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

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Abstract

This paper is the first attempt to estimate the hydropower rent in Italy. We focus on the County of Sondrio, home to 18% of the overall hydropower capacity, where concession renewals are about to take place. We find very high estimates for the hydropower rent, averaging from 42.3 €/MWh to 70.8 €/MWh. The Italian generation portfolio, which relies heavily on natural gas, is the main explanation of such a rent. These high values explain also why, in the context of the renewal procedure, the current rent sharing mechanism can be deemed as not satisfactory for local authorities, as they keep less than 50% of the rent; the introduction of a 30% revenue sharing fee, instead, would guarantee almost 90% 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 improve ecosystem integrity. These measures entail significant investments, consequently increasing capital costs and reducing the possibility to pay such a high revenue sharing percentage. A resource rent tax, instead, would reduce the trade-off between rent maximization and environmental protection.

KEYWORDS: Hydropower; economic rent; concession fees.

JEL Classification: H27, K23, Q25, Q48.

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Hydropower Rent in Northern Italy: a Key Factor for Concession Renewals

Antonio Massarutto and Federico Pontoni

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 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 we 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.

These three points are the pillars on which this paper is built upon. Foremost, our study is the first attempt to estimate the hydropower rent in Italy, focusing on hydropower rent sharing procedures in the County of Sondrio, where the first tender procedures will take place; secondly, we study the interactions between the revenue sharing mechanism and the environmental mitigation measures; as means of comparison, we will see the effect of a Resource Rent Tax (RTT) similar to the one currently adopted in Norway.

Our 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 across several countries and 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 maximization, unless an RTT scheme is introduced.

Our paper unfolds as follows: section 2 is devoted to the discussion of the theoretical aspects of the hydropower rent and to the review the relevant literature; section 3, instead, describes the hydropower sector in Italy and in the County of Sondrio; in section 4 we estimate the rent and we 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.

2 The hydropower rent and its capture

2.1 Theoretical 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:

$$R = \int_P^\infty D(p)dp + \int_0^P S(p)dp \qquad [1]$$

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:

$$\frac{dR}{dP} = -D(P) + S(P) = 0 \qquad [2]$$

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).

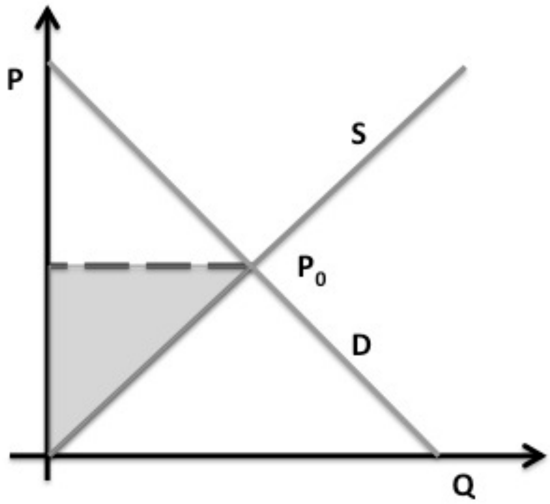

Figure 1: Graphic representation of the rent.

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, we 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 normally a yearly payment that the grantee has to make to the grantor, 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.

Grantors might opt for a revenue sharing mechanism, which is a simple 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. 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.

Grantors can decide to seize the rent by mixing these mechanisms. For instance, the Norwegian state has opted for 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%.

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 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 we shall see later on, Italy has a generation mix that relies a lot on CCGT, which has very high variable costs.

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

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)

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.

As for rent extraction in the hydropower sector, there are just few papers that estimate the impact of different taxation mechanisms. Amundsen & Andersen (1992) 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. 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 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 we think that the adoption of well designed RRT should be promoted.

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 resource, 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 generous subsidies, 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.

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.

3.1 Hydroelectricity in the County of Sondrio

The County 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.

Table 2: Structure of the sample.

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

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 figure 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.

