How regulation affects efficiency and investments in the water sector: a theoretical approach and a case study of the Italian water integrated system in Tuscany

Daniele Aurigi

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Introduction

In the developed countries citizens can take the water sector for granted, but the water sector is one of the most relevant sectors not only for our everyday life but also for population hygiene and health and for the environment. In the developing countries, the absence of a functional water and sewerage system is one of the first causes of health issue and mortality. Moreover it is essential for the primary sector and for several industries.

The water and sanitation sector has some typical characteristics: Littlechild (1988) and Allouche et al.(2008) among others underlines that it displays the features of a natural monopoly and duplication of infrastructure have no economic sense; it supply public and merit goods that have lack of substitutes and it is highly capital-intensive with a massive presence of sunk costs, which increase private-sector risks (Rees 1998); another main feature is the local nature of the service: transporting water does not make sense economically and also raises quality problem (Allouche et al. 2008). As Massarutto (2009) stated for all this characteristics the critical issue is to understand the better way to regulate it and this is not a simple choice between public and private ownership or between state and market: we have a rich theoretical literature that surpasses these limited paradigms.

In the general structure of regulation, a special place is reserved for tariffs regulation. The price is, of course, a key issue for a variety of reasons. Rogers et al.(2002) listed a series of objectives tariffs could fulfil. Prices are important for users: as every product the less the price, the more is their surplus, but in the case of water, as we said before, water is a merit good, essential and virtually with no substitutes. Prices are important to firms because they want to recover costs and make profits; prices should allow them to make investments but also promote efficiency. Tariffs should favour an efficient allocation of the resource. In addition to that tariffs should encourage resource conservation and including environmental costs.

Italy's water regulation was last reformed in 2011 (law 214/11). The sector regulation have been experienced a lot of small changes after Galli law in 1994, and the process it’s still in progress. For an overview of the process you can see Asquer (2014 and 2018) and Massarutto (2012). However, entrusting the sector regulation to a National Authority with actual powers, as it happened in 2011, was a very important step in reforming the industry (Bardelli 2018). So from 2012, based on law 214/11, the supervision of the industry was given to an independent Authority (AEEGSI, now

ARERA). Before that the tariff method was the MTN, introduced in 1996 and then reformed in 2006. This method was a form of revenues cap regulation (Fazioli 2014 and Romano et al. 2015). After a brief period for collecting data and studying the system, the Authority introduced the first tariff model (MTI). The first tariff model holds for 2014 and 2015, and then the national Authority introduced the second tariff model (MTI-2) for the period between 2016-2019. Romano et al. (2015) analysed the differences between MTN and MTI founding that the prices are increased, the firms are low incentive to control their costs and there is no use of benchmark regulation (e.g.yardstick competion). Fazioli (2014) too analysed the two methods comparing with some international experiences: he underlined the revenues cap nature of the MTN opposed to the cost-plus structure of MTI and suggested to use some benchmarking to induce cost saving approaches by the firms and increasing prices per water unit above a minimum quantity for the essential needs per person, in order to balance equity and incentives to water savings. Stroffolini (2014) investigated the features that a tariff method should have to incentivize the minimization of operating costs.

I created a simple model in order to describe some aspect of the regulation with special attention In this Italian new regulation. I would like to analyse the effects of tariffs regulation on efficiency and investments and if and how the new regulation system can improve these features in the sector. Particularly, I investigated the effect of the tariff methods on the providers' efficiency improvements and the effect of the multi-level regulation system on the investments. Both aspects are hardly examined in the theoretical literature.

In the first chapter, I describe this simple theoretical model in which I represent how the Authority can regulate gain in operative efficiency by monopolists. Although Fazioli (2014) described the tariff methods as revenues cap (MTN) or cost plus (MTI), in each tariff methods there was a part of the price (or revenues) formula that took into account the efficiency gain the firms have made and shared a fraction with the consumers. First, I focused my attention on this part of the tariffs methods. To focus on this, my model is a revenue sharing model in which the price is decreased when the Authority verifies a gain in efficiency. The model shows that the Authority should exploit the more information they can collect in order to maximise Social Welfare. So it gives one possible justification to revising the tariffs method so often as Arera has been doing. In the last part of the chapter I analyse theoretically another segment of the tariff methods: the incentive to improve efficiency. The literature like Patti (2006) and Passerini et al (2008) and many reports (see REF 2014 and 2016) pointed out that the Italian water sector lacks in efficiency. One goal of regulation system is to make the sector reducing this inefficiency and the type of regulation can be crucial in achieving this goal (Brocas et al. 2006). I used a modified version of my basic model to understand the possible impact of the incentive. In order to have numerical results I used a Matlab program to run a simulation: I found out that the type of incentive in the Italian tariff methods works only for the firms that have the operative costs near the average.

In the second chapter, I use an adjusted version of the same model to analyse how the interaction between the system of Authority and the firms affects Investments in the sector. Smith (2000) described the advantages and the disadvantages of centralised and decentralised system of regulation and Danesi at al. (2008) applied that analysis to the Italian case suggesting that a two level system could have the benefits from both type of regulation. I try to add new elements that provide other possible justification for a system with a national Authority and several sub-national Authorities. From my analysis, if local Authorities have enough skills and expertise, they could help the sector increased the amount and the social value of the Investments: as far as I'm concern, it's the first time that staff's skills and expertise are introduced in this type of model.

In the third chapter, I used the Tuscan Water system as a case study, in particular, I've examined data of the past 6 years describing the technical characteristic of the infrastructure and the economic and financial characteristic of the 7 monopolist firms operating in the Tuscan territory. I explore the Tuscan data in order to see the actual results of the regulation, in an environment with relatively good local regulator, on a set of providers with mixed ownership where the public administration have the majority. I managed to find some interesting empirical facts like the fact that no provider raise the price up to maximum allowed, even if it would be rational for a maximizing profit firm point of view. All the providers but one have a private partner, but the public administrations have always the majority and so, among other consideration, we inferred that providers' mixed property seems to be a good structure to balance achieving efficiency and increasing investments with tariffs control, confirming and expanding Macchiati et al. (2019).

Chapter I - Regulation in the water sector: tariffs and efficiency

I.1 Introduction

Everybody understands the importance of water sector in developing countries, especially for health, rate mortality, but also higher costs for poor household and what all these issues imply in terms of obstacles for the economic development and poverty trap. In developed countries, the water sector is sometimes taken for granted or not considered much important, but clean water is essential for households, industries, agriculture and how states manage water and sewerage system is exceptionally relevant for our health and hydrogeological structure of our territories. Water provision is one of the standard textbook examples of natural monopoly. Hence, in a given zone is not efficient to have more firms supplying it and so the critical issue from the government point of view is to find the best method to regulate these monopolists. This consists of several aspects, including how to entrust the service, regulate tariff, incentivise investment or set the quality of the water and the service. Italy water sector has many delays as compared to European countries, especially in terms of efficiency and investments(Ref Ricerche, 2014 and 2016). In the thesis, I have focused my attention on how tariff regulation can have a role in those two elements.

In this chapter, I introduce a simple model, with some extensions, trying to capture a few main elements of water provision regulation. I have analysed the regulation of water distribution in Italy, and I focused on modelling some aspects of the regulator-regulated interaction. The goal is to study the actual Italian tariff methods analysing different elements separated to better understand the methods and then provide some hints for the Authority. In particular, the purpose of this first chapter is to analyse two aspects of tariff regulation that influenced the firm's choices on improving efficiency and provide some insights for the regulation. The first part I focus on is the sharing of the efficiency gain: I present a basic framework with an Authority and a monopolist interacting for three periods. In this framework, via price reduction, the Authority imposes the monopolist to share the efficiency improvement with the consumers.

Then I compare this basic model with a model without profit sharing and a model with full profit-sharing. Then I extend this model first to four periods introducing three different alternative ways of sharing. In addition, I generalise these three models to a generic T periods model.

Finally, I use a modified version of the model to describe the theoretical consequences of an incentive to increase efficiency, presently adopted in Italy with the new tariff methods: MTI, MTI-2 and MTI-3[1]. MTI was the first method adopted by the national Authority and it regulated tariffs for the year 2014 and 2015; The mehod was updated with MTI-2 that regulated tariffs for the period 2016-2019. The current method is MTI-3 for the period 2020-2023.

I.2 Literature Context

Literature (Patti 2006, Passerini et al. 2008) and many reports (REF 2014 and 2016, Coviri 2008) pointed out that the Italian water sector lacks in efficiency. One goal of regulation system is to make the sector reducing this inefficiency. The type of regulation can be crucial in achieving this goal (Brocas et al. 2006).

As Vogelsang (2002) underlined, profit sharing regulation (also called sliding-scale) is one of the oldest regulatory schemes and dates back to late 19th century; this type of regulation lets the customers gain a quota of excess utility's profits. Even if there are several types of regulation, the main literature focuses its attention on the comparison between price cap and rate of return regulations with sliding scale remaining somewhat aside with some exceptions like Mayer and Vickers (1996) or Lyon (1996). However, sliding-scale regulation has been used, in a variety of forms, in different countries and markets, see for example Hawdon et al. (2007) or Parker (2002).

Water tariffs regulation in Italy have only a few element of sharing regulation.

Fazioli (2014) and Romano et al. (2015) analysed and compare the tariff methods MTN[2] used from 1997 to 2011 and the MTI, the first tariff method elaborate by the national Authority (AEEGSI at that time, now ARERA).

Following Fazioli (2014), we can write the tariff formula of the MTN as:

$t_n = t_{n-1} (1 + rpi_n - x_n + k) = (c + a + r)_{n-1} \cdot (1 + rpi_n - x_n + k)$

where

- t_n is the tariff in the *n* year;
- *c* is the planned costs corrected with a mechanism for efficiency improvements
- *a* accounts for the depreciations of the infrastructure
- rpi_n is the inflation rate in the year n
- *r* is the rate of return of the net capital

1 MTI stands for "integrated tariff method"

2 Normalized tariff method (introduced by a ministerial decree: DM 01/08/1996)

- k is the price cap
- x is the value shared with consumers

And following Romano et al. (2015) we can write the tariff formula of MTI[3]

$VRG_n = CAPEX_n + FONI_n + OPEX_n + ERC_n + Rc_n$

Where:
- VRG are the maximum revenues the firm are allow to collect;
- CAPEX (capital expenditure) accounts for the cost of fixed assets ;
- FONI is a part of the tariff to finance new investments;
- OPEX includes operating costs;
- ERC accounts for the environmental costs;
- Rc is the adjustment for the previous years' tariff.

OPEX are composed by the exogenous costs and the endogenous costs.

The first ones are costs that firms cannot control. On the contrary, endogenous costs are costs that firms could lower in order to become more efficient. The value of those in the tariff are a mean of planned and effective expenses of the year before (2013 in the case of MTI, 2014 in the case of MTI-2, 2018 for MTI-3), so the firms that manage to lower the costs gain for this then a fraction of the gain is given to the consumers in the next year through the next tariff method.

So, I decided to use a sliding scale model in order to describe this aspect of the current regulation of the water sector.

I.3 Basic Model

Consider a country divided to in zones, wherein each zone there is a monopolist selling one good (water) to consumers. A National Authority regulates the markets. In the basic model, all the zones and all the firms are equal to each other, so we can use one firm as a representative agent for all the firms. I, also, assume for simplicity that the quantity demanded is fixed over the years and completely inelastic. Firms maximise profits $\Pi = R - C$, where R are the revenues; so R=QP. The symbol Q stands for the quantity sold and, as said, we take it fixed while P is the unit price. C, finally, are costs. The consumer surplus is instead defined as S = (B-P)Q, with B being the consumers' benefit in monetary terms of 1 unit of the good. We assume for simplicity B equal across consumers and constant over quantity.

3 MTI-2 and MTI-3 are very similar

As a general rule, through the chapters, when it's not otherwise specified, we use the number in the subscript to indicate the period at which the value is referred to.
The model has three periods: in the first period, the firm chooses the amount of effort 'e_1' in order to reduce operating costs (increasing efficiency), bearing a cost of $g(e_1)$. We assume g(.) is its cost function with g'>0 and g">0. In the second period, operational costs are reduced by 'e_1' and the firm can make an additional effort to increase efficiency. In the third one, the Authority lowers the price of the good in order to share the gain in efficiency with the consumers. In particular, it reduces the price by $\alpha e_1/Q$ (with $0 \leq \alpha \leq 1$) so in this way consumers surplus goes up by αe (see 1.2) and the firm is left with a $(1-\alpha)$ part of e_1 as we will show (see 1.4). In this basic model the Authority shares with consumers only the first-period effort because there is not a fourth period in which the second-period effort can be shared.
We call p the price before the Authority intervention, that is the price in the first and in the second period, and we take it as given (so $P_1 = P_2 = p$). So consumers surplus in the first two periods are:

$$S_1 = S_2 = (B-p)Q = \overline{S} \qquad (1.1)$$

Since B, p and Q are given $\overline{S}$ is also given.
In the third period the price decreases by $\frac{\alpha e}{Q}$, that is $P_3 = p - \frac{\alpha e}{Q}$, and so the consumers surplus is:

$$S_3 = [B-(p-\alpha e/Q)]Q = \overline{S} + \alpha e \qquad (1.2)$$

Following the literature (Tirole, Laffont, 1993) I assume the Authority maximises the Welfare function:

$$W = S + \lambda \Pi \qquad (1.3)$$

with $0 \leq \lambda \leq 1$

where Π is the profit of the monopolist and λ is the weight the Authority gives to the firm. Π is the firm's profit, and λ is a positive parameter between 0 and 1, representing how much the Authority cares about firms.
This basic model defines a dynamic game between the Authority and the firm. For the sake of simplicity, we do not consider the discount factor.

Calling $\overline{R}$[4] and $\overline{C}$ the revenues and the costs before time 1, that we take as given, the profits of the firm in the 3 years are:

$$\Pi_1 = \overline{R} - \overline{C} - g(e_1)$$
$$\Pi_2 = \overline{R} - (\overline{C} - e_1) - g(e_2) \qquad (1.4)$$
$$\Pi_3 = Q\,(p - \alpha e_1/Q) - (C - e_1 - e_2) = \overline{R} - \overline{C} + e_2 + (1-\alpha)e_1$$

So the objective function the firm maximises, choosing ‘e_1’ and ‘e_2’, is

$$\Pi_{tot} = \sum_{j=1}^{3} \Pi_j = 3(\overline{R}-\overline{C}) + (2-\alpha)e_1 + e_2 - g(e_1) - g(e_2) \qquad (1.5)$$

The consumer surplus in period 3 is

$$S_3 = [B-(p-\alpha e/Q)]Q = \overline{S} + \alpha e_1 \qquad (1.6)$$

and so:

$$S_{tot} = \sum_{j=1}^{3} S_j = 3\overline{S} + \alpha e_1 \qquad (1.7)$$

Given $W = S + \lambda\Pi$, the objective function for the Authority is

$$W_{tot} = 3\overline{S} + \alpha e_1 + \lambda[3(\overline{R}-\overline{C}) + (2-\alpha)e_1 + e_2 - g(e_1) - g(e_2)] \qquad (1.8)$$

This is a sequential game with a finite horizon in which the Authority sets the rules (chooses α), then the firm chooses the effort, so we can solve the game by backward induction.

