NONCOOPERATIVE REGULATION

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Abstract

The regulation of natural monopolies has been widely investigated in economic literature. Particular emphasis has been placed on the relationship between the regulated firm and the regulator. The present work tries to deal with problems that may arise when there is more than one regulator. In this case, if regulators have different objective functions, inefficiency is likely to arise. The water industry seems to suffer from these kind of problems, indeed, given the local dimension of the industry, there are different levels of regulation with possible divergent interests. The analysis is mainly based on the work of David Baron (1985), who investigated the case of a polluting firm in the electricity industry, regulated by two authorities. In my work, I use a similar model to show how noncooperation amongst agencies regulating a firm in the water industry can lead to inefficient equilibria.

1 Introduction

The regulation of natural monopolies has been widely investigated in the economic literature. Particular emphasis has been placed on the relationship between the regulated firm and the regulator. The present work tries to deal with problems that may arise when we have more than one regulator. The analysis focuses on the interaction among regulators rather than on the instruments used.

The theory of regulation in perfect information framework predicts that the regulator can exploit all the rent of the firm, if it is possible to use a two-part tariff[1]. Therefore the firm plays no role. Given this quite unrealistic situation the natural development has been to introduce asymmetric information in the relationship between the regulator and the firm. Several models have been proposed on this subject, among them of particular relevance are Baron and Mayerson (1982) and Laffont and Tirole (1986). These models deals with the construction of an optimal tariff in condition of asymmetric information. The first one considers a situation in which a menu of contracts are offered in order to give the firm an incentive to reveal its private information. In the second

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[1]For a survey of the literature on tariffs, Cervigni and D'Antoni (2001).

one, the firm has to choose a level of effort in order to reduce its marginal costs. Both papers assume the regulating authority cannot observe firm's behavior and characteristics.

However, very few contributions deal with the problem of coordination that may arise if several regulators are present. Some contribution are proposed in the common agency framework. In particular, Martimort and Stole (2001) point out how the relationship among several principals and one agent depends on the nature of the action that is required the agent to do.

Of particular interest is the model proposed by Baron (1985). Baron considers a case in which a firm produces electricity and, as side product, pollution. There are two agencies that influence the behavior of the firm: an environmental agency and a public utility commission. The latter one regulates the natural monopoly by setting a tariff while the former one deals with pollution abatement, by imposing an environmental tax and technology restrictions. The key point of the article is the fact that the negative externality is non localized. People living in the neighborhood of the firm suffer from pollution and benefit from the electricity, whereas people living far from the firm suffer from pollution without getting any benefit in term of electricity supplied. Since the public utility commission must set a tariff that covers all firm's costs, reduction of pollution, by increasing firm costs, leads to a high tariff level. Therefore people served by the firm are going to bear the whole cost of reducing the externality.

This seems a situation in which Coase theorem should apply. Indeed, the problem is just to define property rights. Once it is defined who has to pay, the externality is internalized. It would be possible, for example, to impose a general tax to finance the reduction of pollution, so that the cost is born by everybody. This is not, however, the actual issue of Baron paper. The problem is dealing with is the presence of two agencies with possible different objectives to pursue.

The framework in which these kind of problems have been analysed so far is incomplete information. Inefficiency produced by lack of information is added up to inefficiency that may arise from the conflict between regulators. The conclusion of Baron paper is indeed that cooperation represents the first best scenario. If the agencies do not cooperate the firm can exploit an informational rent because of the conflict between the two agencies. The lack of cooperation represents a further source of inefficiency.

The present work investigates differences in the outcome of the regulation, that may arise when regulators do not cooperate; the analysis is conducted in a complete information environment, in order to single out differences that may arise because of the conflict between agencies alone. The idea is analogue to the analysis of the firm in a duopoly competition model. In that case, firms can get a higher profit if they collude than in the case of noncooperation. Similarly, when agencies cooperate they can get a higher benefit for the interests they represent. The problem is that cooperation cannot be sustainable in some situations. In particular, when considering the effect of pressure groups, it may emerge a situation in which regulators have no interest in cooperating. Obviously, the outcome depends on the way in which the relationship among regulator is designed. Our analysis show that there is a difference in the outcome of the regulation due to the behavior of the two agencies.

The paper is organized as follows. In section 2 a brief overview of the Italian water sector is presented. Historical aspects and recent regulation is analysed in order to point out problems of coordination that may arise in that context. In section 3, a simple model deals with the interaction between two authorities. Section 4 closes the paper with a brief summary of results and a discussion of open issues.

