study the impact of hydropower production management (in terms of, among others, minimal vital flows, hydro-peaking and sediment releases) on several biological indicators. All studies demonstrate that hydropower production significantly impacts both biodiversity and ecosystem services and, what is more important, they show that mitigation measures and a change in production management strategies can dramatically improve the quality of the surrounding environment. Mitigation measures vary from simple fish-passages to complex outflow reservoirs aimed at minimizing flow changes generated by hydro-peaking. Changes in production strategies normally mean to reduce flow alterations by means of re-naturalisation (Nilsson, 1996). This is in sharp contrast with the functioning of electricity markets, as intraday price volatility clearly implicates intraday production volatility.

The scope of this paper is twofold: first I propose a performance-based environmental fee, able to internalize the environmental costs that hydropower production causes. Then, I use the result of a discrete choice model to simulate its effect on a real hydropower plant.

In the next years, Italy will have to renew its hydropower concession. Within the renewal procedure, fees and taxation should be redesigned to take into account both the rent and the environmental impacts generated by hydropower production. In particular, the Water Framework Directive (WFD) requires that all water bodies attain a good ecological status by 2015 and promotes economic instruments, as means for achieving the target.

The Province of Sondrio is the place where renewal procedure will take place first. Moreover, the Province is by far the most important spot for hydropower production, with the highest concentration in Italy of installed capacity per km^2, roughly 680 kW; for comparison, the second highest is the Province of Brescia with some 450 kW/ km^2. For these reasons it was chosen for a case study that has involved the Local Authorities, two universities and several environmental engineers. The main purpose of the research project, named IDEA, has been to clearly assess the cause-effect relationship between hydropower production and environmental impacts. I have used the findings of the IDEA project[10] to conceive the discrete choice experiment and to design and simulate the environmental fee.

The paper unfolds as follows: section 2 sets out the environmental fee; section 3 is devoted to the choice experiment; in section 4 I simulate the impact of the environmental fee; section 5 concludes.

4.2 Steps to build an environmental fee

In this section, I propose an environmental fee. An environmental fee (or tax) is a fee designed to achieve a well-defined environmental effect, at a minimum of excess burden. Contrary to other forms of taxation, if the environmental fee is optimally designed, then its revenue should be zero, as it would make more economic sense to meet the environmental objective than to pay the tax (Backhaus, 1998).

Of course, also an environmental fee should respect all the principles listed by Adam Smith: "the tax which each individual is bound to pay ought to be certain, and not arbitrary. The time of payment, the manner of payment, the quantity to be paid, ought all to be clear and plain to the contributor, and to every other person". Moreover, the environmental fee has to comply also with the polluter pays principle, set forth in the WFD: the fee should in fact be equal to the monetary value of the actual impacts that hydropower production has on the fluvial ecosystem. As I explain below, there are consistent uncertainties on the cause-effect relationship between hydropower production and its environmental impacts; additionally, it is not easy to attach a precise monetary value to each single impact. As a consequence, the proposed fee, instead of being equal, has been designed as proportional to the environmental costs associated with hydropower production.

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[10] Which have not yet been published.

4.2.1 Determining the cause-effect relationship

As anticipated above, the first step for designing an environmental fee is to create a clear cause-effect relationship among different ways of managing production and their impacts on different characteristics of the fluvial ecosystem. This has been done in the first part of the IDEA project, which has assessed and categorized clear cause-effect relationships. The analysis of such relationships is beyond the scope of this paper. Still, it is important to summarize some aspects of the relevant literature and the conceived methodology. The few significant attempts that have been made to formalize the cause-effect relationships between hydropower production and ecosystem components were aimed at defining the most appropriate and effective mitigation measures. In 2001, Bratrich and Truffer have developed a scheme to support the *Greenhydro* procedure for the voluntary certification of environmentally friendly hydropower production, later adopted in Switzerland, known as *Naturemade*. The Greenhydro methodology basically assesses whether the main functions of the fluvial ecosystem are maintained, despite the impacts of hydropower production. To do so, a two-dimensional array relates five "management areas" (minimum flows, hydro-peaking, management of hydroelectric reservoirs, bed-load transport and structural characteristics of the plant) to five "environmental attributes" (hydrology, connectivity, morphology and geo-morphological processes, biotic and landscape). For each management area (including the structural characteristics of the system) the methodology defines mitigation measures for each environmental attribute considered to be representative of the ecosystem. After Greenhydro, other studies have refined such approach (among others, Hydropower Reform Coalition[11] and CH_2OICE[12]).

The IDEA project has built on this approach. In order to move from a case study to a fee applicable to all hydropower schemes, all the cause-effect relationships have been generalized and a simplified.

This means that each management area and each environmental attribute have been divided in few classes, so that the impact can be defined as a variation of the

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[11] http://www.hydroreform.org.

[12] http://www.ch2oice.eu.

environmental attributes under consideration generated by a change in one or more management variables. For instance, this means grouping in *n* discrete classes hydro-peaking levels and relate each class to *j* classes of hydrology variation (or fish population, or any other attribute). The rationale for this simplification stems from the uncertainty of quantifying on a continuous scale the impact of each operating modality. This simplification permits to handle the intensive component (that is, the fact that the alteration might be more or less pronounced) of each single impact. Environmental impacts, though, have also an extensive component, as any impact does not normally disappear after a defined length: more generally, it might persist for several kilometers at a reduced intensity. This raises the problem of how to "weigh" the intensive and the extensive components. The proposed solution is to discretize the length of each impact, i.e. to assess the impact per kilometer.

4.2.2 Estimating the monetary value of the environmental impacts

The second step is to attach a monetary value to each class of impact. There are several techniques to monetize environmental impacts. Again, it is beyond the scope of this paper to discuss the pros and cons of each methodology (for a critical assessment see Bateman *et al.*, 2002). Given the multidimensional and complex nature of ecosystems, there is ample scientific consensus (Hoyos, 2010) that the method most capable of estimating how a combination of changes to one or more ecosystem services affects human welfare is the discrete choice experiment.

DCE involves the design of a hypothetical market, in which people have to choose their preferred "product", which is decomposed in some relevant attributes, each of which has more than one level. For instance, the product *car*, can be decomposed in two attributes, one being *Origin of the producer* and the other one being *Design*. Each attribute can take several levels; for instance, the first attribute can have three levels (*Italian, German, Other European*), while Design might have just two (*Coupé* and *Station Wagon*). Respondents face several choice sets, each containing a certain number of mutually exclusive alternatives, relating the potential product to a change of in the level of its attributes. Clearly, each alternative has a price: consequently, respondents will choose according to their taste, but also according to the price of the product. Repeating the choice with different combinations of levels and prices should return the attribute level that is valued the most.

When it comes to environmental goods, for instance, the fluvial ecosystem, then it is important to relate the change of attribute levels to something, normally a change in policy or a change in managing the resource or something that has an impact on it. A standard procedure when testing DCE for environmental goods is to include in every choice set an alternative that reflects either the current status (status quo) of the good being evaluated or an opt-out alternative, which means the worst possible situation. Normally, the price (or cost) of these alternatives is equal to 0. The DCE format allows marginal utility estimates for changes in the level of each attribute to be easily converted to WTP estimates. Moreover, given that compensating variation measures may be obtained, it is possible to estimate the total value of improvements to the environmental good as a consequence of the policy or managerial change.

Whenever evaluating the environmental impacts in water bodies, the crucial elements for the design of DCE are: the definition of the affected population; the delimitation of the water bodies under analysis and the attributes chosen to describe the environment.

As for population scale, it can vary from just the users or those residing near the water bodies under study (Hynes et al., 2008; Kataria et al., 2012; Stithou et al., 2012) to a representative sample of the regional or national population (Kataria, 2009; Metcalfe et al., 2012). The target population clearly depends, on the one hand, on the expected effects of the policy or managerial changes under consideration, on the other, on the water bodies under consideration, which can vary from a single river (Hanley et al., 2006), to a river catchment (Brouwer et al., 2010; Poirier and Fleuret, 2010), to all the water bodies in a region or country (Kataria, 2009; Metcalfe et al., 2012).