The first-order conditions with respect to e_1 and e_2 for the firm are:

f.o.c.: $2-\alpha = g'(e_1)$; $1 = g'(e_2)$[5]

Given that, the Authority maximises W_{tot}.

$$\alpha^* = \begin{cases} \dfrac{[(1-\lambda)e_1 + 2\lambda e'_1 - \lambda g'(e_1)e'_1]}{(\lambda-1)e'_1} & \text{if } 0 \le \dfrac{[(1-\lambda)e_1 + 2\lambda e'_1 - \lambda g'(e_1)e'_1]}{(\lambda-1)e'_1} \le 1 \\ 0 & \text{if } \dfrac{[(1-\lambda)e_1 + 2\lambda e'_1 - \lambda g'(e_1)e'_1]}{(\lambda-1)e'_1} < 0 \\ 1 & \text{if } \dfrac{[(1-\lambda)e1 + 2\lambda e'_1 - \lambda g'(e_1)e'_1]}{(\lambda-1)e'_1} > 1 \end{cases} \qquad (1.9)$$

4 $\overline{R} = pQ$ since p is the price before the Authority intervention.

5 The game include only the choice of e_1 because the choice of e_2 doesn’t depend on α; hence it does not depend on the Authority behaviour. The second ordered conditions checked for a maximum.

The derivative of e_1 with respect to α (e_1') is negative, because the more the Authority imposed to share with the consumers, the less the incentive in making an effort to reduce the costs. Hence $\alpha^* > 0$ when $(1-\lambda)e_1 + \lambda g'(e_1)|e_1'| > 2\lambda|e_1'|$

Focusing on the non trivial case in which $\alpha^* = \frac{[(1-\lambda)e_1+2\lambda e'_1-\lambda g'(e_1)e'_1]}{(\lambda-1)e'_1}$, and replacing $g'(e_1)$ with 2-α, we find the condition $\alpha^* e_1^{*\prime}+(1-\lambda)e_1^*= 0$.

Rearranging, we obtain

$$\alpha^* e_1'^*/e_1^* = 1-\lambda \tag{1.10}$$

meaning that the elasticity of cost-efficiency optimisation with respect to α is 1-λ, so less than 1.

I.4 Model with T=3 and g(e)=ae²

In order to start extending our analysis, and obtain further results, we choose a specific form for the g(.) function. I suppose $g(e)=ae^2$, with $a>0$ and compute the solution of the game again.

The first-order condition for the firm now is

$$e_1 = \frac{2-\alpha}{2a}. \tag{1.11}$$

Substituting in the Welfare function and maximising under α we find that

$$\alpha^* = \frac{2(1-\lambda)}{2-\lambda}. \tag{1.12}$$

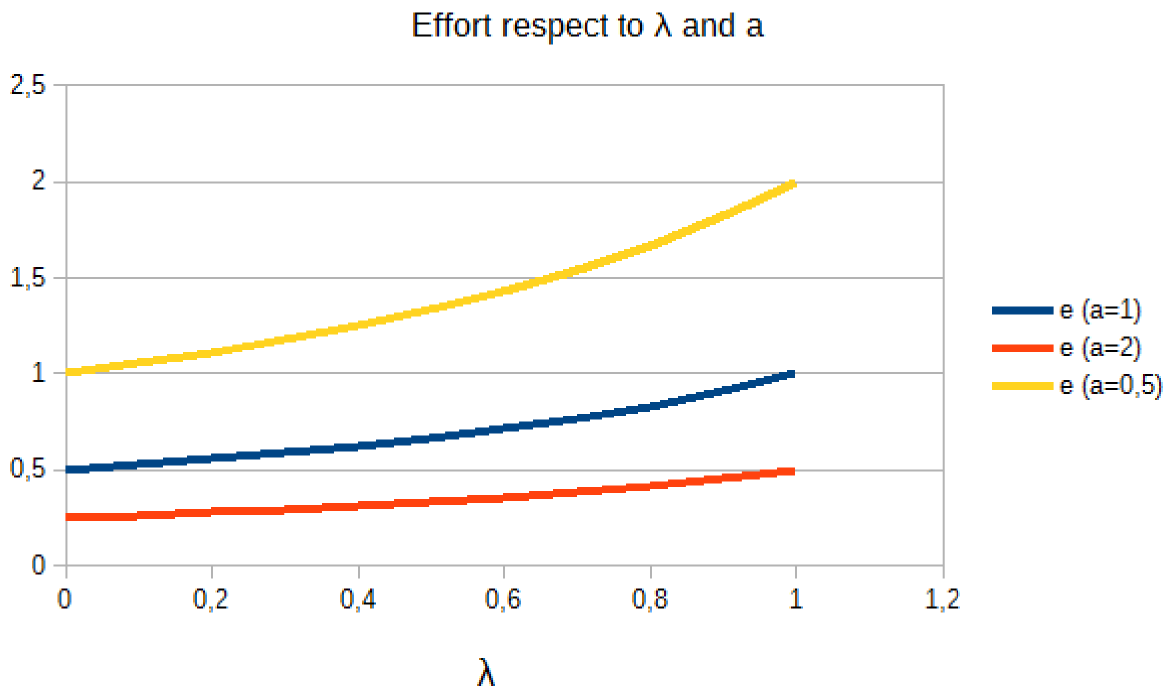
So the level of effort chosen by the firm will be

$$e_1^* = \frac{1}{a(2-\lambda)}. \tag{1.13}$$

The second-order conditions confirm that both value maximize W_{tot}.

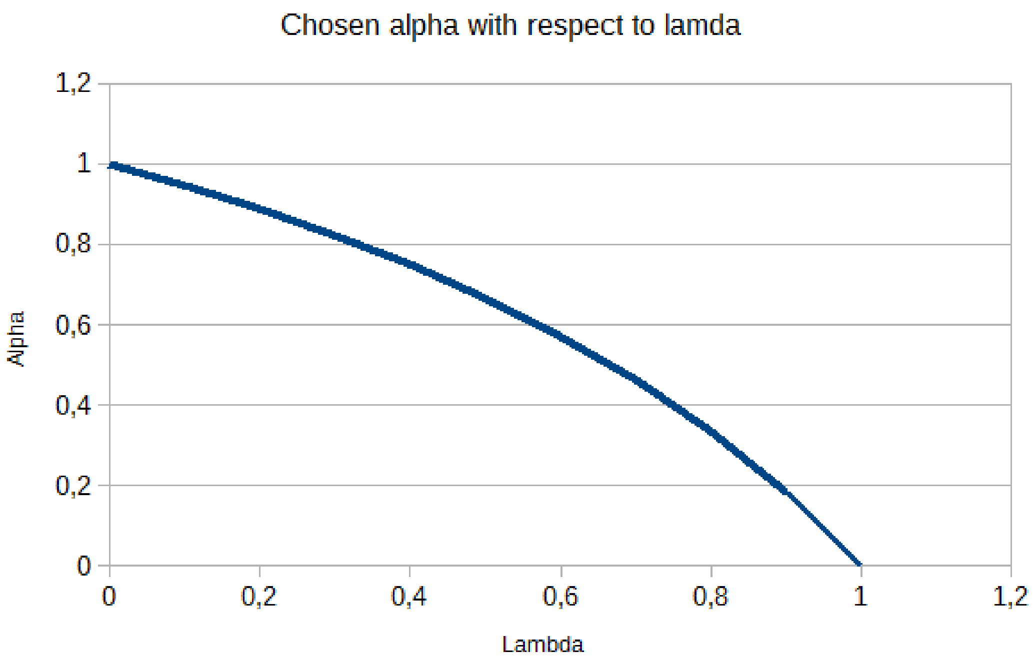
Let's discuss these results. In figure 1.1, you can notice that, as expected, in equilibrium the effort is inversely related to the cost parameter for the firm of making that effort (a). The figure also shows that the firm choose the effort directly proportional to how much the Authority value the firms with respect to consumers (λ). As you can see from figure 1.2, the higher λ the lower would be α and so a higher percentage of e will remain for the firm.

Figure 1.1



Authority's choice (1.12), instead, is independent of the firm's effort cost function. It depends only on λ and, of course, it's inversely proportional to it, as figure 1.2 shows.

Figure 1.2



It is possible now to compute the total profits, that are:

$\Pi_{tot} = 3(\overline{R}-\overline{C}) + e_2 - g(e_2) + 1/(a(2-\lambda)^2) = 3(\overline{R}-\overline{C}) + e_2 - g(e_2) + e_1/(2-\lambda) =$

$$3(\overline{R}-\overline{C}) + 1/a(2-\lambda)^2 + 1/4a \qquad (1.14)$$

The resulting value of the Social Welfare function will be:

$W_{tot} = S_{tot} + \Pi_{tot} = 3(B-p)Q + 2(1-\lambda)/a(2-\lambda)^2 + 3\lambda(\overline{R}-\overline{C}) + \lambda[1/a(2-\lambda)^2 + 1/4a] =$

$$3(B-p)Q + 3\lambda(\overline{R}-\overline{C}) + (\lambda^3-4\lambda^2+8)/4a(2-\lambda)^2 \qquad (1.15)$$

It is now interesting to compare these results with those of a model in which the Authority does not impose any sharing, so α is set equal to zero. In this case, the model is no longer a game, but it is simply a maximisation problem for the firm (I indicate with Π_{ns} the profit in case of no sharing).

$\Pi_{ns\_1} = \overline{R} - \overline{C} - g(e_1)$

$\Pi_{ns\_2} = \overline{R} - (\overline{C} - e_1) - g(e_2)$

$\Pi_{ns\_3} = \overline{R} - (\overline{C} - e_1 - e_2) = \overline{R} - \overline{C} + e_2 + e_1$ (1.16)

$\Pi_{ns\_tot} = 3(\overline{R}-\overline{C}) + 2e_1 + e_2 - g(e_1) - g(e_2)$

F.o.c.: $2 = g'(e_1)$; $1 = g'(e_2)$

The related total profit for the firm after 3 periods is

$$\Pi_{ns\_tot} = 3(\overline{R}-\overline{C}) + 5/4a \qquad (1.17)$$

Comparing the two models we obtain:

$$\Pi_{tot} - \Pi_{ns\_tot} = 1/a(2-\lambda)^2 - 1/a \leq 0$$

The Social Welfare function will be $W_{ns\_tot} = 3(B-p)Q + \lambda\,[3(\overline{R}-\overline{C})+5/4a]$ (1.18)

Comparing this one with our basic model gives:

$$W_{tot} - W_{ns\_tot} = (1-\lambda)^2/a(2-\lambda) \geq 0$$

As we could expect, reducing-cost effort sharing increases Social Welfare despite lowering the profits. We can notice that we have the same results from the two models in case of $\lambda=1$ because, as we have seen in the basic model, this implies $\alpha^*= 0$.

I.5 Extending the model to T = 4: comparing 3 options

The basic model with 3 periods gives us some insights about this type of regulation. Nevertheless, the regulator has to face a horizon that tends to the infinity. When you add periods, you have to decide how to extend the rules. So now we try to understand how the Authority could regulate the monopolist if we extend the time horizon. We start setting T = 4 to show some different possibilities better.

We will analyse the three options that seem to us the most significant:

a) Sharing everything at the end

The Regulator imposes the sharing, of the first 2 years cost-reducing effort, in the last period. In this case we have:

$$\Pi_1 = \overline{R} - \overline{C} - g(e_1)$$
$$\Pi_2 = \overline{R} - (\overline{C} - e_1) - g(e_2)$$
$$\Pi_3 = \overline{R} - \overline{C} + e_1 + e_2 - g(e_3) \qquad (1.19)$$
$$\Pi_4 = \overline{R} - \overline{C} + (1-\alpha)(e_1 + e_2) + e_3$$

summing up:

$$\Pi_{tot} = 4(\overline{R}-\overline{C}) + (3-\alpha)e_1 + (2-\alpha)e_2 + e_3 - g(e_1) - g(e_2)- g(e_3) \qquad (1.20)$$

Maintaining the assumption $g(e)= ae^2$, we can compute first-order conditions for the monopolist and find the players best responses: α^* for the Authority and (e_1^*, e_2^*, e_3^*) for the firm.

From the monopolist's f.o.c. we obtain: $e_1 = (3-\alpha)/2a$; $e_2 = (2-\alpha)/2a$; $e_3 = 1/2a = e_3^*$

$$\alpha^* = 1 \quad ; \quad e_1^* = 1/a \quad ; \quad e_2^* = 1/2a \qquad \text{for} \quad \lambda \leq 1/3$$
$$\alpha^* = \frac{5(1-\lambda)}{2(2-\lambda)} \; ; \; e_1^* = \frac{7-\lambda}{4(2-\lambda)} \; ; \; e_2^* = \frac{3+\lambda}{4a(2-\lambda)} \qquad \text{for} \quad \lambda > 1/3 \qquad (1.21)$$

Replacing these values in the Social Welfare function ($W = S + \lambda\Pi$) we find:

$$W_{tot} = 4(\overline{R}-\overline{C}) + e_3 + g(e_3) + \frac{6+5\lambda}{4a} \qquad \text{for } \lambda \leq 1/3$$
$$W_{tot} = 4(\overline{R}-\overline{C}) + e_3 + g(e_3) + \frac{-\lambda^2+2\lambda+25}{8a(2-\lambda)} \qquad \text{for } \lambda > 1/3 \qquad (1.22)$$

Since e_3 does not depend on the interaction between the players,
$e_3 + g(e_3)$ always have the same value, and this is 1/4a. So we can rewrite:

$$W_{tot} = 4(\overline{R}-\overline{C}) + 1/4a + \frac{6+5\lambda}{4a} \qquad \text{for } \lambda \leq 1/3$$
$$W_{tot} = 4(\overline{R}-\overline{C}) + 1/4a + \frac{-\lambda^2+2\lambda+25}{8a(2-\lambda)} \qquad \text{for } \lambda > 1/3 \qquad (1.23)$$

b) Sharing every period (from the 4th) with 1-period delay

In the second scenario the Authority will lower the price in the fourth period, but he will impose the sharing of efficiency effort of the first period only. The firms's payoff becomes:

$$\Pi_1 = \overline{R} - \overline{C} - g(e_1)$$
$$\Pi_2 = \overline{R} - (\overline{C} - e_1) - g(e_2)$$
$$\Pi_3 = \overline{R} - \overline{C} + e_1 + e_2 - g(e_3) \qquad (1.24)$$
$$\Pi_4 = \overline{R} - \overline{C} + (1-\alpha)e_1 + e_2 + e_3$$

$\Pi_{tot} = 4(\overline{R}-\overline{C}) + (3-\alpha)e_1 + 2e_2 + e_3 - g(e_1) - g(e_2) - g(e_3)$

We can compute the first order conditions for the firm:
f.o.c.: $3-\alpha = g'(e_1)$; $2=g'(e_2)$; $1=g'(e_3)$.

