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Supra-Regional vs. Regional Regulators in the Water Pollution Mitigation: Optimal Exemption Policies[1]

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Abstract

Through the Water Framework Directive, the European Commission urges its Member states to reach a level of "good status" of water for 2015. This level can be different from the regional first-best. Neither the supra-regional regulator (European Commission) nor the regional regulator (Member State) knows perfectly this first-best. Each region can estimate it thanks to a cost-benefit analysis (CBA). If the estimated first-best is lower than the "good status" level, the region can ask to be exempted from reaching the latter. In this paper, we show that regional regulators do not always invest largely in CBA in optimum, although under-investment increases the probability of being urged to reach the highest level of water quality. Besides, the optimal exemption policy announced by the supra-regional regulator, which depends on the CBA's investment, shall also depend on the local risk preferences and environmental vulnerability. If the exemption policy is uniform across the regions, we obtain that more risk averse and/or more environmentally vulnerable populations invest less in the CBA, contrary to the first intuition. Policy implications are discussed.

Key words: Supra-Regional Regulator; Regional Regulators; Exemption Policy; Imperfect Estimation; Local Preferences.

JEL Classification: D8, Q25, Q28

1 Introduction

Despite a half century of environmental policies, Member States in Europe have failed to reach a level of water quality that enables them to obtain an acceptable balance between economic and ecological interests. The economic literature tries to explain this fact with different arguments. Coase (1960), Buchanan and Tullock (1962), and Stigler (1971) point out that the regulator either is under pressure because of lobbies or follows his private interest. Another argument usely enhanced deals with information seeking and the difficulty for a regulator to obtain accurate information, at a fair price, on cost and damage functions (for recent works on this subject, see for instance Bontems and Bourgeon (2005) and Krysiak and Schweitzer (2010)).

In Europe, the failure of the States' policies in reaching a general "good" quality of water led the European Union to implement the Water Framework Directive (European Parliament and European Union Council, 2000). This Water Framework Directive (WFD in the course) represents a major change in the European environmental policy for it presents a unified and relevant legal frame for reducing water pollution in all European countries with respect to a common time schedule and to common criteria. This directive respects the subsidiary principle[1]: each State chooses the actions that it wants to conduct in order to meet the requirements of the European Directive. The Directive sets a binding ambient standard, the "good status" requirement, which is based on chemical and biological considerations (for surface water) and on quantitative considerations (for groundwater).

Following Kaika and Page (2003), environmental interests have had a significant weight during the debates on the directive and on the definition of the "good status". Hence the "good status" requirement imposed by the European Commission to its Members is a tightened constraint which is expected to trigger a new dynamic of water pollution. In the meantime, economic and technical considerations can justify

[1] Article 5(2) and (3), TEU: "[...] In areas which do not fall within its exclusive competence, the Community shall take action, in accordance with the principle of subsidiarity, only if and in so far as the objectives of the proposed action cannot be sufficiently achieved by the Member States and can therefore, by reason of the scale or effects of the proposed action, be better achieved by the Community. [...]".

a less binding norm for some water bodies or some specific types of pollution.[2] Hence the Directive allows Member States to ask for a less demanding environmental target. [3], [4] The demand of exemption must be motivated by a cost-benefit analysis the purpose of which being to provide an estimation of the regional first-best level of water quality. If the estimated first-best is lower than the standard imposed by the supra-regional regulator, the latter can allow the regional regulator to implement the estimated first-best.

In this paper, we want to analyze the following normative issue: what design should the exemption policy present in order to induce optimal investment in the cost-benefit analysis by regional regulators, knowing that up to now they had few incentives to determine and reach the first-best levels of water quality? To answer this question, we propose a simple model based on the relationship between a supra-regional regulator and a regional regulator.

In the theoretical literature, the relation between a supra-regional regulator and regional (local) regulators is analyzed in particular in Cavagnac (2003). He focuses on the adverse selection issue that prevails between both types of agents about some local characteristics. In a context of signalling, he shows that separate contracts, usually considered as optimal, are no longer the best way to deal with adverse selection in this setting. In particular, when pollution does not affect strongly the region, a menu of contracts that strongly discriminates among the different possible types may induce higher costs than the social benefit of the pollution reduction, because of the informational rent to be given to the region. In Hiriart and Martimort (2012) moral hazard is considered: the authors consider risk mitigation and the relation between the Congress and agencies in charge of regulating firms with risky activities. Their important result is that the Congress should combine regulatory policies imposed to the firms through the intervention of the agencies with some discretionary actions conducted by these same agencies. Much more earlier Roberts

[2] Huntchison and Kennedy (2008) consider air pollution regulation in the United States (Clean Air Act). They show that it can be optimal for the federal State to let states applying less stringent actions against non-compliant firms located close to the downwind state border relative to firms located in the interior of the state.

[3] See articles 3, 4 and 5 of the WFD.

[4] See Grönlund and Määttä (2008) for a complete description of the different types of exemptions at stake within the European WFD.

and Spence (1976) already proposed a mix policy to reduce pollution due to the firm's activities. In their model, the regulator can misestimate the total abatement costs, such as in our model, and this can lead to inefficiencies on the market of pollution rights that is at stake.

These results highlight different relationships that may prevail between supra-regional regulators and regional regulators when the latter have an informational advantage over the former. Nevertheless they do not discuss the other important issue, which deals with imperfect, but symmetrical, information. We do it in this paper.

By considering a supra-regional regulator who builds an exemption policy on the basis of the investment in the CBA made by the regional regulators, we show that regional regulators do not always have incentives to invest largely in CBA although under-investment increases the probability of being urged to reach the highest, and then the costliest, level of water quality.

Formally, the estimation of the regional first-best is characterized by a random variable which takes values in an interval centered on the effective (unknown) first-best. Any positive investment in the CBA improves the distribution of this random variable in such a way that the higher the investment, the higher the probability that the difference between the true value of the first-best and its imperfect estimation be lower than a given value: the distribution of the risk of misestimation is improved in the sense of the second-order stochastic dominance. Risk-averse individuals from a given region dislike the randomness of the estimation and they are willing to pay for a decrease of it. Their preferences are represented by an increasing and concave utility function. The environmental (or health) loss suffered by this regional population, and induced by a level of water quality that would be lower than the level required by the supra-regional regulator, is defined by an increasing and convex loss function.We derive the characteristics of an optimal exemption policy.

First, in a perfect information setting, we show that a more risk averse and/or more environmentally vulnerable population wants to reach a higher first-best level of water quality. A direct consequence of these results obtained under perfect and complete information is that, under imperfect information about the effective regional first-best, different regional regulators invest differently in the cost-benefit analysis for given and identical water body and exemption policy decided by the supra-regional regulator. Surprisingly at first sight, the more the risk aversion of the population, the lower the level of investment in the CBA. The same is observed for environmental vulnerability: the more the population's vulnerability to environmental damage, the lower the level of investment in the CBA. Actually, populations highly risk-averse and/or environmentally vulnerable have also (not perfectly known) first-bests of water quality that are closer to the standard, making the CBA less valuable.

