The Swiss hydropower rent system - the most appropriate?

Alice Tognetti
Federal Polytecnic School, Zürich, Switzerland. 2011

Abstract

The hydropower covers 56% of the electricity production in Switzerland. The choice of the rent system for water use has strong political insights because the rent revenues cover an important part of the public balances of many Cantons and communes. The actual rent system consists in a fixed rate based on the installed power. Because the electricity market is moving toward liberalization another rent system more flexible on electricity prices and considering the geographical differences would be suited. The goal of the present study was to model the electricity market with the actual water fee system and compare it with a resource rent system. The results have shoved that, for hydropower production, a resource rent tax system might be very interesting. In fact it allows generating higher total rent revenues. Additionally the plants needing higher investments have lower water fees to pay. This could allow an increase of the exploitation of the water resources in Switzerland. With this rent system incentives for the cost minimization (minimization of the cost of production) should be implemented.

Keywords: hydropower, water fees, resource rent
1. Introduction

1.1. The hydropower in Switzerland

In Switzerland, the electricity generation amounts to 66.5 GWh/year (BFE, 2009). The main agents of production are represented in Figure 1. It appears that the hydropower plants contribute for around 56% of the total electricity production. In most cases they exploit the hydraulic power provided naturally by the water cycle.

The run-of-river plants work continuously with the fluent water and their production varies with the hydraulic load. The storage plants with reservoir use the water cumulated by the dams and, depending on the requirements, could be activated or deactivated. In a certain measure, the plants of pump-waterwheel use also the hydraulic power produced artificially. When there is low consumption (off-peak), the electricity is employed to pump the water in the accumulation reservoirs. When it is needed, this cumulated water could be used for electric energy production.

The plants are not distributed homogeneously over the Swiss territory: they are mainly concentrated on the mountain cantons. Argau, Bern, Graubünden, Tessin, Uri and Wallis produce around 80% of the hydroelectric energy. Graubünden and Wallis alone represents around the 50% (UFAEG, 2002).
Technically it is possible to increase the actual hydroelectric power production of around 15% to 41’000 GWh (BFE, 2010). From an economic point of view, 90% of the profitable sites are exploited today (Filippini et al., 2001).

1.2. Actual rent policy in the hydropower sector

The Swiss law regulates the water present on nature as a public good. So, its use by the hydropower plants constitutes a particular use. To get the water it is necessary to pay a water fee (“Wasserzinse”) to the public entity, which holds the sovereignty on water.

According to the Swiss Confederation, the Cantons own the right to dispose of the water resources (art. 76 of the federal constitution). Through legislative acts, this right could be granted to the Communes or other corporations. In Source: UFAEG, 2002 Figure 3 is represented the actual sharing between the beneficiaries of water fees revenues.
In a general way, the owners of the rights have not yet exercised in a first person those rights, but they have transferred them to private companies. So, actually the use of the hydrological power is mainly based on concessions. Because the sovereignty on water belongs to the Cantons, the juridical regulation of water use presents a strong federalist print. However, the Confederation can legislate the fundamental principles as the norms about the water fees (LUFI, RS 721.80). The water fees are a tribute that the concessionaire has to pay for the economic use of the hydrologic power accorded by the concession. The federal right defines the method for the calculation of the maximal rate to be applied to each hydroelectric plant. The maximal imposition depends on the maximal rate and on the mean annual gross power of the plant. The Cantons could apply their own criteria for the collection of the water fees. Since when the water fees have been introduced, more than 80 years ago, the maximal federal rate per gross kWh is gone from 6 CHF to the actual 80 CHF per gross kWh (art. 49 cpv. 1 LUFI). The plants with a power smaller than 1000 kW are exempted from paying the water tax. The maximal rate for the other plants is given with more detail in Figure 4.

