Rent seizing and environmental concerns: a parametric valuation of the italian hydropower sector

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Abstract

This paper is the first attempt to estimate the hydroelectricity rent in Italy, as several concessions are about to expire, and the first to analyze the implications of different redistribution mechanisms. Due to budgetary constraints, local authorities want to capture a higher part of the rent, thought to be considerable. At the same time, the renewal procedure entails the implementation of environmental mitigation measures, as set forth in the water framework directive. Hence, rent-seizing and environmental protection generate a major trade-off. We focus our analysis on the County of Sondrio, home to 18% of the overall hydropower capacity, where the first renewals will take place. We obtain the highest rent ever estimated for hydropower production, averaging from 30.3 €/MWh to 82.4 €/MWh. These high values explain why local authorities are pushing for the introduction of a 30% revenue sharing fee, as they would earn almost 90% of the rent, much more than the 50% currently seized. Albeit satisfying the rentseizing objective, the proposed fee hinders the implementation of costly mitigation measures. In this paper, we advocate the adoption of a resource rent tax, as we show that it would reduce the trade-off between rent-seizing and environmental protection.

1. Introduction

After nearly one century, Italy is in the process of reforming the institutional background of its hydroelectricity (HE) sector. Many things changed since 1933, when the first discipline was introduced. HE is not anymore the sole nor the most important source of energy; even if its share has declined to about 15% of the total, however, it still remains strategic for the power balance and for the contribute to the production from renewable sources. New societal demands have arisen with respect to water, including environmental protection, ecological restoration, recreation and landscape. These circumstances determine the case for a substantial change in the patterns of apportioning of the economic rents generated by HE. Until now, these have been shared between HE producers, government and local communities in the absence of precise data and studies, favouring the emergence of a fuzzy public debate, in which each actor claims for a higher share of the pie and blames the others for receiving too much.

The present study offers two contributions to the debate. First, it estimates the magnitude of the HE rent. We focus on a case study area, the County of Sondrio, hosting 18% of the total HE installed capacity. To our knowledge, this is the first attempt in this direction in the Italian context; even at an international level the existing literature is rather scarce.

Secondly, it discusses alternative mechanisms for apportioning the economic rent and the incentives that these different mechanisms provide to foster a transition to a more sustainable HE sector, with particular reference to environmental mitigation measures. The present one, based on a royalty calculated as a function of nominal production, is compared with two alternatives: a royalty based on actual turnover and a resource rent tax calculated as a function of the net economic rent, similar to the one adopted in Norway.

As for the fi rst issue, our study shows that HE generates a significant rent, which averages from 30.3 € /MWh to 82.4 € /MWh, which corresponds to 0.94– 1.57 billion euro per year at the national scale (0.1% of the GDP). These are the highest values ever estimated for the HE rent across several countries.

As for the second issue, we show how the current fee system is inefficient both in terms of rent seizing and in promoting a transition to a more environmentally friendly HE sector. By contrast, both the proportional system and the RRT perform well in terms of rent seizing, as the slice that would accrue to the State would be 90% and 75% respectively. However, the latter scheme is the only one that automatically deducts from its taxable base all the investments, including those in environmental mitigation measures.

Consequently, we demonstrate that only an RTT scheme solves the trade-off between environmental sustainability and rent seizing.

The paper is structured as follows: in Section 2, we start with a short theoretical introduction regarding the economic concept of rent, its function in the resource allocation process, its sharing options. We then provide some background information on the HE sector in Italy and in the County of Sondrio, our case-study area. Sections 3 and 4 outline the main results, while Section 5 is devoted to policy implications and recommendations arising from the study.

2. Background and methodology

2.1 Hydroelectricity and rent generation: some stylized facts

The economic attractiveness of HE depends on three main characteristics. First, HE is cheap, in particular once investment costs have been recovered (IEA et al., 2010; Larsson et al., 2014; Hall et al., 2003). Secondly, HE is a cost-effective balancing technology, possibly the sole renewable with such a capability, as it allows meeting different load profiles (Førsund, 2012). Finally, HE is flexible, since production can be adapted to effective demand (Edwards, 2003).

HE production depends on the availability of a usable water flow. This can simply be the natural run-of-the-river, but in this case, the natural variability through seasons and years would condition production potential. However, upstream water storage facilities may regulate flows and guarantee a much more stable and reliable production (Edwards, 2003). Moreover, since water release from upstream allows activation in real time and at zero cost, HE is particularly suitable for production in peak periods.

Both reasons make the production from regulated outflows much more lucrative in principle – though obviously the cost of upstream facilities should also be accounted for. Contrary to several other renewable sources, water is an excludible good, in the sense that it is generally not possible to use the same water in the same place more than once. Sometimes it is possible to use a water flow in a sequential way, or share it for uses that are not mutually exclusive (e.g. water used for generating HE can be later used for irrigation): but these possibilities are ultimately finite. Moreover, suitable sites for building reservoirs are limited by geographical, environmental and social factors, thus the development of further facilities is extremely difficult and costly, at least for large storage plants and especially in developed countries (Ansar et al., 2014).