Hence local behaviors in terms of CBA choice for a given exemption policy are different from one population to another one and, in terms of efficiency, the exemption policies should take into account the local preferences. Nevertheless, such a sophisticated policy could be costly to be implemented. Thus, if the exemption policy is homogenous from one region to another one, the properties of such a policy shall be as follows: the probability of refusing to exempt the region from applying the water quality standard shall be decreasing and concave in the announced level of investment in the CBA if the objective of the supra-regional regulator is to push the regional regulator to invest the maximum possible amount in the CBA. This may be an optimum if the abatement cost function is not too convex compared to the increase in the financial investment. On the contrary, a decreasing and convex probability of refusal may lead to an alignment of the supra-regional optimum with the regional first-best. In that case, maximum investment in the CBA may not be the rule.

The paper is organized as follows. Section 2 presents the results relative to the regional first-best when its estimation is perfect and common knowledge. In Section 3, we consider the more realistic case that concerns imperfect estimation of the regional first-best. Our normative results are discussed with regard to policy implications in Section 4.

All proofs are given in the appendix.

2 First-best water quality when information is perfect

We consider a regional regulator i who must improve the quality Q^i of a given water body in her (administrative) region. The first-best level of quality Q^{iR} for Region i is known neither by the regional regulator nor by the supra-regional regulator. Yet, it can be estimated thanks to a cost-benefit analysis, which technology is owned by the regional regulator and not by the supra-regional regulator[5]. For exogenous reasons, the supra-regional regulator imposes to all administrative regions to reach a level of water quality $\overline{Q}$. This level can be different from some regional first-bests. We are interested in regions for which the first-best level of water quality is lower than the imposed $\overline{Q}$, which we call the standard in the course of the paper. Thus we have $Q^{iR} \in \left[0, \overline{Q}\right]$. Whenever these regions conduct a cost-benefit analysis in order to demonstrate that their first-best level Q^{iR} is lower than $\overline{Q}$, then the supra-regional accepts that Q^{iR} is implemented instead of $\overline{Q}$. The regional regulator must invest in the CBA a financial amount denoted $\overline{I}$, with $0 < \overline{I} < +\infty$, in order to obtain a perfect estimation of Q^{iR}.

The depollution technology is identical from one region to another one[6]: it is represented by a cost function $C(Q)$, with Q the level of water quality. It is strictly increasing and, for the sake of simplicity, linear.

The regional population suffers from an environmental (or health) loss $L_i(Q^i)$ that we normalize at zero for $Q^i = \overline{Q}$. This loss function satisfies $L_i'(Q^i) < 0$, $L_i''(Q^i) > 0$, and $L_i(\overline{Q}) = 0$. Besides, the preferences of the region i's population are represented by a social utility $U_i(.)$, increasing in wealth at a decreasing rate:

[5] The informations that the cost-benefit analysis must reveal are local, so that it is relevant for the supra-regional regulator to ask the regional regulator to implement the CBA in her region. Also recall that, even though he would have the technology, it is more efficient that the CBA be done by the region regarding to the subsidiarity principle.

It is assumed that the regional regulator is honnest and will conduct the CBA the best she can, knowing the financial investment I. No moral hazard issue is considered in this paper.

[6] This assumption seems to be unrealistic when considering the European union for instance. Indeed it encompasses 28 countries with different economic and ecological situations. Nevertheless, one expects that the European union has the objective to provide acces of all of its members to the most developped technologies.

$U_i'(.) > 0$ and $U_i''(.) \leq 0$. And finally, her initial and certain wealth is denoted w. Region i's utility of depollution is $U_i(w - L_i(Q^i))$.

Region i's first-best level Q^{iR} is such that it maximizes the regional welfare denoted W^i. It is equal to the population's utility of depollution minus the regional costs of depollution and the investment in the cost-benefit analysis. Formally:

$$\max_{Q^i} W^i = U_i(w - L_i(Q^i)) - C(Q^i) - \overline{I} \tag{1}$$

With $L_i(.)$ convex, $C(.)$ linear, and $U_i(.)$ concave by assumption, the second order conditions are satisfied. The first-best level Q^{iR} for Region i satisfies the following first-order condition:

$$-L_i'(Q^{iR}).U_i'(w - L_i(Q^{iR})) = C'(Q^{iR}) \tag{2}$$

The left-hand-side term of (2) is the marginal benefit of an increase in the water quality, while the right-hand-side term is the marginal cost. Despite the fact that each region i has access to the same depollution technology, their first-best level of water quality for a given water body differs from one to the other one because of their different characteristics. Precisely, both the valuation of their marginal utility of depollution captured by the curvature of $U_i(.)$ and their vulnerability to ecological damages captured by the curvature of $L_i(.)$ enter in (2).

In the course of the paper, a population is said to be more environmentally vulnerable than another population if the damage function of the former is a convex transformation of the damage function of the latter. This higher convexity can illustrate either subjective characteristics such as a higher environmental sensitivity, or more objective ones such as a higher health vulnerability.

Proposition 1 *Let us assume that regions are able to perfectly estimate their first-best level of water quality.*

i) Consider two regions 1 *and* 2 *having the same loss function* $L(.)$, *but with a higher marginal utility of depollution for Region* 1 *than for Region* 2. *Also assume that their marginal utility are equal when there is no environmental pollution:* $U_1'(w) = U_2'(w)$. *Then at optimum* $Q^{1R} > Q^{2R}$.

ii) Consider two regions 3 *and* 4. *They have the same preferences* $U(.)$ *but Region 4 is more environmentally vulnerable than Region 3. Also assume that their marginal* *loss are equal when there is no environmental pollution:* $\lim_{Q \uparrow \overline{Q}} L_3'(Q) = \lim_{Q \uparrow \overline{Q}} L_4'(Q)$*. Then at optimum* $Q^{4R} > Q^{3R}$*.*

An important consequence of this proposition is that regions will want to reach different levels of quality for some identical water bodies, while the supra-regional regulator imposes a unique level $\overline{Q}$ for a given water body to all regions. Actually, imposing a unique $\overline{Q}$ to all regions is not costly for Society if the estimation of the regional first-bests can be perfect. Indeed, anouncing $\overline{Q}$ is a non costly threat that induces regions to conduct the costly cost-benefit analysis in order to prove that their first-best is lower than $\overline{Q}$. Knowing that the estimation is perfect, the supra-regional regulator has no incentives to refuse the first-best level Q^{iR} to Region i. And the regions who know that their first-best is lower than the threat $\overline{Q}$ have no incentives to give up the cost-benefit analysis.