Normally, attributes used in the DCE surveys relate the ecology of the water body to recreational opportunities and to the aesthetics of the water body. It is important to bear in mind that the attributes chosen for the choice experiment should differ from the attributes studied for determining the environmental impacts. Why so? In order to have a successful choice experiment, there is the need to test attributes that are relevant for the stakeholders involved, which normally means the general public. Consequently, the attributes or the levels used in the questionnaires have to be linked to the environmental attributes used to assess the impacts, but they need not to be the same. A simple example might help: an attribute such as *Water quality* can be expressed in terms of its different levels of chemical components or in simpler terms such as *swimmable* or *non-swimmable*; it is straightforward that this familiar attribute to the general public depends on the level of some chemical substances. This means that attribute levels are commonly qualitative (Hanley et al., 2005; Alvarez-Farizo et al., 2007; Birol et al., 2008a) and sometimes with images or visual descriptions (Doerthy et al., 2013). The most common attributes are: biodiversity levels, generally described as different quantities of native species (Morrison and Bennett, 2004; Kragt et al., 2011); recreational activities, that is the possibility to practice them or not (Doerthy et al., 2013); and aesthetics often described as a conglomerate of the effects of litter, smell and clarity (Alvarez-Farizo et al., 2007), sewage (Hanley et al., 2006) and pollution (Stithou et al., 2012).

To my knowledge, only one paper has used DCE to estimate how individuals value different environmental improvements for rivers where hydropower production takes place, that is Kataria (2009). The paper focuses on Swedish rivers and is aim is to assess the market share of environmentally friendly producers, which are expected to face higher production costs.

4.2.3 Designing the fee

Once the steps have been completed, it is possible to design the performance-based environmental fee. First, given the assumption that the impact is a variation of the class of a given environmental attribute, the cost has to be measured in such a way that a monetary value can be attached to this variation. For instance, the cost of the impact on hydrology will be the cost of the downgrade from class *j* to class *j-1*. Moreover, given that I have decided to discretize the length of the impact per kilometer, the cost will be a unitary cost per kilometer, i.e. the cost of the impact on hydrology will be the cost of the downgrade of 1 kilometer from class *j* to class *j-1*.

Finally, in order to take into account both the intensive and the extensive components, I propose to multiply the unitary cost of the impact that is the variation of class, for the length that has suffered that variation. This would give the following:

Equation 4-1

$$c_i = \sum_{j=1}^{k} a_{i,j} L_{i,j}$$

Where c_i is the cost for impact *i*, *j* is the discrete level (or class) of impact *i*, $a_{i,j}$ is the unitary cost of the impact *i* at level *j*; $L_{i,j}$ is the length of the river that has been impacted by impact *i* at level *j*.

According to the impacts relevant for the water body taken into, then the proposed fee would look like the following:

Equation 4-2

$$EF = \sum_{i=1}^{n} c_i$$

Where *EF* is the environmental fee and *n* is the number of impacts taken into account.

This formula, however, does not distinguish between water bodies. A hydropower scheme, though, might insist on more than a water body, for instance, by capturing water from a river and releasing it into another. In order to reconcile simplicity and accuracy, water bodies should be classified in a limited and manageable number of categories, to estimate the unitary cost per impact for each category. Then, the final structure of the proposed fee becomes:

Equation 4-3

$$TEF = \sum_{w=1}^{W} EF_w$$

Where *TEF* is the total environmental fee and *w* is the number of categories into which water bodies have been divided.

The construction and operation of hydropower plants inevitably involves environmental changes in the features of the water bodies where they are located. These impacts are often evaluated under different authorization procedures, such as, for example, the environmental impact assessment. These authorization procedures normally require proponents to modify either the project or the management of the plant in order to comply with the existing environmental regulation. Within this framework what is the role of our performance-based environmental fee?

The answer is that the fee has been conceived as an incentive mechanism, based on the successful experience of performance-based regulation in several sectors (for instance, see Joskow, 2008). Consequently, existing environmental regulation can be seen as the minimum requirements that an operator has to achieve. The fee is then a monetary mechanism that should stimulate the operator to outperform. I discuss this within an extremely simplified setting. For instance, let's imagine that hydropower production only impacts fish population and the impact has been divided into four classes, which range from "no impact" (or reference state j^*) to $j-4$. Environmental regulation requires the attainment of $j-2$, otherwise the plant is not authorized (or for what it matters, it cannot operate). Then, the environmental fee is simply the cost of the downgrade from j^* to $j-2$. If properly conceived, the fee should stimulate the operators to reduce its impact and consequently pay a lower fee (or no fee at all).

It follows that the payment of the fee does not exempt from the careful application of all environmental rules, but that it can be an instrument to (partially offset) the residual environmental alterations. To my knowledge, it is the first time that a performance-based environmental fee is proposed for hydropower production. Higher design and compliance costs are the main reason behind the difficulty in introducing such a fee.

4.3 The choice experiment

4.3.1 The setting

The Province of Sondrio is geographically located in northern Lombardy, close to Switzerland. It is home of some 2.2 GW of hydropower plants, roughly 18% of the overall Italian hydropower capacity. The Province has the highest concentration in Italy of installed capacity per km^2, roughly 680 kW. The second highest is the Province of Brescia with some 450 kW/ km^2.

In the next four years, the concessions of half of the installed capacity will expire. The renewal procedure, as anticipated before, is therefore an opportunity to introduce a pricing scheme compliant with the WFD.

Considering the weight and importance for Lombardy of the hydropower capacity located in Sondrio, I have addressed the choice experiment to a representative sample of 1,000 households in Lombardy (obtaining a 100% of valid responses).

Variable	Mean	Std. dev.
Age	40.8	12.4
Household components	2.9	1.1
University education	.29	-
In favor of incentives to renewable energies	.502	.50
Travel at least once to the Province of Sondrio	0.505	.49
Membership in an environmental organization	0.100	.30

Table 4-1: Descriptive statistics.

The mean age of the respondents is 40.8 years and household components are just below 3, at 2.9; finally 29% of the sample has a university degree. All these data are precisely in line with the descriptive statistics from the National Institute for Statistics, ISTAT, and confirm that I have a representative sample. Half of the sample has visited at least once the Province of Sondrio; more, half of the sample is in favor of incentives to renewable energies, which means that they have positive attitudes towards higher electricity bills to support environmentally friendly electricity production.

The respondents were not previously informed of the relevant characteristics of hydropower production, in order not to influence their choices. Still, the questionnaire contained concise information on why each attribute was chosen and why it mattered for hydropower production. The questionnaire[13] consisted of three parts. In the first part respondents were asked questions that could reveal their attitude towards the environment and renewable energy sources in general and towards the Province of Sondrio and its rivers in particular. The second part contained the choice experiment, with eight choice sets; the third part consisted of questions regarding the respondent's socio-economic status.

A preliminary pilot study was conducted in the process of designing the questionnaire. Both the attributes and the levels chosen for the choice experiment were based on the output of the IDEA project.

Before proceeding further, it is important to clarify what the IDEA project has studied, that is the impact of hydropower production on the fluvial ecosystem. Consequently, the study did not assess the impacts on terrestrial ecosystems not directly related to the dynamics of the water bodies (e.g. the impact on birds related to the construction of access roads or transmission lines), although these impacts can be relevant. Also, the project did not take into account the impact on the landscape, basically for the impossibility of formalizing a unique cause-effect relationship between hydropower plants and an index of landscape alteration. In the end, the underlying principle behind these choices is that the environmental fee should be primarily used for mitigating or offsetting just the impacts on the fluvial ecosystem.

Following this approach adopted in the IDEA project, the regulated water bodies in the Province of Sondrio were divided into two categories:

1. Main water bodies: total length 92 kms;
2. Tributaries: total length 6,320 kms.

[13] It was a Computer Assissted Web Interview.