This circumstance represents the pre-condition for the existence of an economic scarcity rent, a situation that descends from the combination of exclusive rights and non-reproducible scarce resources (Amundsen and Andersen, 1992). According to the Economist's online glossary, the concept of rent in economics identifies “the difference between what a factor of production is paid and how much it would need to be paid to remain in its current use”. More precisely, it corresponds to the surplus value accruing to the owner of a resource, on top of the long-run marginal costs of supplying it. The market value of a factor of production depends on the market price of the most valuable alternative output that could be obtained using that same factor as an input; while the long-run marginal cost corresponds to operational and capital costs, the latter including depreciation of assets and the opportunity cost of financial resources that have been anticipated. In a perfectly competitive market, marginal cost and price tend to converge, since the existence of a positive gap encourages new suppliers to enter: this is precisely what cannot happen when neither reproduction nor substitution of an essential input are feasible, thence impeding entry of new suppliers. Hence, a rent can stem from differences in quality of factors of production or from scarcity. In the HE 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 HE sites.
- Scarcity rent, as the restricted availability of water makes it impossible to produce electricity only with HE.

- Technological rent, as it is cheaper than other production technologies.

According to this definition, a surplus value can accrue to HE producers even in perfectly competitive markets, as there can be intrinsically different production costs that characterize each individual supplier. Fig. 1 illustrates how all three types of rent can happen simultaneously: since it is not possible to expand HE production beyond HE_{max}, the supply curve becomes vertical. In case no alternative technology exists, the price would jump to p_1, and the scarcity rent would be the area ABEF. In case it is possible to produce electricity with some other technique (more costly than HE), this latter cost will determine the market price (pn), leaving the scarcity rent equal to CDEF.

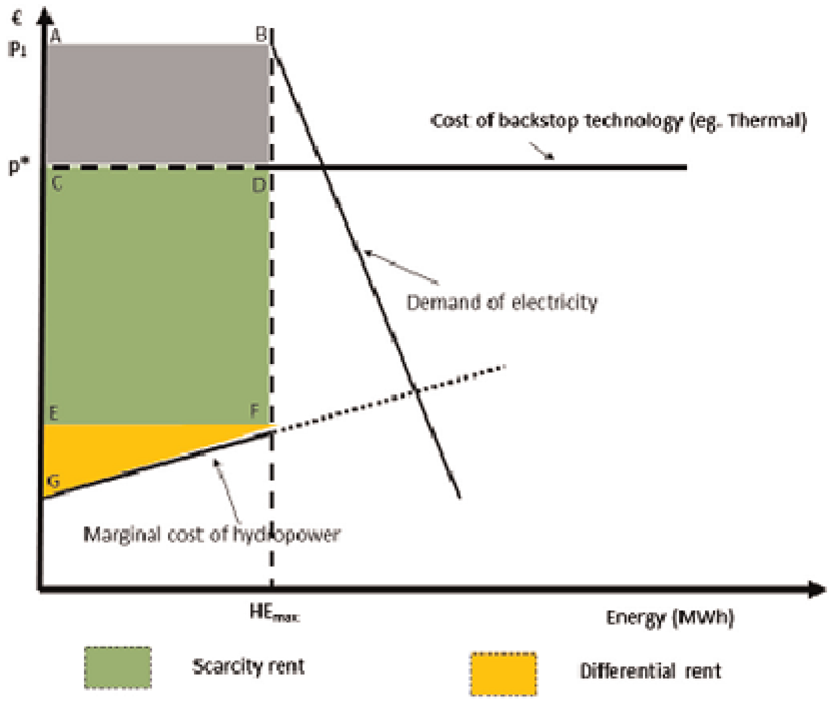

Fig. 1. Graphic representation of differential and scarcity rent.

2.2 *Rent estimation: methods and applications*

While the concept of HE rent is straightforward, its practical determination is diffi cult, since normally neither the market price nor the costs are readily observable in the context of regulated electricity markets (Rothman, 2000). In a liberalized market, prices are actually available; however, getting information about costs may be even more difficult, given that companies are arguably more reluctant to share data.