Source: UFAEG, 2002

Figure 4: Maximal annual water fee rate depending on the gross installed power of the hydropower plants (since 1997)

At the Swiss level, the water fees corresponds to around 400 millions francs per year which corresponds to around 1.2 cents per kWh electricity produced (UFAEG, 2002). Depending on the firms this can constitute 15-20% of the production costs per kWh. For some regions of the Switzerland, the revenues of the water fees determine an important part of the public balance. In some district they constitute 25% of the total fiscal income and in some communes could reach until the 70-90% (Filippini et al., 2004).
The monopolistic regime that until now has characterized the electricity market has strongly influenced the political debates that in the past have accompanied each increase in the maximal tax rate. In these last years the environmental organizations also participate to the discussions trying to defend the needs of environmental protection. The liberalization of the electricity market and the consequent new regime of concurrence give a new dimension to the electricity producers. Because of that it is important to try to understand if, in a liberalized market, the actual legislation concerning the water fees will still be appropriate. Today, thanks to the monopoly regime the utilities can increase their prices to compensate the water fees. But, in a liberalized market it would not be possible anymore to set the prices on the production costs. The prices would be regulated by the demand, this involve an uncertainty on the prices evolution. If the market prices would be low in the long run, this can make some hydropower plants unprofitable. On the other hand, if the prices would be high in the long run, the company would have high revenues but the fix fee will exploit only a small part of them. So, one of the main disadvantages of the actual fee policy is its inflexibility in report to the market prices. Additionally, it does not take into account the differences in the production costs. Effectively, depending on the geographic location of the site the production costs might vary considerably. In order to avoid those drawbacks it might be good to move toward a system, which is based on the amount of rent generated from each utility.

Any change in the tax policy is politically controversial because the revenues of the water fees have a strong impact on the regional and cantonal economy.

Because of that the present study tries to estimate which would be the impact of a change in the water fee system. More precisely, the revenues generated with the present policy are going to be compared with the revenues generated by the application of a policy which is rent oriented.

Some studies on the Swiss electricity consumption and on the hydropower market and rent policies have already been realized (Filippini, 1995; Filippini and al. 2004; Banfi et al., 2005; Filipini and Banfi, 2010). Because of the lack of data, especially concerning the electricity production costs, the results of those studies have been used as starting point for the present research.
2. Resource rent tax

2.1. Definition

A resource rent is usually defined as the amount of money given to an owner of a resource for its rent. Usually it is a measure of the surplus revenue of the resource after accounting for the factors of production employed to exploit it (input as capital, labour and material) (Rothman, 2000). In Figure 5 is represented the resource rent concept.

The main assumptions behind the used model are (Banfi et al., 2005):

- There is a competitive market without uncertainties and externalities.
- The marginal costs are assumed to correspond to the average cost and might reflect the market input prices.
- There are not market distortions (government subsidies,...).
- Hydropower is the only electricity source available.
- Based on the demand variation two main periods can be distinguished: peak period (high demand) and off-peak period (low demand). Each period last 12 hours.
- There are four types of utilities producing electricity: U1 and U2 are run-of-river plants and U3 and U4 are storage plants.

The equilibrium corresponds to the crossing point of the demand curve and the marginal cost curve. The total production is $q_4$ and the effective market price is $p_m$. The resource rents of one period for the different utilities are $R_1$ (light grey area), $R_2$ (white area) and $R_3$ (dark grey area). They correspond to the difference between the market price and the production costs. The marginal producer $U_4$ does not generate any rent. To get the total rent the rent generated during the peak period has to be aggregated to the rent of the off-peak period.
The Rent of each utility has two components: the scarcity rent and the utility rent (Rothman, 2000). The scarcity rent occurs when one utility has production costs lower than the market price but the supply is restricted. The run-of river plants and the storage plants without pump have lower production costs but they cannot produce enough electricity to satisfy all market demand. The quality (or Richardian) rent is due to the different characteristic of the location of the natural resources. This involves different productivity. The distinction between the scarcity and the quality rents is not easy to define in the reality.

In the case of hydropower production a resource rent tax system might be very interesting. Several studies trying to estimate the rent revenue have been realized in Norway (Amundsen et al., 1992) in Canada (Bernard, 1982) and in Switzerland (Banfi et al., 2005). For the Swiss case, Banfi and Filippini (2010), estimating the frontier variable cost function for hydropower rent, have identified one main drawback of the resource rent system. This consists in the absence of strong incentives to operate efficiently, at the minimum cost. One solution could be to leave to the firms the extra profits (quasi-rent) they generate thanks to good management and decisions. Another possible solution could be to set a tax rate lower than 100% of the revenues. So that an efficiency increase would benefit both: the firm and who receive the rent revenue. (Banfi and Filippini, 2010).