As stated above, an effective DCE has to have understandable attributes, which means attributes expressed in qualitative and figurative terms. Experts provided me with images and visual descriptions of the attributes described below. Moreover, in order to obtain an effective choice experiment, I asked the experts to gather the environmental attributes so to have a reduced number of attributes to show to the general public. This is what I have done with the attribute *integrity of the fluvial ecosystem*, which is the sum of several environmental attributes. Consequently, the levels of the *integrity of the fluvial ecosystem* attribute depend on the variations and interactions of the levels of the environmental attributes that *integrity of the fluvial ecosystem* incorporates. Of course, this choice has a consequence on the design of the fee. In fact, this means that I can attach a monetary value only to this composite attribute and not to all the single attributes with which the composite attribute is made of.

As stated above, the first attribute is the *integrity of the fluvial ecosystem*, which was represented with images taken from the water bodies in the Province of Sondrio. Assessing the integrity of a water body means taking into account many aspects, ranging from water quality to the presence of suitable habitats for aquatic organisms; from the morphology to the presence and abundance of vegetation on the banks. In the questionnaire I showed pictures able to capture all those aspects.

The second attribute is *hydro-peaking*. At first, the choice of this attribute may sound counterintuitive, as this is a managerial variable and not an attribute of the fluvial ecosystem. The idea behind this choice is that sudden variations of the flows, if not frequent, might not alter in the long run the integrity of the fluvial ecosystem, but they could still have a consistent negative impact on the natural reproduction of fish population (Renofalt *et al.* 2010). Still, introducing an attribute such as fish population (with, for instance, different levels of fish stock) might have brought misleading results, as fish stock can be increased also artificially, by introducing cultivated fishes (a common practice in the Italian rivers). This artificial repopulation would attain the same result without preventing operators from doing hydro-peaking. Consequently, I thought that a more direct attribute (such as fish population) might have brought results overestimating the willingness to have an abundant fish stock, without taking into account its natural life cycle. Also for this attribute, I showed pictures capturing different levels of hydro-peaking.

Finally, the third attribute is *canoable length*, which indicated the percentage of the river suitable for canoeing. The idea behind this attribute is that it gives (or at least it should) an immediate conceptualization of a "natural river", with no man-made obstacles. I used this attribute to see how much the respondents would value a naturally flowing water body. In fact, if properly designed, built and managed hydropower plants might not alter significantly the integrity of the fluvial ecosystem (meaning a minimization of their intensive impact): still, they would create (minor) extensive impact on its natural hydrology.

In Table 4-2, I show that all the attributes used are described with more than two levels. The questions, in fact, were not restricted to whether or not to have a certain remedial measure; they all asked to what extent the remedial measure should be undertaken.

Attribute	Description	Level
Integrity of the fluvial ecosystem	Closeness to natural conditions	High; moderate; bad.
Hydro-peaking	Sudden variations of the flows.	High; medium; none.
Canoable length	Percentage of the river suitable for canoeing.	5%; 15%; 60%.
Bill increase	Additional annual cost per household (in EUR)	0; 10; 50; 100.

Table 4-2: Attribute and attribute levels.

Each choice set contained three alternatives, inclusive one opt-out alternative, which was included in all of the choice sets. Of course, I deleted strictly dominating choice sets. The design was finally blocked into two versions, one for each category of water bodies, each containing eight choice sets. The opt-out alternative is not the status quo, but the worst possible situation. This choice was taken, as it is the only one that gives the possibility to attach a monetary value to all possible class variations.

I labeled each alternative as "electricity supplier *x*"(with *x* ranging from 1 to 3), following Kataria (2009). This means that, for the sake of the choice experiment, suppliers differed from each other for their remedial measures; that is for the level of the environmental attributes attained.

As a consequence, respondents faced a choice where they could choose the preferred method for producing hydropower. The bid vehicle used in this study was the increased electricity payments for the household. The opt-out alternative implied no increase in the annual bill; instead, all other alternatives implied a certain increase. There are two reasons why I opted for increased electricity bills as the bid vehicles: the first one is that an improvement of the fluvial ecosystem can be achieved by changing the operation of the hydropower stations, implying a cost increase which normally is passed onto consumers; the second one is that the objective is to estimate the consumers' willingness to pay a higher price for a more environmentally friendly hydropower production.

4.3.2 The econometric model

I used the standard random utility model (RUM) developed by McFadden (1973) to study respondents' choices. RUM is a standard practice within DCE data analysis as its basic assumption is that the utility for an individual is composed of an observable component and a random component, which gives a utility function of this form:

Equation 4-4

$$U_{ij} = V_j + \varepsilon_{ij} = V(X_j, P_j) + \varepsilon_{ij}$$

where V_j represents the observable component, ε_{ij} the random component, $X_j$represents a vector of attributes used to describe alternative j, and P_j is the price associated with alternative j.

This means that individual i chooses alternative j over any other alternative, which means that the satisfaction obtained from choosing j exceeds the one obtained from any alternative k. The outcome $y_i = j$ happens only if the utility received from j is greater than the one from any other alternative of the choice set t. Therefore, the probability of the individual i choosing j over alternative k can be written in terms of utility, that is in terms of the observable and error parts of the utility function.

As stated before, I follow McFadden specification, where the probability of an alternative being chosen is expressed on terms of the logistic distribution. Within this framework, errors terms are assumed to be independently and identically Gumbel-distributed. This means that individual choices are based on utility differences between alternatives; moreover, the error component gives the information, in terms of probability, about individuals' behavior when they face multi-attribute choices, according to the formula:

Equation 4-5

$$P(y_i = j|t) = \frac{\exp(V_j)}{\sum_{h \in t} \exp(V_h)}$$

The most flexible model specification used in the literature is the random parameters logit (RPL) model, where the indirect utility function below:

Equation 4-6

$$U_{ij} = a_j + X_j' \beta_i + P_j' \beta_p + \varepsilon_{ij}$$

is specified in the subsequent form:

Equation 4-7

$$U_{ij} = a_j + X_j' \beta_x + P_j' \beta_p + X_j' \nu_i + \varepsilon_{ij}$$

where X_j' is a vector of alternative j-specific regressors, β_i, that is the vector of preference parameters associated to X_j', takes the form $\beta_i = \beta_x + \nu_i$ and $\nu_i \sim N(0, \Sigma_{bx})$. This means that β_x represent the population mean, while ν_x is the stochastic deviation, representing the individual's preference relative to the average preferences in the population. Moreover, the combined error $X_j' \nu_x + \varepsilon_{ij}$ is correlated across alternatives. Consequently, Equation 4-5 becomes:

Equation 4-8

$$P(y_i = j|t)| = \frac{\exp(a_j + X_j'\beta_x + P_j'\beta_p + X_j'\nu_i)}{\sum_{h\in t}\exp(a_h + X_h'\beta_x + P_h'\beta_p + X_h'\nu_i)}$$

Within this framework, the standard estimation procedure, which I have opted for, is a maximum likelihood. Given a sample of i individuals, each making T choices, where each choice set has j alternatives, I can define a dummy variable d_{ijt} that takes value 1 if *i* opts for alternative *j* in the choice set *t*. The likelihood function is given by:

Equation 4-9

$$L(\beta_x, \beta_p) = \prod_{i=1}^{I}\prod_{t=1}^{T}\prod_{j=1}^{J}(\tilde{P}(y_i = j|t))^{d_{ijt}}$$

where $\tilde{P}$ is a simulator for P, which integrates ν_i on a limited number of draws. In this study, the distribution of the parameters is simulated using 400 Halton draws. Finally, the logarithm of L returns the log-likelihood.

4.3.3 Results

The utility function that I have considered is the following:

Equation 4-10

$$U_{ij} = \beta_1 \times Asc + \beta_2 \times Integ2 + \beta_3 \times Integ3 + \beta_4 \times Hypeak2 + \beta_5 \times Hypeak3 + \beta_5 \times Canoe15 + \beta_6 \times Canoe60 + \beta_7 \times Bill + \varepsilon$$

where *Asc* is the dummy that indicates the choice of the opt-out alternative; *Integ2* and *Integ3* are dummies for, respectively, moderate and high level of fluvial ecosystem integrity; *Hypeak2* and *Hypeak3*, instead, are dummies for medium and high level of hydro-peaking; *Canoe15* and *Canoe60* are dummies for 15% and 60% of canoable length; *Bill* is the annual increase for each household; all betas represent the marginal utility of each attribute. Below, I display the results for the main water bodies.