Setting again $g(e)= ae^2$, we obtain:
$e_1= (3-\alpha)/2a$; $e_2 = 1/a = e_2^*$; $e_3 = 1/2a = e_3^*$.

Applying the same method used above, we can find the optimal players' choices:

$$\alpha^* = 1 \quad ; \quad e_1^* = 1/a \qquad \text{for } \lambda \leq 0.5$$
$$\alpha^* = 3(1-\lambda)/(2-\lambda) \quad ; \quad e_1^* = 3/2a(2-\lambda) \qquad \text{for } \lambda > 0.5 \qquad (1.25)$$
$$e_2^* = 1/a \; ; \; e_3^* = 1/2a \, .$$

That leads us to the following Social Welfare function value:

$$W_{tot}= 4(\overline{R}-\overline{C}) + 1/4a + (2\lambda +1)/a \qquad \text{for } \lambda \leq 0.5$$
$$W_{tot}= 4(\overline{R}-\overline{C}) + 1/4a + \frac{9+4\lambda(2-\lambda)}{4a(2-\lambda)} \qquad \text{for } \lambda > 0.5 \qquad (1.26)$$

c) Sharing in every period (from the 3rd)

The Authority can impose the sharing in the third period like in the basic model, and then it shares the second-period increasing-efficiency effort (e_2) reducing the price in the fourth period.
In this case we can write the part of the model regarding the monopolist in the following way:

$$\Pi_1 = \overline{R} - \overline{C} - g(e_1)$$
$$\Pi_2 = \overline{R} - (\overline{C} - e_1) - g(e_2)$$
$$\Pi_3 = \overline{R} - \overline{C} + (1-\alpha_1) e_1 + e_2 - g(e_3) \qquad (1.27)$$
$$\Pi_4 = \overline{R} - \overline{C} + (1-\alpha_1)e_1 + (1-\alpha_2) e_2 + e_3$$
$$\Pi_{tot} = 4(\overline{R}-\overline{C}) + (3-2\alpha_1)e_1 + (2-\alpha_2) e_2 + e_3 - g(e_1) - g(e_2)- g(e_3)$$

The related first order conditions are

f.o.c.: $3-2\alpha_1 = g'(e_1)$; $2-\alpha_2=g'(e_2)$; $1=g'(e_3)$

Assuming again $g(e) = ae^2$

we can find: $e_1= (3-2\alpha_1)/2a$; $e_2 = (2-\alpha_2)/2a$; $e_3 = 1/2a = e_3^*$ (1.28)

In the last three periods, players face a sub-game equivalent to the basic model, so we already know e_2^* and α_2^*, (1.12) and (1.13):

$\alpha_2^* = \frac{2(1-\lambda)}{2-\lambda}$; $e_2^* = \frac{1}{a(2-\lambda)}$

Given those we can solve the game backwards, using the same technique applied before. Solutions to this problem are:

$e_1^* = \frac{3}{2a(2-\lambda)}$; $\alpha_1^* = \frac{3(1-\lambda)}{2(2-\lambda)}$ (1.29)

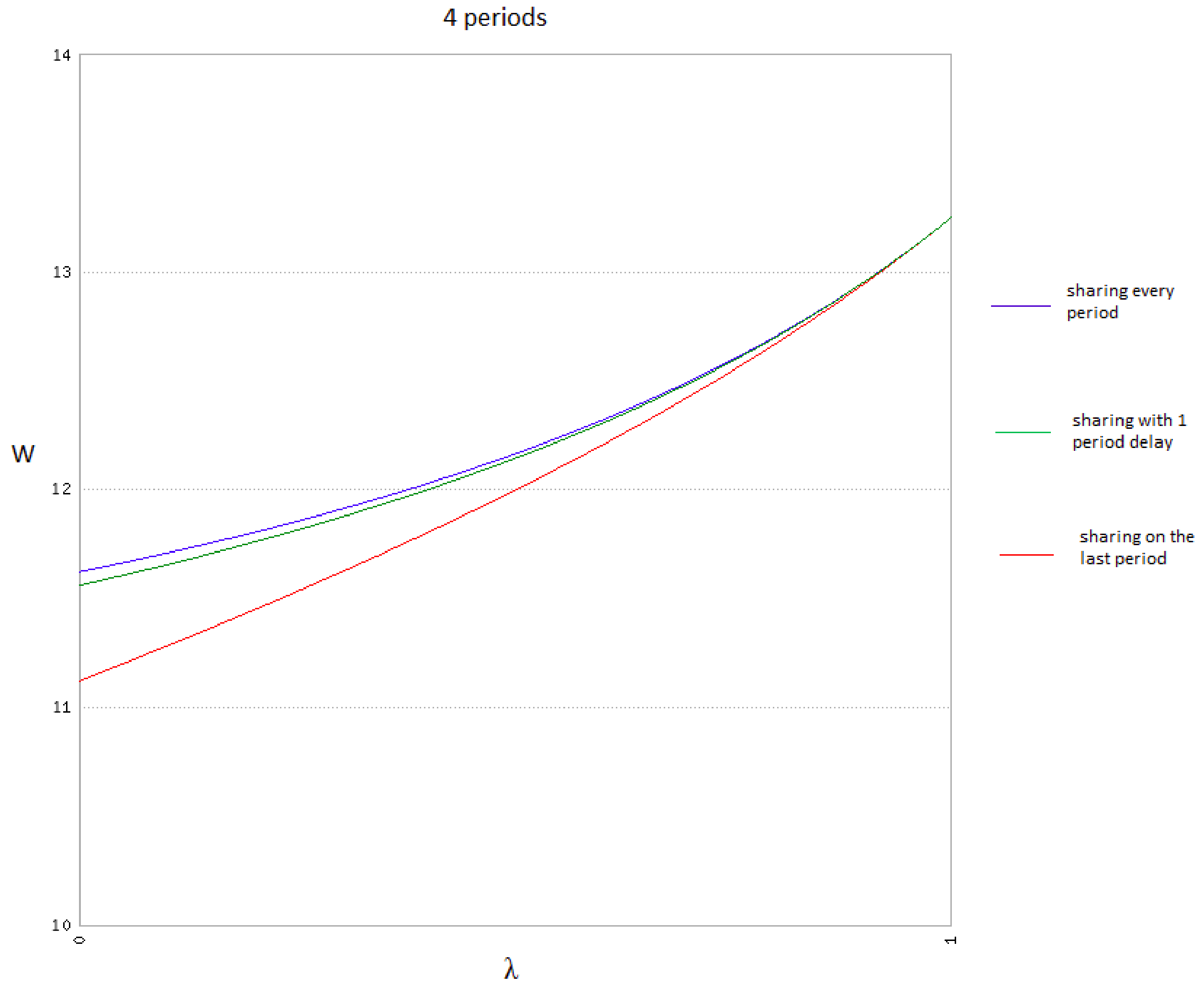
The resulting Social Welfare is:

$W_{tot} = 4(R-C) + \frac{1}{4}a + \frac{13}{4a(2-\lambda)}$ (1.30)

To compare graphically the 3 options we normalise 4(R-C) + 1/4a to 10 and we set a=1. This allows us to represent the Social Welfare functions in the graph below better. We plot those expressions as a function of λ.

From the figure below, you can see that the options have the same ranking for every λ:

Figure 1.3



As expected, except the case in which the Authority care entirely for the firm (λ=1), the more information the Authority uses, the higher will be the value of her objective function. As a matter of facts, the option in which the Authority reaches the maximum value of the welfare function is when it can use the information about the firm costs and adjust the price every time.

We can easily notice that the 3 models converge for λ=1 because in that case, as we saw before, α is always 0. Moreover, we can argue that if we consider the discount factor these results are even stronger: Authority weight consumers surplus more than profits, but in the second and third scenario consumers gains are postponed, so with the discount factor are lower. So it seems reasonable that the 3 alternatives keep the same ranking when we introduce a discount factor.

I.6 Generalising the 3 alternatives in T periods

The 3 options described can be generalised to generic T periods. We want to understand if using a generic T change the ranking of the options in terms of Social Welfare function.

a) Sharing everything at the end

We can generalise the number of periods after which the Authority decides how much to share the cost-reducing effort with the consumers.

If the price is lowered at period T > 3 we have this sequence of profits:

$\Pi_1 = \overline{R} - \overline{C} - g(e_1)$

$\Pi_2 = \overline{R} - (\overline{C} - e_1) - g(e_2)$

$\Pi_3 = \overline{R} - (\overline{C} - e_1 - e_2) - g(e_3)$

.

$\Pi_t = \overline{R} - \overline{C} + \sum_{j=1}^{t-1} e_j - g(e_t)$ (1.31)

.

$\Pi_T = \overline{R} - \overline{C} + (1-\alpha)\sum_{j=1}^{T-1} e_j + e_{T-1}$

$$\Pi_{tot} = T(\overline{R}-\overline{C}) + \sum_{j=1}^{T-1}\left[(T-j)e_j - g(e_j)\right] - \alpha\sum_{i=1}^{T-1} e_j$$

In this case we obtain the following first order conditions:

for t=1...T-2 : $T-t-\alpha = g'(e_t)$

for t= T-1 : $1 = g'(e_{T-1})$

Given these conditions, the Authority maximises W choosing α. The result we find is a generalisation of the one we obtain in the basic model (1.10):

$$\alpha^* = (\lambda-1)\sum_{j=1}^{T-t} e_j^* / \sum_{j=1}^{T-t} e_j^{*'} \quad (1.32)$$

Given this response the firm maximizes its profits choosing an effort for each period but the last:

for t=1...T-2 $e_i^* = (T-t)/2a - (T+1)(1-\lambda)/[4a(2-\lambda)]$ (1.33)

for t=T-1 $e_{T-1} = 1/2a$

We can now compute α in equilibrium:

$$\alpha^* = (T+1)(1-\lambda)/2(2-\lambda) \quad \text{if} \quad (T+1)(1-\lambda)/2(2-\lambda) \leq 1 \qquad (1.34)$$
$$\alpha^* = 1 \qquad \text{otherwise}$$

The resulting social welfare function value for the not trival case ($\alpha^* = 1$) is

$$W_{tot} = T(\overline{R}-\overline{C}) + 1/4a + [(T-2)/48a(2-\lambda)^2][(4T^2+2T+51)\lambda^3 - 4(4T^2-28T+51)\lambda^2 + (16T^2-142T+249)\lambda + 30(2T-3)] \qquad (1.35)$$

b) Sharing every period (from the 4th) with 1-period delay

We can also extend option b. As in the 4th period case, Authority shares the effort made in period 1, so in any other period $t \geq 4$ Authority shares the effort made by the firm in period t-3. The regulator has to choose T-3 values of α since in the first 3 periods there is no sharing. The firm has to choose T-1 values of *e* since in the last period there is no sense in making an effort.

for t=1...T-3 $\quad e_i^* = (T-t)/[2a(2-\lambda)] \quad ; \quad e_{T-2}^* = 1/a \quad ; \quad e_{T-1}^* = 1/2a$
for t=1...T-3 $\quad \alpha_i^* = (T-t)(1-\lambda)/(T-t-2)(2-\lambda)$ (1.36)

As before, α_i is fraction of e_i the Authority makes the firm sharing with consumers,
so α_i appears in the profit of period *i+3.* The resulting social welfare function value is

$$W_{tot} = T(\overline{R}-\overline{C}) + 1/4a + [(T-3)(2T^2+3T+10)+24\lambda(2-\lambda)]/(24a(2-\lambda)) \qquad (1.37)$$

c) Sharing every period (from the 3rd)

Finally we extend option c. As in the 3rd period Authority shares effort made in period 1, so at any other period t after 3rd the Authority shares the effort made by the firm in period t-2. The regulator has to choose T-2 α (from period 3 to period T) since in the first 2 periods there is no sharing. The firm has to choose T-1 e since in the last period there is no sense in making an effort.
We can find the equilibrium choices as in the other cases.
for t=1...T-2 $\quad \alpha_t^* = (T-t)(1-\lambda)/(T-t-1)(2-\lambda)$

for t=1...T-2 $e_t^* = (T-t)/2a - (T-t)(1-\lambda)/[2a(2-\lambda)]$; $e_{T-1}^* = 1/2a$

The resulting social welfare function value is

$$W_{tot} = T(\overline{R}-\overline{C}) + 1/4a + (T-2)(2T^2+T+3)/(24a(2-\lambda)) \quad (1.38)$$

Comparing the Social Welfare functions founded, we can extend the results for T=4 to T > 4 . The options remain ranked in the same way considering W, both along λ and T.

Sharing every period is the socially preferred alternative; the second best is sharing after one period of delay.

I.7 Efficiency incentives:

In Italy, the tariff regulation named MTI-2 has been in effect since 2016 to 2019[6].

The method is similar of MTI that we have seen above and is based on 2014 data collected from all the local monopolists.

In the period 2016-2019, each firm could have increased their revenues according to the following table:

Table 1.1

	$\frac{OPEX2014}{pop} \leq OPM$	$\frac{OPEX2014}{pop} > OPM$
$\frac{IP^{2016\text{-}2019}}{RAB_{MTI}} \leq \omega$	Scheme I 6 %	Scheme II 5,5 %
$\frac{IP^{2016\text{-}2019}}{RAB_{MTI}} > \omega$	Scheme IV 8,5 %	Scheme V 8 %

(from: “Verso il nuovo periodo regolatorio: Metodo Tariffario 2.0”,ottobre 2015, REF Ricerche)

In the table $IP^{2016\text{-}2019}$ are the planned investments for the 2016-2019 period, while RAB_{MTI} is the value of the firm's assets and ω is a parameter chosen by the Authority. We will focus on the implications of this incentive scheme in the next chapter.

6 Authority's *delibera 664/2015/R/idr* introducing *Metodo Tariffario Integrato 2 (MTI-2)*

Opex2014 are the firm operating costs in 2014, pop stands for the population while OPM is the average operating costs among firms in that year. So, looking at the columns, we notice that firms which have kept their operating costs(corrected by population) under the sector average could raise the revenues by another 0,5 % .