The story is significantly different when the estimation cannot be perfect, which is the case in many situations in practice. In the next section, we consider imperfect estimation. The supra-regional regulator still decides either to accept or to refuse to exempt a given region from reaching the level $\overline{Q}$. But now, his decision will be based on the amount of investment made by Region i in the cost-benefit analysis: Now, the investment I becomes a strategic variable for Region i.

3 Optimal Strategies when information is imperfect

Assume now that the first-best level of water quality of a given region cannot be perfectly known neither by the supra-regional regulator nor by the regional regulator herself. As in the previous section, the regional regulator is the sole owner of the technology that permits her to conduct the cost-benefit analysis. Nevertheless, the estimation is no longer perfect. Formally, there exists a risk of misestimation such that the estimator is a random variable defined by $\widetilde{\widehat{Q}^{iR}} = Q^{iR} + \widetilde{\varepsilon}$, with $\widetilde{\varepsilon}$ taking realizations in $[-\overline{\varepsilon}; +\overline{\varepsilon}]$, $\overline{\varepsilon} > 0$, and having a zero mean. Although the regional regulator does not know the first-best Q^{iR}, she knows the interval $\left[Q^{iR} - \overline{\varepsilon}; Q^{iR} + \overline{\varepsilon}\right]$ which it belongs to. Still here, we assume that only regions with estimated first-bests lower than the imposed level $\overline{Q}$ ask for an exemption. Thus we assume $\widehat{Q}^{iR} \leq \overline{Q}$.

On the basis of the estimation $\widehat{Q}^{iR}$, the regional regulator asks the supra-regional regulator to be exempted from implementing $\overline{Q}$. If the supra-regional regulator accepts the exemption, then the regional regulator is allowed to implement $\widehat{Q}^{iR}$ instead of $\overline{Q}$. If the exemption is refused, then she must implement $\overline{Q}$.

The level of ressources invested in the CBA is now denoted I and it varies within the interval $\left[0,\overline{I}\right]$. In this section, we assume that the estimator $\widehat{Q}^{iR}$ of Q^{iR} is imperfect whatever the level I of investment in $\left[0,\overline{I}\right]$. Both the regional regulator and the supra-regional regulator know the distribution of the misestimation error $\widetilde{\varepsilon}$. This distribution depends on the level of investment put into the CBA: the more the investment in the CBA, the more the accuracy of the estimation. Formally, and with ε a realization of $\widetilde{\varepsilon}$, the (cumulative) distribution is $F(\varepsilon \mid I)$. It satisfies[7] $F_I(\varepsilon \mid I) \leq 0$ for any $\varepsilon \in \left]-\overline{\varepsilon};0\right[$, $F_I(\varepsilon \mid I) \geq 0$ for any $\varepsilon \in \left[0;+\overline{\varepsilon}\right[$, and $F_I(-\overline{\varepsilon} \mid I) = F_I(+\overline{\varepsilon} \mid I) = 0$. These assumptions illustrate the fact that an increase in the investment I improves the distribution of the misestimation in the sense of the second order stochastic dominance: the higher the investment I, the higher the likelyhood to observe an error ε smaller than a given (absolute) value.

Figure 1.a. shows an example of such a distribution's improvement thanks to an increase in the CBA investment I; it displays the graph of two different density functions of the estimation error. The horizontal curve is a uniform density function: each possible error has the same frequence of occurence. It can correspond to the distribution of the error when no cost-benefit analysis is made: for $I = 0$, ε is likely to take any value with the same density in the interval $[-\overline{\varepsilon};+\overline{\varepsilon}]$. For a strictly positive investment I, the density of ε is tightened around zero and small errors are likely to be more frequent than high ones when compared to the case with a uniform distribution. Figure 1.b. presents the associated cumulative distributions.

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Figures 1.a. and 1.b. about here

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Recall that the supra-regional regulator can either accept the exemption - and the regional regulator implements $\widehat{Q}^{iR}$ -, or refuse it - imposing $\overline{Q}$ to the regional regulator. The supra-regional regulator observes I without cost and he makes depend

[7] Subscripts denote partial derivatives.

his exemption policy on this investment. At the beginning of the game, the regional regulator knows that the exemption will be refused by the supra-regional regulator with a probability p strictly lower than 1 and depending on I: $0 < p(I) < 1$.[8]

Both the depollution technology and the loss function have the same characteristics as in the perfect information model above: they are represented respectively by $C(Q)$ and $L_i(Q)$. Nevertheless, now the argument of these functions is no longer the true value of the first-best Q^{iR} for a given region i, but an imperfect estimation $\widehat{Q}^{iR}$ of it.

The timing of the decisions is illustrated on Figure 2. R is the regional regulator and SR is the supra-regional regulator. The level I^{iR} is the optimal investment in the CBA decided by the regional regulator i.

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Figure 2 about here

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Let us write the objective functions and the first order conditions for each party. Contrary to what happened in the preceeding section, the regional regulator does no longer look for the first-best level of water quality that maximizes the region's welfare. Now, she must announce a level of investment in the CBA to the supra-regional regulator, and this investment becomes a strategic variable for her. She must choose a level of investment that permits her to make an optimal trade-of between lower expenses for the CBA but a higher chance (or threat) to have to implement the undifferentiated level $\overline{Q}$ of water quality. Formally, the regional regulator is conducting a cost minimization: she must choose the financial level I to be invested in the cost-benefit analysis, which is solution to

$$\min_{I} \mathcal{C}(I) = I + (1 - p(I)). \int_{-\overline{\varepsilon}}^{+\overline{\varepsilon}} C(\widehat{Q}^{iR}) dF(\varepsilon \mid I) + p(I).C(\overline{Q}), \tag{3}$$

[8] This assumption is in line with some current practices. Concerning water quality in Europe, the European commission is using questionnaires in order to assess the methods used for, and the means invested in the cost-benefit analysis by each region (or country). See "The third implementation report – assessment of the River Basin Management Plans (2012)",
http://ec.europa.eu/environment/water/water-framework/implrep2007/index_en.htm#third
In our model, those methods and means are captured by the variable I.

This is different from looking for the first-best regional level, that is the one that maximizes the regional welfare.Yet recall that the estimator $\widehat{Q}^{iR}$ takes values in $\left[Q^{iR}-\overline{\varepsilon};Q^{iR}+\overline{\varepsilon}\right]$. Although Q^{iR} is unknown from both the regional and the supra-regional regulator, the interval $\left[Q^{iR}-\overline{\varepsilon};Q^{iR}+\overline{\varepsilon}\right]$ is known: a given region knows the mean quality of the water body at stake. And from Proposition 1, we know that populations with different preferences have different first bests Q^{iR} and, thus, different intervals $\left[Q^{iR}-\overline{\varepsilon};Q^{iR}+\overline{\varepsilon}\right]$ for their estimator. Finally, the regional regulator has an idea about an approximate value of the first best, and she must choose how much to invest in the cost-benefit analysis in order to obtain (or not) a more precise estimation.