Source: Banfi and Filippini, 2010

Figure 5: Calculation of the natural resource rent for different producers (marginal costs=average costs).
3. Data and empirical estimation of tax revenues

3.1. Data

3.1.1. Electricity supply

Because of the lack of consistent data about the costs it was assumed that the marginal costs correspond to the average production cost.

For the production costs the data estimated from Filippini et al (2004) have been used. Those were calculated using the data of 54 hydropower utilities. Those utilities could be divided into four main category of plants: run-of-river plants with water drop below 25m, run-of-river plants with water drop above 25m, storage plants without pumps and storage plants with pumps. Their characteristics are summarized in Table 1. These plants differ from each other for the electricity production, the production costs but also the water fees per kWh. The storage plants with pumps are those having the highest production capacity but they have very high production costs per kWh. The run-of-river plants are those allowing electricity production at the lower price but they have some supply constraint.

<table>
<thead>
<tr>
<th>Table 1: Electricity production and production cost per utility category</th>
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<tbody>
<tr>
<td></td>
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<tr>
<td>Run-of-river plants</td>
</tr>
<tr>
<td>Drop &lt; 25 m</td>
</tr>
<tr>
<td>Drop &gt; 25 m</td>
</tr>
<tr>
<td>Storage plants</td>
</tr>
<tr>
<td>Without pumps</td>
</tr>
<tr>
<td>With pumps</td>
</tr>
<tr>
<td>Total</td>
</tr>
<tr>
<td>Number of utilities</td>
</tr>
<tr>
<td>Average annual production (GWh)</td>
</tr>
<tr>
<td>Total production costs (cts.kWh)</td>
</tr>
<tr>
<td>Total production costs without water fees and direct taxes (cts./kWh)</td>
</tr>
</tbody>
</table>

Source: for the production Banfi et al. (2005), for the costs Filippini et al. (2004)

In Figure 6 are represented the different components of the total costs for the different types of utilities.
The water fees constitute an important part of the production costs. They go from 16% for the storage plants with pumps to around 25% for the run-of-river plants with water drop below 25m. The other two major components of the production costs are the capital costs and the interest expenses.

3.1.2. Electricity demand

For the electricity demand, the log-linear stochastic equations for peak and off-peak electricity consumption by residential households estimated by Filippini (1995) were used. These equations were estimated using aggregated data referring to four years and 40 cities. Using two different econometric models they have estimated the short-run and long-run demand. In the present study the long-run equations (OLS method) were implemented.

Peak period electricity demand:
\[ \ln \hat{E}_p = 5.95 - 0.71 \ln P_{EP} + 0.65 \ln P_{EO} + 0.04 \ln Y + 0.63 \ln HS + 0.16 \ln HDD + 0.01 DG - 0.15 DR \] (1)

Off-peak period electricity demand:
\[ \ln \hat{E}_o = -1.75 + 2.16 \ln P_{EP} - 1.92 \ln P_{EO} - 0.03 \ln Y + 2.15 \ln HS + 0.75 \ln HDD + 0.14 DG + 0.312 DR \] (2)
with (Filippini, 1995):

- $E_P$ annual per household electricity consumption in the peak period (kWh)
- $E_O$ annual per household electricity consumption in the off-peak period (kWh)
- $P_{EP}$ Electricity price\(^1\) during the peak period (CHF/kWh)
- $P_{EO}$ Electricity price during the off-peak period (CHF/kWh)
- $Y$ Local income tax revenue per household (CHF)
- $HS$ Household size
- $HDD$ Heating degree days
- $DG$ Dummy variable: 1 if the city has natural gas supply; 0 otherwise
- $DR$ Dummy variable: 1 if all households face a two-part-time differentiated tariff for electricity; 0 otherwise

For the modelling, the median values of the dependent variables were used. For the demand during the peak period, all variables were kept constants with exception of the electricity price during the peak period ($P_{EP}$). For the off-peak demand the only unfixed variable was the electricity price during the off-peak period ($P_{EO}$) (see Table 2).