We try to capture the effect of this type of incentive adapting our model.
We extend the model to n monopolists firms. We assume there are n areas and in each area, there is a monopolist. We assume the revenues before the first period $\overline{R}$ are the same across firm, while costs are different. In particular, we assume

$\overline{C}_1 < \overline{C}_2 < \ldots < \overline{C}_{n-1} < \overline{C}_n$

where the subscript indicates the firm. Using C_{ti} for the costs of firm *i* in the period *t*
We can write the sequence of profits for monopolist *i* in the 3 periods as
$\Pi_{1i} = \overline{R} - C_{1i} = \overline{R} - \overline{C}_i - g(e_i)$
$\Pi_{2i} = \overline{R} - C_{2i} = \overline{R} - (C_{1i} - e_i)$
$\Pi_{3i} = \overline{R} - C_{3i} = \overline{R}(1+r) - C_{1i} + e_i$
and so:

$$\Pi_{tot} = 3(\overline{R}-\overline{C}_i) + \overline{R}r + 2e_i - g(e_i) \tag{1.39}$$

If M_t is the average of C_{ti} in the industry (with *t* indicates the period and *i* again the firm: $M_t = \sum_{j=1}^{n} \frac{C_{tj}}{n}$) the Authority sets r according to this rule:

$$\begin{cases} \text{if } C_{2i} \leq M_2 & r > 0 \text{ (0,005 in the current tariff regulation)} \\ \text{if } C_{2i} > M_2 & r = 0 \end{cases} \tag{1.40}$$

M_2 is a function of C_{2i} too, so we rearrange these conditions, so that C_{2i} has to be lower or equal the average of all the other firms ($M_{2\text{-}i} = \sum_{j \neq i} \frac{C_{tj}}{n}$) in order to have r > 0

$$\begin{cases} \text{if } C_{2i} \leq M_{2\text{-}i} & r = \overline{r} > 0 \\ \text{if } C_{2i} > M_{2\text{-}i} & r = 0 \end{cases} \tag{1.41}$$

We can model this situation with a game in which all the firms choose simultaneously. They select an effort in the first period, and if in the second period a firm has an operating costs less, or equal, than the average of all the firms she will have additional revenues in the third period. If not she will have r = 0 so revenues won't increase for her.

So, like in the basic model, also in this model in period 1 each firm chooses the amount of effort 'e' paying g(e). In the second period, each player will end up with a given C_{2i}. Players with $C_{2i} \leq M_{2\text{-}i}$ will have $r = \bar{r}$ in period 3.

We know that $C_{2i} = \overline{C}_i - e_i$ and $M_{2\text{-}i} = M_{1\text{-}i} - e_{\text{-}i}$, where $e_{\text{-}i}$ is the average of the choices of the other firms. So each firm end up having $r = \bar{r}$ if and only if

$$e_i \geq \overline{C}_i - M_{1\text{-}i} + e_{\text{-}i} \qquad (1.42)$$

We can find, in this simple framework, the minimum effort a firm chooses is 1/a :

$e_{min} = \frac{1}{a}$ is the optimal effort when there is no incentive or when the incentive is negligible for the firm. How much is the maximum effort a firm would choose? In order to find it, we normalise the profit of the firm without the effort($\overline{R}$-$\overline{C}_i$) to zero.

Total payoff become $\Pi_{tot} = \overline{R}r + 2e - g(e)$ if the conditions wrote above hold;

$\Pi_{tot} = 2e - g(e)$ if not. Assuming $g(e)=ae^2$, we can draw the graph of the two situations.

Figure 1.4

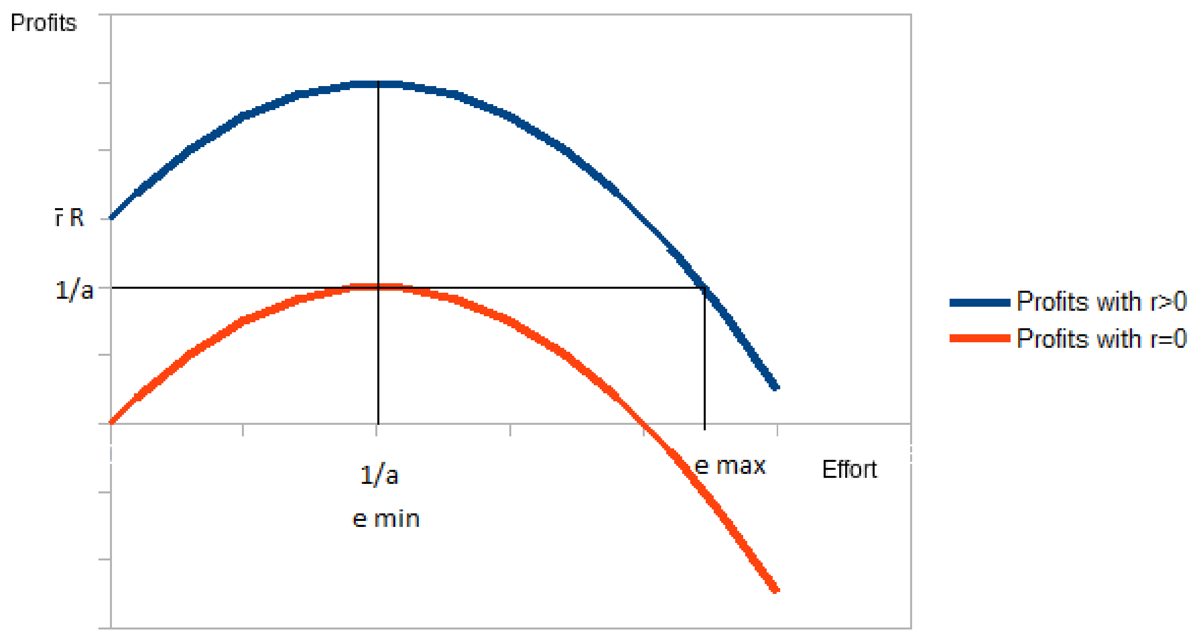


Figure 1.4 show that e_{max} is the maximum effort a firm would perform, aiming to obtain the incentive: if a player needs to make an effort bigger than e_{max} to satisfy the requirement, that is to decrease her costs, she'll be better off choosing e = $\frac{1}{a}$ ending up with r = 0 . As a matter of facts, you can see in the figure that for e greater than e_{max} the blue curve is below the profits the firm can make choose e = $\frac{1}{a}$ and not obtaining the incentive (staying in the orange curve).

Now we can calculate e_{max} . With r = 0 and e = $\frac{1}{a}$, $\Pi_{tot} = \frac{1}{a}$; therefore e_{max} can be found by solving this equation: $\frac{1}{a} = \overline{rR} + 2e - ae^2$.

The result is $e_{max} = \frac{1}{a} + \frac{\sqrt{rRa}}{a}$. (1.43)

Hence we can safely write $\frac{1}{a} \leq e_{-i} \leq \frac{1}{a} + \sum_{j=1}^{3} s_j$.

From that, it results that all the firms for which: $\overline{C}_i - M_{1-i} \leq -\frac{\sqrt{rRa}}{a}$ don't risk to have r = 0 in the third period, so, for sure, they will choose e =1/a.

On the other side, players which have $\overline{C}_i - M_{1-i} \geq \frac{\sqrt{rRa}}{a}$, don't have enough incentive to reach the sector cost average, so they choose e = $\frac{1}{a}$ too.

Firms instead for which $-\frac{\sqrt{rRa}}{a} \leq \overline{C}_i - M_{1-i} \leq \frac{\sqrt{rRa}}{a}$ hold will choose $\overline{C}_i - M_{1-i} + e_{-i}$ if 1/a is not enough to get $\overline{r}$ in the last period.

Since the effort of each firm depends on the effort of the others, you can not find a closed solution. We can find a numerical solution instead; in particular, we can find the exact value of $\overline{C}_i - M_{1-i} + e_{-i}$ using an iterative method.

In the appendix at the end of the paper, there is the MATLAB® script you can use to perform the iterative method.

We start with $e_i = \frac{1}{a}$ for all *i*, so $e_{-i}=\frac{1}{a}$; we then find the firms that could have the incentive to raise e in order to gain r ; for the firms in this situation which with $e_i = \frac{1}{a}$ doesn't get r ($C_{2i} > M_2$) we change e_i to $\overline{C}_i - M_{1-i} + e_{-i}$.

Then we calculate again e_{-i}, C_{2i} and M_2 and again for the agents for which $-\frac{\sqrt{rRa}}{a} \leq \overline{C}_i - M_{1-i} \leq \frac{\sqrt{rRa}}{a}$ hold, but they have $C_{2i} > M_2$ we impose

$e_i = \overline{C}_i - M_{1-i} + e_{-i}$.
We continue iterating these operations until for each of these firms $C_{2i} \leq M_2$.
So if $\frac{1}{a}$ isn't enough to reach the average or to remain under the mean, they have the incentive to make a bigger effort in order to align themselves to the average. The simulations show that only the firms having the initial costs ($\overline{C}_i$) "close" to the average are influenced by the incentive scheme. How much "close" depends on how big the incentive ($\bar{r}$) is: the higher $\bar{r}$ the more firms would make an extra-effort for increasing efficiency.

I.8 Conclusions

In this section, we summarise some consideration from the results we have found.
In the 5th and 6th paragraph, we have analysed 3 alternative options for the regulator. Our model shows that setting the tariff system as frequently as possible is socially better. It is not possible to actually set the tariffs every year, but setting the tariffs every few years like it is done now could be sensible in order to maximise the social welfare. In reality, the Authority never lower the price, especially because of investments and inflation, but the tariffs incorporate operating costs.

The last model shows us that the incentives to increase the sector efficiency seem to affect only firms with costs "near" the average. How near it depends on the value of the incentive ($\bar{r}$): the bigger, the more firms can be persuaded to improve efficiency. However, the use of this incentive raises an issue. Generally, authorities try to improve efficiency in order to lower prices for the consumers; however, these incentives often lead to higher prices. The Authority justifies this strategy with the sector very low average efficiency (Massarutto, 2012a).

From our analysis another issue emerges: tariffs may have too many targets (see also Rogers et al. 2002). Some of them tend to contrast with other. Tariffs should allow access to everyone to a vital good, provide incentives to efficiency and investment. Can tariffs deal with all these targets? Is it possible to design a tariff scheme differentiating prices for household income, or quantity in order to achieve all the goals at the same time? The analysis of the current scheme to answer this question would be an interesting topic to develop.

The model I presented has some possible improvements. For example, we can introduce discount factors and heterogeneity in effort-cost function.

In the following papers, I extend my analysis investigating the role of regulation in investments for infrastructures.

Appendix: Matlab script for iterative numerical solution to solve the "efficiency incentive model".

```
% Numerical simulation paper 1:
% Setting a, r, R, N
a = 1;
r = 0.005;
R = 1000;
N = 90;
% Calcolating e max
K = sqrt(a*R*r)/a;
emax = K+1/a;
% Creating period 1 cost array
C1 = zeros (N,1);
for n=1:N
    C1(n)= 700 + 0.25*n;
end
% Creating M1-i
M1_i=zeros(N,1);
for n=1:N
    X=C1;
    X(n,:) = [ ];
    M1_i(n) = mean (X);
end
% Creating the array describing effort firm choice
e = ones(N,1);
for n=1:N
    e(n)=1/a;
end

% Creo le basi dei vettori che userò
e_i=zeros(N,1);
% Media dei costi nel secondo periodo
M2_i=zeros(N,1);
% Vettore che mostra se un'azienda riceverà r o meno
bonus =zeros(N,1);
inc_eff= zeros(N,1);

for j=1:50
% Media degli efficientamenti
for n=1:N
    X=e;
    X(n,:) = [ ];
    e_i(n) = mean (X);
end
% Creating the array signalling the firms willing to chose an effort higher
% than 1/a in order to keep or to reach the incentive r
for n=1:N
```

```
    if (-K<= (C1(n)- M1_i(n)) && (C1(n)- M1_i(n))<= (K+(1/a)-e_i(n)))
        inc_eff(n) = 1 ;
   else inc_eff(n) = 0 ;
    end
end

f=find(inc_eff==1);
fl=length(f);

% Second period's costs
C2 = C1-e;
% Mean of second period's costs
for n=1:N
    X=C2;
    X(n,:) = [ ];
    M2_i(n) = mean (X);
end
% Array saying if a provider is going to receive the premium
for n=1:N
    if C2(n)<=M2_i(n)
        bonus(n) = 1 ;
    else bonus(n) = 0 ;
    end
end

 % If a firm have the incentive to reach the premium, but it doesn't have
 % yet, we increase the effort in order to get it
for n=1:N
    if (inc_eff(n)==1 && bonus(n)==0)
        e(n)= C1(n)- M1_i(n)+ e_i(n);
    end
    if (inc_eff(n)==0)
        e(n)= 1/a;
    end
end
if (bonus((f(1)):(f(fl)))==1)
       break
end
end
```

Chapter II - Regulation in the water sector: tariffs and investment in infrastructure

II. 1 Introduction

In the first chapter I stressed the importance of water sector in developed countries and I presented a simple model in which a National Authority interacts with a given number of monopolistic firms, each one providing water in a given zone. As in the first paper, in this chapter we still consider a model in which a country is divided in several zones and in each zone a monopolist is selling water to consumers.

In this chapter we focus on investments in infrastructures, in particular on how the system of regulation can affect the level and the "quality" of the investments. The first purpose of this chapter is to compare different rules the Authority can set to allow the firms to recover the investments with tariffs. The second goal is to give some theoretical justifications for having a two-level Authority system. In Italy there is a peculiar system of regulation for the water sector: there is (at least for now[7]) an independent National Authority called Arera which regulates also the gas and electricity markets. Then, there is a series of local Authorities, which are regulated by Regional laws, each of which supervises the sector in one or more areas. Local Authorities are entitled to give the concessions to the firms (see Bardelli 2018 for a more comprehensive overiview of local Authorities competences). Italy lacks years of investments in the sector, as Camerano (2018) pointed out wastewater treatment plants are lower than those needed and the pipelines are very old on average. The last part of the chapter is an analysis of an incentive scheme which has the purpose to increase investments. In order to focus only on the relationship between regulation and investments we assume investments don't affect operative costs. Smith (2000) described the advantages and the disadvantages of centralised and decentralised system of regulation and Danesi at al. (2008) applied that analysis to the Italian case suggesting that a two level system could have the benefits from both type of regulation. Bardelli (2018) described the actual Italian system of regulation as an innovative approach that seems to guide the sector in a better path. I try to add new elements that provide other possible justification to a multi level regulation system.

7 A law proposal has been presented in the Italian Parliament in order for the public sector to acquire the property of all water providers again (Ddl 52/18 Camera dei deputati).

II.2 The model

II.2.1 Presentation

We start with the model of the first chapter. A country is divided into zones. In each zone, there is a monopolist who sells water to consumers and a National Authority (NA) regulating the markets. For simplification, we assume the quantity demanded to be fixed over the years and completely inelastic.
Firms maximize profits and profits are as usual $\Pi = R - C$ where R are revenues. So $R=Qp$, with Q the quantity sold and p is the unit price. C are the costs.
Assuming all firms are equal, we can consider a representative firm which maximizes profits over two periods. We assume banks finance the investments (I). In the first period the firm bears a cost $\varphi_F(I)$, that represents the cost of the effort (b_F) for making a "good" investment; choose the type of Investment, design it etc.. In the second period she receives the authorization from the regulator to increase tariffs by *r* per cent.
The National Authority sets the rules, and the firm knows the rules. In particular, NA decides r as a function of I. In the second period, the firm (F) has also to pay interests to the bank.
The country is divided into areas including one or more zones. In each area, there is a Local Authority (LA) who controls the firms and helps them to make the most important and useful investment. They value the investment in relation to the effort making to design it. We can think of this value as an indication of how much the infrastructure is important for the environment, future consumers or in terms of compliance with new European laws.