Costs can either come from annual reports (Gillen and Wen, 2000; Banfi et al., 2005) or can be estimated (Amundsen and Tjøtta, 1993). The former approach has the advantage of relying on actual data; however, such information is difficult to obtain for single facilities. In most cases, power companies own a varied set of facilities and technologies, and it is not possible to break down HE facilities alone. Moreover, historical costs may be biased by operational inefficiency, which is more likely to take place in costbased regulated industries. Banfi and Filippini (2010) argue that Swiss companies' costs are on average 19% higher than the efficient cost frontier. Parametric functions can replace actual historical costs and revenues. While this allows keeping the estimate free of inefficiency, it neglects site-specific factors that influence both costs and productivity in each site. Many reference studies report significant variability of both investment and operational costs for HE sites; this variability cannot be easily connected to readily measurable characteristics of each site (Førsund, 2007; IEA et al., 2010; IRENA, 2012; Hall et al., 2003). Moreover, parametric estimates cannot reflect the cost of actions that companies undertake in order to improve environmental performance.

Since HE costs depend on investments that date back to a long time before, a further difficulty concerns the need to update the asset value, which might not only mean to adjust for inflation, since in the meanwhile costs may have changed, for example because of tighter environmental or safety requirements (Ansar et al., 2014).

In order to estimate total revenues in the lack of unbundled historical records for each facility, one could start from production volumes and real competitive prices for electricity, possibly breaking them down in order to consider peak/load issues (Banfi et al., 2005). In case such market does not exists, proxies may be long-run backstop technologies (Amundsen and Tjøtta, 1993) or bilateral long-term prices (Gillen and Wen, 2000). Actual historical production may be proxied by parametric estimates of the production potential; however, limitations are similar to those of parametric costs, due to site-specific variables and the trade-off between environmental impact and productivity.

Other less conventional sources of revenue should as well be considered from the viewpoint of developers. For example, HE plants may be entitled towards direct and indirect subsidies that many states recognize that renewable energy sources. In many EU countries, this possibility concerns new facilities, particularly small ROR ones; sometimes (e.g. in Germany) already existing facilities may negotiate with water authorities environmental improvements in exchange for the assimilation to renewables (Mattheiss,2011). From a social cost-benefit perspective, revenues arising from incentives and subsidies are clearing entries; in turn, society benefits from the associated positive externalities.

Furthermore, HE production is often associated to large water management projects that also support other valuable functions (e.g. flood protection, irrigation, drinking water supply). From a social perspective, this makes it more difficult to estimate HE rents, since costs have to be shared and/or best alternatives for providing these functions should be considered (Rothman, 2000) (Table 1.)

The applied economic literature on the subject is surprisingly thin. The few published studies concern Canada (Zucker and Jenkins, 1984), Norway (Amundsen and Tjøtta, 1993) and Switzerland (Banfi et al., 2005). They all adopt a combination of the above approaches, and find that HE generates a significant rent (see Table 1). This is quite remarkable, given that the generation mix in all these Countries is cost effective: in Canada, 60% of the electricity is produced with HE, another 30% with nuclear and coal; in Norway almost 99% of the electricity is produced with hydro; in Switzerland, HE accounts for 58% and nuclear for almost 40%. As the Italian generation mix relies a lot more on fossil fuels, with HE covering only about 15%, we expect therefore that the higher variable cost is reflected in a higher value of the economic rent

Table 1
Comparison of different estimates of the HE rent in €/MWh.
Source: Adapted from Banfi et al. (2005).

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

Table 2
Macro-regional distribution of HE plants in 2009.
Source: our elaboration on GSE (2010).

	No. of plants	MW	%
North-West	955	8364	47.2
North-East	811	4983	28.1
Center	303	1.475	8.3
South	146	2281	12.9
Islands	34	618	3.5
Italy	2249	17,721	

2.3 Rent extraction

The economic literature on water pricing provides little support on rent extraction mechanisms, since it has mostly focused on issues like (i) the allocation of scarce water resources among competing uses, (ii) internalization of externalities, e.g. caused by pollution and (ii) cost recovery of water services (Griffin, 2006; Hanemann, 2006). More useful insights for our issue come instead from the literature in the field of exhaustible resources (Heaps and Helliwell, 1985) as well in that of land and urban development (Foldvary, 2005). Theorists of natural resource economics tend to attribute a positive allocation function to the scarcity rent, since it represents a measure of the opportunity cost. If the price of the scarce resource would be lower, inefficient allocation of resources would arise (Harris and Roach, 2013). Accounting for the scarcity cost ensures that the scarce resource accrues to the most valuable uses. From another angle, however, the rent constitutes an unjustified "unearned income", providing an argument in favor of the appropriation of scarce resources by the State, or at least for a substantial seizing of the rent through taxation. Public economics acknowledges that economic rents are particularly desirable as a tax base, since they minimize distortions and deadweight losses.

There are several rent extraction mechanisms and not all are conceived as taxes (for instance, in Norway, operators are 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 specific to the HE sector. Here, we will briefly discuss three extraction mechanisms: concession fee; revenue sharing and resource rent tax. All these extraction mechanisms are something that adds on top of "standard" taxation – namely, taxes that any business has to pay, such as corporate income tax or property taxes.