Variable	Coefficient	Std. error	Coefficient std. dev.
Random parameters			
Integ2	1.0068***	0.3391	1.6799***
Integ3	1.9376***	0.4135	2.9945***
Hypeak3	-1.1860***	0.4063	3.3039***
Non random parameters			
Asc	-0.6408***	0.1130	
Bill	-0.0168***	0.0008	
Canoe15	-0.0652	0.0853	
Canoe60	-0.3875***	0.0840	
Hy_peak2	-0.4258***	0.0978	
Heterogeneity in mean			
Integ3*age	0.0250	0.0564	
Integ3*male	0.1555	0.1492	
Integ0*age	-0.0185	0.0689	
Integ0*male	0.0780	0.1803	
Hy_peak3*age	0.0368	0.0667	
Hy_peak3*male	0.0829	0.1753	
Individuals	1,000		
Observations	24,000		
Pseudo r squared	0.28		
LL	-3,164.69		
Replications	400		
Significant	*** at 1% ** at 2.5% * at 5%		

Table 4-3 Random parameters logit for Main Water Bodies.

Most of the variables are significant at 1% level and have the expected sign; *Canoe60* is significant at 1% but, surprisingly has a negative sign; *Canoe15*, instead is not significant. This unexpected results can be interpreted as, one the one hand, an absence of any interest for canoeing; on the other, the (wrong) perception that a long canoable length implies a reduction of the quality of river hydrology. Finally, it is important to highlight that individual characteristics do not influence the results.

Let's see the results for the tributaries.

Variable	Coefficient	Std. error	Coefficient std. dev.
Random parameters			
Integ_2	1.9938***	0.3281	1.6656***
Integ_3	2.9429***	0.3723	2.5138***
Hy_peak_3	-0.9504**	0.3860	3.1993***
Non random parameters			
Asc	-0.5332***	0.1119	
Bill	-0.0157***	0.0008	
Canoe_15	-0.0914	0.0833	
Canoe_60	-0.2923***	0.0809	
Hy_peak_2	-0.3923***	0.0952	
Heterogeneity in mean			
Integ_3*age	-0.1686***	0.0555	
Integ_3*male	-0.0794	0.1441	
Integ_0*age	-0.2355	0.0622	
Integ_0*male	-0.2030	0.1609	
Hy_peak_3*age	-0.0047	0.0638	
Hy_peak_3*male	0.0457	0.1671	
Individuals	1,000		
Observations	24,000		
Pseudo r squared	0.27		
LL	-3,473.29		
Replications	400		
Significant	*** at 1% ** at 2.5% * at 5%		

Table 4-4: Random parameters logit for Tributaries.

Results are pretty similar to the ones obtained for the main water bodies: most of the variables are significant and have the expected sign. Again, canoable length behaves differently from what expected and its 15% level is again not significant. In this model, older people seem to care a bit less for high level of ecological integrity, but, at the same time, the marginal utility of *Integ_3* is much higher for tributaries than for main water bodies.

The results of the models allow to estimate the marginal willingness to pay. As anticipated before, the betas can be seen as the marginal utility of each level of each attribute; therefore, observing the choices that individuals make when some attribute level changes and observing the price associated with this particular scenario of change, I can derive marginal values for each attribute when moving from the opt-out level to each other level of the attribute, according to the formula:

Equation 4-11

$$MWTP_{x,a} = -\frac{\beta_{x,a}}{\beta_p}$$

where $MWTP_{x,a}$ is the marginal willingness to pay to move from the opt-out level to level a of attribute x; $\beta_{x,a}$ is the marginal utility of level a of attribute x; β_p is the marginal utility of money.

Variable	Main water bodies (€/year)	Tributaries (€/year)
Integ_2	80	85
Integ_3	119	120
Hy_peak 2	-25	-25
Hy_peak_3	-56	-57

Table 4-5: Marginal willingness to pay for attributes (90% confidence interval).

Table 4-5 shows that households have a significant marginal willingness to pay: the amounts can be compared to the average amount that is paid by consumers in their electricity bill to support renewable generation, that is close to 90 €/year per household (AEEG, 2013). Moreover, the MWTP is slightly higher for tributaries than for the main water bodies: it seems that people value more rivers that are perceived to be more pristine, such as mountain streams.

The estimates can be used to calculate the total WTP for different management scenarios. Since the utility function that I am using is linear, its value is the sum of its parts, that is, attributes can be combined in different ways to estimate welfare effects of discrete changes of the set of attributes. This situation can be calculated with the log-sum formula, (Hanemann, 1999):

Equation 4-12

$$E(WTP) = \frac{1}{-\beta_p}(ln\, e^{V_n^1} - ln\, e^{V_n^0})$$

Where V_n^1 and V_n^0 represent the utility after and before the change and β_p is the marginal utility of money.

Scenario	Main water bodies (€/year)		Tributaries (€/year)	
	Single Household	Whole Lombard households	Single Household	Whole Lombard households
1. From opt-out to high level of ecosystem integrity	66.65	293,920,539	96.16	424,015,305
2. From opt-out to high level of ecosystem integrity and no hydro-peaking	97.31	429,116,691	122.45	539,945,269
3. From moderate level of ecosystem integrity and medium hydro-peaking to high level of ecosystem integrity and no hydro-peaking	35.07	154,643,423	37,11	163,624,214

Table 4-6: Compensating surplus (WTP) for different scenarios.

As shown in scenario 2, the overall value of pristine rivers (that is high level of ecological integrity and no hydro-peaking) in the Province of Sondrio is not far from 1 billion euro, considering that in Lombardy there are 4.410 million households. Moreover, considering that the average level of ecosystem integrity has been estimated as moderate and that normally hydro-peaking is medium, scenario 3 tells that the total willingness to pay to move from a situation similar to the current one to a situation where there is no hydro-peaking and a high level of ecosystem integrity is equal to 318 million euros. Pontoni (2013) has estimated that the yearly total rent generated by hydropower producers in the Province of Sondrio averages 282 million euros. This means that internalizing environmental costs would shrink the rent to zero, but would still make hydropower production profitable. I now compare my findings with Kataria (2009). Of Course, it is important to bear in mind that he has adopted different attributes. The maximal willingness to pay for the improvement of a bundle of attributes that he has estimated is equal to 223 euros per household and per year; mine is 122. This 100 euros difference can be explained by the fact that his choice experiment does not focus exclusively on the fluvial ecosystem but it takes into account the terrestrial ecosystem, which was excluded in the designing of the IDEA project.

4.4 Simulating the performance-based environmental fee

As shown before, since the utility function is linear, it is possible to calculate the value of the variation of just one attribute, all other things being equal. This means that I can use those results to estimate the unitary cost needed for the performance-based environmental fee. Precisely, the unitary cost is estimated as follows: I divide the cumulated willingness to pay to move from level *j-2* to level *j-1* and from *j-1* to *j** of both impacts by the total length of each water body category.

This method entails one very important assumption: each km of a given river has the same value, thus impacting a point or another has no difference in terms of value loss. This might not be true as certain parts of a water body can be more valuable than others. At the same time, the estimation of the monetary value of different segments of one water body would require the design of specific DCEs for each segment, increasing the complexity and reducing the immediate understanding of the general public. A partial solution would be to weigh the unitary cost by the average water flow.

The results are shown below:

	Unitary cost for River 1 (thousand euro)	Unitary cost for River 2 (thousand euro)
Ecosystem integrity		
From bad to moderate (1)	2,041	48
From moderate to high (2)	1,153	18
Hydro-peaking		
From high to medium (1)	1,735	7
From medium to none (2)	527	21

Table 4-7: unitary cost

As shown in table 4-7, unitary costs vary differently if one takes into account the main water bodies or the tributaries: this is so because there is a difference in the overall length of each water body. At the same time, given the difference in water flow between, let's say, a big river and a mountain stream, withholding water from the second one normally has a much higher extensive impact, increasing the overall environmental cost. This might be a second rationale for adjusting the unitary cost per km according to the average water flow.