II.2.2 Model setting

The National Authority maximizes social welfare.

$$W = S + \lambda\Pi + \gamma I \qquad (2.1)$$

where to the social welfare function used in the first chapter, we added a term which captures the NA's objective to increase the investments in the country: so
$\gamma > 0$.

As in the first chapter, S is the Consumer Surplus which is given by

$$S = (B-P)Q \qquad (2.2)$$

where Q is the consumed quantity of the good, B the consumers benefit of one unit of the good and P the unit price. We assume, for simplicity, B to be equal among consumers and constant over time.

Π is the firm's profit, and λ is a positive parameter between 0 and 1, and it represents how much the Authority cares about F as compared to consumers.

I is the amount of investment F does, and γ is a strictly positive constant that indicates how much NA desires firms to invest.

The firm profits in the first and the second period are:

$\Pi_1 = R - C - \varphi_F(I)$

$\Pi_2 = R(1+r(I)) - C - iI = R - C + rR - iI \qquad (2.3)$

R=pQ, where p is the price of the good at time 1 (so at time 1: P=p), Q is the quantity sold, C are the operative costs, while i is the interest rate. We take p as given and so R is given.

The Local Authority, controlled by municipalities, can collaborate with the firms to choose the most urgent and important investment. The investment value depends on the effort of F, and LA makes to design it. LA objective function is U_L

$$U_L = v(b_F, b_L, I) - \varphi_L(b_L, I) \qquad (2.4)$$

φ_L is the analogous for LA of φ_F and we assume is a simple cost function with the effort b_L(that is the same of b_F) strictly positive:

$\varphi_L' > 0$ in both variables, and $\varphi_L'' > 0$ mixed and pure ones.

We impose v'> 0 for each argument (b_F, b_L, I) since we assumed the more effort F and LA exert the higher the value the investments has for the Local Authority. The pure second-order derivatives with respect to the efforts are non positive because we suppose the "productivity" of effort is non-increasing.

II.2.3 Time-line

In this paragraph we describe the sequence of decisions taken in the model.

First NA chooses the function r(I), then F chooses I, then LA chooses b_L. We assume b_F is exogenously determined by the balance of power between LA and F.

To obtain the model equilibrium outcome, we proceed by backward induction.
First, we find b_L with I given. Then we find I that maximizes profits as a function of r and then we maximize the Welfare Function with respect to r.
To keep things simple we assume that r(I) = kI and so NA has only to choose k.
The choice of b_L is a Local Authority's choice that doesn't have effects in other players behaviour:

LA max $u_L = v(b_L) - \varphi_L(b_L, I)$ under b_L f.o.c.: $v' - \varphi_L' = 0$

$$v' = \varphi_L' \qquad (2.5)$$

From this expression we can find b_L^* [8]

The second step concerns the firm. If for simplicity we do not consider the discount factor, we can sum the expressions 2.3 obtaining:
$\Pi_{tot} = 2(R - C) + r(I)R - iI - \varphi_F(I)$
To find the firm's choice we compute the first-order conditions, to maximize Π_{tot} with respect to I
f.o.c. : $r'(I)R - i - \varphi_F'(I) = 0 \quad \rightarrow \quad r'(I)R = i + \varphi_F'(I)$
Assuming for simplicity $\varphi_F = b_F I^2$ and r(I) = kI , it follows

$$\text{f.o.c.} : kR - i - 2b_F I = 0 \quad \rightarrow \quad I^* = \frac{kR - i}{2 b_F} \qquad (2.6)$$

National Authority maximizes its welfare function W choosing r(I).
Since r(I)= kI , choosing r(I) means choosing k.
The Welfare function is the following: $W = S + \lambda\Pi + \gamma I$.
So NA maximizes W, where *I* is replaced by the expression 2.6

The result is $k^* = \frac{[\gamma + (1-\lambda) i]}{(2-\lambda) R}$ (2.7)

The resulting optimal amount of Investment is

$$I^* = \frac{(\gamma - i)}{2(2-\lambda) b_F} \qquad (2.8)$$

It makes sense only if $\gamma > i$; $I^* > 0$ if and only if the Authority value the Investment more than its costs.

8 Since $v'' \leq 0$ and $\varphi_L'' > 0$, second-order conditions are satisfied.

The resulting Social Welfare function is

$$W^{*}= 2(BQ-R) + 2\lambda(R-C) + \gamma \frac{(\gamma - i)}{2(2-\lambda)b_F} \qquad (2.9)$$

II.3 Model 2

In the second version of the model, the weight NA gives to the investment is its value for the community v(I) so the welfare function can be written as:

$$W = S + \lambda\Pi + v(I) \qquad (2.10)$$

We specify the v() function as $v(b_F, b_L, I)= b_F b_L \theta I$ so $U_L = b_F b_L \theta I - b_L^2 I$
$b_F, b_L \geq 1$; $\theta > 0$,
θ captures the authority skills and expertise which may vary a lot over the country.

$$\max_{b_L} U_L \longrightarrow b_L^{*}= \frac{\theta b_F}{2} \qquad (2.11)$$

First order conditions for the Firm do not change:

$$\text{f.o.c. : } r'(I)R - i - 2b_F I = 0 \qquad \rightarrow \quad I^{*} = \frac{r'(I)R - i}{2b_F} \qquad (2.12)$$

Since r(I) = kI , by backward induction, we find that

$$\text{NA max W under k with } k^{*}= \frac{\theta b_F b_L + (1-\lambda)i}{(2-\lambda)R} \qquad (2.13)$$

$$\text{and the related optimal Investments are } I^{*} = \frac{\theta b_F b_L - i}{2(2-\lambda)b_F} \qquad (2.14)$$

The resulting value for the Social Welfare function is:

$$W^{*}= 2(BQ-R) + 2\lambda(R-C) + \frac{(\theta b_F b_L - i)\left[\theta b_F b_L - 2i(1-\lambda)(2-\lambda)\right]}{4(2-\lambda)^2 b_F} \qquad (2.15)$$

II.4 Why a National and a Local Authority?

We now investigate the possible reasons for a two-level system of regulation, currently operating in Italy. To do so, we compare our model to modified versions of it in which we eliminate one level.

II.4.1 Model without LA (only National Authority)

First, we analyse the consequence of eliminating the Local Authorities. In our model, this means that no one supervises what investments in infrastructure are made, but let us suppose NA also does this job. We replace θ and $b_L$with θ_N and b_N so $v(I) = \theta_N b_N b_F I$. We argue that $\theta_N < \theta$, because would be so much expensive for a central agency to collect all the data needed to decide the most urgent and useful infrastructure for all the zones.
All the other variables remain the same; the game will have the same result (2.16) we have already seen except for θ_N and b_N.
In particular, $I^* = \frac{\theta_N b_F b_N - i}{2 b_F}$ (2.16)
So we end up with a lower amount of investment and less valuable ones.

II.4.2 Model without NA (only Local Authority)

While the National Authority is independent of political power, Local Authorities are controlled by municipalities and regional government. So Local Authorities tend to be less reliable than the National Authority or at least, so they are perceived by the monopolists. Local Authorities are not independent, they are controlled by the regional government and the municipalities.
In this framework, the Local Authority maximizes the Social Welfare function, and we assume that this function is a combined version of the first model NA and LA objective functions:

$$W_L = S + \delta\Pi + v(I) - \varphi_L(I), \qquad (2.17)$$

with δ capturing also dividends municipalities earn: local administrations (Municipalities and Regions) had at least 50% of the share of all the firms in Italy except for a few providers. If the firm expects that Authority could change rules (i.e. lower prices) they will act as the Authority could change them, even if She promised not to. So it is like a game in which Authority plays first setting the rules, then Firms plays deciding how much to invest, then Authority plays again with the possibilities of applying different rules. The firm profits in this case are:

$\Pi_1 = R - C - b_F I^2$

$\Pi_2 = R - C + rR - iI$

$$\Pi_{tot} = 2(R-C) + rR - iI - b_g I^2 \quad (2.18)$$

While the surplus:

$S_1 = BQ-R$

$S_2 = BQ-R-rR$

$$S_{tot} = 2\,(BQ-R) - rR \quad (2.19)$$

$$W_{Ltot} = 2(BQ-R) + 2\delta(R-C) + rR(\delta-1) + \delta(-iI-b_F I^2) + \theta b_F b_L I - b_L^2\, I \quad (2.20)$$

We use backward induction again. The first step is to analyze the last decision, that is Authority maximizes after firm has decided how much Investment. Maximizing W_{tot} with respect to r gives: r = 0.

We have a problem of time consistency: if firms consider the Authority not trustwhorty it would be like having a game in which, firstly LA choose r than the firm choose the investment and than LA can change r. In this case if firms anticipate that LA would choose r = 0 after the Investments have been made, they would choose I=0 no matter what r is set at the beginning. We can also see this as a problem of moral hazard. Authority has an incentive to have an opportunistic behaviour after the Firm commits to the Investment.

In the case of a situation without NA, we have another reason why firms could not invest. To show it we should insert another agent in the model: banks. Banks lend money only if they expect to receive them back with interests. In the simplest form, we can consider a favourable case in which the bank receives money back with the interests (with π being the probability of ending up in the favourable case) and an unfavourable case in which the bank lose a part of the capital. If we assume Bank as a risk-neutral agent, we can write its utility as:

$$U(B) = \pi(1+i)I + (1-\pi)(1-s)I - (1+f)I = \pi(i-f)I + (1-\pi)(-sI) - fI \quad (2.21)$$

where i is the interest rate, *f* is the risk-free rate of return so is the opportunity costs for the bank and *s* is the part of the capital bank loose in the unfavourable case. Bank lend money if

$$\pi > (f+s)/(i+s). \quad (2.22)$$

We can easily argue that the probability to receive back the capital if a National independent Authority sets the tariffs is perceived much higher than when the tariffs are regulated by a Local Authority controlled by the same municipalities that own the Firms and have to respond to the consumers. This is what we have seen in Italy before the Integrated Water System was entrusted to the former Authority of Electricity and Gas (now ARERA): banks were not financing the water sector and investments were very low (Anwandter and Rubino 2006; see also Ref ricerche 2014d and 2015c).

II.5 Premium to reach a certain level of Investments

As we have seen in the previous chapter, the Authority allows Firms to increase tariffs in the next periods more than others if they meet some conditions. In the first chapter, we focused on the incentives to efficiency. In this one, we analyse the incentives to reach a certain level of Investments.

In the figure below, we can see the maximum increase in tariffs granted to the providers. $IP^{2016\text{-}2019}$ are the planned investments for the period 2016-2019, e

If we pay attention to the rows, we can figure out that a monopolist which had planned a certain level of Investment is allowed to raise their expected revenues by 2,5% more than the others. We are going to use a modified version of our model in order to analyse this aspect of the Authority tariffs method.

Table 2.1

	$\frac{OPEX\,2014}{pop} \leq$ OPM	$\frac{OPEX\,2014}{pop} >$ OPM
$\frac{IP^{2016\text{-}2019}}{RAB_{MTI}} \leq \omega$	Scheme I 6 %	Scheme II 5,5 %
$\frac{IP^{2016\text{-}2019}}{RAB_{MTI}} > \omega$	Scheme IV 8,5 %	Scheme V 8 %

Source: “METODO TARIFFARIO IDRICO 2016-2019” from AEEGSI (now ARERA)

Let us assume that N cannot observe $\varphi_F(I)$ and let us introduce heterogeneity among firms in b_F. We have n firms, and we can rank them from the firm having the lowest b to the highest. So we have F_1, F_2, … F_n with:

$b_F^1 < b_F^2 < \ldots < b_F^n$

For simplicity we can rewrite them as: $b_1 < b_2 < \ldots < b_n$

NA has to decide ω and ρ in order to maximize the Welfare function, whereas Firms decide Investments.

In this case we assume r=iI , where i is the interest rate, then

$\Pi_{tot} = 2(R-C) + \rho R - b_j I^2$ (with j = 1, 2 … , n)

So for each Firm $\Pi_{tot} = 2(R-C) + \rho_j R - b_j I^2$

with $\rho_j = 0$ if $I < \omega$ and $\rho_j = \rho > 0$ otherwise. So F_j will chose I=0 if ρ and ω don't provide the right incentive. More precisely: $\rho R - b_j \omega^2$ need to be positive in order for F to chose I = ω.

So F_j will chose I = ω if $b_j \leq \frac{R\bar{\rho}}{\omega^2}$ (2.23)

and I = 0 otherwise.

National Authority as usual maximizes the Social Welfare function

W=S +λΠ + γI that in this case we can write as:

$$W = (B-p)Q - R\sum_{j=1}^{n} \rho_j + \lambda \sum_{j=1}^{n} \left[R\rho_j - b_j I_j^2\right] + \gamma \sum_{j=1}^{n} I_j \qquad (2.24)$$

After substituting the Firms choice in the Welfare function, we can Maximize W.

After some computation[9], we find that maximizing W is equivalent to maximizing $m(\lambda-1)R\rho - \lambda\,\omega^2 \sum_{j=1}^{m} b_j + \gamma m\omega$ under ρ, ω and m with m being the number of firms that end up with $\rho_i = \rho$, that is $b_m = \frac{R\bar{\rho}}{\omega^2}$ (2.25)

Since it' s impossible to reach an analytical solution, I used MATLAB® to find numerical solutions and see how they vary along λ and γ.

I insert the MATLAB® script as an appendix at the end of the paper.