<table>
<thead>
<tr>
<th></th>
<th>Peak period</th>
<th>Off-peak period</th>
</tr>
</thead>
<tbody>
<tr>
<td>$P_{EP}$ (CHF/kWh)</td>
<td>0 to 0.9</td>
<td>0.056</td>
</tr>
<tr>
<td>$P_{EO}$ (CHF/kWh)</td>
<td>0.028</td>
<td>0 to 0.8</td>
</tr>
<tr>
<td>$Y$ (CHF)</td>
<td>4’178</td>
<td></td>
</tr>
<tr>
<td>$HS$</td>
<td>2.21</td>
<td></td>
</tr>
<tr>
<td>$HDD$</td>
<td>3’374</td>
<td></td>
</tr>
<tr>
<td>$DG$</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>$DR$</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

*Source: median value of the Filippini’s (1995) sample*

\(^1\) 40% of the electricity prices were taken. In fact, according to swissgrid (2009) 40% is the average share of the household electricity price that goes for the electricity production, trade and delivery.
Total electricity demand for a given electricity price:

\[
\hat{E}_i[GWh] = 10^{-6} \frac{Pop_{CH}}{\% E_{HH} HH_{dim}} \exp\left(\ln \hat{E}_i\right) \text{ with } i=P,O
\]  

where:

\(Pop_{CH} = 7'785'800\) (Swiss Federal Office of Statistics, 2010) Swiss resident population

\(\% E_{HH} = 32.1\%\) (BFE, 2009) electricity consumption by the household out of the total Swiss electricity consumption

\(HH_{dim} = 2.21\) (Filippini, 2005) average household dimension

### 3.2. Empirical estimation of tax revenues

An ideal market with electricity produced only by the hydropower plants was simulated using Matlab. For modelling the aggregate electricity demand, the equation (3) was used. Two different graphs were produced, one for the peak demand and one for the off-peak demand. For the supply curve the data from Table 1 were used. The marginal costs were assumed to be equal to the average production costs. \(U_i\) are the different utilities with production costs \(c_i\) and production capacity \(q_i\). \(U_1\) corresponds to the run-of-river plants with water drop below 25m. \(U_2\) are the run-of-river utilities with water drop above 25m. \(U_3\) are the storage plants without pumps and \(U_4\) are the storage plants with pumps. The crossing point between demand and supply gives the electricity consumption.

#### 3.2.1. Actual fixed water fee system

With the actual rent system, the water fees are included in the production costs. The water taxes revenues depend on the amount of energy produced and on the water fees per kWh of each type of utilities.

In the peak period the market is represented in Figure 7. The total electricity consumption is of 22’983 GWh.
In the off-peak period the market is represented in Figure 8. The total electricity consumption is much lower and corresponds to 639 GWh.

The rents paid by each group of power plant are summarized in Table 3. The total rent revenue is of 29'993 million Swiss francs per year. Under this water fee policy there are
rent paid in both peak and off-peak period. The bigger contribution to the total rent is from the storage plants without pumps. Those plants are also paying the highest average rent per kWh.

Table 3: Production and rent under the actual water fee system

<table>
<thead>
<tr>
<th></th>
<th>Run-of-river</th>
<th>Storage</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>&gt; 25m</td>
<td>&lt; 25m</td>
<td>without pumps</td>
<td>with pumps</td>
<td>Total</td>
</tr>
<tr>
<td>Peak production (GWh)</td>
<td>7'006</td>
<td>7'872</td>
<td>6'325</td>
<td>1'780</td>
<td></td>
<td>22'983</td>
</tr>
<tr>
<td>Off-peak production (GWh)</td>
<td>639</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
<td>639</td>
</tr>
<tr>
<td>Total production (GWh)</td>
<td>7'645</td>
<td>7'872</td>
<td>6'325</td>
<td>1'780</td>
<td></td>
<td>23'622</td>
</tr>
<tr>
<td>Water Fee (CHF/kWh)</td>
<td>0.92</td>
<td>0.94</td>
<td>1.25</td>
<td>1.13</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Direct taxes (CHF/kWh)</td>
<td>0.13</td>
<td>0.14</td>
<td>0.45</td>
<td>0.37</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average rent (CHF/kWh)</td>
<td>1.05</td>
<td>1.08</td>
<td>1.71</td>
<td>1.50</td>
<td></td>
<td>1.27</td>
</tr>
<tr>
<td>Total rent (Moi CHF)</td>
<td>8'058</td>
<td>8'469</td>
<td>10'797</td>
<td>2'669</td>
<td></td>
<td>29'993</td>
</tr>
</tbody>
</table>