I know apply this fee to a hydropower plant with 70 MW of installed capacity. The choice of this plant resides on the fact that it represents the average dimension of hydropower plants in the Province of Sondrio. Its environmental impacts can be summarized as follows:

- Moderate hydro-peaking on 2 km of a main water body;
- Reduction from high to moderate ecosystem integrity on 1 km of a main water body;
- Reduction from high to moderate ecosystem integrity on 50 km of a tributary.

This results in an environmental fee of 3.12 million euros. For comparison, the actual concession fee paid by the hydropower plant is approximately 1.29 million euros.

	Values in million 2012€
Revenues	13.9
OPEX and amortization	4.6
Concession fee	1.3
Performance-based environmental fee	3.1
Taxes	1.3
Profits	2.8
Cost of capital	1.7
Rent	1.1

Table 4-8: Simulated impact of the performance-based environmental fee on a hydropower plant.

If its average revenues and average costs are taken into account, as done in the table above, it is possible to show that the performance-based fee would not hinder its profitability, but it would just reduce the rent (all the data come from Pontoni, 2013).

4.5 Discussion and policy implications

Studies demonstrate that hydropower production significantly impacts both biodiversity and ecosystem services and, what is more important, they show that mitigation measures and a change in production management strategies can dramatically improve the quality of the surrounding environment. According to the

WFD, these costs should be internalized and in this paper I propose a performance-based environmental fee, which is a monetary mechanism that should stimulate hydropower producers to outperform existing environmental regulation: the more they outperform the less they pay. In fact, contrary to other forms of taxation, if the environmental fee is optimally designed, then its revenue should be zero, as it would make more economic sense to meet the environmental objective than to pay the tax.

In order test the validity of the fee and to obtain a consistent monetary value of the fluvial ecosystem to be used as the monetary input for the performance-based environmental fee, I have conducted a DCE in the Province of Sondrio. The DCE is the method most capable of estimating how a combination of changes to one or more ecosystem services affects human welfare. The Province of Sondrio, instead, was chosen as it is by far the most important spot for hydropower production, with the highest concentration in Italy of installed capacity per km^2

Results show that people are willing to pay more than € 122 per household and per year to increase the ecological status of regulated rivers. In particular, both ecological integrity and hydro-peaking are considered as significant attributes worth a monetary effort.

Results have also been used to simulate the impact of the newly conceived performance-based environmental fee on a representative hydropower plant. The simulation shows that the introduction of the fee would not hinder its profitability, but it would just reduce the rent.

This paper provides policy-maker with a new instrument for environmental regulation. In particular, I show that:

- DCE can be used as a way to internalize environmental costs generated by hydropower producers;
- The magnitude of the performance-based environmental fee is such that it would certainly stimulate environmentally friendly production.

Of course, there is scope for further research. On the one hand the performance-based environmental fee could be refined, for instance by taking into account the fact that different segments of a water body might have different values. Moreover, the results of the DCE could be largely influenced by its design, so it could be useful to replicate the study. Still, I think that this paper is a first step to a more comprehensive implementation of the WFD, as the renewal procedure for hydropower schemes is about to start.

4.6 Acknowledgments

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4.7 References

AEEG, 2013. Annual Report.

Alvarez-Farizo, B., Hanley, N., Barberan, R., Lazaro, A., 2007. Choice modeling at the “market stall”: individual versus collective interest in environmental valuation. *Ecological Economics*, 60, 743–751.

Backhaus, J.G., 1998. When should the ecotax kick-in? A cost and choice approach. *Kyklos*, 51(4), 565-575.

Bateman, I., Carson, R., Day, B., Hanemann, M., Hanley, N., Hett, T., Jone-Lee, M., Loomes, G., Mourato, S., Ozdemiroglu, E., Pearce, D., Sugden, R., Swanson, J., 2002. *Economic Valuation with Stated Preference Techniques: A Manual*. Edward Elgar Publishing Limited, Cheltenham.

Bratrich C, Truffer B., 2001. *Green Electricity Certification for Hydropower Plants—Concepts, Procedure, Criteria*. EAWAG Ökostrom Publikationen 7: Kastanienbaum.

Birol, E., Koundouri, P., Kountouris, Y., 2008. Using the choice experiment method to inform river management in Poland: flood risk reduction versus habitat conservation in the upper Silesia Region. In: Birol, E., Koundouri, P. (Eds.), *Choice Experiments Informing Environmental Policy*. Edward Elgar, Cheltenham, UK.

Brouwer, R., Martin-Ortega, J., Berbel, J., 2010. Spatial preference heterogeneity: a choice experiment. *Land Economincs*, 86, 552–568.

Brown, L.E., Hannah, D.M., Milner, A.M., 2007. Vulnerability of alpine stream biodiversity to shrinking glaciers and snow-packs. *Global Change Biology*, 13, 958–966.

Céréghino, R., Cugny, P., Lavandier, P., 2002. Influence of intermittent hydro-peaking on the longitudinal zonation patterns of benthic invertebrates in a mountain stream. *International Review of Hydrobiology*, 87, 47–60.

D. McFadden. Conditional logit analysis of qualitative choice behaviour. In Zarembka P. (Ed.), *Frontiers in Econometrics*, Academic Press, New York, 1973.

Doherty, E., Campbell, D., Hynes, S., 2013. Models of site-choice for walks in Ireland: exploring cost heterogeneity. *Journal of Agricultural Economics*, , http://dx.doi. org/10.1111/1477-9552.12002.

Hanemann, M., 1999. Welfare analysis with discrete choice models. In: Herriges, J., Kling, C. (Eds.), *Valuing Recreation and the Environment*. Edward Elgar, Cheltenham, pp. 33–64.

Hanley, N., Adamowicz, W., Wright, R., 2005. Price vector effects in choice experiments: and empirical test. *Resource and Energy Economics*, 27, 227–234.

Hanley, N., Wright, R., Alvarez-Farizo, B., 2006. Estimating the economic value of improvements in river ecology using choice experiments: an application to the water framework directive. *Journal of Environmental Management*, 78, 183–193.

Hoyos, D., 2010. The state of the art of environmental valuation with discrete choice experiments. *Ecological Economics*, 69, 1595–1603.

Hynes, S., Hanley, N., Scarpa, R., 2008. Effects on welfare measures of alternative means of accounting for preference heterogeneity in recreational demand models. *American Journal of Agricultural Economics*, 90, 1011–1027.

Joskow, P., 2008. Incentive regulation and its application to electricity networks. *Review of Network Economics*, 7(4), 547-560.

Kataria, M., 2009. Willingness to pay for environmental improvements in hydropower regulated rivers. Energy Economics 31, 69–76.

Kataria, M., Bateman, I., Christensen, T., Dubgaard, A., Hasler, B., Hime, S., Ladenburg, J., Levin, G., Martinsen, L., Nissen, C., 2012. Scenario realism and welfare estimate in choice experiments – a non-market valuation study on the European Water Framework Directive. *Journal of Environmental Management*, 94, 25–33.

Kragt, M., Newham, L., Bennett, J., Jakeman, A., 2011. An integrated approach to linking economic valuation and catchment modelling. *Environmental Modelling & Software*, 26, 92–102.

Metcalfe, P., Baker, W., Andrews, K., Atkinson, G., Bateman, I., Butler, S., Carson, R., East, J., Gueron, Y., Sheldon, R., Train, K., 2012. An assessment of the nonmarket benefits of the water framework directive for households in England and Wales. *Water Resource Research*, 48 (WO3526),

Morrison, M., Bennett, J., 2004. Valuing New South Wales rivers for use in benefit transfer. *Australian Journal of Agricultural and Resource Economics*, 48, 591–611.

Nilsson C., 1996. Remediating river margin vegetation along fragmented and regulated rivers in the north: what is possible? *Regulated Rivers: Research and Management*, 12, 415–431.

Poirier, J., Fleuret, A., 2010. Using the choice experiment method for valuing improvements in water quality: a simultaneous application to four recreation sites of a river basin. In: Proceedings of the 59th Conference of Association Francaise de Science Economique. Nanterre Université.