The solution I^{iR} to Program (3) satisfies the following first order condition for an interior solution:

$$1=p'(I^{iR}).\left[\overline{C}(\widetilde{\widehat{Q}^{iR}})-C(\overline{Q})\right] \tag{4}$$

with

$$\overline{C}(\widetilde{\widehat{Q}^{iR}})=\int_{-\overline{\varepsilon}}^{+\overline{\varepsilon}}C(\widehat{Q}^{iR})dF(\varepsilon\mid I) \tag{5}$$

the expected (or estimated) depollution costs. The detailed computation is given in the appendix.

The left-hand-side term in (4) is the marginal cost of investing in the CBA. The right-hand-side term is the expected marginal benefit of the investment. It represents the expected marginal costs that are saved thanks to the exemption. The function $p'(.)$ concerns the supra-regional regulator's policy and its design is imposed to the regional regulator. It is common knowledge.

Proposition 2 *Assume that the regional regulator decides to ask for an exemption.*

i) A necessary condition for observing a strictly positive investment in the CBA from the regional regulator is that the exemption policy implemented by the supra-regional regulator satisfies $p'(I)<0$.

ii) A sufficient condition for an interior solution $I^{iR}<\overline{I}$ is $p''(I)>0$.

iii) If $p''(I)<0$, then either $I^{iR}=0$ or $I^{iR}=\overline{I}$.

Point i) of Proposition 2 implies that investing in the CBA must be rewarded by the supra-regional regulator in order to observe a strictly positive investment. This seems rather natural since, by assumption, the higher the investment, the higher the accuracy of the estimation of the first-best level of quality. From Point ii), the regional regulator makes a trade-off between a higher investment in the cost-benefit analysis and a higher probability of having to implement the *ex ante* imposed level of quality $\overline{Q}$. Point iii) suggests that a specific exemption policy is required to induce the highest possible investment in the CBA by the regional regulator.

Now let us focus on the supra-regional regulator's program. He must implement an exemption policy that encourages the regional regulator to choose a level of investment in the CBA that maximizes the social welfare of Region i knowing that perfect estimation of the regional first-best is not possible. Formally, he must, first, determine the level of investment, called I^{iSR}, that is optimal for Region i. Second, he must implement the exemption policy $(1-p(.))$ that leads the regional regulator to choose $I^{iR} = I^{iSR}$. Recall that, although there is no asymmetrical information, the supra-regional regulator does not own the technology for the cost-benefit analysis. Thus even though he is able to evaluate the optimal level of investment to be put in the CBA by the regional regulator, the latter is the only one who can conduct it.

The supra-regional regulator chooses the exemption policy $(1 - p(.))$ for a given region i that maximizes the expected regional welfare W^{iS}. His program is

$$\begin{aligned}\max_{I,p(I)} W^{iS} &= (1-p(I)) \int_{-\overline{\varepsilon}}^{+\overline{\varepsilon}} U_i\left(w - L_i(\widehat{Q}^{iR})\right) dF(\varepsilon \mid I) + p(I)U_i(w) - \mathcal{C}(I) \\ & \quad s.t. \quad I \arg\min \mathcal{C}(I), \qquad (6)\end{aligned}$$

By implementing an exemption policy, the supra-regional regulator recognizes implicitely that the standard $\overline{Q}$ may be too harsch for some regions regarding costs and benefits. Hence the interests of both the supra-regional regulator and the regional regulator may merge. Investing more in the cost-benefit analysis reduces the probability of a large error of estimation of the regional optimum, but the cost of such an investment is borne by these same citizens. As a direct consequence, encouraging the regional regulator to invest the maximum possible amount $\overline{I}$ in the CBA may not be the right objective of the supra-regional regulator. Finally, there exist conditions under which $I^{iSR} = I^{iR}$ at optimum.

Proposition 3 *Assume that the second order conditions of both optimization programs are satisfied.*

i) It is necessary that the exemption policy satisfies $p'(I) < 0$ and $p''(I) > 0$ in order to have $I^{iSR} = I^{iR} \leq \overline{I}$.

ii) The optimal exemption policy satisfies

$$p'(I^i) = -\frac{(1 - p(I^i))}{\left[U_i(w) - \overline{U_i}(\widetilde{\widehat{Q}^{iR}})\right]} \cdot \frac{\partial \overline{U_i}(\widetilde{\widehat{Q}^{iR}})}{\partial I} < 0,$$

with $\frac{\partial \overline{U_i}(\widetilde{\widehat{Q}^{iR}})}{\partial I} = \int\limits_{-\overline{\varepsilon}}^{+\overline{\varepsilon}} U_i' \left(w - L_i(\widehat{Q}^{iR})\right) . L_i'(\widehat{Q}^{iR}) . F_I(\varepsilon \mid I) d\varepsilon.$

If depollution costs are important compared to the decrease in the depollution utility caused by the exemption, the supra-regional regulator chooses to implement a convex exemption policy ($p''(I) > 0$). By doing so, he makes a trade-off between less risk of misestimation and less investment in the CBA. Hence the optimal level of investment may be lower than the maximum one. Besides, $U_i'(.)$ and $L_i'(.)$ appear in the design of $p'(I)$: the optimal exemption policy depends on the risk attitude and on the environmental vulnerability of the local population. This suggests that the exemption policy should be differentiated from one region to another one.

Nevertheless, because it is costly for a supra-regional regulator to implement taylored-made policies, one can expect to observe unified policies in practice. In such a context, the investment in the CBA will be different for two regions having to manage identical water bodies with identical current water quality. Recall that the effective first-best value Q^{iR} for a region i depends on her local preferences and, as a direct consequence, its estimated value depends on them too.

Proposition 4 *Consider two populations that differ either by their risk attitude or by their environmental vulnerability. None of them have access to a technology that yields a perfect estimation of the first-best level of water quality.*

The higher the risk-aversion of the population, the lower the level of optimal investment in the CBA.

The higher the environmental vulnerability of the population, the lower the level of optimal investment in the CBA.

Those results seem counterintuitive: one expects that risk averse and/or environmentally vulnerable populations are willing to pay for an accurate cost-benefit analysis. Actually, we must discuss these results by recalling those that were obtained in Section 2 with perfect information. Point i) of Proposition 1 states that the higher the marginal utility of depollution of a population, the higher her first-best level of water quality. Hence in the case of imperfect estimation, the estimator $\widehat{Q}^{iR}$ takes values in $\left[Q^{iR} - \overline{\varepsilon}; Q^{iR} + \overline{\varepsilon}\right]$ that are closer to $\overline{Q}$ compared to the estimator of a population less risk averse. In such a context, being exempted from applying $\overline{Q}$ does not induce a high decrease in the depollution utility.

This explanation also holds when considering Point ii) of Proposition 1 and the second result given by Proposition 4.