Resource-based taxes may take the form of royalties or rent taxes, where the former more simply applies a rate to the quantity of resource extracted, possibly disregarding actual revenues and costs; while the base of the latter is the net rent that survives after accounting for all costs.

The simplest and most common water royalty is the concession fee. In Italy, it assumes the form of a yearly lump-sum payment, based on the "nominal production potential" (resulting from the average volume of granted water multiplied by the net hydraulic head). 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 rule out HE production, seizing the 100% or even more); it does not take into account differences in production sites; it is not neutral to investment decisions, as capital costs cannot be deducted. In turn, it stimulates cost saving and productivity maximization, since extra profits are left untaxed.

Grantors might opt for a revenue sharing mechanism, which is a simple percentage of gross revenues calculated ex post. 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. A concession scheme based on RRT is, from an economic point of view, the most efficient one, because it refers directly to the economic value of the resource and is neutral to investment decisions, because capital costs are taken into account and deducted from the taxable basis.

Several arguments are raised to show the advantages of this approach with respect to royalties. Rent-extraction regimes concern allocation of the economic risk of resource development projects (Land, 2008). With this respect, RRT allows a more equitable sharing of risks that arise from external sources (e.g. market value of resources), while it also reduces the time-inconsistency problems associated to state regulation (Boadway and Keen, 2008).

Tax design also matters: in order to achieve the greatest allocative benefits, RRT should be targeted at the project rate-of-return than at actual profits (Land, 2008). A further advantage concerns the possible existence of a tradeoff between rent maximization and social costs and benefits. Thisis typical of urban development projects, which may generate positive externalities or reduce negative ones (e.g. provision of public goods; urban landscape; traffic congestion) by renouncing to some development potential. Rent extraction via RRT favors the attainment of a socially desirable outcome, contrary to any royalty scheme. In turn, RRT compares negatively with royalties in terms of fiscal risk (i.e. variability of tax revenues) and administrative costs (Land, 2008).

Only a few papers estimate the impact of different taxation mechanisms. Amundsen and Andersen (1992) simulate the impact of different taxation mechanisms on new hydro investments in Norway, showing that an RRT is the only extraction scheme to be neutral to investment decisions and the most appropriate in capturing the rent. Given the ongoing reform of the Italian hydroelectric institutional background, we want to test the effects of these different extraction mechanisms and show how an RTT favours the introduction of environmental mitigation measures.

2.4 A brief description of the Italian HE sector

In Italy HE accounts for 15% of total electricity production. In 2011, the production stood at 45.8 TWh. It is by far the most important renewable resource, accounting for 59% of RES installed capacity and 55% of energy produced from renewable sources.

HE is a mature sector in which further developments are hardly achievable. Large facilities (4 10 MW) represent the largest share of the total production, accounting for more than 85%. 77% of capacity is concentrated in facilities having some upstream flow regulation capacity (Table 2).

The regional distribution of HE installations is very uneven: 74% of the installed capacity resides in the Alpine region. The abundance of favorable sites results in lower costs and higher profitability for plants set in the North. As for the ownership, all the most important players have HE plants in their generation portfolio. Following the liberalization of the market, a power exchange is in operation since 2004, which intermediates approximately 60% of the total electricity produced; therefore it is very liquid and its price is representative (GME, 2013).

Water and waterbeds belong to the public domain. Hence, the use of the resource is subject to a concession agreement. The licensee has to pay a fixed annual fee calculated on the basis of the nominal power capacity, plus further compensations to local communities whose territory is concerned by the project (Massarutto, forthcoming). Although this mechanism was supposed to drain a certain part of the rent, its amount was set at that time keeping into account the need to maintain the economic attractiveness for private developers. After the nationalization of the electricity sector in 1963 (De Paoli, 2001), the state preferred not to update the charges and let consumers instead benefit from the rent; this became de facto a sort of a clearing entry for the public budget. This situation remained crystallized for decades, but started to change with the liberalization of the electricity sector. At present, four driving forces assume paramount importance.

First, the economic conditions are now completely different from one century ago, since assets are already in place and fully amortized; they may possibly need refurbishments and maintenance, sometimes revamping and rehabilitation, but this is likely to require only a fraction of the real initial investment.

Second, in 1999, Regions have inherited State competences over the water domain; this devolution gave them the opportunity to set freely either the amount or the structure of abstraction charges. This causes a strong local variability on the amount of royalties collected. The range varies from a maximum of 35.05 €/kW of nominal power capacity in Molise and Basilicata to a minimum of 13.32 €/kW in Emilia Romagna; in Lombardy it is equal to 14.9 €/kW.

Third, due to budgetary constraints, and encouraged by delegation of fiscal powers, Local Governments are willing to capture a higher part of the rent; the political discourse about HE assumes in general that the actual patterns of rent sharing are unfairly favourable to HE companies, and this perception is reinforced by the mounting social consensus about the idea that water is a “common property of mankind” and its use should generate the maximum of benefits to the community as a whole.