2 The Italian water sector

The Italian water sector has been characterized by a very fragmented and localized administration. A very large role has been played by local councils (*comuni*) and provinces. The main causes of this situation are the peculiar geographic structure of the Italian territory, and its political history. A territory characterized by the presence of mountains and hills, and the historical predominance of local independent administrations have enhanced a certain degree of localism in the Italian water sector.

The water sector, however, has been characterized by no public policy neither by the central or the local government, until a law issued by Giolitti's government (1904) introducing local public companies. Before that period there were just a few private companies that managed the service in limited areas. In the rest of the country there was no public intervention on water distribution, water was available in public fountains or in private wells.

Before the introduction of the new regulation, the water sector has been characterized by the local administration of the service. Local councils were directly involved both in the administration and the actual management of the service.

This scenario presents two main drawbacks. First there is confusion of control and management functions. The same institution is, at the same time, responsible for both the management of the service and the activity of control. The other problem is the small dimension of the area served by each institution. In this case, the operator cannot exploit the huge economies of scale and scope that characterize this industry.

2.1 The new regulation: legge Galli 36/94

The recent law, (*legge Galli 36/1994*, has introduced a revolutionary change in the Italian water service, establishing the so called Integrated Water Service. This service includes supply of water, sewerage services and depuration service. For the first time these services are thought of as a unique service. This is important, given the high connection among these services, especially in terms of economies of scope. The main objectives of the law can be summarized in the following three issues:

1. Restructuring the fragmented water sector by the creation of optimal territorial basins, ATO (*Ambito territoriale ottimale*) , which are responsible of the integrated service in a determined geographical area.

2. Clear separation between control functions and management functions.

3. Defining a tariff that covers firm costs and at the same time gives the firm an incentive to improve the quality of the service.

In order to reach these goals new institutions has been designed. At the central level there is a supervising committee on the use of water resources, the *Comitato per la vigilanza sull'uso delle risorse idriche*, whose main objective is to control the application of the law 36/94 by the local authorities. At the local level Regions have to define the ATOs territorial competence and prepare a general plan that the ATOs must follow in their activities. The other local authorities, *provincie* and *comuni* have lost most of the role that they had played in the past. In fact, they must cooperate to the management of the ATO to whom they belong.

It is clear that the main innovation is the creation of the ATO itself. With this instrument the legislator wants to deal with the high fragmented situation of the water service. The Regional laws have designed about 91 ATOs, against about 8100 organizations[2], of various type, that used to run the water service. This reorganization is very important in order to exploit the economies of scale that are present in this industry.

The main functions of the ATOs are to directly regulate the firm that is running the service and to monitor and control its activity. As regards direct regulation, the ATOs set the tariff that the company is going to impose, and defines the "plan" which states general lines on how the operator has to run the service in order to improve it, in terms of quality of the product and of the service. The ATOs have also the task to assign the concession for the management of the water service. Indeed, one of the main feature of the new integrated system relies on the fact that the service cannot be run directly by local authorities[3].

As regards the tariff, the legislator with the law 36/94 deals with a problem that was present in the Italian water sector since the seventies. Until 1974 the tariff was designed by a government committee (*CIP - Comintato Interministeriale Prezzi*) without any reference to management costs. In the 1984 a norm established that any increase in the tariff cannot be larger than the forecasted inflation rate. Therefore in this period, the tariff was mainly an economic policy instrument to contrast price inflation. This system was very confused because was not clear who was entitled to set the tariff, some norms state that the local government had this faculty, others that the CIP had that administrative power.

This quite confusing scenario reached an end with the law 36/94. The norm establishes that the ATOs are entitled to define the tariff. But this discretional power must be used in accordance with a "tariff of reference" defined by the Public Work Ministry (*Ministero dei Lavori Pubblici*), the Environmental Ministry (*Ministero dell'Ambiente*) and the Committee on the use of water resources (*Comitato per la vigilanza sulle risorse idriche*). The same norm also prescribes that the tariff must cover costs for the improvement of the quality of the service, as stated in the "plan", and that the temporal adjustment of the tariff follows a logic of *price cap*[4].

[2]Data from a 1999 survey. Previous companies are still present since the law has not been applied completely. In particular, up to the 30th June 2002, it has been created 74 ATOs. They cover 44 millions citizens

[3]The article 35 of the law "*legge finanziaria 2002*", establishes that the concession for the service must be assigned through an auction procedure.

[4]Regulation literature considers the price cap method useful to give the firm an incentive to improve its internal efficiency.

