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Abstract

Nonpoint source pollution is characterized by the fact that individual emissions are not observable at a reasonable cost. This constitutes a moral hazard problem. Furthermore, we explicitly consider adverse selection, a second type of asymmetric information that arises because of the difficulty to differentiate the polluters with respect to their type (marginal benefit of polluting). In this paper, we design a tradable permits market between nonpoint sources of pollution. In order to involve all the polluters contributing to a measured ambient pollution, we consider a collective performance based mechanism. This sanction mechanism is activated if the collective fails to build itself. The threat remains active along a negotiation process in order to make it converge to the equilibrium solution. Indeed, the agents are induced to reveal their real type (polluter, non-polluter) through a negotiation on their initial allocation of permits.

Keywords : nonpoint source pollution, tradable permits, collective performance, revelation mechanisms, moral hazard, adverse selection, negotiation.

JEL codes : C78, H23, Q1, Q18, Q25, Q28, Q5, L51

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1 Introduction

Nonpoint source pollution (NPSP) is characterized by the impossibility to measure individual emissions of pollution at a reasonable cost. Indeed, the random nature of pollutants' transport and accumulation renders the identification of the polluting units. This is a moral hazard issue. Furthermore, polluters can have an interest in hiding their type (individual marginal benefit of polluting). This is an adverse selection problem. Thus, the design of efficient policies to manage NPSP should account for both kinds of informational asymmetries. Three ways to overcome these informational issues have been analysed in the literature.

First, one can assume that the regulator has a sufficiently good understanding of the polluters' determinants of practice choice. This amounts to setting the analysis in a perfect information framework as proposed by Griffin and Bromley [8] in their seminal paper. These authors analyse four types of instruments to manage NPSP in a second best framework, namely incentives and norms on emissions and inputs. Griffin and Bromley [8] show that these four instruments are efficient under the assumption of perfect information[1]. Criticized afterwards for this assumption, this approach has the interest to have opened the way to a research line on the determinants of practice choice[2].

Second, one can assume that the quantity of emitted pollutant is closely linked to some individually observable and controllable entity, characteristic of the farm's activity (inputs or outputs). This forms the basis of Shortle and Dunn's analysis [19]. They show that in the case of a single farmer, only incentives on inputs are efficient. Accounting for informational asymmetries, these incentives can induce a farmer to maximize the regulator's objective function using his private information (marginal benefit of input use). When the incentive scheme is extended to n farmers, it becomes inefficient because of agents' heterogeneity. Indeed, it is then necessary to specify the incentive according to each farm's characteristics. This process can become extremely costly, thus difficult to implement.

[1] They also assume zero transaction costs.

[2] See Rio et al. [16] and Biarnès et al. [1]

Third, one can suppose that the collective of agents, located on a well-defined zone, can be approached as a single moral person. Contrary to the previous cases there is no ”denial” of the informational problem. The perfect information framework is explicitly reconstituted through the building of a collective of agents. In this perspective, the regulator uses the only piece of information he has, namely the collective contribution to ambient pollution. This idea underlies the analysis of Segerson [17]. The author studies a system of penalties, based on the variation between an aggregate level of pollution, measured at a given site, and a pollution target defined in advance. For this reason, these penalties are coined ”ambient taxes”. As ambient taxes depend on the global level of pollution, the regulator doesn't need to monitor individual compliance. Thus monitoring costs are lowered. However, as noted by Cabe and Herriges [3], it is necessary to assume that the agents are aware that their behaviour has an impact on the global level of pollution. Furthermore, this system is fiscally neutral only if the norm is respected. Indeed, if pollution is above the target, the tax revenue exceeds the value of the damage, as each agent pays a tax equal to the marginal damage. However, as the ambient tax induces each agent to choose the equilibrium level of emission, this objection is unfounded *in fine*.

In these various approaches, theoretical instruments to manage NPSP are highly centralized. This is questionable since, even without considering control costs, the efficiency of these instruments depends on random variables that skew the regulator's perception. For this reason, Segerson's analysis has been extended to decentralized solutions to NPSP, taking advantage of the building of a collective.

Pushkarskaya [14] addresses NPSP in a principal-agent framework. She treats the informational problems associated with NPSP through the design of incentive contracts; in practice a subsidy to reduce pollution awarded by the regulator (the principal) to the farmers (the agents). A critical assumption is the perfect information each farmer has about his, and the others', abatement cost functions. The combination of this hypothesis with the economic gains from cooperation incites the polluters to organize themselves as a collective. The moral hazard problem is solved and the regulator is left to observe ambient pollution only. The perfect information hypothesis solves adverse selection within the collective. Consequently, its members optimally share the subsidy awarded by the regulator to the collective.