The numerical simulation shows us the following results(see table 2.1), indicating

9 Since a firm chooses ω or 0 and it is giving ρ or 0, calling m the number of firms choosing ω and so having ρ, $\sum_{j=1}^{n} \rho_j$ is equal to mρ , $\sum_{j=1}^{n} I_j$ is equal to mω and $\sum_{j=1}^{n} b_j I_j^2$ is equal to $\omega^2 \sum_{j=1}^{m} b_j$

with * the values that maximize the social welfare function:
- ρ* goes up both when lambda grows and when gamma grows;
- m* follows ρ*
- ω* grows with gamma, but does not have clear path respect to lambda

Table 2.1 Optimal rho respect to lambda and gamma

	rho*	lambda								
		0,1	0,2	0,3	0,4	0,5	0,6	0,7	0,8	0,9
gamma	0,1	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01
	0,2	0,02	0,02	0,01	0,01	0,01	0,01	0,01	0,01	0,01
	0,3	0,01	0,01	0,02	0,02	0,02	0,02	0,02	0,02	0,03
	0,4	0,02	0,02	0,02	0,03	0,03	0,03	0,04	0,04	0,05
	0,5	0,03	0,03	0,04	0,04	0,05	0,05	0,06	0,06	0,07
	0,6	0,04	0,05	0,05	0,06	0,06	0,07	0,08	0,09	0,1
	0,7	0,06	0,06	0,07	0,08	0,09	0,1	0,11	0,12	0,14
	0,8	0,08	0,08	0,09	0,1	0,11	0,12	0,14	0,15	0,15
	0,9	0,1	0,1	0,11	0,13	0,14	0,15	0,15	0,15	0,15
	1	0,12	0,13	0,14	0,15	0,15	0,15	0,15	0,15	0,15

Table 2.2 Optimal omega respect to lambda and gamma

	omega*	lambda								
		0,1	0,2	0,3	0,4	0,5	0,6	0,7	0,8	0,9
gamma	0,1	10,08	10,08	9,64	9,64	9,64	9,64	8,84	8,17	7,76
	0,2	6,87	6,87	6,87	6,46	6,46	6,46	5,69	5,32	6,97
	0,3	7,92	9,71	9,14	9,14	10,22	10,22	9	9,86	9,22
	0,4	11,9	11,2	12,09	12,09	12,93	13,71	12,07	12,72	12,48
	0,5	13,71	13,71	14,46	15,16	16,48	17,1	15,05	16,09	15,52
	0,6	15,83	17,1	17,7	18,85	19,39	20,95	17,99	19,3	18,44
	0,7	18,85	19,93	20,44	21,44	22,86	24,19	20,91	22,04	20,62
	0,8	21,44	22,39	23,75	24,62	25,04	22,04	22,04	20,62	20,12
	0,9	24,19	25,04	25,04	25,04	22,04	22,04	20,62	20,12	20,12
	1	25,04	25,04	25,04	22,04	20,62	20,62	20,62	20,12	20,12

This results show us that if the Authority cares more for Investment (i.e. greater γ) it would raise the threshold ω, pushing firms to invest more but also raise the premium ρ, that increase the number of firms which have the willingness to reach that amount of Investment.

It is evident that raising ρ the number of firms choosing to invest in taking the incentive grows. It is also quite clear that the less NA value consumers utility with respect to providers profits (i.e. if lambda goes up) the more would allow price to raise and so ρ could be higher. We cannot say something definite about the behaviour of ω^* with respect to lambda.

II.6 Conclusions

A main goal for the Authority is to reduce the significant lack of investments. Italy is still very far from National Authority goal for investments per inhabitants of 83 €, the European average, since in 2016 actual investments per inhabitants were 32 €. This is due to a variety of reasons. Historically Italy starts later to pay attention on Investment in the sector, many firms have a small size etc. Besides that, till 2012, there was not an independent National Authority. Now Arera has in her goals to support the growth of the Investment and this start to push them up. Theoretically having a National Authority supervising the sector should support and led investment growth and the investment recovery began in 2014 shows that the Italian water sector has started a new phase (Camerano 2018).
We modeled the Authority system in Italy water sector in order to explain what would be one possible justification of having a two-level system focusing on Investment. Firms need a National Authority in order to trust Public Administration that they can recover the Investment via tariffs and by the banking system in order to have more certainty of recover the financing. Local Authorities, if they work properly help firms choosing the more important investment to do and in the investment design hence, in the end, contributing to increase its amount level. As a matter of fact, LAs in the last decade are decreased in number to reinforce their functions and to improve the quality of their staff (Bardelli 2018).

Appendix: MATLAB script for numerical simulation

```
% Script for numerical simulation paper 2
% Setting N = Number of Firms and R = revenues
N = 90;
R = 80;
rho = [0.01:0.005:0.15];
lambda = [0.1:0.1:0.9];
gamma = (0.1:0.1:1);
m_ar=zeros(20,1);
rho_ar=m_ar;
omega_ar=m_ar;
m_s = zeros (length(gamma),length(lambda));
rho_s = zeros (length(gamma),length(lambda));
omega_s = zeros (length(gamma),length(lambda)) ;
% creating the vector of bj
b = 0.001 + (0.03 - 0.001)*rand(N,1);
b=sort(b);
% omega's matrix for every bj and rho
omega = zeros(length(rho),N);
for l=1:length(lambda)
for g=1:length(gamma)
for j= 1:length(m_ar)
for i=1:length(rho)
for m=1:N
omega(i,m)= sqrt((R*rho(i))/b(m));
end
end
% creating W matrix for the Social Welfare function for every possibilities
W=zeros(length(rho),length(b));
for i=1:length(rho)
for m=1:N
W(i,m)=       (m*(lambda(l)-1)-1)*R*rho(i)-lambda(l)*(omega(i,m))^2*sum(b(1:m-1))
+m*gamma(g)*omega(i,m);
end
end
% finding maximum value of W
[max_val,pos_idx]=max(W(:));
% Identifing coordinates(row,column) of maximum value; row tell me optimal rho
and column tell me optimal m
[row_idx,col_idx]=ind2sub(size(W),pos_idx);
% optimal m
m_star = col_idx;
% optimal rho
rho_star = rho(row_idx);
% optimal omega
omega_star = omega(row_idx,col_idx);
% results storage
m_ar(j)= m_star;
rho_ar(j) = rho_star;
omega_ar(j)= omega_star;
end
% calculating the average of the found optimal results
m_s(g,l) = mean (m_ar);
rho_s(g,l) = mean(rho_ar);
omega_s(g,l) = mean(omega_ar);
end
end
```

Chapter III – Tariffs, efficiency and investment – Case study: Tuscany

III.1 Introduction:

In this chapter, I'm going to analyse the case of Tuscan Integrated Water System in the last few years with particular reference to the national and local regulation and its implications on the performances of the water providers, especially in terms of efficiency and investments.

Guerrini et al. (2011) search the factors that affect Italian water providers while Romano et al. (2011) measure and compare the efficiency of Italian water utility company: both article found that publicly owned company perform better than mixed ones in the term of efficiency and investments. However Romano et al. (2017) show that, accounting for quality, firms with mixed ownership have higher efficiency, apply higher tariffs, and invest more.

Lo Storto (2013) made an efficiency analysis showing that a private partner in the management of the infrastructure assets and water services delivery can improve the water industry efficiency.

In this chapter, I want to add to that literature some other empirical points showing that, with a well functioning national and local Authority, providers with mixed ownership could have good performances.

The vast majority of the data we used are for six years (2012-2017): I managed to find some relevant empirical facts, which I try to interpret.

III.2 A brief recent history of Italian Integrated Hydric System

Here, I summarise the recent history of Italian Integrated Hydric System, for a more comprehensive overview see Asquer (2009 and 2017) and Massarutto (2012).

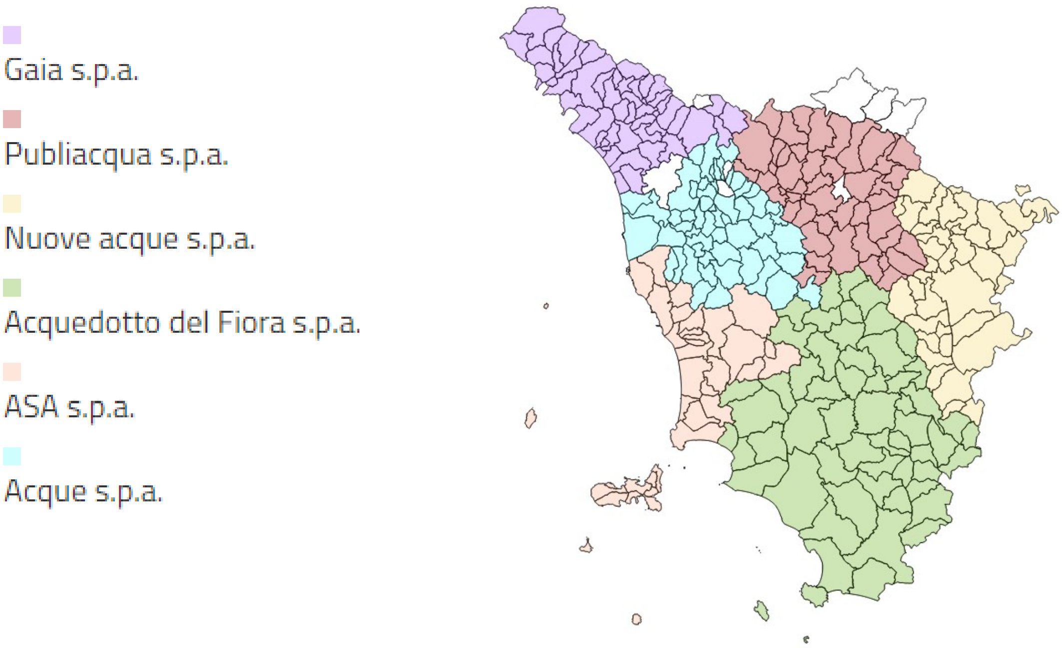
For the Italian Integrated Hydric System, the first turning point was the 1994 Galli Law which opened the sector to private partners. Until this law, the industry was totally in public hands. For the first time, business logic is introduced in the water management and from then on, private partners can enter the companies (however, more than 50% of each firm should remain public). The Galli law also introduced the first type of local Authorities called AATO. In the following years, Italian Parliaments had to adopt several European Directives introducing many obligations such as, for example, about the number of chemical agents in the water. In the meantime, Regional Laws started to regulate the functioning of Local Authorities: from giving concessions to setting tariffs. In 2009 the government approved another reform which was stopped by a National Referendum in 2011.

Since 2012 the regulation and supervision of the sector are entrusted to the National Authority for electric energy and gas (first AEEG, then AEEGSI, now ARERA) and the Regions have the power to organize the Local Authorities. Tuscany decided to concentrate the 6 AATO in one Local Authority called AIT[10].

The figure 3.1 shows the municipalities covered by the providers.

FIGURE 3.1

Legend:



(source: www.autoritaidrica.toscana.it)

10 AIT stands for Tuscan Hydric Authority.

Table 3.1

provider	Gaia	Geal	Publiacqua	Acque	Nuove Acque	Asa	Acq. del Fiora
Number of served municipalities	46	1	46	53/55	36	33	55
Contract starts date	01-01-2005	06-11-1995	01-01-2002	01-01-2002	01-06-1999	01-01-2002	01-01-2002
Contract end date	31-12-2034	31-12-2025	31-12-2021	31-12-2031	31-05-2027	31-12-2031	31-12-2026
Property structure	public	mixed	mixed	mixed	mixed	mixed	mixed
% private partner	-	48	40	45	46	40	40
Main private partner	-	ACEA*	ACEA	ACEA	SUEZ	IREN	ACEA

(AIT General Director report 2017)

*ACEA is a mixed property Firm with the municipality of Rome owning its 51%.

III.3 Data and sources description

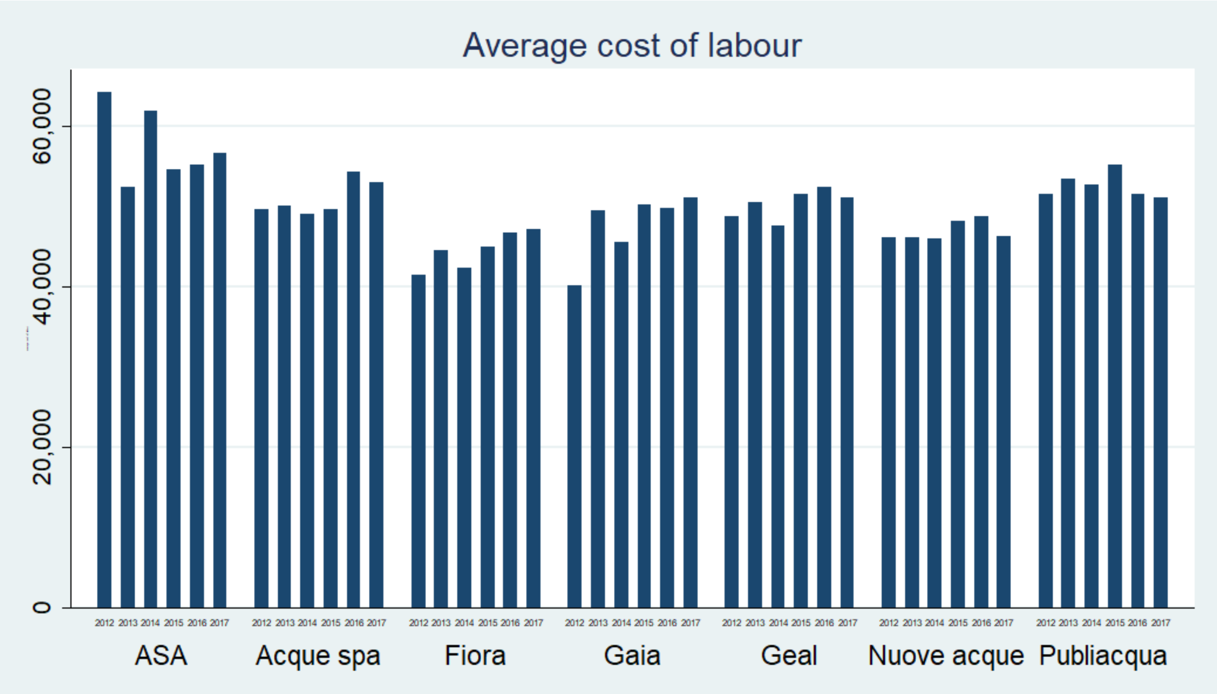
The vast majority of the data I have used come from the reports of General Director of AIT from 2012 to 2017 and other AIT documents. Data contain many technical data like the length of water pipeline or the volume of water extracted from the environment and a series of providers' economic and financial data. From these data, I also created some variables to perform a better and more precise analysis.