2.2 Problems of coordination

The brief survey of the legislation on the Integrated Water Service shows a scenario characterized by the presence of several ATOs, each one regulating its own area, and several levels of administration. Therefore, problems of coordination may arise at several levels.

First of all, at a longitudinal level, there is the issue of coordinating the activities of several ATOs. It may be the case that the same company is operating in two or more ATOs. Then at a local level there are problems with other institutions, such as *Consorsi di bonifica* or *Enti parco*, that may interfere with the ATO's regulation.

At a national level, the issue is coordinating several national authorities regulating public utility services. An example of that is a conflict already set off between Regione Marche and the authority for the competition and the market (*Autorita' per la concorrenza ed il mercato*), about the way in which the concession for the service has been designed.

It is important to distinguish between two different level of political influence. One level concerns the definition of the policy of the ATO itself, which may be influenced by different pressure groups. This kind of problems has been mainly analyzed using a Common Agency approach[5], in which the action of an agent (the policy maker) is influenced by several principals (pressure groups), each one offering a reward to the agent to take the action they prefer.

On another level there is the conflict between different regulators. Once we take as given the objective function of each regulator[6], we can consider the case in which these authorities have conflicting objective functions. It is this latter case which is considered in the following model.

3 A simple model

The model is designed thinking about the following scenario: two authorities are regulating a natural monopoly firm operating in the water sector. One of the two authorities is concerned with the preservation of the environment while the other has a more general objective: the maximization of consumers' welfare.

The kind of regulation considered is the "one-and-for-all" type described in Robert and Spence (1976). This way of modelling regulation has been followed also by Baron (1985), which represents the main reference of the present work.

3.1 Firm behavior

A firm is running the public utility service in a natural monopoly regime. In particular, we can think about a company that supply water in a certain area. The water is collected through the underground and then is distributed to consumers. This simplified assumption allows to focus on the main point that the model wants to investigate: the interaction between the two regulators on the use of a natural resource.

[5]As a reference Dixit, Grossman and Helpman (1997).

[6]Objective function that may be the outcome of a common agency game between the pressure groups and the agent (policy maker).

The firm chooses the level of water to pump up from the underground resource, and to distribute to consumers. However, given the perfect information scenario and assumptions presented in the next section, the tariff is always fixed at a level that guarantees profits equal to zero. In this case, the firm has just a "passive" role. It is the authority that actually chooses the quantity q of water, by setting the tariff.

The following is the profit function of the firm:

$$\pi = p * q + A - C(q) - t * max\{q - \gamma, 0\} \tag{3.1}$$

where symbols have the following meaning:

π	firm profit
p	tariff unit price
A	tariff fixed price
q	quantity of underground water pumped out and distributed
C	cost function
γ	inflow of water in the underground resource
t	tax rate on underground water pumped out, $t \in [0, 1]$

The following assumptions are imposed on the cost function of the firm:

1. Costs for distribution of water are zero.
2. $C(q)$represents the only cost. It refers to the process of pumping out water from the underground resource.
3. $\frac{\partial C}{\partial q} > 0$, the cost of extracting water increases with the quantity extracted, and the condition $C''(q) < 0$ to take into account of the natural monopoly condition in which the firm operates[7].

3.2 Regulatory agencies

We consider two agencies: Agency A and Agency B. They represent a water regulator and an environmental agency, respectively.

Agency A sets a two part tariff $T(q) = pq + a$, where p is the price of water consumed and a is the fix fee to access the service. In order to make the model easier we assume that all consumers agree on paying the fix amount a, i.e. the demand of water does not depend on the fixed component of the tariff. Assuming the number of consumers is N, the revenue of the firm is given by: $pq + A$, where $A = N * a$. The level of p and A depends on total costs and on the tax imposed by agency B, because a break even condition is imposed[8].

Therefore its objective function is:

$$W^A = S(p) - A + \beta\pi(q(p)) \tag{3.2}$$

Equation (3.2) represents Agency A's utility , which is given by the consumer's surplus (i.e. willingness to pay for water) $S(p) = \int_p^\infty q(p)dp$ (where $q(q)$ is the demand function)[9].

[7] Increasing return of scale is a sufficient, even if not necessary, condition to have cost subadditivity, which is the condition that qualifies natural monopoly.

[8] See Caillaud *et al.*(1988) for an account on the effect of imposing this condition

[9] Consumer surplus is a good monetary measure of the variation of welfare due to a change in prices, if there is no income effect. This can be the case if we assume that consumers have

This approach works if we assume that the fixed part of the tariff A does not affect the choice of consumers. In other words, it does not affect the demand to access the service, i.e. it is perfectly rigid. This latter assumption is somehow justified by the fact that when considering public utility industries, we are dealing with goods and services that are "essential" for households.