4 Discussion

Because Member States are failing, since several years, to reach a "good" level of quality of their water bodies, the European Commission decided to set a binding ambient standard for water quality through the Water Framework Directive (WFD).[9] Nevertheless each Member State can ask to be exempted from achieving the imposed standard. To do so, they must invest in a cost-benefit analysis which permits them to estimate their own regional first-best. If, for economic reasons for instance, this first-best is lower than the standard, then the Commission can (but is not obliged to) accept that the region reaches her estimated regional first-best instead of the standard. The higher the investment in the CBA, the more accurate the estimation of the regional first-best level and the higher the chance to be exempted from applying the imposed standard.

In this paper, there is no asymmetric information: imperfect information on the true first-best hold for both parties (except in Section 2 where information was perfect for both parties). Our normative analysis focused on the design of an optimal exemption policy. The supra-regional regulator (the European commission)

[9] This "good status" requirement represents the second best class of quality out of five predetermined classes: "high status", "good status", "moderate status", "poor status" and "bad status". Quality classes are based on chemical and biological considerations (for surface water) and on other quantitative considerations (for groundwater). In particular, the "high status" characterizes water which was never exposed to any anthropogenic disturbance.

must choose the exemption policy which maximizes the social welfare, knowing that the local regional regulator chooses her level of investment in the CBA as a best response to the exemption policy.

In this simple setting, we have shown that an optimal exemption population should take into account both the population's risk preferences and environmental vulnerability. Nevertheless, such a policy that is differentiated with respect to each region or each country at stake can be costly to implement in practice, so that a uniform exemption policy can be preferred by the supra-regional regulator *in fine*. In this case, it shall display a probability of exemption refusal that is decreasing and convex in the investment in the CBA (honestly) announced by the regional regulator. Moreover regional and supra-regional interests can merge on an interior solution: it is not desirable to try to reach the best estimation of the firt-best level of water quality in a given region. Actually, a trade-off is made between obtaining more information about the first-best level of water quality for a given, local, population, and the risk of being compelled to apply the high standard initially imposed by the supra-regional regulator.

In such a setting one may then expect different behaviors of regional regulators regard a given and uniform exemption policy. In particular, one might expect that a regional regulator in charge of the environmental policy of a risk-averse (and/or vulnerable) population invests more in the cost-benefit analysis than another regional regulator who has to consider a less risk averse (and/or less vulnerable) population. Actually, we obtain the reverse results: the more the risk aversion (and/or the environmental vulnerability) of a given population, the lower the optimal level of the investment in the CBA. To explain those behaviors, the conclusions that we obtained in Section 2 are useful. In this context of perfect and complete information, we have shown that more risk-averse and/or more environmentally vulnerable populations are concerned by higher first-best levels. Thus their levels are closer to the standard imposed by the supra-regional regulator. Hence an exemption that is refused to those populations is less detrimental than for others, making the investment in CBA less valuable.

Finally, these results suggest that the supra-regional regulator will have to implement harsher exemption policies for more risk averse or more damage sensitive populations if his objective is to induce high investments in the CBA. But recall that such a strategy is not always the optimal one. The optimal investment in the CBA is the result of a trade-off between the benefit of reducing the risk of misestimation and the financial cost of the investment. In some cases, the cost can counterbalance the benefits, in particular if the effective first-best level of quality is not so far from the standard or if the conditional distribution of the risk of misestimation is inelastic.

Our static model is based on a one-step game between the supra-regional regulator and the regional regulators. The supra-regional regulator announces an exemption policy to the regional regulators, who invests in the CBA, and asks for an exemption[10]. In practice and unlike this model, the European Water Framework Directive displays three periods with deadlines in 2015, 2021 and 2027. Regional regulators can ask for many exemptions in the first period, but finally, few in the term of the third period. Then, during the first period, most of the exemptions are extensions of deadline beyond 2015, fewer concern less stringent objectives. So, our one-step model concerns much more the third period, when extension of deadlines will not be possible anymore.

Still notice that concerning surface water, the exemptions from reaching the ecological and chemical good status on the first period (deadline in 2015) represent about 30% of the water bodies in Europe.[11] Cyprus, Finland, or Slovenia ask for less than 10% of exemptions, whereas Czec republic, Germany, Hungary, Luxembourg, Netherlands or Sweden more than 40%. According to our model, these differences could be explained by heterogeneities in risk-aversion and environmental vulnerability in these countries. Obviously, others factors can explain it, like the spatial heterogeneity of the environmental pressures which induces a more or less high cost to reach the good status. In our model, the cost function is identical from one regional regulator to another one.[12]

[10] Recall that we have considered only firms that decide to ask for an exemption.

[11] See Turner (2007) for a detailed discussion on the use of CBA in European environmental policies.

[12] Brouwer, Hofkes and Linderhof (2008) provide some interesting study about the estimation of the direct and indirect economic impacts of different water quality policy scenarios in the Netherlands. Besides, Hanley and alii (2006) focus on the UK water quality improvement policy. They test the transferability of benefits estimations between two small catchments.

Lastly, our model also omits an important factor which can influence the willingness to ask for an exemption, namely the fear of being penalised if the objectives are not reached. So, more exemptions can be asked if the fear of not reaching the objectives, and then of being financially penalised, increases.

APPENDIX

Proof of Proposition 1

Consider two different populations with utility U_1 and U_2. Assume that population 1 is more risk averse than population 2 in the sense of Rothschild and Stiglitz (1970): it exists an increasing and strictly concave function $f(.)$ such that $U_1(.) = f(U_2(.))$. Both populations have the same loss function in this proposition: $L_1(.) = L_2(.) = L(.)$. Let us consider Q^{2R} that satisfies (2) for Population 2. We have:

$$-L'(Q^{2R}).U_2'(w - L(Q^{2R})) - C'(Q^{2R}) = 0 \tag{7}$$

Consider the following equality:

$$\begin{aligned} & -L'(Q^{2R}).U_1'(w - L(Q^{2R})) - C'(Q^{2R}) \\ = \quad & -L'(Q^{2R}).f'(U_2(w - L(Q^{2R})).U_2'(w - L(Q^{2R})) - C'(Q^{2R}) \end{aligned}$$

With $f'(.) < 0$ and $U_2'(.) > 0$, we have $0 < f'(U_2(w)) < f'(U_2(w - L(Q^{2R}))$. Hence, by using (7) we have:

$$\begin{aligned} & -L'(Q^{2R}).f'(U_2(w - L(Q^{2R})).U_2'(w - L(Q^{2R})) - C'(Q^{2R}) \\ > \quad & -L'(Q^{2R}).\left(f'((U_2(w)) - 1\right).U_2'(w - L(Q^{2R})) \end{aligned} \tag{8}$$

With $U'^1(w) = U'^2(w)$ by assumption, we have $f'(U_2(w)) = 1$ (because $U'^1(w) = f'(U_2(w)).U_2'(w)$). Thus Expression (8) equals zero so that $-L'(Q^{2R}).U_1'(w-L(Q^{2R})) - C'(Q^{2R}) > 0$.