Taylor [21] relaxes the hypothesis of perfect information within the group: NPS are assumed to know their own abatement cost functions only. The author analyses an auction mechanism between NPS and point sources of pollution, the latter taking part in a pollution permits market. More precisely, the point sources offer the NPS a contract based on their collective performance. Each NPS bids for a quantity of pollution and an associated price. The point source accepts the lowest-cost bids until his pollution target is reached. At this stage, the point source and the successful bidders agree upon an explicit contract. The contract is honoured only if the target is reached, leading the author to consider this mechanism as a collective building process. We highlight that the main problem with this mechanism is that it doesn't exclude two types of free-riding: (1) within the collective of successful bidders, (2) outside the collective, by the agents whose bid was rejected or who didn't bid. Taylor [21] makes the assumption that the agents outside the collective will stick to their previous levels of emission. This assumption is reasonable for the agents who didn't bid, as they have no abatement effort to provide to comply with the pollution norm. It is more difficult to sustain for the bidders whose offers were rejected because of their high marginal cost of depollution. Consequently, Taylor's mechanism excludes some agents who participate in the emission of pollution. It doesn't guarantee that these agents will comply with the ambient pollution target. One retains from this analysis the necessity to account for all the agents contributing to the pollution.

In this paper, we use the principle of "collective building" developed by Pushkarskaya [14] to solve the moral hazard problem. Involving all the potential polluters from a given geographical zone is crucial for the regulator to assign responsibility for a measured ambient pollution[3] to the collective as a unique moral person. For this purpose, we design a penalty system, inspired by the incentive schemes developed by Segerson [17], if the collective fails to build itself.

[3]The only information available to the regulator.

In the second step of this mechanism, an individual ambiant tax will be applied if the pollution exceeds the ambiant target. Consequently, once constituted, the collective is subject a stability constraint. In other words, the individual ambiant tax has to be designed, so that no one feels "injured". We address this aspect through the resolution of adverse selection. We consider the implementation of a tradable permits market between the NPS grouped as a collective. If the market works properly, it has the potential to allocate the pollution permits in an efficient manner in order to attain the ambient pollution target, despite an incomplete information structure [22]. This consists in a transfer of strategy from the regulator to the polluters. More precisely, the regulator allocates an initial amount of permits to the collective for free. Through a negotiation process, the members of the collective distribute this initial allocation among themselves. The free allocation creates a wealth effect that we use to design a revelation mechanism of the agents' type (polluter, non-polluter). This mechanism takes the form of a tax, associated to the market, and is activated if the ambient target is exceeded. It effectively cancels the wealth effect, under the assumption that any agent prefers telling the truth if it does not pay less that lying.

Thus, through the innovative use of mechanisms inspired from Segerson's ambient tax [17], to induce the agents to join the collective and associated to the tradable permits market, we solve both moral hazard and adverse selection in a NPSP context.

Our paper is organized as follows. In section 2, we introduce collective and revelation mechanisms. Then in section 3 we explain the building of the collective. In section 4, we present the tradable permits market and describe the negotiation process on the initial allocation of permits. This negotiation ensures the stability of the collective by inducing the agents to reveal their real type. Finally we provide somme concluding remarks in section 5.

2 Collective procedures and revelation mechanisms in the NPSP case : a review

Economic instruments to manage NPSP are difficult to design and implement, because of informational asymmetries such as moral hazard and adverse selection. Indeed, the regulator doesn't know the units involved in pollution; also he can't infer individual contributions to pollution from the observation of ambient pollution. Consequently, a regulator can only address NPSP in a second best framework. He has to leave the agents an informational rent. However, the regulator's problem is not only to choose ways to intervene when uncertainty prevails on the economic functions characterizing the agents. Indeed, nothing guarantees that they will respect the policy spontaneously.

We use collective mechanisms to solve the moral hazard problem due to the non-observability of emissions. Such mechanisms were designed to address moral hazard in teams [10] in labour economics. Holmström [10] recommends an incentive scheme linked to the performance of the group, when the players' types are independent[4]. Within a collective, free-riding is due to the opportunity to hide one's actions to avoid compliance to the collective rule. This opportunity arises from the lack of interaction between individual utility functions and collective performance. Then, implementing collective mechanisms amounts to creating these interactions. Consequently, when an agent doesn't comply with the rule, it has an impact on both his and the collective's utilities.