The objective function takes into consideration also the profit of the regulated firm. In particular, with $\beta = 1$ the agency values in the same way the surplus of the firm and the surplus of consumers, and therefore W^A represents the social welfare. In the literature[10] on regulation, it is often assumed $\beta < 1$, i.e. the agency values more the surplus of consumers than the surplus of the firm.

Agency B has the administrative power to set a tax on the use of underground water. It is concerned with the sustainable exploitation of the underground water resource. It is assumed that the agency is concerned with the flow of underground water, given by $\Delta\omega = q - \gamma$[11] . Its objective is to maintain an "optimal" level of underground water. This optimal[12] amount is equal to $\Delta\hat{\omega} = 0$. A *disutility* function $D(\Delta\omega - \Delta\hat{\omega})$ is defined in order to measure the negative value of the excessive use of the underground resource. This function assumes positive values when $\Delta\omega > \Delta\hat{\omega}$, and is equal to zero otherwise. Since $\Delta\hat{\omega} = 0$ the disutilty function depends only on $\Delta\omega = q - \gamma$. The following equation represents Agency B's objective function

$$W^B = -D(q - \gamma) + t * max\{q - \gamma, 0\} \tag{3.3}$$

The welfare function of Agency B depends only on the disutility function and on the revenue from the "environmental" tax. We assume that the disutility function is continuously increasing and convex, while not differentiable in all its in support. In particular, it has the following properties:

$D(q - \gamma) = 0$ for $q \leq \gamma$
$D'(q - \gamma) = 0$ for $q \leq \gamma$ and $D'(q - \gamma) > 0$ for $q > \gamma$
$D''(q - \gamma) > 0$ for $q > \gamma$

These assumptions reflect the fact that the disutility function is zero when the level of water is under the γ sustainable limit, and that the increase in disutility is more than proportional on q.

The objective function of the two agencies is potentially divergent. Agency A would like to have the firm produce a higher q than Agency B, in order to reduce unit costs and to apply a lower tariff. At the same time Agency B, which is concerned with environmental issues, wants a lower level of q, i.e. a lower degree of underground water exploitation.

In the next subsections the outcome of regulation under two different regimes is analysed.

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quasilinear preferences. This last assumption seems sensible since the importance of water in the family budget is very low.

[10] See for example Cervigni D'Antoni (2001) and Caillaud *et al.*(1988).

[11] The inflow and outflow of underground water is given only by the exogenous inflow and the quantity pumped by the water company. Basically, other outflow ways are supposed to be zero.

[12] The optimal level could be thought of as a level determined by hydrogeological studies.

3.3 Cooperative equilibrium

The firm maximize profit choosing q, given p, A, t. That choice is, however, not really independent. Since the hypothesis on perfect information, Agency A can always set p, A in order to force the firm to choose the level of q compatible with $\pi = 0$. In other words, it is as if Agency A can indirectly set the level of q and π, through the choice of p and A.

The two agencies behave as one. The 'joint" regulator chooses the rate of environmental taxation and the tariff to maximize the joint welfare function. It faces the following maximization problem:

$$\begin{aligned} \max_{\{p,A,t\}} W &= S(p) + \beta\pi(q(p)) - D(q(p) - \gamma) + t * max\{q(p) - \gamma, 0\} \quad (3.4) \\ \text{s.t. } \pi(q(p)) &\geq 0 \end{aligned}$$

In this case W represents the joint welfare function, i.e. $W = W^A + W^B$. The regulator chooses the level of p, the unitary price for the service, A the access price and t the tax rate. The only constraint is to guarantee the firm non negative profits.

Under the hypothesis made about the demand function, in particular the fact that the access price does not influence consumers' choice, A can be thought of as a lump-sum transfer to the firm with non distortionary effects.

Substituting out A in equation (3.4), a different expression for the joint welfare function is obtained.

$$W = S(p) + pq(p) - C(q(p)) - D(q(p) - \gamma) - (1 - \beta)\pi(q(p)) \quad (3.5)$$

Since $\beta \leq 0$, the maximization of the above equation requires $\pi = 0$. Therefore, the optimal choice for the joint regulator is to define A in order to have $\pi = 0$. In this case, the optimization problem becomes

$$\max_p W = S(p) + pq(p) - C(q(p)) - D(q(p) - \gamma) \quad (3.6)$$

From equation (3.6) we get the following first order condition that characterizes the *first best* solution, i.e. price equal to marginal cost.

$$P = C'(q(p)) + D'(q(p)) \quad (3.7)$$

The same problem can be analyzed using q and π as choice variable. In fact, once p and A are set, the equilibrium quantity and profit are univocally determined. In appendix A, the problem is solved with this approach and the same solution as equation (3.7) is obtained.