$>$From our assumptions, the second order conditions are satisfied. Finally, $Q^{1R} > Q^{2R}$ with Q^{1R} the optimal level of quality for population 1. This is Point i).

For Point ii), by assumption we have $L_4(.) = g\left(L_3(.)\right)$ with $g'(.) > 0$ and $g''(.) > 0$. Knowing that $L_4(\overline{Q}\ ) = L_3(\overline{Q}\ ) = 0$ we have also $g(0) = 0$. Recall that both population have the same preferences $U(.)$ over final wealth in this proposition. Let us consider Q^{3R} that satisfies (2) for Population 3, that is:

$$-L_3'(Q^{3R}).U'(w - L_3(Q^{3R})) - C'(Q^{3R}) = 0 \tag{9}$$

Consider the following equality:

$$\begin{aligned} & -L_4'(Q^{3R}).U'(w - L_4(Q^{3R})) - C'(Q^{3R}) \\ = \;& -L_3'(Q^{3R}).g'(L_3(Q^{3R})).U'(w - L_4(Q^{3R})) - C'(Q^{3R}) \end{aligned} \tag{10}$$

Since $L_4(\overline{Q}\ ) = L_3(\overline{Q}\ ) = 0$, $L_i'(.) < 0$, $g'(.) > 0$ and $g''(.) > 0$, we have $L_4(Q^{3R}) > L_3(Q^{3R})$ for any $Q^{3R} < \overline{Q}$. With $U''(.) < 0$, we obtain $U'(w - L_4(Q^{3R})) > U'(w - L_3(Q^{3R})) > 0$. Hence:

$$\begin{aligned} & -L_3'(Q^{3R}).g'(L_3(Q^{3R})).U'(w - L_4(Q^{3R})) - C'(Q^{3R}) \\ > \;& -L_3'(Q^{3R}).g'(L_3(Q^{3R})).U'(w - L_3(Q^{3R})) - C'(Q^{3R}) \end{aligned}$$

Using (9) we have:

$$\begin{aligned} & -L_3'(Q^{3R}).g'(L_3(Q^{3R})).U'(w - L_3(Q^{3R})) - C'(Q^{3R}) \\ = \;& -L_3'(Q^{3R}).(g'(L_3(Q^{3R})) - 1).U'(w - L_3(Q^{3R})) \end{aligned} \tag{11}$$

Because $\lim\limits_{Q \uparrow \overline{Q}} L_3'(Q) = \lim\limits_{Q \uparrow \overline{Q}} L_4'(Q)$ by assumption and L_4 is decreasing and more convex than L_3, we have $-L_4'(Q) = -g'(L_3(Q)).L_3'(Q) \geq -L_3'(Q)$ for any Q in $\left[0, \overline{Q}\right]$. Thus $g'(Q) \geq 1$ for any Q. Then Equality (11) is strictly positive so that $-L_4'(Q^{3R}).U'(w - L_4(Q^{3R})) - C'(Q^{3R}) > 0$ (equ. (10)). The second order conditions being satisfied we have that $Q^{4R} > Q^{3R}$. This is Point ii). ♦

Computation of the first-order-condition (4).

Differentiating the objective function $\mathcal{C}(I)$ in Program (3) with respect to I gives:

$$\frac{d\mathcal{C}(I)}{dI} = 1 + (1 - p(I)).\frac{\partial \overline{C}(\widetilde{\widehat{Q}^{iR}})}{\partial I} - p'(I)\left[\overline{C}(\widetilde{\widehat{Q}^{iR}}) - C(\overline{Q})\right] \tag{12}$$

>From (5) and after integrations by part we have:

$$\frac{\partial \overline{C}(\widetilde{\widehat{Q}^{iR}})}{\partial I} = \int\limits_{-\overline{\varepsilon}}^{+\overline{\varepsilon}} C(\widehat{Q}^{iR}) dF_I(\varepsilon \mid I) = \left[C(\widehat{Q}^{iR}).F_I(\varepsilon \mid I)\right]_{-\overline{\varepsilon}}^{+\overline{\varepsilon}} - \int\limits_{-\overline{\varepsilon}}^{+\overline{\varepsilon}} C'(\widehat{Q}^{iR}) F_I(\varepsilon \mid I) d\varepsilon$$

With $F_I(-\overline{\varepsilon} \mid I) = F_I(+\overline{\varepsilon} \mid I) = 0$ and $C'(\widehat{Q}^{iR})$ constant by assumption we have:

$$\frac{\partial \overline{C}(\widetilde{\widehat{Q}^{iR}})}{\partial I} = -C'(\widehat{Q}^{iR}) \int_{-\overline{\varepsilon}}^{+\overline{\varepsilon}} F_I(\varepsilon \mid I) d\varepsilon = 0$$

>From (12), we have finally:

$$\frac{d\mathcal{C}(I)}{dI} = 0 \Leftrightarrow 1 = p'(I) \left[\overline{C}(\widetilde{\widehat{Q}^{iR}}) - C(\overline{Q}) \right]$$

This is Condition (4). ♦

Proof of Proposition 2.

With $C(\overline{Q}\ ) = C_{\max} > \overline{C}(\widetilde{\widehat{Q}^{iR}})$, $p'(I) < 0$ is a necessary condition for $\frac{d\mathcal{C}(I)}{dI} = 0$. This is Point i). A sufficient condition for an interior solution is that the objective function be convex. We must have $\frac{d^2\mathcal{C}(I)}{dI^2} = -p''(I^{iR}).\left[\overline{C}(\widetilde{\widehat{Q}^{iR}}) - C(\overline{Q}) \right] > 0$, that is $p''(I^{iR}) > 0$. Thus in optimum $I^{iR} < \overline{I}$. This is Point i). If $p''(I) < 0$ then $\frac{d^2\mathcal{C}(I)}{dI^2} < 0$ and we have $I^{iR} = \overline{I}$ for $\frac{d\mathcal{C}(I)}{dI}\mid_{I=\overline{I}} < 0$ and $I^{iR} = 0$ for $\frac{d\mathcal{C}(I)}{dI}\mid_{I=0} > 0$. This is Point iii). ♦

Proof of Proposition 3.