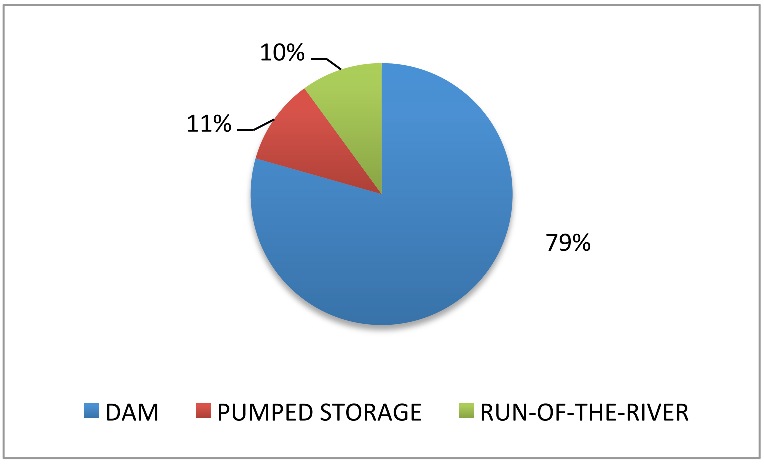

Figure 2: Composition of hydropower plants in the County of Sondrio.

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 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. 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.

The Royal Decree also sets a specific fee in favour of those local authorities (municipalities and provinces), whose territories power plants and derivations are built on. In 2010, this specific fee was 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 2010, 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 County of Sondrio is 49.9 €/kW.

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. <u>A technical offer</u>: which means that candidates are expected to significantly ameliorate the existing infrastructures in order to increase (if possible) the production;
2. <u>An environmental offer</u>: within each project, petitioners have to show their actions to reduce their environmental impact;
3. <u>An economic offer</u>: 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.

4 Rent Estimation

4.1 Estimating production costs

Operators in the Sondrio Valley did not release any information on costs. Still, we were able to construct a dataset on technical and concession-related variables for all hydropower 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 hydroelectric 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 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:

1. Project and licensing;
2. Dams or reservoirs (even the run-of-the-river plants in Sondrio County have at least a daily storage capacity);
3. Intakes, penstocks, surge chambers and outflow systems;
4. 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 hydropower plants. Kaldellis' equation relates CAPEX with the net head and the installed power:

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

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 we 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 our sample, we have iteratively estimated the value of ξ 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 of 267 US plants. It is simpler than the first one has it relates CAPEX just to the installed capacity:

$$C = 3{,}300{,}000 \times P^{0.9} + 610{,}000 \times P^{0.70} \qquad [4]$$

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:

$$C_{phouse} = 4{,}000{,}000 \times P^{0.72} \times H^{-0.38} + 3{,}000{,}000 \times P^{0.86} \times R^{-0.38} \qquad [5]$$

Where R are the rotations per minute of the generator.

Equation [3], [4] and [5] were adjusted for inflation and converted in real euro values with base 2012. In the table below, we show the results for total CAPEX and we 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 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.

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

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.

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

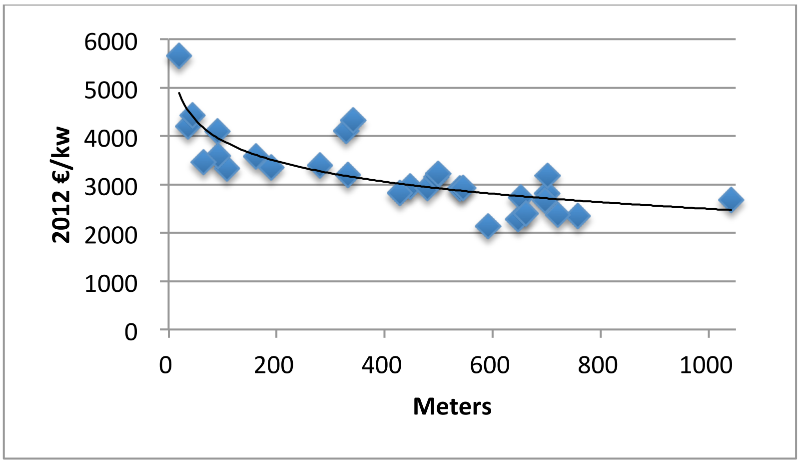

Figure 3: Relation between net head and CAPEX in our data sample.