Collective mechanisms have been analysed in the context of NPSP ([12], [17], [24], [3], [2], [14], [21]). Applying Holmström's analysis of group moral hazard to NPS issues, Segerson [17] proposes a tax/subsidy mechanism based on the difference between a level of global pollution, measured at a given site, and a pollution target defined *ex ante*. Collective performance based instruments are attractive in reason of their theoretical properties of efficiency. However, they have hardly been implemented. The main explanation for the lack of implementation of collective mechanisms lies in the problem of defining the collective as a unique moral person.

[4] In other words, the types' domains are not interdependant.

In this paper we use group mechanisms to induce the agents to form a collective rather than to induce them to comply with a pollution target. Consequently, moral hazard is solved through the management of a variable easily observed by the regulator, ambient pollution. Once the collective is constituted, the regulator monitors collective performance, rather than individual performances. This is the first step of our mechanism.

However, we also want to design a policy instrument capable of managing adverse selection. Revelation mechanisms have been designed to mitigate adverse selection problems through incentive schemes that induce the agents to reveal their private information. Clarke [5] and Groves [9] developed the first mechanisms of this type following Vickrey's auction mechanism [23]. Among these revelation mechanisms, the Groves mechanisms [9] have both properties of efficiency and incentive compatibility. Furthermore, they are the only ones that render truthful revelation a dominant strategy [7]. However, these mechanisms have hardly been applied to the NPSP context. Taylor [21] proposed an auction mechanism between point sources (principal) and NPS (agents) to solve adverse selection. However, as we have already stressed, this mechanism sets aside the agents whose bids were rejected by the principal. The revelation mechanism we develop in this paper benefits from the wealth effect induced by the free initial allocation of permits. In our approach, the free-rider is a non-polluter who has an interest to lie in order to benefit from the sale of the permits he holds in excess. We propose to design a mechanism that cancels this wealth effect so that the agents are induced to tell the truth if it does not pay less than lying.

3 First step : building the collective

Until now, mechanisms to induce agents to participate in agricultural NPSP management programs have consisted in voluntary subsidized approaches. They include agri-environmental measures (1991), integrated to the common agricultural policy through the directive no. 2078/92 (1992), farm contracts such as "Contrat Territorial d'Exploitation" (1999) and more recently "Contrat d'Agriculture Durable" (2002) in France. Based on voluntary participation, these approaches do not guarantee that all the agents under consideration participate in the program. However, to manage NPS in particular in the context of water quality, it is crucial to ensure that all the potential polluters join the collective.

Technically, we consider situations where only the ambient pollution is measured, at the outfall of a catchment for instance. Constituted by the aggregation of individual contributions to pollution, it is compared to a socially accepted norm. If the ambient pollution norm is exceeded, then the measured pollution is the only legally relevant information that the regulator can use against the agents, considered as a unique moral person. This moral person is identified, owns the property rights to the emission and consequently can be held responsible for the ambient pollution. Hence the moral hazard problem is solved.

Building the collective raises the question of how its members will share the depollution effort, or the penalty resulting from non-compliance to the collective norm. In other words, formulating a sharing rule of the depollution effort is a condition of stability of the collective. Before that, we address how the regulator can substitute a unique moral person to the dispersed agents located in the zone affected by pollution. For this purpose, we use a type of ambient tax, as developed by Segerson [17], to sanction the agents outside the group differently from those joining it, when the ambient pollution norm is not respected.

The threat is formulated as follows. Let x be the ambient pollution measured at the outfall of a catchment and x_0 the socially accepted ambient pollution. The tax inducing the agents to join the collective is:

$t_i = t(x - x_0) = D'(x - x_0)$ if $x > x_0$,

$t_i = 0$ otherwise

with D' the marginal damage function.

An agent will pay this tax if the ambient pollution norm is violated, unless this agent joins the collective. The will to reduce pollution, expressed by the choice to join the collective, justifies the recourse to another sanctioning mechanism $t_i^{collective}$ more favourable to the agents[5].

$$\forall i \text{ , max } \pi_i = \begin{cases} F_i(x_i) - t_i^{collective} \text{ if in the collective} \\ F_i(x_i) - \gamma D'(x - x_0) \text{ otherwise} \end{cases}$$

where F is the production function, x_i is agent i's pollution and γ is a parameter measuring the environmental policy's credibility[6], $0 \leq \gamma \leq 1$[7].

With $\gamma D'(x - x_0) \gg t_i^{collective}$, any rational agent will prefer to join the collective rather than face an ambient tax if the regulator's threat is credible. This tax is purely persuasive: it is applied only if the collective fails to build itself. This tax ensures that each agent would be worse off in any other situation than joining the group. The assumption of individual rationality ensures that no one will stay out of the collective[8].