For an interior solution I^{iSR}, differentiating (6) with respect to I gives:

$$p'(I^{iSR}) \left(U_i(w) - \overline{U_i}(\widetilde{\widehat{Q}^{iR}}) \right) + (1 - p(I^{iSR})) \frac{\partial \overline{U_i}(\widetilde{\widehat{Q}^{iR}})}{\partial I} - \mathcal{C}_I = 0 \qquad (13)$$

with $\overline{U_i}(\widetilde{\widehat{Q}^{iR}}) = \int_{-\overline{\varepsilon}}^{+\overline{\varepsilon}} U_i \left(w - L_i(\widehat{Q}^{iR}) \right) dF(\varepsilon \mid I)$ the expected social utility of wealth of region i when an exemption is granted. $\mathcal{C}_I = \frac{d\mathcal{C}(I)}{dI} = 0$ for an interior solution I^{iR} regard the regional optimum. And, from Proposition 2, necessary and sufficient conditions are $p'(.) < 0$ and $p''(I) > 0$. We must still check that condition (13) can be satisfied. U being increasing, we have $U_i(w) - \overline{U_i}(\widetilde{\widehat{Q}^{iR}}) > 0$. Thus, the first term is negative. With $\mathcal{C}_I = 0$, the second one must be positive. >From (**??**) and thanks to an integration by part, we have:

$$\begin{aligned}
\frac{\partial \overline{U_i}(\widetilde{\widehat{Q}^{iR}})}{\partial I} &= \int_{-\overline{\varepsilon}}^{+\overline{\varepsilon}} U_i\left(w - L_i(\widehat{Q}^{iR})\right) dF_I(\varepsilon \mid I) \\
&= \left[U_i\left(w - L_i(\widehat{Q}^{iR})\right).F_I(\varepsilon \mid I)\right]_{-\overline{\varepsilon}}^{+\overline{\varepsilon}} + \int_{-\overline{\varepsilon}}^{+\overline{\varepsilon}} U_i'\left(w - L_i(\widehat{Q}^{iR})\right).L_i'(\widehat{Q}^{iR}).F_I(\varepsilon \mid I)d\varepsilon \\
&= \int_{-\overline{\varepsilon}}^{0} U_i'\left(w - L_i(\widehat{Q}^{iR})\right).L_i'(\widehat{Q}^{iR}).F_I(\varepsilon \mid I)d\varepsilon + \int_{0}^{+\overline{\varepsilon}} U_i'\left(w - L_i(\widehat{Q}^{iR})\right).L_i'(\widehat{Q}^{iR}).F_I(\varepsilon \mid I)d\varepsilon \quad (14)
\end{aligned}$$

The last equality is obtained by noticing that $F_I(-\overline{\varepsilon} \mid I) = F_I(+\overline{\varepsilon} \mid I) = 0$.

By assumption $\widetilde{\varepsilon}$ follows a standard normal distribution on $[-\overline{\varepsilon}; +\overline{\varepsilon}]$. Thus for any $\varepsilon > 0$, we have: $f(-\varepsilon \mid I) = f(\varepsilon \mid I)$ and $-F_I(-\varepsilon \mid I) = F_I(\varepsilon \mid I) > 0$. Expression (14) becomes:

$$\begin{aligned}
\frac{\partial \overline{U_i}(\widetilde{\widehat{Q}^{iR}})}{\partial I} = &- \int_{-\overline{\varepsilon}}^{0} U_i'\left(w - L_i(\widehat{Q}^{iR})\right).L_i'(\widehat{Q}^{iR}).F_I(|\varepsilon| \mid I)d\varepsilon \\
&+ \int_{0}^{+\overline{\varepsilon}} U_i'\left(w - L_i(\widehat{Q}^{iR})\right).L_i'(\widehat{Q}^{iR}).F_I(|\varepsilon| \mid I)d\varepsilon
\end{aligned}$$

With $U(.)$ increasing and concave and $L_i(.)$ decreasing and convex, this last equality is positive. We obtain Point i).

With $\mathcal{C}_I = 0$, Equation (13) can also be written $p'(I^i) = -\frac{(1-p(I^i))}{\left[U_i(w) - \overline{U_i}(\widetilde{\widehat{Q}^{iR}})\right]}.\frac{\partial \overline{U_i}(\widetilde{\widehat{Q}^{iR}})}{\partial I} < 0$. This is Point ii). ♦

Proof of Proposition 4.

Let us apply a total differentiation to (4) with respect to I^{iR} and to Q^{iR}. We have:

$$\left[-p''(I^{iR})\left(\overline{C}(\widetilde{\widehat{Q}^{iR}}) - C(\overline{Q})\right) - p'(I^{iR}).\frac{\partial \overline{C}(\widetilde{\widehat{Q}^{iR}})}{\partial I^{iR}}\right] dI^{iR} + \left[-p'(I^{iR}).\frac{\partial \overline{C}(\widetilde{\widehat{Q}^{iR}})}{\partial Q^{R}}\right] dQ^{iR} = 0 \quad (15)$$

In the proof of the first-order condition (4) in this appendix (first proof) , we have shown that $\frac{\partial \overline{C}(\widetilde{\widehat{Q}^{iR}})}{\partial I} = 0$, $\forall I$, for a linear cost function. By denoting c the constant marginal cost, we have:

$$\frac{\partial \widetilde{\overline{C}(\widehat{Q}^{iR})}}{\partial Q^{iR}} = \int_{-\overline{\varepsilon}}^{+\overline{\varepsilon}} C'(\widehat{Q}^{iR}) dF(\varepsilon \mid I) = \int_{-\overline{\varepsilon}}^{+\overline{\varepsilon}} c.dF(\varepsilon \mid I) = c$$

Thus Expression (15) yields:

$$\frac{dI^{iR}}{dQ^{iR}} = \frac{p'(I^{iR}).c}{p''(I^{iR})\left(C(\overline{Q}) - \widetilde{\overline{C}(\widehat{Q}^{iR})}\right)}$$

With $c > 0$, $p'(.) < 0$, $p''(.) > 0$ and $\left(C(\overline{Q}) - \widetilde{\overline{C}(\widehat{Q}^{iR})}\right) > 0$ we have $\frac{dI^{iR}}{dQ^{iR}} < 0$. From Proposition 1, we know that a population with a higher marginal utility than another one (or more environmentally vulnerable) is concerned by a higher Q^{iR}. As a direct consequence, her investment I^{iR} will be lower. ♦