III.4 Data descriptive analysis

III.4.1 Workers

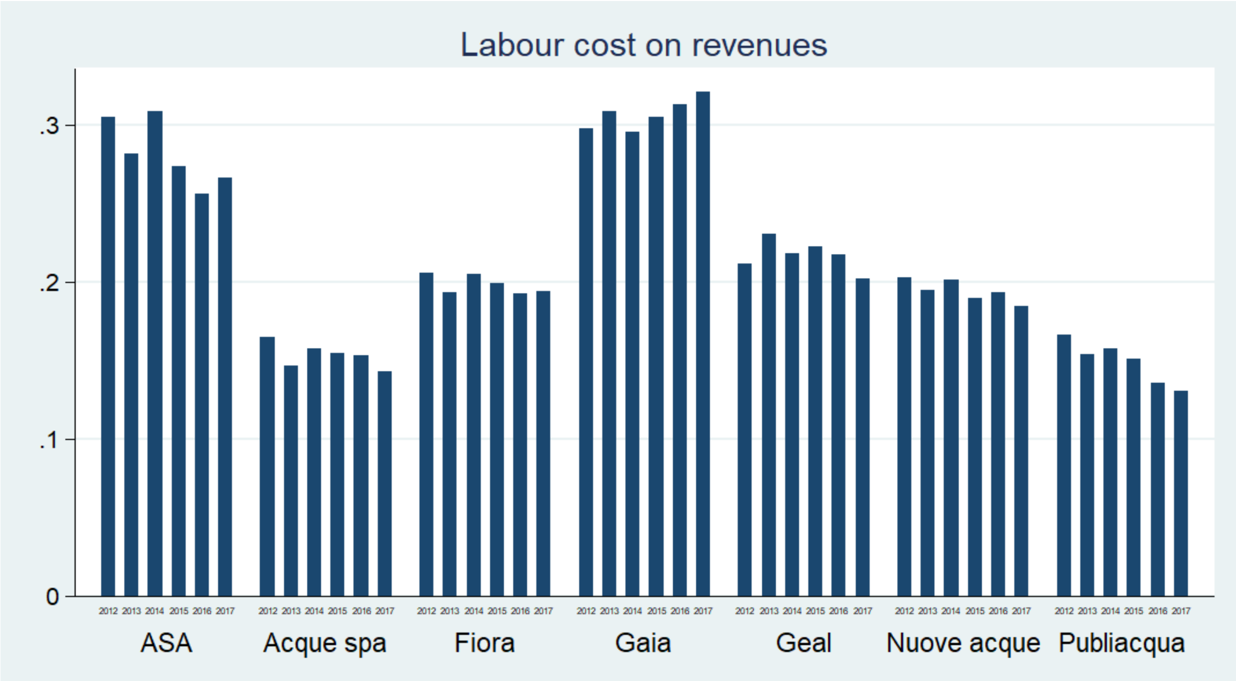
Here they are some graph comparing how much the cost of labour weights on companies and how much they are efficient in managing the workers. In the Figure 3.1, I compute the average cost of a worker.

Figure 3.1



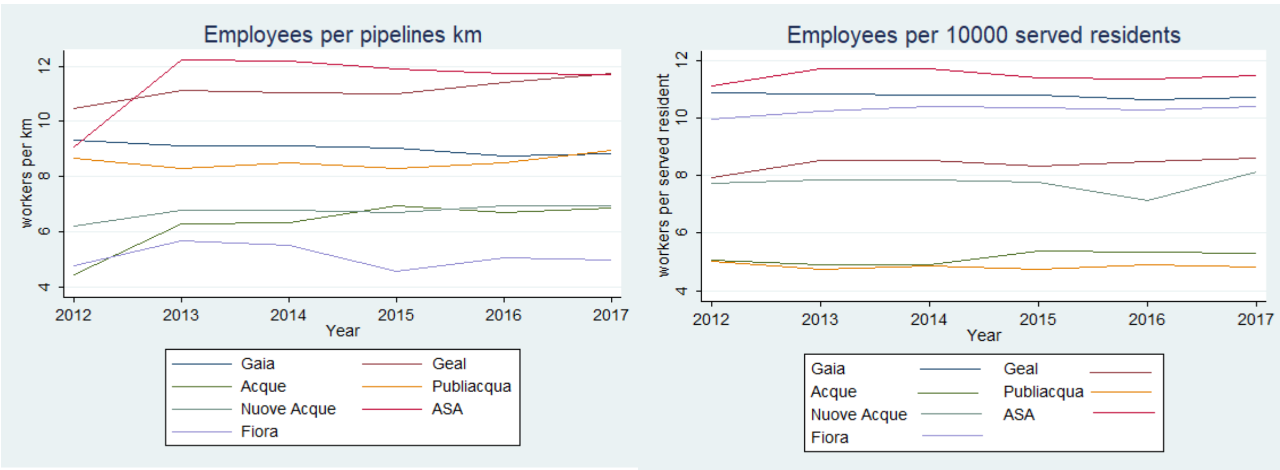
The next graph compares labour cost to revenues. Gaia and Asa are the worst in keeping labour cost low, while Acque spa and Publiacqua are more efficient on this point.

Figure 3.2



Moreover, in the Fig. 3.3 we have the number of employees. To compare the providers, data are referred to the aqueduct length and the served residents.

Figure 3.3



We have to bear in mind that labour costs it's a part of the costs that are price capped, so it doesn't affect tariffs, but they affect the provider economic result.

III.4.2 Technical data:

For most technical data, we have to say that they are estimates, tough in the last few years they have been collected with more accuracy. In some of the series, the previous years' data are actual, confirmed, data while the early data estimates. We have to consider this before describing and interpreting the evolution of some variables.
Areas, where the providers operate, are very different from each other in population density, infrastructure to maintain and demanded volume of water. In particular, as the AIT points out[11]:

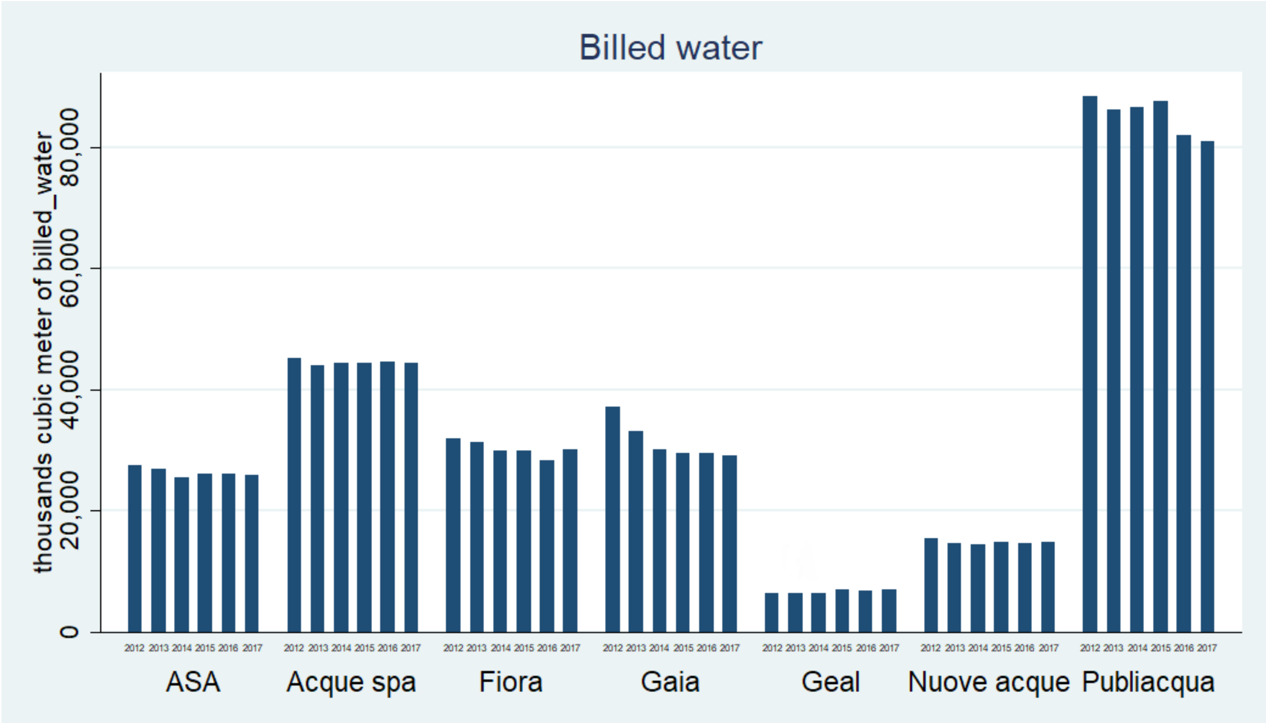
- the territory, where "Acquedotto del Fiora" operates, has the second lowest population density in Italy;
- the percentage rate of residents served by the aqueduct is over 95% in each area in Tuscany;
- providers have continuously extended sewerage services. As a result, the percentage rate of residents served goes from 77% and 95%.

III.4.3 Collected, billed and leaked volumes of water

Figure 3.4 shows billed water volume in recent years. We can observe a slight decrease over the years, even if, recently, numbers seems to stabilize.

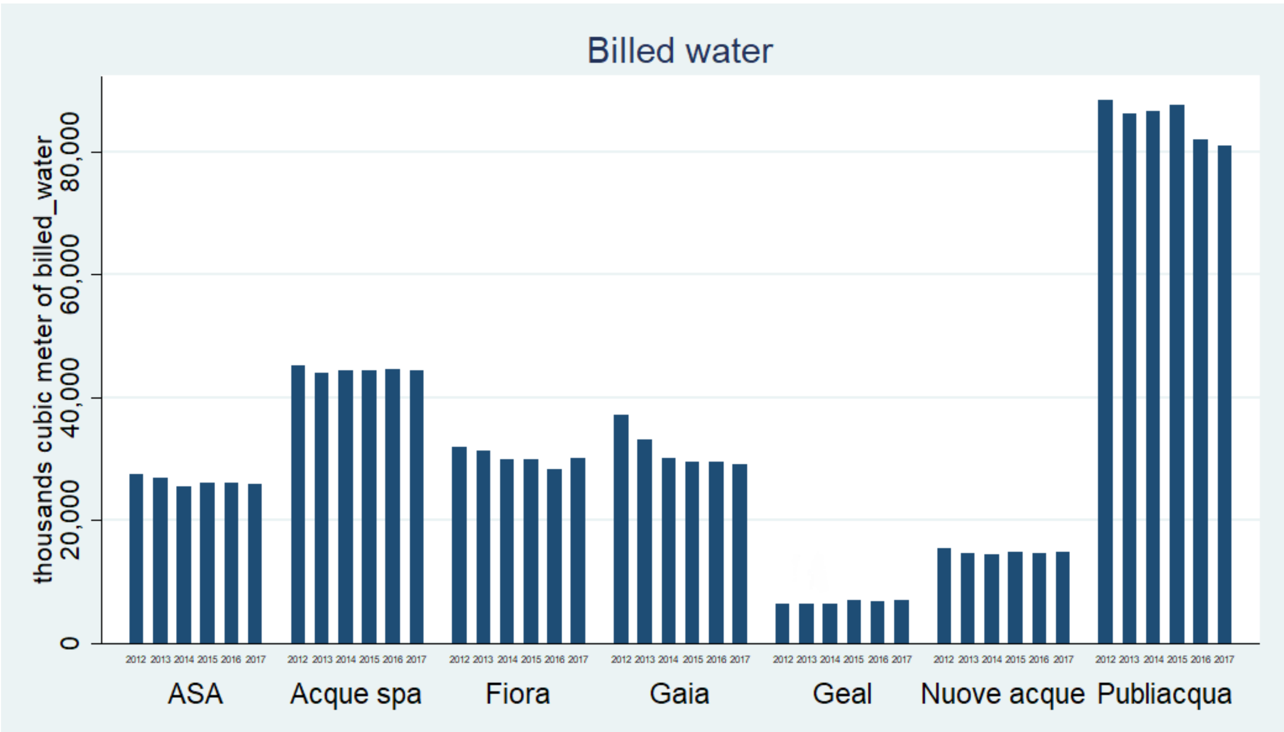
11 "2017 - Relazione Annuale del Direttore Generale sul servizio idrico integrato in Toscana."

Figure 3.4



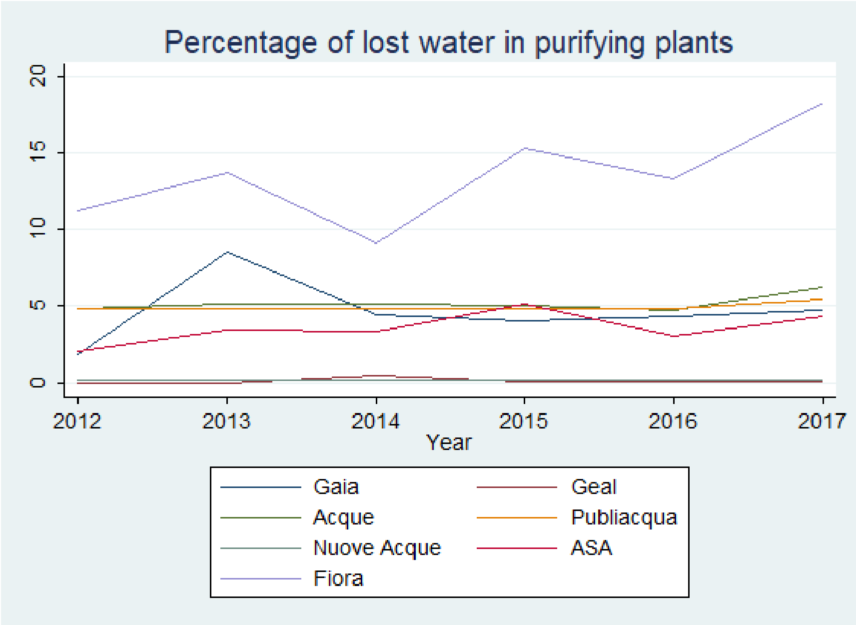
In the Figure 3.5, we can compare the total amount of water collected from the environment with the volume of billed water. The graph shows that much of the water collected from the environment is wasted. A share of it depends on the amount of water lost in the treatment to make water potable.

Figure 3.5



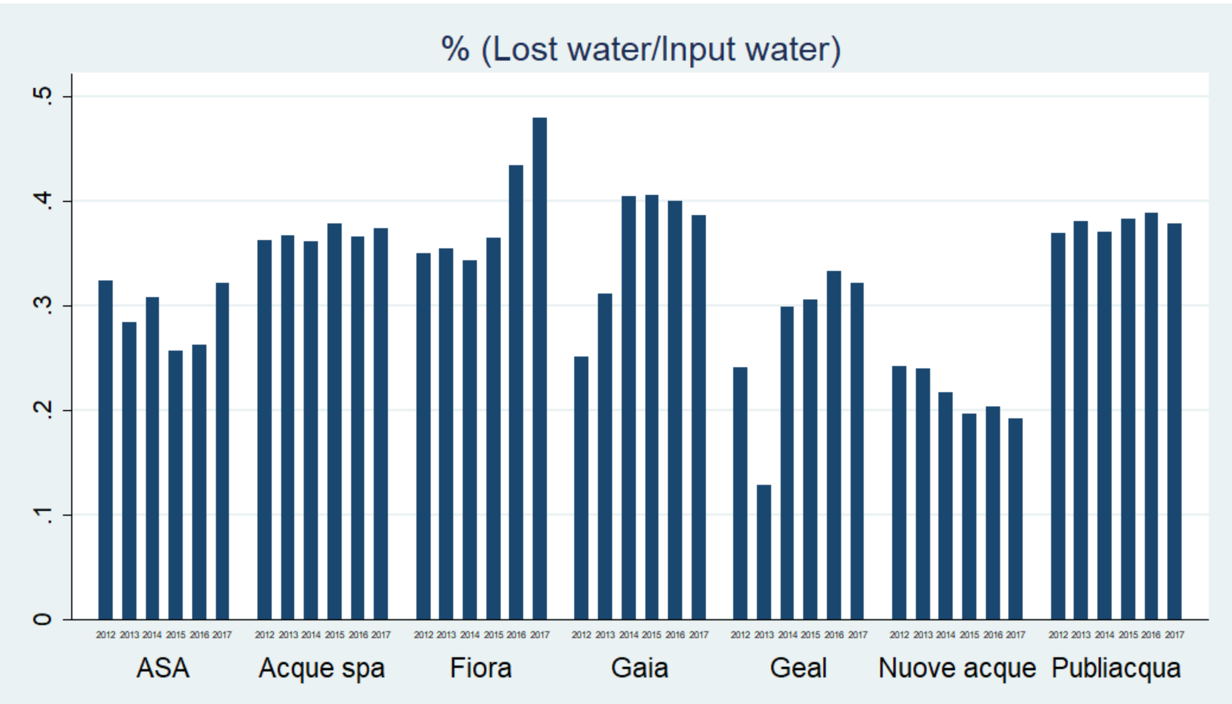
Publiacqua has a larger share of water collected from surface water. The treatment of this type of resource implied a more significant percentage of lost water, as compared to other kinds of provisions.
Nevertheless, Acquedotto del Fiora is less efficient in this sense.