Equation (3.7), defines the level of unit price that gives the maximum level of welfare. It also implicitly defines the optimal level of quantity q^* , that represents the level of water "produced" in equilibrium by the monopolist.

The tax rate does not influence directly the level of welfare. This is because the possible disutility of agency B is directly taken into account in the joint welfare function. The welfare of agency B is taken into account directly when deciding the optimal level of q. Agency A will choose a tariff compatible with the firm producing at q level.

3.4 Non cooperative equilibrium

As in Baron (1985) we consider a case in which one regulator has more power than the other. We model the relationship between the two agencies as a sequential game à la Stackelberg, with complete and perfect information.

Description of the game:

- **Players:** three players, Agency A, Agency B and the monopoly firm.
- **Information:** complete and perfect information. The game is characterized by a SPE, Subgame Perfect Equilibrium.
- **Timing:** Agency B (the environmental authority) moves first, it decides the tax rate t to impose on the use of underground water; Agency A (the water authority) observes that choice and sets the tariff; the firm, given the tariff and the tax chooses q as to maximize its profit.

In order to solve for a SPE, backward induction method is used. Hence the firm maximization problem is analysed first. The firm maximises profit given the values of p, A and t. The optimal quantity chosen depends on the tariff and the tax rate, $q(p, A, t)$.

$$\max_{q} \pi = pq + A - C(q) - t * max\{q - \gamma, 0\} \tag{3.8}$$

Actually, given the full information framework, Agency A is always able to set a tariff that exactly covers the firm costs, and leaves no profits. The firm is a "passive" player, once agency A has fixed the tariff, the level of q and π are univocally determined. In practice, the level of q which maximises the profit function would give a level of $\pi = 0$. Therefore it is possible to skip this stage and focusing on the game between the two agencies.

Agency A has to choose the tariff in order to left zero profit to the firm, given the tax level fixed by Agency B. Therefore it faces the following maximisation problem:

$$\begin{aligned} \max_{\{p,A\}} W^A &= S(p) - A + \beta\pi(q(p,t)) \qquad (3.9) \\ \text{s.t.}\pi(q(p,t)) &\geq 0 \end{aligned}$$

It is optimal to set $\pi = 0$, as in the previous section. Hence the optimization problem of Agency A becomes a non constrained maximization program. Note that the quantity produced by the firm depends on both p and t, however for sake of simplicity we do not indicate both, but only the variable relevant for the maximization problem we are dealing with.

$$\max_{p} W^A = S(p) + pq(p) - C(q(p)) - t * max\{q(p) - \gamma, 0\} \tag{3.10}$$

In practice, the access price A is residually set by agency A in order to cover firm costs and obtain $\pi = 0$. Since the objective function is not differentiable in all its domain, when solving the maximisation problem we need to consider two separate cases.

Firs order condition in case of $q - \gamma > 0$

$$\begin{aligned} 0 &= S'(p) + q(p) + pq'(p) - C'(q(p))q'(p) - t * q'(p) \\ p &= C'(q) + t \end{aligned} \tag{3.11}$$

In the other case, i.e. $q - \gamma \leq 0$, we get the following first order condition:

$$P = C'(q) \tag{3.12}$$

This is the case in which there is no environmental problem and therefore the optimal price is set equal to marginal cost.

Equation (3.11), which defines the unit price that Agency A is willing to set given the firm marginal costs and the environmental tax rate, implicitly defines also the optimal level of q. In the backward induction process, equation (3.11) represents the best response function of Agency A to the tax rate defined by Agency B. The optimal quantity $\hat{q}$ defined in that equation depends on the tax rate, i.e. $\hat{q}(t)$.

Now the attention is turned to Agency B. It chooses the tax rate t taking into account the optimal behavior of Agency A, i.e taking into account its response function.

$$\max_t W^B = -D(\hat{q}(t) - \gamma) + t * max\{\hat{q}(t) - \gamma, 0\} \tag{3.13}$$

Also in this case it is better to consider two cases separately.