4 Second step : market for tradable permits and negotiation on the initial allocation

To address moral hazard, we proposed to implement a mechanism to induce all the agents to join a collective entity recognized by the regulator. This moral person endowed with complete rights is responsible and punishable in case of non-compliance with the pollution target. Of course this penalty will be shared out between the members of this entity. Without any mechanism to identify the responsibilities of each member, the collective may not be robust to deviation. At this stage, we have no such mechanism to ensure the stability of the collective. This section is devoted to the building of such a stability mechanism.

What is at stake? We need a policy instrument to differentiate the members of the collective according to their type. Indeed, without the possibility to

[5]in case the pollution norm is exceeded.

[6]See Segerson and Wu [18].

[7]It is possible to add a parameter reflecting individual beliefs about the others' strategies. Then we would compare the possible solutions given the probability formulated by one player that the others choose a depollution strategy.

[8]However, one can admit the existence of agents outside the collective, having turned to another activity, either non-polluting or controllable.

assign a permit to each agent, it is not possible to allocate his responsibility to each agent a priori. The best instrument will be the one that induces each agent to reveal his abatement cost function truthfully. As this information is private, the regulator can only be ”information taker” - in the extreme case, he could even abstain from trying to get this information. Adverse selection is directly managed by the agents rather than by the regulator. Nonetheless, the outcome of this exchange of information between the agents is of interest to the regulator - it is a condition of stability of the collective.

If each agent's rights were verifiable, a naturally efficient instrument to reach the stability of the collective would be the tradable permits market, because it is a decentralized policy instrument. Instead of searching for information, the regulator lets the agents reveal their type through the market. Compared to standard instruments, the interest of this solution appears when the regulator does not have enough information about the potential maximum emissions for each farm. The regulator sets an ambient pollution norm and distributes the corresponding number of permits according to a predetermined criterion.

As the rights are not verifiable, can we use such instrument anyway?

In their initial version, permits are introduced through an auction mechanism. Such a mechanism implies a high initial cost for the farms we can reduce by a free initial allocation. Indeed, the equilibrium is reached whatever the initial allocation [22] if the market is competitive[9]. However, this free allocation places the beneficiaries in different position, depending on their abatement costs. In case of low abatement costs, the beneficiary will turn into a seller of the permits he holds in excess. Thus this process generates a wealth effect in his favour. We exploit this wealth effect to incite the agents to reveal their type.

[9]However, this poses the question of the optimal size of the market.

4.1 Market for pollution permits: functioning and wealth effect

To ensure the stability of the collective the agents must be treated according to their type. This necessitates an exchange of information between the members of the collective. With heterogeneous agents with respect to their abatement costs functions, the market for tradable permits is an efficient decentralised instrument to do it. Under the hypothesis that the pollution permits are individually verifiable, the market sets the individual emission levels. Then the agents exchange permits in such a way that the marginal cost of depollution of each agent after exchange equals the price of the permit (see figure 1).

Let ξ_i be the initial allocation of permits, x_0 the socially accepted ambient pollution target and $D(x_0)$ the corresponding damage, such that:

$$\sum_i \xi_i = x_0 \;\Leftrightarrow\; D(x_0) = 0$$

Figure 1 illustrates how agents adjust to the market's equilibrium price.

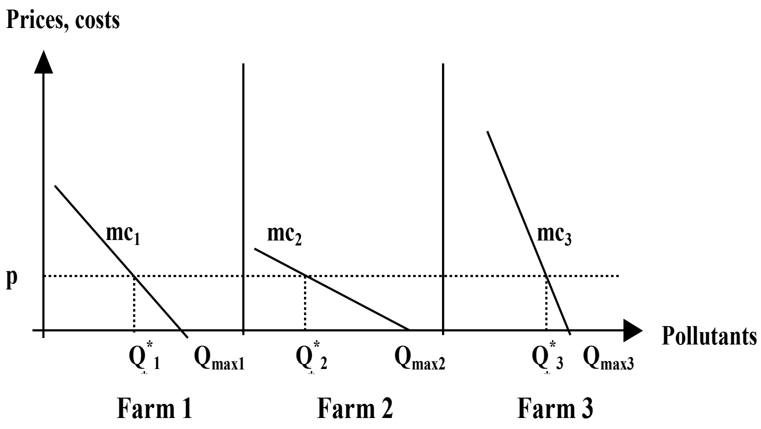

Figure 1: Farms' adjustment to the permits' price

$Q_{max\,i}$: pollution level without any reduction policy,
Q_i^* : pollution level after implementation of the market,
mc : marginal cost,

p : exchange price.