Pontoni, F., 2013, Hydropower rent in Northern Italy: economic and environmental concerns in the renewal procedure, forthcoming.

Renofalt, B. M., Jansson, R., Nilsson, C. 2010. Effects of hydropower generation and opportunities for environmental flow management in Swedish riverine ecosystems. *Freshwater Biology*, *55* (1), 49-67.

Stithou, M., Hynes, S., Hanley, N., Campbell, D., 2012. Estimating the value of achieving "Good Ecological Status" in the Boyne River Catchment in Ireland using choice experiments. *The Economic and Social Review*, 43, 397–422.

5 Cheaper electricity or a better river? Estimating fluvial ecosystem value in Southern France

Abstract

In the next years, France will have to renew a consistent share of hydroelectric concessions, among which we can find those insisting on the Aspe and its tributaries (for a total of almost 100 MW of installed capacity). Beauty contests will take place, where bidders have to present offers for technical and environmental improvement, as well as a revenue sharing percentage for Local Authorities.

This framework generates a potential trade-off between revenue-sharing and environmental improvements. This paper investigates this trade-off by means of a discrete choice experiment (DCE) in order to estimate people's preferences. In my DCE, I translate the revenue sharing in an immediate rebate in the electricity bill. Respondents could choose higher rebates and lower ecosystem improvements or lower (or no) rebates and higher levels of ecosystem amelioration.

Results are clear: people are willing to pay to increase the ecological status of the Aspe river; the highest total willingness to pay (WTP) is above € 96 per household and per year. Moreover, people's marginal WTP for a satisfactory fish stock reaches 154 €/year, that is twice the maximum rebate that was offered. Finally, all environmental attributes are considered as significant and worth a monetary effort. The implications are straightforward: people value considerably the improvement of the Aspe ecosystem, which means that bidders should react accordingly and develop specific bids for the environmental aspects.

JEL Classification: H23, Q2, Q4, Q5

Keywords: Water Framework Directive, Choice Experiment, Hydropower.

5.1 Introduction

In the next years, France will have to renew a consistent share of hydroelectric concessions, among which we can find those insisting on the Aspe and its tributaries (for a total of almost 100 MW of installed capacity). The Aspe is the torrential river flowing through the Aspe valley, one of the three main valleys of the High-Béarn, in the Southwest of France. The Aspe river is part of Natura 2000, an ecological network of protected areas within the European Union.

Back in 2008, The EU forced the French Government to adopt a transparent and non-discriminatory procedure to renew all hydropower concessions. Accordingly, France modified the procedure pursuant to which concessions of hydroelectric plants with an installed capacity of more than 4.5 MW are awarded to private operators. Whereas, under the former procedure, the incumbent had a preference right when concessions expired, the new provision introduces publicity and competition requirements in the selection process. Within the tender procedure, the environmental aspects will weigh significantly as, in compliance with the Water Framework Directive (WFD, 2000/60/EC), French rivers are expected to attain a good ecological status by 2015.

The procedure introduced by the French Government is structured as a beauty contest, where petitioners have to fulfill different criteria determined by the French Ministry of energy and Environment (MEEDDM), and namely:

1. Technical improvements, which means that candidates are expected to significantly ameliorate the existing infrastructures in order to increase (if possible) the production;
2. Environmental impact, within each project, petitioners have to show their actions to reduce their environmental impact;
3. Revenue sharing, candidates are expected to present a financial business plan in which they will show the expected revenues and a revenue sharing percentage (which will then be divided among the State and Local Authorities).

Despite being an emission free technology, hydropower impacts the environment in several other ways. In particular, hydropower production harms biodiversity, fluvial ecosystems and their services (among others: Céréghino *et al.*, 2002; Croze et al., 2008; Brown *et al.*, 2009; Renofalt *et al.*, 2010).

Impacts vary greatly according to the (non) adoption of mitigation measures and to production strategies. Mitigation measures vary from simple fish-passages to complex outflow reservoirs aimed at minimizing flow changes generated by hydro-peaking. Changes in production strategies normally mean reducing flow alterations by means of re-naturalisation (Nilsson, 1996). This is in sharp contrast with the functioning of electricity markets, as intraday price volatility clearly implicates intraday production volatility.

For instance, the impact of different mitigation and management choices on fish migration was tested by Chanseau *et al.* (1999) on one hydropower scheme on the Aspe river. The authors conducted two experiments, the first one in 1995 and the second one in 1998, to test the efficiency of two different downstream bypasses for salmon smolts. In 1995, the bypass efficiency was very low (with a success rate of 17%), due mainly to hydraulic conditions. A training wall was built in 1997 to reverse the flow pattern in the canal and to better guide the fish to the water intake of the new bypass. This simple change improved the bypass efficiency to 55%. Moreover, the authors demonstrated that efficiency of both devices and the smolt behavior were directly affected by the turbine operation and the hydraulic conditions in the intake channel.

As specified above, the renewal procedure introduced by the French Government is structured as a beauty contest, where bidders have to offer a revenue sharing percentage and to propose environmental improvements. I expect that the higher the offer for environmental improvements, the lower the offer for revenue sharing.

The scope of this paper is straightforward: I study the emerging trade-off between a better environment and a higher percentage of money handed down to Local Authorities by estimating people's preferences. Therefore, I have conceived a discrete choice experiment (DCE), whereby I translate the revenue sharing in an immediate rebate in the electricity bill. Respondents could opt for a higher rebate, with the consequence that the fluvial ecosystem remains at its current status (that is, operators cannot perform worse than the incumbent from an environmental point of view), or for a lower (or even no) rebate for (substantial) fluvial ecosystem improvements.

In real life, there will be no rebate; still, an increased amount of money for local communities should mean either less local taxes or better local services. This justifies also why I targeted only people leaving in the Region and not people from anywhere in France: a consistent part of the revenue sharing percentage will, in fact, accrue to local authorities.

The paper shows that people are willing to pay to increase the ecological status of the Aspe river; the highest total willingness to pay (WTP) is above € 96 per household and per year.

The paper unfolds as follows: section 2 sets out the experimental design; section 3 is devoted to the results of the choice experiment; section 4 concludes.

5.2 The experimental design

5.2.1 Background

As discussed in my previous paper, there are several techniques to monetize environmental impacts. Given that this analysis presented here is similar to the one conducted in the study in the previous chapter, I will adopt again the method most capable of estimating how a combination of changes to one or more ecosystem services affects human welfare, which is the discrete choice experiment.

DCE involves the design of a hypothetical market, in which people have to choose their preferred "product", which is decomposed in some relevant attributes, each of which has more than one level. Respondents face several choice sets, each containing a certain number of mutually exclusive alternatives, relating the potential product to a change in the level of its attributes. Clearly, each alternative has a price: consequently, respondents will choose according to their taste, but also according to the price of the product. Repeating the choice with different combinations of levels and prices should return the attribute level that is valued the most.

When it comes to environmental goods, it is important to relate the change of attribute levels to something, normally a change in policy or a change in managing the resource or something that has an impact on it. A standard procedure when testing DCE for environmental goods is to include in every choice set an alternative that reflects either the current status (status quo) of the good being evaluated or an opt-out alternative, which means the worst possible situation. Normally, the price (or cost) of these alternatives is equal to 0. The DCE format allows marginal utility estimates for changes in the level of each attribute to be easily converted to WTP estimates. Moreover, given that compensating variation measures may be obtained, it is possible to estimate the total value of improvements to the environmental good as a consequence of the policy or managerial change.

The peculiarity of the DCE I have conducted is the bidding vehicle that I have used. Instead of an electricity bill increase, the vehicle is a bill rebate, which is normally associated with a willingness to accept. How is it possible to design a rebate as a willingness to pay?

Within the renewal procedure, bidders are asked to offer a percentage of revenue sharing and an improvement of the fluvial ecosystem. First of all, this means that the opt-out alternative is the current status. Secondly, this means that whoever wins will either pay to Central and Local Authorities the current revenue sharing percentage (which is 0%) or, more probably, a higher one. Consequently, bidders will present offers which mix different levels of environmental improvement and revenue sharing percentages. Both strategies have minimum thresholds: from an ecosystem point of view, they cannot be below the current status; as for the percentage, it cannot clearly be below 0%.