3.4.1 Case I: $q - \gamma \leq 0$ (*sustainable use*)

In this case, the welfare function of Agency B (3.3) is identically equal to zero. In other words, Agency B plays no role. Once the underground water resource is used at a "sustainable" rate, Agency B does not care about the amount of water pumped up. This peculiar situation stems from the fact that we are dealing with a static model, in which the future availability of water is assured by the "sustainable" condition. Indeed, there is no dynamic optimization program looking for an optimal path for the use of water. This optimal path is actually exogenously determined by the "sustainable" condition.

3.4.2 Case II: $q - \gamma > 0$ (*non sustainable use*)

In this case, the first order condition of the maximization problem (3.13) is the following

$$q'(t)[t - D'(q(t) - \gamma)] = \gamma - q(t) \tag{3.14}$$

Since the RHS of the above equation and $q'(t)$ is negative[13], the term into square brackets must be positive. Hence we get $t > D'(\cdot)$.

It means that the SPE of the game, in case of excessive use of the underground water resource, is characterized by Agency B (the environmental authority) setting a tax rate which is above the marginal disutility from exploiting the resource.

The subgame Nash equilibrium is characterized by the strategies $\hat{q}(\hat{t})$ and $\hat{t}$. The values of these two strategies are given by the following implicit functions:

[13] See Appendix B

$$\begin{aligned} P(\hat{q}(\hat{t})) &= C'(\hat{q}(\hat{t})) + \hat{t} \\ \hat{q}'(\hat{t})[\hat{t} - D'(\hat{q}(\hat{t}) - \gamma)] &= \gamma - \hat{q}(\hat{t}) \end{aligned}$$

4 Comparing solutions

In this section we analyse the results of regulation in both cases: cooperative and non cooperative equilibrium. In particular, the analysis is focused on the level of q in the two situations. That is useful to highlight the influence of different cooperation regimes in the use of a scarce natural resourse.

4.1 Case I: Sustainable use of the water resourse, $q - \gamma \leq 0$

In this case we have:

$$\begin{array}{lll} (i) & \text{cooperative solution} & P(q^*) = C'(q^*) \\ (ii) & \text{noncooperative solution} & P(\hat{q}) = C'(\hat{q}) \end{array}$$

The first equation comes from the fact that $D'(q^* - \gamma) = 0$ by assumption, while the second one comes from $t * max\{\hat{q} - \gamma\}$ being equal to zero.

Hence, the two equilibrium levels of q are the same. It does not matter how the agencies behave, the outcome of the regulation, in term of quantity, is the same.

4.2 Case II: Excessive use of water resources, $(q - \gamma > 0)$

The two optimality conditions are as follow.

$$\begin{array}{lll} (i) & \text{cooperative solution} & P(q^*) = C'(q^*) + D'(q^* - \gamma) \\ (ii) & \text{noncooperative solution} & P(\hat{q}(\hat{t})) = C'(\hat{q}(\hat{t})) + \hat{t} \end{array}$$

In order to compare these two equation in terms of the outcome in the regulation, it is sensible to subtract the second equation to the first one.

$$[P(q^*) - P(\hat{q})] - [C'(q^*) - C'(\hat{q})] = D'(q^* - \gamma) - t * (\hat{q} - \gamma) \tag{4.1}$$

The first thing to notice is that the outcome of the cooperative and non cooperative game, q^* and $\hat{q}$ respectively, are the same only in case $D'(q^* - \gamma) = \hat{t}$. This can be easily seen because the two implicit functions are the same. Whatsoever value q^* assumes, it will be equal to $\hat{q}$. The economic intuition behind this result is that when the marginal disutility of exploiting the water resource is equal to the tax rate imposed by agency B, then the behavior of the two agencies is irrelevant for the outcome of the regulation. Or in other words, the marginal cost to the firm of imposing a tax or to internalize environmental disutilities is the same.

Now we need to consider what happens when $D'(q^* - \gamma)$ is greater and smaller than t.

4.2.1 Case: $D'(q^* - \gamma) > t$

Assuming $q^* < \hat{q}$, the first part of the LHS (left hand side) of equation (4.1) is always positive because of the assumption of downward sloping demand curve, the sign of the second part depends on the assumption on the second derivative of the cost function. With $C''(q) = 0$ the second part is equal to zero and therefore the assumption $q^* < \hat{q}$ is verified. With $C''(q) > 0$ the second part is negative, but considering the minus sign, the assumption $q^* < \hat{q}$ is verified also in this case. With $C''(q) < 0$ the second part has a positive sign and therefore the result is undetermined.

In the latter case, however, it is possible to show that in a neighborhood of $C''(q) = 0$ the assumption $q^* < \hat{q}$ is verified. This implies that for a small negative quantity of $C''(q)$ the assumption is verified, but for a large negative quantity the assumption is no more verified and therefore $q^* > \hat{q}$.