Fourth, many HE concessions are now expiring, and their reissue constitutes the occasion for updating the rules that discipline the formation and the allocation of the rent. Since EU internal market rules impede a mere renewal and require competitive procedures, a new discipline has been introduced, though not yet implemented. The law-decree of June 22, 2012, no. 83 introduces a tender process, which foresees that the new concession will last 20 years, and it requires petitioners to present:

A technical offer: which means that candidates are expected to ameliorate the existing infrastructures in order to increase (if possible) the production.

An environmental offer: within each project, petitioners have to show their actions to minimize their environmental impact.

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 other two offers. As in France, Italy has decided that the
economic offer takes the form of a revenue sharing percentage that does not replace the existing fees. We now study the effects of such renewal procedure in terms of rent generation, rent extraction and environmental mitigation measures in the County of Sondrio, that is where the fi rst concessions have expired.

2.5 The case study area

The County of Sondrio is geographically located in northern Lombardy, close to Switzerland. It is home of some 2.2 GW of HE plants, roughly 18% of the overall Italian HE 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 Edipower 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, while the most recent ones were built in the fi f ties. Major refurbishments (mainly for the powerhouse) took place in the 80s for Edipower, in the 90s for Edison and Enel and at the beginning of 20 0 0 for A2A (Tables 3–6).

A2A manages both the biggest plant and the second biggest one (which is 226 MW). As the data suggest, all operators manage HE schemes relying on one big plant to which smaller ones depend. In fact, as Fig. 1 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 (Figs. 2–4).

The overall amount paid by the operators in the County of Sondrio is 49.9 €/kW, which includes the basic abstraction charge (14.9 €/kW), the riparian fee (7 €/kW) and the BIM fee (28 €/kW).

Table 3
Structure of the sample.
Source: direct inquiry.

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	4096

Table 4
Total CAPEX. Results from our sample compared to "real world" data.

Estimation (2012€/kW)	Weighted average	Min	Max	Std. dev.
Kaldellis approach	2395	1964	5223	668
Hall approach	2960	2545	4760	515
IRENA big hydro EU (> 100 MW)	1879	918	2923	N.A.
IRENA small and medium hydro EU (< 100 MW)	2274	1086	6681	N.A.
IEA et al. (2010) (weighted average, excl China)	2411	1970	14,092	5616

Table 5
Powerhouse equipment CAPEX. Results from our sample (€$_{2012}$/kW).

	Weighted average	Min	Max	Std. dev
Hall approach	409	137	1252	233

Table 6
OPEX. Results from our sample compared to IRENA and GSE data (€$_{2012}$/MWh).

	Average	Min	Max
Hall approach	18.5	12.4	33.7
IRENA	20.1	13.6	61.5
GSE	28	–	–

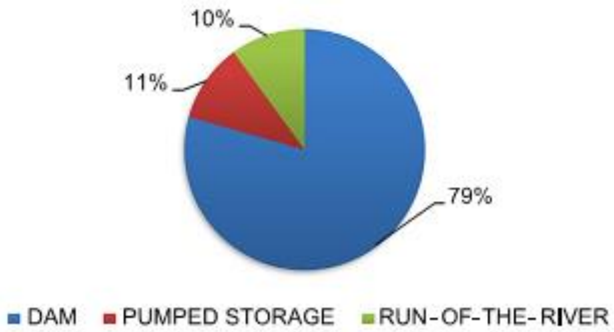

Fig. 2. Composition of HE plants in the County of Sondrio.
Source: our elaboration.

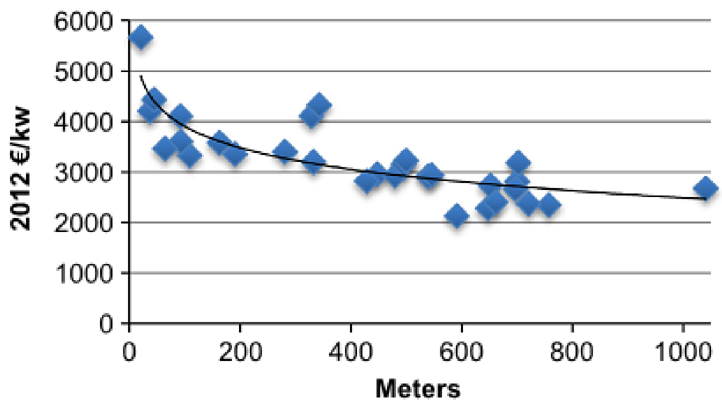

Fig. 3. Relation between net head and CAPEX in our data sample.