3.2.2. Resource rent system

When resource rent is applied the water fees and the direct taxes are not included in the production costs. This involves lower marginal costs. In Figure 9 is represented the aggregated electricity demand and the supply. R1, R2 and R3 are the resource rent paid by the utilities U1, U2 and U3 respectively. U4 do not has to pay any resource rent and its production costs determine the electricity price. The total electricity consumption is of 25’883 GWh. It could be noticed that the demand is higher than with the actual water fee system.
Figure 9: Electricity demand and supply during the peak period and under the resource rent system

The Figure 10 represents the electricity demand in the off-peak period. In this case there is no resource rent being paid. The total electricity consumption is of 3’044 GWh.

Figure 10: Electricity demand and supply during the off-peak period and under the resource rent system

In Table 4 are summarized the electricity production and the rent paid from the different types of utilities. Under this water tax policy the total rent revenues are of 35’027 million
francs per year. The main contribution to the total rent comes from the run-of-river plants with a water drop above 25m. Those plants have the highest average rent per kWh.

Table 4: production and rent under resource rent system

<table>
<thead>
<tr>
<th>Run-of-river</th>
<th>Storage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&gt; 25m</td>
</tr>
<tr>
<td>Peak production (GWh)</td>
<td>7'006</td>
</tr>
<tr>
<td>Off-peak production (GWh)</td>
<td>3'044</td>
</tr>
<tr>
<td>Total production (GWh)</td>
<td>10'050</td>
</tr>
<tr>
<td>Average costs (CHF/kWh)</td>
<td>3.75</td>
</tr>
<tr>
<td>Market price peak period (CHF/kWh)</td>
<td>5.50</td>
</tr>
<tr>
<td>Market price off-peak (CHF/kWh)</td>
<td>3.75</td>
</tr>
<tr>
<td>Revenue peak period (CHF/kWh)</td>
<td>1.76</td>
</tr>
<tr>
<td>Revenue off-peak (CHF/kWh)</td>
<td>0</td>
</tr>
<tr>
<td>Average rent (CHF/kWh)</td>
<td>1.22</td>
</tr>
<tr>
<td>Total rent (Moi CHF)</td>
<td>12'293</td>
</tr>
</tbody>
</table>

4. Conclusion

For hydropower production, the actual water fee policy is based on fixed taxes rates per kW depending on the installed power. The tax is applied to the plants having more than 1000 kW power installed. The plants with more than 2000 kW have to pay the higher tax rate, which corresponds to 80 francs per kilowatt. This water fee system is very rigid and is not appropriate if there is prices volatility. Additionally it does not take into account the geographical and territorial characteristics of the places where the plants are constructed. Today we are in a turning point for the electricity market. Effectively, at an European level the electricity production market is moving toward liberalization. This might have a very strong impact on electricity prices. A strong decrease in price can make some hydropower plants run into deficit because of the high fixed water fees imposed with the actual system. The use of another, more flexible policy has to be seriously considered.

Models the electricity market has allowed to analyze the differences between the actual fix rent system and a resource rent system. More precisely the total rent revenues and the average rent generated were investigated. It was found that the resource rent is a very interesting policy. In fact it allows generating higher revenues (5’034 million francs more
per year). With a resource rent policy the taxes would be distributed differently and the revenues of the different companies are standardized. The companies paying the higher average rent are the run-of-river utilities with water drop above 25m. Those plants give also the bigger contribution to the total rent. On the other hand, with the fix water fee system, the higher average rent comes from the storage plants without pumps. This implies that the new policy will make the big investments for the construction of big storage plants more alluring.

With the resource rent system no rent is paid during the off-peak period.

The results obtained are only a starting point. Effectively, the present study was made with a weak data set. Further models should be implemented with more consistent data and taking into account the total electricity production market (with also nuclear and thermic plants).

Additionally, further investigations concerning the possible incentives to increase production efficiency (minimize production costs) should be better analyzed.
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