Since improving fluvial ecosystem is costly, I expect that higher levels of ecosystem recovery be associated with lower economic offers; conversely, higher economic offers will come at the price of lower levels of ecosystem recovery. Whenever a trade-off emerges, it is important to test people's preferences. In order to do so, it is fundamental to find a good way of presenting the situation. In this case, I have imagined that this revenue sharing percentage can be translated into immediate rebates in the electricity bill. Actually, there will be no rebate; still, an increased amount of money for Local Authorities should mean either less local taxes or better local services. In this case, though, rebates are not associated to ecosystem degradation: in fact, at the highest level of rebate is associated the status quo. As a consequence, the experiment has a willingness to pay approach: we are asking people whether they are ready to renounce to money they could spend on something else in order to have a better fluvial ecosystem.

Whenever evaluating the environmental impacts in water bodies, the crucial elements for the design of DCE are: the definition of the affected population; the delimitation of the water bodies under analysis and the attributes chosen to describe the environment (see the previous chapter for details). Given that Local Authorities will benefit from the renewal procedure, I decided to target only people leaving in the Region and not people from anywhere in France.

5.2.2 Structure, attributes and levels

The questionnaire consisted of two parts. In the first part respondents were asked questions about their attitude towards the Aspe river and their socio-economic status. The second part, instead, contained the choice experiment.

Attributes and levels relevant for the Aspe river ecosystem have been chosen with a Delphi survey, which involved 15 selected experts and which was coordinated by the local Water Agency (Agence de l'eau Adour-Garonne). The Delphi survey was crucial not only to define the attributes and their levels, but it also confirmed that different ways of managing hydropower production are effective in increasing the quality of the riverine ecosystem.

The results of the Delphi showed that there are three attributes that are more relevant for the Aspe ecosystem, namely *water quality*, *fish population* and *hydro-morphology*. Moreover, with the Delphi was possible to define the present situation of the three attributes describing the fluvial ecosystem. For the sake of understanding, all attribute levels have been expressed in qualitative and figurative terms. Finally, experts provided me with images and visual descriptions of the attributes described.

As stated above, the first attribute is *water quality*, representing the chemical and physical conditions of the waters. The attribute is represented qualitatively, according to the scale provided by the Water Agency. The present situation is sufficient, while the foreseen improvements are good and very good.

The second attribute is *fish population*. Hydropower production normally has a consistent negative impact on the natural reproduction of fish population (Renofalt *et al.* 2010). The Aspe River is one of the last rivers in the Pyrenees where the Atlantic salmon and the sea trout migrate for reproduction (DRE, 2008). The protection of these species is crucial and those fishes are essential elements of the Aspe ecosystem. The levels chosen were qualitative and based on the scale defined by DRE, 2008. The actual status is unsatisfactory.

The third attribute is *hydro-morphology*, which indicates whether a river has a natural flow. The attribute was represented with images taken from the Aspe river. I used this attribute to see how much the respondents value a naturally flowing water body. In fact, if properly designed, built and managed hydropower plants might not alter significantly the natural flow of the river, which in turn increases the riverine ecosystem. The actual status is artificial.

In the table below, I show that two attributes have two levels, while *water quality* has three.

Attribute	**Description**	**Level**
Water Quality	Chemical conditions	Sufficient; Good; Very Good.
Fish Population	Abundance and evolution of the stock	Unsatisfactory; Satisfactory.
Hydro-morphology	Closeness to natural conditions	Natural; Artificial.
Rebate	Reduction of electricity bill per household (in EUR)	0; 10; 45; 75.

Table 5-1: Attribute and attribute levels.

The maximum rebate was determined by taking into account how much could accrue to a single household. At present, the only Concession where the revenue-sharing mechanism has taken place is the one on the Rhone, held by CNR. The revenue sharing has been set at 25% (CNR, 2013), a percentage that I have used for my computation. Considering that:

- the average electricity price on the Power Exchange for 2013 was around 50 €/MWh (CRE, 2013);

- according to the French law 75% of that 25% goes to the Local Authorities (Code de l'Energie);
- that in the Aspe Region there are approximately 13,000 households (INSEE, 2013);

the maximum rebate could not exceed 75 euro per household, corresponding to a considerable 15% of the average electricity bill (CRE, 2013).

Each choice set contained three alternatives, inclusive the status quo alternative, which was included in all of the choice sets. Of course, I deleted strictly dominating choice sets. The final design contained eight choice sets. I labeled each alternative as "electricity supplier *x*"(with *x* ranging from 1 to 3), following Kataria (2009) and the choice experiment done in the previous chapter. This means that, for the sake of the choice experiment, suppliers differed from each other for their remedial measures; that is, for the level of the environmental attributes attained. As a consequence, respondents faced a choice where they could choose the preferred method for producing hydropower.

5.2.3 Econometric model

I used the standard random utility model developed by McFadden (1973) to study respondents' choices. RUM is a standard practice within DCE data analysis as its basic assumption is that the utility for an individual is composed of an observable component and a random component, which gives a utility function of this form:

Equation 5-1

$$U_{ni} = V_{ni} + \varepsilon_{ni} = \beta x_{ni} + \varepsilon_{ni}$$

where V_{ni} represents the observable component, ε_{ni} the random component, x_{ni}represents a vector of attributes used to describe alternative *j*, and β a vector of parameter coefficients to describe preferences for the x attributes. DCE analysis normally starts with a conditional logit (CL) model. Under the CL model, the choice probability for individual *n* can be represented as follows:

Equation 5-2

$$Prob_{ni} = \frac{\exp(\beta x_{ni})}{\sum_j \exp(\beta x_{nj})}$$

CL model, though, has some restrictive assumptions. For instance, the model is underpinned by the "independence and identical distribution" condition of the error terms. Consequently, it is now commonplace to compare CL results with more flexible specifications, for instance the random parameters logit (RPL) model. In the RPL model, the parameters vary over decision-makers in the population with density $f(\beta)$. Therefore, the unconditional choice probability represents the integral of the logit probabilities over all possible values of β_n. As a result, the choice probability can be represented by a product of logits.

Equation 5-3

$$Prob_{yn} = \int \prod_{t=1}^{T} \frac{\exp(\beta x_{ni})}{\sum_j \exp(\beta x_{nj})} f(\beta) d\beta$$

where T is the number of choices observed for each respondent and represents the fact that the model is estimated to account for the panel nature of the data. I have decided to model the distribution of the heterogeneity in the non-cost random coefficients with a Normal distribution. Finally, both models have been further specified to enable observed factors to enter as explanatory variables. The distribution of the parameters in the RPL model is simulated using 400 Halton draws.

5.3 Results

The choice experiment has been addressed to a representative sample of 200 households in the Aspe Region (obtaining a 100% of valid responses).

Variable	**Mean**
Age	41.2
Household component	2.2
Female	0.6
Retired/inactive	0.42
Knowledge of concession renewal	0.16
Membership in an environmental organization	0.02

Table 5-2: Descriptive statistics.

The mean age of the respondents is 41.2 years and household components are just above 2. Almost half of the sample is made of retired or inactive people. All these data are precisely in line with the descriptive statistics from the INSEE and confirm that I have a representative sample. The respondents were not previously informed of the relevant characteristics of hydropower production, in order not to influence their choices. Still, the questionnaire contained concise information on why each attribute was chosen and why it mattered for hydropower production. The utility function that I have considered is the following:

Equation 5-4

$$U_{ni} = \beta_1 \times fish2 + \beta_2 \times hydro2 + \beta_3 \times wquality2 + \beta_4 \times wqaulity3 + \beta_5 \times bill + \varepsilon_{ni}$$

where *fish2* is the dummy for satisfactory level of fish population; *hydro2* is the dummy for the natural level of hydro-morphology; *wquality2* and *wquality3*, instead, are dummies for good and very good level of water quality; *bill*, finally, represents the cost increase with respect to the maximum rebate. For the sake of understanding, in fact, to all level of rebates, I have subtracted the maximum level of rebate to create the variable *bill*: this guarantees that I obtain the standard negative sign for the monetary component of a WTP estimation. All betas represent the marginal utility of each attribute. Below, I display the results.