2.6 *Estimating production costs and revenues*

Operators did not release any information on costs. Still, we were able to construct a dataset on technical and concession-related variables for all HE plants currently operating in the County of Sondrio. 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 HE production of each plant. To estimate both investment costs and operation costs we opted for parametric approaches. We opted to estimate CAPEX as overnight investment costs for a greenfield project. This gives the possibility to take into account the long-run capital costs. In the parametric formulas all the components needed to set up a HE scheme are included, namely:

- Project and licensing.
- Dams or reservoirs (even the run-of-the-river plants in the County of Sondrio have at least a daily storage capacity).
- Intakes, penstock s, surge chambers and outfl ow systems.
- Turbines, generators, transformers and related powerhouse civil works.

CAPEX were estimated with two equations to see if we would get similar results. The first approach stems from Kaldellis (2007), whose sample consisted of 50 small and medium Greek HE plants. Kaldellis' equation relates CAPEX with the net head and the installed power:

$$C = (1 + \xi) \times 3300 \times (P^{-0.122} \times H^{-0.107}) \quad (1)$$

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 ofξ we used the only publicly available information on HE investment costs provided 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 2244 €/kW (real 2012 value); for small dams, instead, 2459 €/kW; finally CAPEX for small run-of-the-river plants (less than 20 MW) they sum up to 1924 €/kW. Consequently, in order tohave the same weighted average value from our sample, we have iteratively estimated the value ofξ and found it to be equal to 4.06.

The second parametric approach, instead, was developed by Hall et al. (2003) and was tested on a sample from 267 US plants. It is simpler than the first one as it relates CAPEX just to the installed capacity:

$$C = 3,300,000 \times P^{0.9} + 610,000 \times P^{0.70} \quad (2)$$

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

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

results were seriously influenced by three big facilities in China, we have preferred to omit these from calculations[1].

As shown in the table below, both parametric estimations 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 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. 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 m, as both suggested by Kaldellis et al. (2005) and shown in the graph below.

Consequently, we have opted to keep the values found with Kaldellis' approach.

As for OPEX, we 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 and once again the average load factor has been defined. GSE, finally gives just a punctual value. As for the powerhouse, Hall's formulas 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). 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 we have defined CAPEX and OPEX, we 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 ¼0 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:

$$V_n = \int_n^N g_s e^{-r(s-n)} ds = e^{rn} \int_n^N g_s e^{-rs} ds \tag{4}$$

The amortization of an asset is simply its fall in value over its lifetime; differentiating (4), we obtain the instantaneous rate of amortization (A_n)

$$A_n = -\frac{dV}{dn} = -rV_n + g_n \tag{5}$$

From Eq. (5) it can be derived that

$$g_n = rV_n + A_n \tag{6}$$

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.

Table 7
Modelized Opex and Capex for the sample (€2012/MWh).

	Opex + Amortization	Capital	Total
A2A	33.2	16.4	49.6
Edipower	20.3	4.6	24.9
Edison	22.4	6	28.4
Enel	34.2	8.9	43.1
Average	28.2	10.3	38.5

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.

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. This is an intermediate value between those adopted by IEA et al. (2010) (where two "polar" rates, 5% and 10%, are used). While OPEX and amortization are time a-specific (in the sense that the value is the same, given the assumptions, whatever the time of investment), the cost of capital, calculated in this way, depends on the time of investment since the rate of return multiplies the residual net value of assets in each period. This choice allows "historicizing" the rent calculation (i.e. to refer it to a precise period).

Table 7 summarizes the model output applied to the field data of each facility in the database, grouped according to the owner company. While 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. The estimation of revenues from the sale of HE on the power exchange would require detailed data on the temporary profile of sales, since the price varies significantly between peak and load periods. As pointed out in the introduction, HE generation from regulated flows is flexible enough to allow producers to concentrate activity in the most lucrative hours; however, due to technical and regulatory constraints, extreme hydro-peaking is not always feasible, and facilities could be obliged to release water also in load periods.

Unfortunately, only yearly production data are available. Consequently, we have made two extreme estimates, using the average zonal price and the average peak zonal price of the power exchange. Rent estimations have been performed since 2004, the first year of operation of the power exchange, was 2011, the last year of available production data. Yearly prices have been converted into 2012 values using the electricity deflator of the harmonized index of consumer products. The mean values obtained are respectively 79.9 and 107.3 €2012/MWh. Given that almost all HE production in the County is programmable and that we expect operators to be profit maximizers, then it is likely that the overall rent is closer to our second estimate than to our first one.

3. Results

Table 8 displays the result obtained for each of the 4 companies, using respectively the normalized average and the peak zonal price. The value of the rent is considerable and much higher than those found in previous studies (see Table 2). In fact, even if we value HE production at the average price, the rent is comprised between 30.3–55.0 €$_{2012}$/MWh (average prices) and 57.7–82.4 €$_{2012}$/MWh (peak prices).