The results of the model shows that when the marginal disutility from exploiting the underground resource is higher than the maximum tax rate, the cooperative equilibrium level of water q^* is greater than the noncooperative equilibrium $\hat{q}$ because in the former case the disutility is internalized in the choice of q, while in the latter is limited to the maximum tax rate.

However, there seems to be a counterintuitive result when there are strong economies of scale, i.e. $C''(q) < 0$. In this case, $q^* > \hat{q}$, the cooperative behavior produce a greater use of the underground resource. This is not really unexpected because it accounts for the fact that the economies of scale are so strong that it is convenient, in term of social welfare, to over exploit the underground resource. This result is due, however, mainly to the fact that the model is not dynamic. Future utility from consuming water is not considered in the objective functions of Agency A, and therefore does not affect the utility of people. The decision of not considering the future utility of water in the objective function of agency A is justified if we think that this Agency is subject to political judgement by citizen and therefore it tends to favour today consumption against future consumption.

4.2.2 Case: $D'(q - \gamma) < t$

Assuming $q^* < \hat{q}$, the RHS of equation (4.1) is negative, while the first part of the LHS is positive. Therefore, to have the equation verified, we need the second part of the LHS to be positive, and larger than the first part. The assumption, $q^* < \hat{q}$, is not verified with $C''(\cdot) > 0$, and it is indeterminate with $C''(\cdot) < 0$. We can say, however, that as $C''(\cdot)$ assumes large negative numbers the probability that the assumption is satisfied increases. In other words, with large economies of scale the noncooperative equilibrium value of q is larger than the cooperative one.

Assuming $q^* > \hat{q}$, the first part of the LHS is negative. Thus it needs to be negative as well or positive but smaller than the first part. With $C''(\cdot) > 0$ the assumption is always verified, whereas with $C''(\cdot) < 0$ the assumption is verified only with a small value.

4.3 Summary of results

Table 1 summarizes the results, pointing out the cases in which the cooperative optimal quantity is less than the noncooperative one. It is important to note

Table 1: Summary of results in case $q > \gamma$ (*non sustainable use of the water resource*)

$D'(q-\gamma) = 0$	always $q^* = \hat{q}$
$D'(q-\gamma) > t$	with $C''(q) \geq 0$ and $small C''(q) < 0 \Rightarrow q^* < \hat{q}$
	with $large C''(q) < 0 \Rightarrow q^* > \hat{q}$
$D'(q-\gamma) < t$	with $C''(q) \geq 0$ and $small C''(q) \Rightarrow q^* > \hat{q}$
	with $large C''(q) < 0 \Rightarrow q^* < \hat{q}$

that, from the maximization problem of Agency B in case of non cooperation, emerges the condition $t - D'(q-\gamma) > 0$. This implies that the optimal tax rate must be always greater than the marginal disutility of overusing the natural resource. Therefore, given this result and the presence of economies of scale which characterizes the water industry, we can conclude that under cooperation the level of water pumped up from the underground resource is smaller than the quantity in case of non cooperation.

5 Conclusion

The analysis conducted shows how important is implementation phase in the regulation process. Most of the time it is not enough to design a good regulation law, it is necessary to consider the biasing effect on outcomes of the subjects who are going to implement it. In particular, the actual behavior of institutions involved in the process is crucial for matching forecasted and actual outcome of the regulation.

The simple model presented shows how the outcome of regulation may change according to agencies' behavior, even in the presence of perfect information. In particular, in case of noncooperation the interest of Agency B is not taken into account when deciding the tariff which influence the quantity of water, therefore Agency B raises an environmental tax to compensate from excessive use of the underground resource. In the cooperative case there is no need to put an environmental tax because the same result can be reached with the tariff, which takes into account both efficiency and environmental issues. It is important, therefore, for the policy maker to take into account this biasing effect when designing a regulation.

The application of this model to the water sector case, shows that the non cooperation produce a larger exploit of the water resource than the cooperation. This result, however, is heavily conditioned by the simple structure of the model. It would be interesting to check the validity of these results in a dynamic setting, where the possibility of saving water for the future matters.

However, the environmental-tariff conflict is not the only one that may emerge. There could be other cooperation problems that the law does not take into account. For example, the presence of more than one ATO regulating the same firm, or the presence of local councils and provinces in the same ATO.