As for the powerhouse, Hall's 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).

Table 4: Powerhouse equipment CAPEX. Results from our sample.

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

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 again once the average load factor has been defined. GSE, finally, gives just a punctual value, estimated in 2010 on newly operating hydropower plants.

Table 5: OPEX. Results from our sample compared to IRENA and GSE data.

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

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=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:

$$V_n = \int_n^N g_s e^{-r(s-n)} ds = e^{rn} \int_n^N g_s e^{-rs} ds. \qquad [6]$$

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

$$A_n = -\frac{dV}{dn} = -rV_n + g_n. \qquad [7]$$

From equation [7] it can be derived that:

$$g_n = rV_n + A_n \qquad [8]$$

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. 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.

4.2 Results

The total rent generated, of course, is given by total revenues net of total costs, including the cost of capital. Unfortunately, we have only yearly production data, which have not enabled us to better estimate companies' revenues. As a consequence, we 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, we have multiplied the quantity by the average peak zonal price of the power exchange.[1] Rent estimations 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.

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

Values in 2012€	A2A	Edipower	Edison	Enel	Total

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

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 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. In fact, even if we 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 we consider that the County of Sondrio represents a bit less than 20% of the Italian 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.

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

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

In Table 7 we 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 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.

4.3 *Taxing the rent: comparing the three different mechanisms*

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 rentability 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 percentage used in Norway.

Table 8: Rent sharing with average prices.

In million 2012€ for the whole County	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*

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, we show how the three different systems would affect such investment decisions.

Finally it is important to bear in mind that we 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" taxation, 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.

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 County of Sondrio. Here we just want 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 significant environmental investments. Using again a parametric estimation by Hall *et al.* (2003),[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.

Table 9: Fish, wildlife and quality related CAPEX.

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

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.

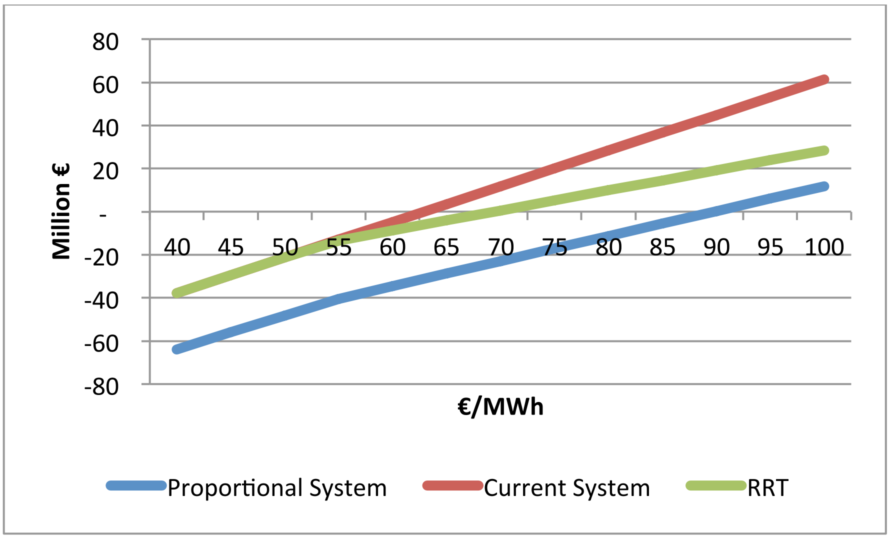

Figure 4: Sensitivity analysis of the net rent to the electricity price.

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[2] $C_{environ} = 310{,}000 \times P^{0.96} + 400{,}000 \times P^{0.44}$, where P is the installed capacity. The study by Hall et al. (2003) has found a significant relation between mitigation costs and installed capacity. This is not surprising, as bigger plants require bigger civil works, modifying more heavily the surroundings.

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.

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 our simple estimations.

6 Conclusions

Our paper is the first attempt to estimate the hydropower rent in Italy. Our 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. 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, our results are based on important assumptions with regard to CAPEX, OPEX and revenues. Hence, our results are a first approximation Future lines of research should go towards a more precise estimation of the hydropower rent both in the County 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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