Clearly, the estimated value depends crucially on the fact that the Italian generation mix is particularly costly and unbalanced, since natural gas constitutes the marginal technology in the power exchange for almost 50% of the hours every year (GME, 2013).

Table 9 illustrates the same calculation on an yearly basis, and the cumulative value for the entire period. We obtain an amount of 170–282 million euro per year and 1.36–2.26 billion euro for the whole period. Considering that our sample corresponds to 18% of total national HE production, a simple extrapolation allows to estimate an yearly magnitude of the rent of 0.94–1.57 billion euro per year.

Table 8
Average revenues, costs and rent in the period 2004–2011 (€$_{2012}$/MWh).

	A2A		Edipower		Edison		Enel		Total	
	Average	Peak	Average	Peak	Average	Peak	Average	Peak	Average	Peak
Revenues	79.9	107.3	79.9	107.3	79.9	107.3	79.9	107.3	79.9	107.3
OPEX+amort.	33.2	33.2	20.3	20.3	22.4	22.4	34.2	34.2	28.2	28.2
Cost of capital	16.4	16.4	4.6	4.6	6.0	6.0	8.9	8.9	10.3	10.3
Rent	30.3	57.7	55.0	82.4	51.5	78.9	36.8	64.2	41.4	68.8

Table 9
Average yearly revenues costs and rent and cumulated rent 2004–2011 (Million €$_{2012}$).

	A2A		Edipower		Edison		Enel		Total	
	Average	peak	Average	peak	Average	peak	Average	peak	Average	Peak
Revenues	142.1	190.6	64.7	68.1	50.8	68.1	69.9	93.6	327.4	439.5
OPEX and amort.	57.2	57.2	15.8	15.8	13.6	13.6	28.8	28.8	115.3	115.3
Cost of capital	27.5	27.5	3.5	3.5	3.6	3.6	7.3	7.3	42.1	42.1
Rent	57.4	105.9	45.4	48.8	33.6	50.9	33.8	57.5	170.0	282.1
Rent 2004–2011	458.1	847.2	362.6	543.4	268.7	406.7	269.6	458.9	1359.4	2256.3
Projection-national level (yearly rent)									944.4	1567.2

4. Discussion

4.1 *Comparing alternative mechanisms*

As discussed in Section 2, there are many different ways to apportion the rent. In principle, it could be destined to the HE operator, in form of higher profits; to clients, if the price of electricity is set at the marginal cost; to the state, through taxes and fees charged on the operator; to the local community, either in cash or indirectly in the form of compensative measures; to the river environment, in the form of measures aimed at restoring the river ecology, and so on. Actual sharing patterns depend on institutional factors.

In this paragraph, we compare the actual Italian fee system with the other two different extraction mechanisms described above, in order to show how this could affect the profitability for private operators, a major issue in the renewal procedure. In the table below, we show how, in practice, the rent is split between the State and the operators. In Italy, overall corporate taxation is equal to 31.4% of the taxable income; the revenue sharing has been set at 30% (as it has been proposed in France); the RTT at 30% as well, the same as in Norway.

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 not leaving a 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 does not 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 RRT, 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 (Table 10).

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. In Section 4.2, we show how the three different systems would affect such investment decisions. Before proceeding further, we present in Table 11 a sensitivity analysis on our results. The table above shows the effect and the magnitude of the variation of some crucial parameters. For instance, if we use Hall et al. (2003) parametric approach, that is an average 19% increase in CAPEX, we obtain a reduction in the total value of the rent. The reduction, though, is less than proportional (7%), as a consistent portion of the CAPEX has been already amortized. Increasing OPEX has marginal effects, while the effects of a change in capital remuneration are more evident. In particular, reducing capital remuneration implies higher values for the estimated rent. For instance, if we use the current risk-free rate (the yield of the 10 years Italian Government bond), we obtain a 17% increase in the rent. Finally, Table 11 shows the impact of a reduction of the amortization period: even a consistent reduction (20%) has marginal impacts on the rent. This happens because most of the assets have already been amortized (Table 12).

4.2 The impact of environmental mitigation measures

HE impacts the surrounding ecosystem. For instance, there is a wide literature on the impacts of HE production on biodiversity and ecosystem services (among others, Céréghino et al., 2002; Brown et al., 2007 and Renofalt et al., 2010). These studies have a clear biological perspective: they study the impact of HE production management (in terms of, among others, minimal vital flows, hydro-peaking and sediment releases) on several biological indicators. All studies demonstrate that HE 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.

Table 10
Rent sharing with average prices (Million €$_{2012}$).

In million 2012€ for the whole county	Actual system	Proportional system	RTT
Revenues	327.4	327.4	327.4
(-) 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
Ratio (operators:State)	49:51	9:91	24:76

Table 11
Sensitivity analysis (Million €$_{2012}$).