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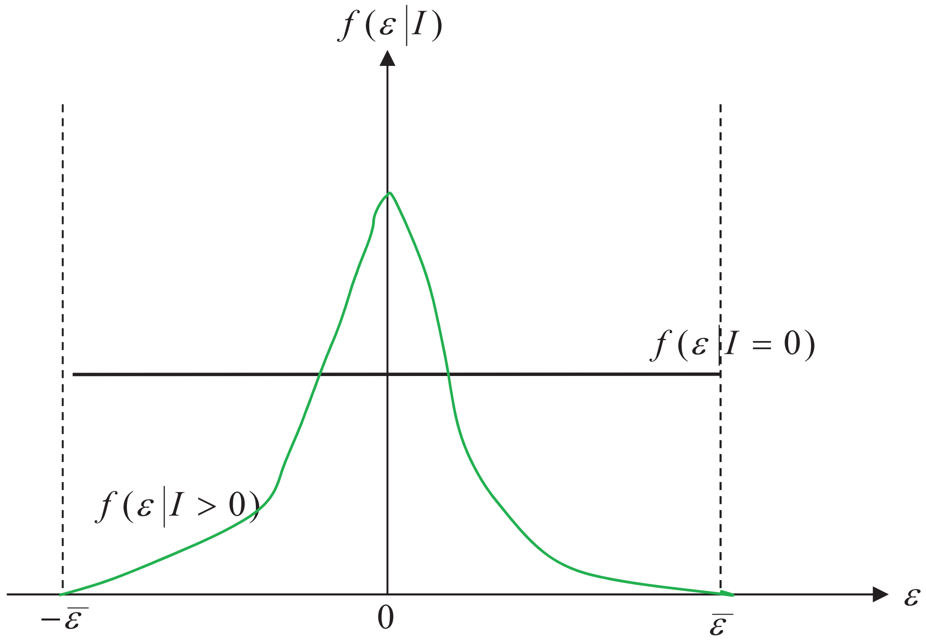

Figure 1.a. Impact of I on the density function of ε

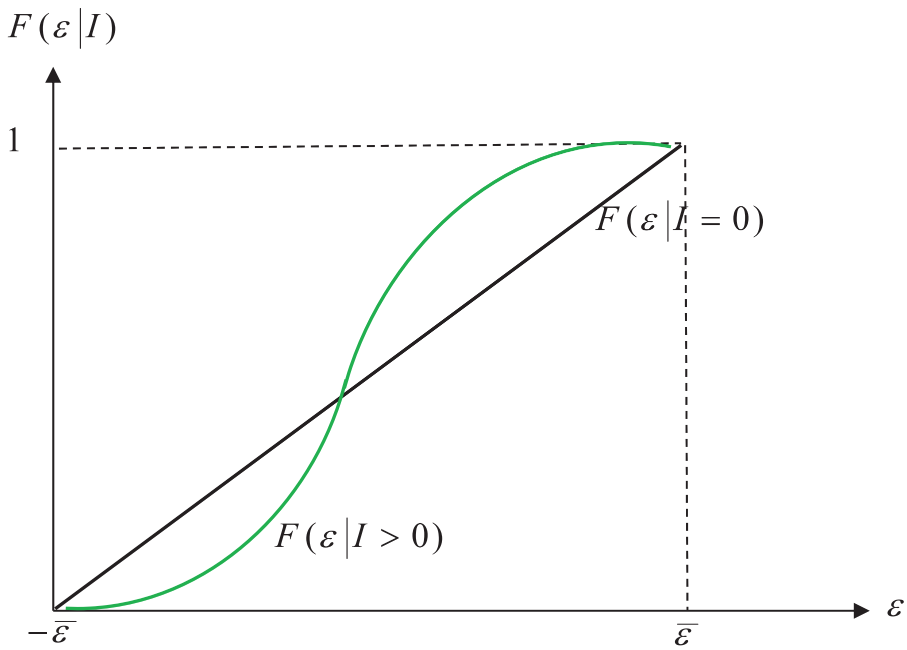

Figure 1.b. Impact of I on the distribution of ε

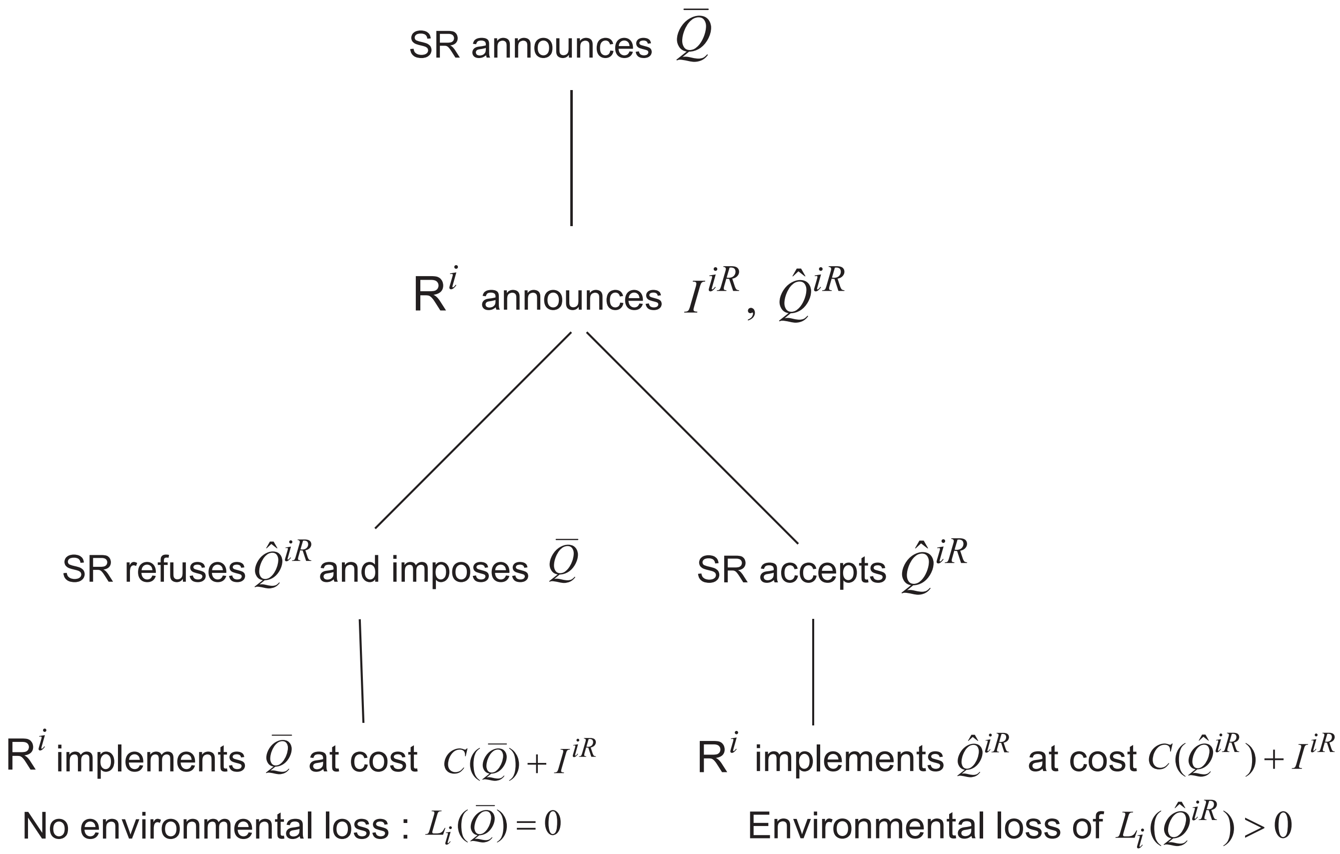

Figure 2. Timing of decisions and payoffs