Figure 3.6



In the Figure 3.7, instead, we can see the percentage rate of lost water over input water. There are no improvements over time, on this issue, except for Nuove Acque.

Figure 3.7



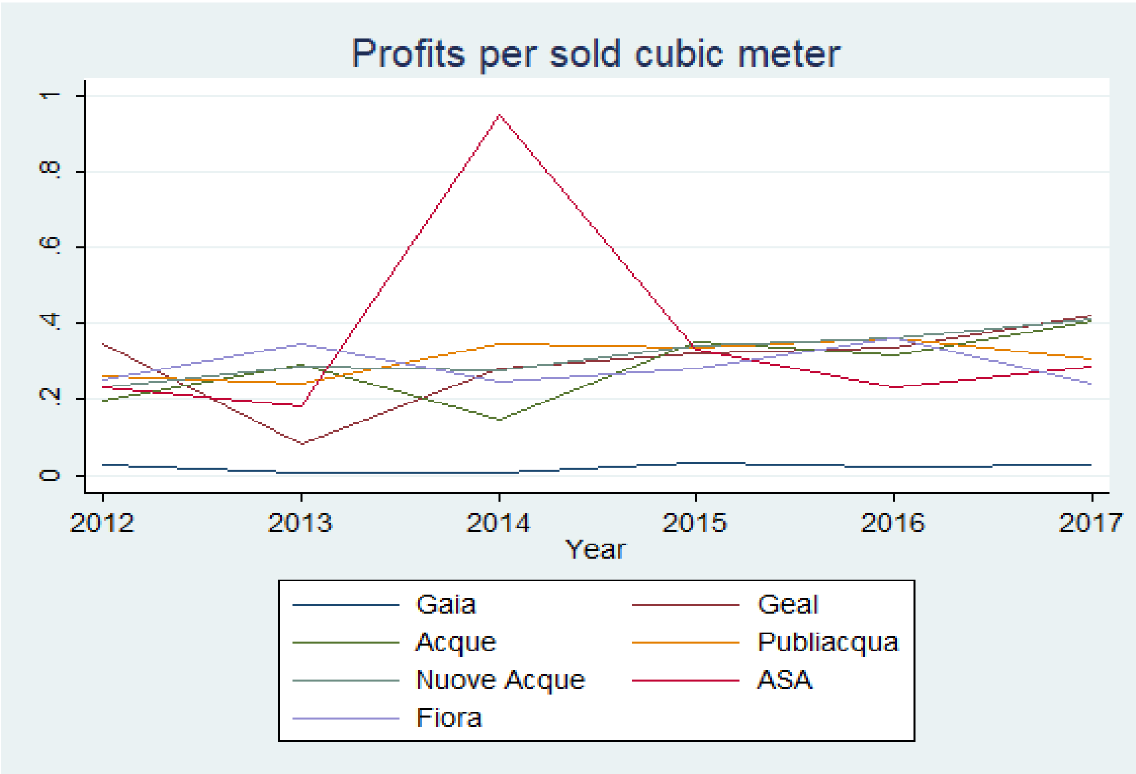
III.5 Significant empirical facts:

Even if we can exploit data of only a few years, we can draw from the analysis some significant empirical facts.

III.5.2 Profitability

- Profits per sold cubic meter are very similar among providers, except for "Gaia" (the only full public firms)

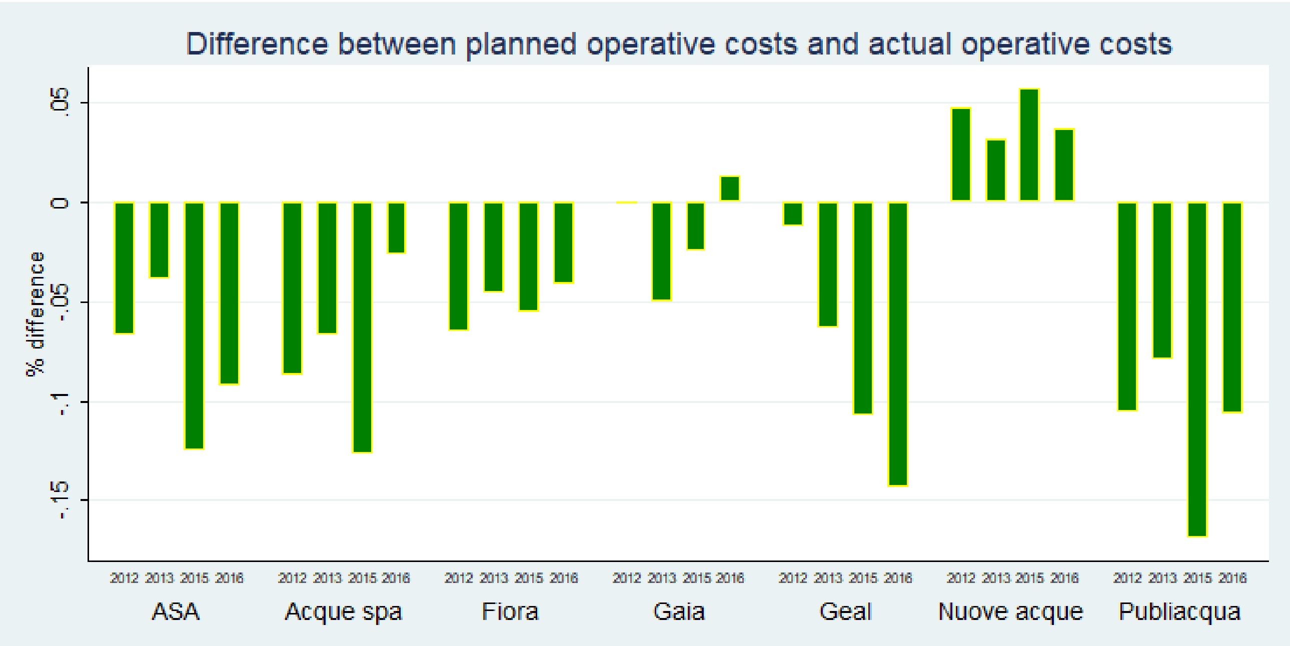
Figure 3.8



III.5.3 Efficiency

In each year vast majority of actual operative costs were lower than what was planned.

Figure 3.9



We can argue that providers are becoming more efficient, even if they are already among the top half in Italy for efficiency. As we will see in the following paragraphs, almost all Tuscan firms for 2015 and 2016 satisfied the incentive for having the operative costs lower than the 2014 national average. The only exception is “Nuove Acque”.

II.5.4 Investments

The amount of Investments, among other factors, also depends on the territorial structure and the population distribution. In areas with low population density, it will be usually more expensive having the same investment for inhabitants (Fiora).
Nevertheless, net investments for inhabitants increased in Tuscany in the last few years. However, in Tuscany, we cannot spot a real breakthrough after the Government entrusted the National Authority to regulate and supervise the sector. In Tuscany Investment are higher than the national average. Moreover in 2017 five providers have had a very the percentage of actual net Investment, with respect to the planned one, two of them even higher than 100%.
However, as we saw before lost water has not decreased in recent years and this is true also if we consider water lost for kilometre pipeline. They are indeed slightly raising despite the investments. This is because, on one side, investments are not only

in aqueducts as we can see from the figure below. On the other side because the pipelines are still very old: "from data presented by AEEGSI in the 2017 Report to the parliament, 36% of national water supply network are from 30 to 50 years old and the 22% are older than 50 years" (AIT General Director 2017 Report).

Table 3.2

Gross Investments in 2017, subdivided by service in %

	Aqueduct	Sewerage	Purification	General/others
Gaia	43%	37%	9%	12%
Geal	31%	55%	9%	6%
Acque	54%	18%	16%	13%
Publiacqua	53%	15%	15%	17%
Nuove Acque	70%	15%	11%	4%
ASA	58%	18%	22%	2%
Fiora	41%	15%	23%	21%
Total	52%	18%	16%	14%

As we can see from the figure below (Fig. 3.10), not all the providers have growing net investments, but the total amount is increasing and way over the National mean (€ 32 in the period 2014-2017).

Figure 3.10

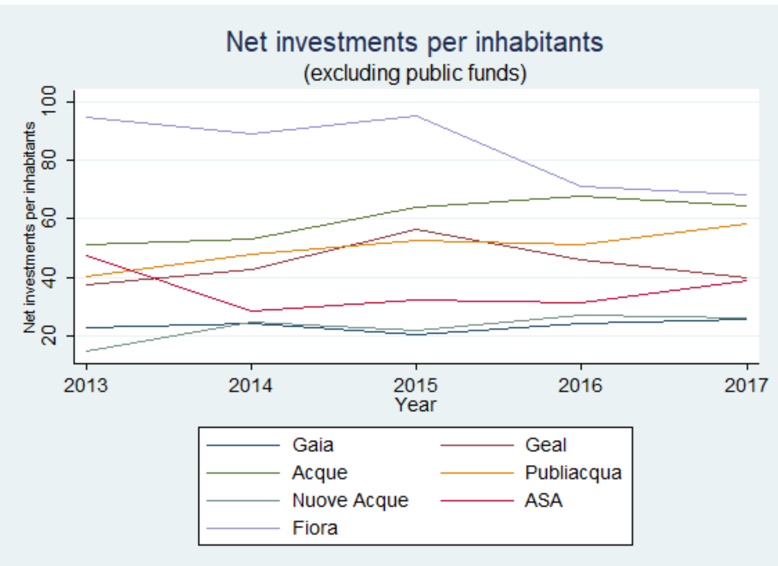


Table 3.3

Year	Tuscan investment per inhabitants
2013	45,10 €
2014	46,61 €
2015	51,24 €
2016	49,51 €
2017	51,81 €

III.5.5 Tariffs

Tariffs increase, established by each provider in 2014 and 2015, are in the great majority of cases lower than the possible maximum: the only exception is the 2015 increase for Nuove Acque. In a monopolistic environment the only reason not to increase price would be that it has been reached the point in which marginal revenues is equal to the marginal costs. However, giving that water is almost inelastic and Tuscan prices are still below the prices in other OECD countries, the more plausible explanation is that other reasons. We have to remember that for each provider, at least 50% of the share is controlled by the public administrations; so the political aspect is likely to affect the firm strategic decisions: public administrations are more likely to want not to increase tariffs too much in order to avoid citizens complains.

Table 3.4
Comparing the tariffs maximum possible increase with the actual increase in 2014 e 2015

Provider	Scheme	Max increase	Increase 2014	Increase 2015
Geal	III	9,0%	6,50%	6,50%
Gaia	IV	9,0%	6,50%	6,50%
Acque	III	9,0%	6,50%	6,50%
Publiacqua	III	9,0%	3,40%	6,40%
Nuove Acque	I	6,5%	5,20%	6,50%
Asa	III	9,0%	6,50%	6,50%
Acq. del Fiora	III	9,0%	6,50%	6,50%

III.6 Conclusions:

Planned investments in the first regulatory period (2014-2017), have a national average per inhabitants per year of approximately 32 Euro; adding public funds the sector reaches 41 Euro.

A value still far from the European average of 80 Euro that is what they need to cover the estimated requirements (Blue book 2017) As a matter of fact, ARERA's target is an annual investment of about €5 billion per year (€83/inhab./year).

In Tuscany, this value is higher than the national average.

We can explain investments higher than national average also with the fact that AIT is one of the Local Authority with more experience and acknowledged skills among all the Italian Local Authorities. This may be helped in investment identification and design.[12]

In Tuscany, investments grew after the entrusting of the sector to the National Authority, even if not for all the providers.

Looking at Tuscany, we can state that the sector is improving on efficiency, at least for the providers that have medium-high efficiency with respect to the national system.

Even if the incentives to increase investments and efficiency push tariffs up, data show that this regulation doesn't produce too high profits. This tells us the rules are balanced in this aspect.

The providers' property structure seems to have an important role in addressing the balancing between keeping tariffs not too high for consumers and giving the right incentives to firms.

Public choice theory (Niskanen 1994) suggest that bureaucracy would maximizes the budget firms and so, in this case, we could expect that it would maximizes tariffs. However, as we saw before, the decision on how much to raise the tariffs seems to be more affected by political thinking and consideration.

Looking at the Tuscan case, in this period and within this regulatory system, the public-private partnership seems to be effective in balancing the search of efficiency and investments from one side with setting the tariffs not too high (see also Macchiati et al. 2019); also in Canada, Ohemeng and Grant (2014) found that PPPs is better when compared to solely public or private services delivery.

Generally speaking, municipalities may be tempted to increase tariffs, also in order to

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receive higher dividends, but the fact that no provider raise tariffs at the maximum allowed, seems to exclude this possibility for this case.

We are still far from being in an ideal situation. The sector has lots of steps to climb. However, the relatively high investments (table 3.3) and the efficiency gain (figure 3.9) in Tuscan firms suggest that, at least in Tuscany, the water sector seems to be heading in the right direction, even with many years of delay. Nevertheless some problematic issues persist. National Authority is working on finding the proper tools to improve several aspects of the service. "General standard system (whole service quality indices) impose, through the measurement of several indicators, that the provider progressively evolve towards a performance ability more and more efficient until the reaching of an optimal class called maintenance class (class A). A system of incentive-based on annual or bi-annual improvements objective is established with a reward for reaching the objective and penalties in case of failure" (AIT General Director 2017 Report).

It's extremely important that the Authority has power and independence.

The providers' property structure being with a public majority and private partner chosen with a competitive mechanism may be an excellent way to combine seeking efficiency and willingness to invest and attention towards consumers (citizens) when increasing tariffs.

This, of course, turn out to be right with this regulation system, which seems to be effective at this moment to help the sector evolving.

On the other hand, we cannot be sure that this is not a restraint on investments. A further and more comprehensive analysis is needed to verify it.

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