	Effect on the rent	Value	% Change
Estimated rent		1.359	
Hall CAPEX (+19%)	−	1.269	−7
OPEX increase	−		
By 10%		1.358	0
By 20%		1.354	−0.5
Capital remuneration decrease	+		
5%		1.474	8
Risk free (2.4%)		1.589	17
Amortization period decrease	+		
−10% (54 years)		1.431	5
−20% (48 years)		1.452	7

Table 12
Fish, wildlife and quality related CAPEX (2012 €/kW).

	Average	Min	Max
A2A	150	138	156.6
Edison	154	144	171

Moreover, many socially relevant alternative water uses have emerged in the meanwhile (e.g., tourism, fishing). The opportunity costs of developing sites and using water for HE are substantially different (higher) today; the renewal procedures are considered a good opportunity for implementing the requirements set forth in the Water Framework Directive (WFD), from the attainment of the “good ecological status” to the “users' pay principle”, all measures that will affect HE production.

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-nuturalization (Nilsson, 1996). This is in sharp contrast with the functioning of electricity markets, as intraday price volatility clearly implicates intraday production volatility. Investments for rehabilitation of existing facilities may offer an opportunity in this direction, since technically improved equipment can allow to maintain or increase the production potential while reducing environmental impacts (Goldberg and Lier, 2011).

It is beyond the scope of this paper to assess and to monetize the environmental impacts of HE production in the County of Sondrio. Here we just would like to show how the proposed Brown et al., 2007 and Renofalt et al., 2010). These studies have a clear biological perspective: they study the impact of HE production management (in terms of, among others, minimal vital flows, hydro-peaking and sediment releases) on several biological indicators. All studies demonstrate that HE 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.

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It is beyond the scope of this paper to assess and to monetize the environmental impacts of HE production in the County of Sondrio. Here we just would like to show how the proposed proportional system might reduce the scope for environmental investments. At present, operators in the County of Sondrio have not undertaken major mitigation measures. There are just some 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 signifi cant environmental investments. Using again a parametric estimation by Hall et al. (20 03)[2], we 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. 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.

The figure 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 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. 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 HE 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. 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 þ26% from the average. With the highest levels of production, which would mean working for 2670 h instead of the average 2178 h used for the estimations, the thresholds would become: for thecurrent 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 our simple estimations.

5. Conclusions and policy implications

HE concession renewals are a major challenge for the Italian electricity market, as HE accounts for more than 15% of total electricity generation. In our paper we show that HE production generates the highest rent ever estimated, averaging from 30.3 €/MWh to 82.4 €/MWh. The unbalanced generation portfolio is the main source of such a rent.

In the paper we also show that the current rent sharing mechanism is not satisfactory for local authorities, which keep less than 50% of the rent. Consequently, from an economic standpoint, the renewal procedure is an opportunity to redistribute the rent that HE generates: for instance, with the introduction of the proposed 30% proportional fee on revenues, almost 91% of the rent would accrue to local authorities.

On the other hand, the WFD requires that all water bodies should attain a good ecological status by 2015 and that water users should pay its full cost, which means internalizing both environmental externalities and estimating the opportunity cost of the resource. Consequently, the renewal procedure is also the occasion to implement the requirements set forth in the WFD. To this respect, in this paper we show how environmental mitigation measures alone, which would significantly reduce flow alterations and would improve ecosystem integrity, entail considerable investments, therefore decreasing HE rentability. It is immediate to see that rent seizing and WFD requirements generate a trade-off, which has to be governed and solved. For instance, in our simulations we show that the implementation of such mitigation measures together with the proposed proportional fee might result in the impossibility either to carry out these investments, either to pay the fee. Our paper has straightforward policy implications: we suggest to partially revise the renewal procedure and to introduce a different taxation mechanism in order to seize the rent. As for the first issue, we think that within the framework of the competition, the economic offer should not have priority over the technical and the environmental offer. This explicitly puts a higher weight on rent seizing, increasing the risk of non-compliance with the WFD. To this respect, there is already a EU infringement proceeding against Italy for the fact that concession and renewal procedures are not compliant with the WFD, as they do not require an environmental impact assessment at a catchment level.

Therefore we think that the provision of an environmental offer being less important than an economic offer might result in a second infringement proceeding.

As for rent seizing, in the paper we show how a RRT is neutral to investment decisions, thus reducing the trade-off between rent maximization and environmental protection. Consequently, we suggest changing the current HE taxation system not by introducing a proportional fee, but by introducing a RTT similar to the one that has been adopted in Norway.

Of course, our results depend on important assumptions with regard to CAPEX, OPEX and revenues. Hence, our results are a first approximation and require caution before immediate translation into policy. Future lines of research should go towards a more precise estimation of the HE rent both in the County of Sondrio 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.

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