A Appendix: Cooperative solution with respect to q

Cooperative solution of the regulation game. The welfare functions are expressed as functions of q and π.

$$\begin{aligned} \max_q W &= CS(q) - p * q - A + \beta\pi(q) - D(q-\gamma) + \\ &\quad + t * max\{q-\gamma, 0\} \\ \text{s.t. } \pi(q) &\geq 0 \end{aligned} \tag{A.1}$$

Since we are considering a case of perfect information Agency A can always set a tariff that covers costs perfectly, and as long as $\beta \leq 1$ it is optimal to set profit equal to zero. Given this proposition, the constraint in the maximization problem becomes an equality constraint. And therefore the welfare function to maximize become:

$$\max_q W = CS(q) - C(q) - t * max\{q-\gamma, 0\} - D(q-\gamma) + t * max\{q-\gamma, 0\} \tag{A.2}$$

The first order condition of this simple non constrained maximization program is:

$$P(q^*) - C'(q^*) - D'(q^* - \gamma) = 0$$

where P(q) represents the derivative of the gross consumer surplus with respect to q, i.e is the inverse demand for water. We can rewrite the above condition as

$$P(q^*) = C'(q^*) + D'(q^* - \gamma) \tag{A.3}$$

B Appendix: the sign of $\frac{dq}{dt}$

The following equation represents the optimality condition for Agency A maximization problem in case $q - \gamma > 0$, and under noncooperative behavior.

$$P(\hat{q}(t)) = C'(\hat{q}(t)) - t \tag{B.1}$$

In that equation $\hat{q}$ represents the optimal value, which depends on the choice of t by agency A. Differentiating with respect to t we get:

$$\begin{aligned} \frac{\partial P}{\partial \hat{q}} \cdot \frac{d\hat{q}}{dt} &= \frac{\partial C'(q(t))}{\partial \hat{q}} \cdot \frac{d\hat{q}}{dt} - \frac{dt}{dt} \\ \frac{d\hat{q}}{dt}\left[\frac{\partial P}{\partial \hat{q}} - \frac{\partial C'}{\partial \hat{q}}\right] &= -1 \\ \frac{d\hat{q}}{dt} &= (-1)\left[\frac{\partial P}{\partial \hat{q}} - \frac{\partial C'}{\partial \hat{q}}\right]^{-1} \end{aligned} \tag{B.2}$$

The value of the derivative of q with respect of t is negative when $\frac{\partial P}{\partial \hat{q}} > \frac{\partial C'}{\partial \hat{q}}$. It is possible to interpret this relation in economic terms if both side of the inequality is multiplied by $\frac{q}{p}$, where $q \geq 0$ and $p > 0$.

$$\frac{\partial P}{\partial q}\frac{q}{p} > \frac{\partial C'}{\partial q}\frac{q}{p} \Longrightarrow \frac{1}{\epsilon_p} > \frac{1}{\epsilon_{MC}} \tag{B.3}$$

ϵ_p represents the elasticity of the quantity demanded to price, while ϵ_{MC} represents the elasticity of the quantity produced to variation in marginal costs.

Since in our case, the product produced by the firm is water, the demand for such good is quite rigid and it is sensible to assume that $\epsilon_p < \epsilon_{MC}$. Hence $\frac{dq}{dt} < 0$.

C Appendix: Solution of the noncooperative game with respect to "q"

Agency A faces the following maximization problem:

$$\begin{aligned} \max_{\{q,\pi\}} W^A &= \int_0^q P(q)dq - p(q)q - A - \beta\pi(q) \qquad \text{(C.1)} \\ s.t. \pi(q) &\geq 0 \end{aligned}$$

Since for Agency A is always optimal to set $\pi = 0$ we get the following maximization problem:

$$\max_q W^A = \int_0^q P(q)dq - C(q) - t * max\{q - \gamma, 0\} \tag{C.2}$$

We get the following first order condition:

$$P(q) - C^{'}(q) - t = 0 \tag{C.3}$$

This is the optimal level of q fixed by the firm given the level of taxation. It is the response function of Agency A: $\hat{q} = f(t)$.

Agency B anticipates the behavior of agency A by internalizing this condition in its maximization problem.

$$\max_t W^B = -D(q(t) - \gamma) + t * max\{q(t) - \gamma, 0\} \tag{C.4}$$

In order to differentiate that equation we need to separate two cases: $q - \gamma > 0$ and $q - \gamma \leq 0$. In the former case, we get the following first order condition for the maximum.

$$q'(t)[t - D'(q(t) - \gamma)] = q(t) - \gamma \tag{C.5}$$

In the latter case, i.e. when the use of the underground water resource is less than the critical level no maximization is needed because the objective function is identically equal to zero.

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