All of the attributes are significant and with the expected sign. The comparison between the CL and the RPL shows how taking into account heterogeneity permits to better estimate the coefficients. Not surprisingly, the most important attribute is fish population: people leaving close to the Aspe river are willing to preserve the wild salmon and the sea trout population. Finally, it is important to highlight that doing leisure activities in the Aspe valley does not influence the results.

	CL		RPL		
Variable	Coefficient	Std. error	Coefficient	Std. error	Coefficient std. dev.
Random parameters (RPL)					
fish2	1.1986***	0.2508	2.0957***	0.5523	1.8927***
hydro2	0.6056**	0.2870	0.9175*	0.5391	1.7639***
wqaulity3	0.5117**	0.2507	0.9136**	0.4695	1.5448***
Non random parameters					
bill	-0.0092*	0.0054	-0.0135**	0.0068	
wquality2	0.2052	0.2169	0.5527**	0.2797	
Heterogeneity in mean					
noactivity*fish2	-0.3062	0.2802	-0.3943	0.6785	
noactivity*hydro2	0.2919	0.2500	0.2634	0.53411	
noactivity*wqaulity3	0.1339	0.2266	0.5350	0.6193	
Individuals	200		200		
Observations	4.800		4.800		
Replications			400		
Significant	*** at 1% ** at 5% * at 10%		*** at 1% ** at 5% * at 10%		

Table 5-3 Conditional and Random Parameters Logit for Main Water Bodies.

The results of the models permit to estimate the marginal willingness to pay. As anticipated before, the betas can be seen as the marginal utility of each level of each attribute; therefore, observing the choices that individuals make when some attribute level changes and observing the price associated with this particular scenario of change, I can derive marginal values for each attribute when moving from the opt-out level to each other level of the attribute, according to the formula:

Equation 5-5

$$MWTP_{x,a} = -\frac{\beta_{x,a}}{\beta_p}$$

where $MWTP_{x,a}$ is the marginal willingness to pay to move from the opt-out level to level a of attribute x; $\beta_{x,a}$ is the marginal utility of level a of attribute x; β_p is the marginal utility of money.

Variable	CL (€/year)	RPL (€/year)
fish2	130.28	154.66
hydro2	65.83	67.71
wqaulity2	-	40.79
wqaulity3	55.62	67.42

Table 5-4: Marginal willingness to pay for attributes (90% confidence interval).

Table 5-4 shows that households have a significant marginal willingness to pay and that both models give similar results. As already anticipated above, MWTP for a satisfactory fish population is considerable: between 130 and 154 euro per household per year. Households are also willing to pay for natural flow and higher water quality.

These estimates can be used to calculate the total WTP for different management scenarios. Since the utility function that I am using is linear, its value is the sum of its parts, that is, attributes can be combined in different ways to estimate welfare effects of discrete changes of the set of attributes. This situation can be calculated with the log-sum formula, (Hanemann, 1999):

Equation 5-6

$$E(WTP) = \frac{1}{-\beta_p}(ln\, e^{V_n^1} - ln\, e^{V_n^0})$$

Where V_n^1 and V_n^0 represent the utility after and before the change and β_p is the marginal utility of money.

Scenario	CL (€/year)		RPL (€/year)	
	Single Household	Aspe households	Single Household	Aspe households
From status quo to satisfactory fish population, natural flow and very good water quality	85.17	1,101,438	96.93	1,253,522
From status quo to satisfactory fish population and natural flow	61.01	788,996	67.54	873,433

Table 5-5: Compensating surplus (WTP) for different scenarios.

As shown in scenario 2, the willingness to pay for a pristine Aspe (that is a satisfactory level of fish population, a very good water quality and a natural flow), lies between 85 to

96 euro per household per year. Considering that in the Aspe region there are a bit less than 13.000 households, the cumulated willingness to pay is close to a million euro per year. Moreover, the WTP is higher than than the maximum rebate that hydropower operators could offer, meaning that the fluvial ecosystem is something that really matters to the local community.

5.4 Discussion and policy implications

In the next years, France will have to renew the Concession of a consistent part of its hydropower capacity. Beauty contests will take place, where bidders have to present offers for technical and environmental improvement, as well as a revenue sharing percentage for Local Authorities.

This framework generates a potential trade-off between revenue-sharing and environmental improvements. Both bidders and Authorities should be interested in estimating the value of the fluvial ecosystem and people's willingness to pay for pristine rivers. This knowledge should bring about a better structured beauty contest and more effective bids.

Consequently, the paper investigates this potential trade-off between a better environment and a higher percentage of money handed down to Local Authorities by estimating people's preferences, with a discrete choice experiment.

The peculiarity of the DCE I have conceived is that I have translated the revenue sharing in an immediate rebate in the electricity bill. Respondents could choose higher rebates and lower ecosystem improvements or lower (or no) rebate and higher ecosystem amelioration. In real life, there will be no rebate; still, an increased amount of money for local communities should mean either less local taxes or better local services. This explain why I targeted only households in the Aspe region: a consistent part of the revenue sharing percentage will, in fact, accrue to local authorities.

The paper shows that people are willing to pay to increase the ecological status of the Aspe river; the highest total willingness to pay (WTP) is above € 96 per household and per year.

Results show that people's MWTP for a specific attribute can reach 154 €/year, that is twice the maximum rebate that was offered. Moreover, all environmental attributes are considered as significant and worth a monetary effort.

The implication of this study is straightforward: people value considerably the improvement of the Aspe ecosystem, which means that the beauty contest should stress this element throughout the process. Moreover, bidders should react accordingly and develop specific strategies for increasing their chances.

Of course, there is scope for further research. For instance, the results of the DCE could be largely influenced by its design, so it could be useful to replicate the study, not only in the Aspe, but for all other rivers where the concession renewal is going to take place.

5.5 References

Aquitaine, Direction Régional de l'environnement (DRE), 2008. Plan de gestion de poissons migrateurs 2008–2012.

Brown, L.E., Hannah, D.M., Milner, A.M., 2007. Vulnerability of alpine stream biodiversity to shrinking glaciers and snow-packs. *Global Change Biology*, 13, 958–966.

Céréghino, R., Cugny, P., Lavandier, P., 2002. Influence of intermittent hydro-peaking on the longitudinal zonation patterns of benthic invertebrates in a mountain stream. *International Review of Hydrobiology*, 87, 47–60.

Chanseau M., Larinier, M., Travade, F.1999. Efficacité d'un exutoire de dévalaison pour smolts de saumon atlantique *(salmo salar* l.) et comportement des poissons au niveau de l'aménagement hydroélectrique de Bedous sur le gave d'Aspe etudiés par la technique de marquage-recapture et par radiotélémétrie. *Bulletin France Pêche Piscicole*, 353/354, 99–120.

Commission Régulation de L'Energie, 2013. Annual Report.

Compagnie National du Rhône (CNR) , 2013. Annual Report.

Croze, O., Bau, F., Delmouly, L., 2008. Efficiency of a fish lift for returning Atlantic salmon at a large-scale hydroelectric complex in France, *Fisheries Management and Ecology*, 15, 467-476.

D. McFadden. Conditional logit analysis of qualitative choice behaviour. In Zarembka P. (Ed.), *Frontiers in Econometrics*, Academic Press, New York, 1973.

Hanemann, M., 1999. Welfare analysis with discrete choice models. In: Herriges, J., Kling, C. (Eds.), *Valuing Recreation and the Environment*. Edward Elgar, Cheltenham, pp. 33–64.

Kataria, M., 2009. Willingness to pay for environmental improvements in hydropower regulated rivers. Energy Economics 31, 69–76.

Nilsson C., 1996. Remediating river margin vegetation along fragmented and regulated rivers in the north: what is possible? *Regulated Rivers: Research and Management*, 12, 415–431.

Renofalt, B. M., Jansson, R., Nilsson, C. 2010. Effects of hydropower generation and opportunities for environmental flow management in Swedish riverine ecosystems. *Freshwater Biology*, *55* (1), 49-67.