At the equilibrium, the marginal cost of pollution mc is equal to the permit price p, for each agent:

$$\forall i \ , \ mc_1 = mc_2 = ... = mc_n = p \tag{1}$$

and $\sum_i Q_i^* = x_0$

Assuming that these permits are individually verifiable, an agent's profit function is:

$$\pi_i = F_i(\xi_i^u) + p(\xi_i - \xi_i^u) - t_i^{collective} \tag{2}$$

subject to:

$$\xi_i - \xi_i^u = \xi_i^e$$
$$\sum_j \xi_j = x_0 \ , \ j = 1, ..., i, ..., n$$

ξ_i^u : permits used,
F_i : private production function,
$t_i^{collective}$: ambient tax activated when the pollution target is exceeded.

$\xi_i - \xi_i^u$ is then the quantity of permits exchanged ξ_i^e, either purchased or sold, at the market price p. The initial allocation creates a wealth effect for the sellers of permits, the less polluting agents. Thus it is rational for them to participate in such a scheme. However, it induces a supplementary cost for the buyers (see figure 2). As illustrated in figure 2, even if the investments for abatement are not accounted for, a polluter Farm 1 (weak marginal cost of production mc_1) has to buy permits to cover his emissions.

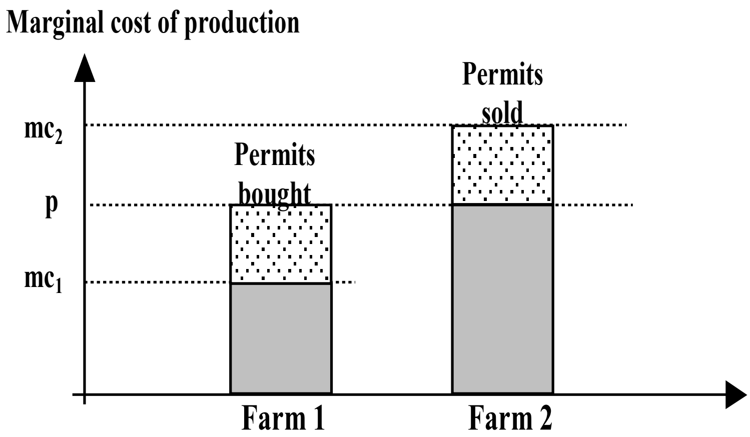

Figure 2: Marginal cost's adjustment to the permit price

The problem is that this mechanism is individually rational if the permits (and their use) are verifiable, but not in the unverifiable case, which focuses our interest.

4.2 Negotiation on the initial allocation

In this section, we use the wealth effect identified in the previous section to induce the agents to reveal their type. As an arbitrary allocation rule doesn't prevent the formation of the market equilibrium [22], we design this allocation rule as a revelation mechanism. Therefore, the wealth effect created by the adoption of a particular allocation rule can be used as a revelation mechanism. Thus, the regulator who doesn't have any particular criterion on the initial distribution of permits involves the members of the collective in a negotiation process to choose the appropriate allocation rule.

In section 4.2.1 we describe the negotiation process. Then in section 4.2.2 we illustrate the strategic behavior leading to the wealth effect in the negotiation process. Finally in section 4.2.3 we describe the revelation mechanism that deletes the wealth effect and leads to the stability of the group.

4.2.1 Negotiation process

We interpret this negotiation mechanism as a bargaining game. A set I of n players have to agree on an allocation ξ, $\xi \in \Xi \subset \Re^n$, with :

$$\xi = [\xi_1, \xi_2, ..., \xi_i, ..., \xi_n] \text{ , such that } \sum_{i=1}^{n} \xi_i = x_0$$

The number of elements in ξ equals the number of players. At the even rounds of the game, the players simultaneously propose $\xi^{(i)}$. This proposal is a vector such that :

$$\xi^{(i)} = [\xi_1^{(i)}, \xi_2^{(i)}, ..., \xi_i^{(i)}, ..., \xi_n^{(i)}]$$

Each player announces the amount of permit that he wishes to allocate to each other player. This proposal results from the individual program of the agent:

$$\forall i, \max_{\xi_i^u, \xi_i^e} \pi_i(\xi_i^u, \xi_i^e)$$

subject to:

$$\xi_i^{(i)} - \xi_i^u = \xi_i^e$$

$$\sum_{j=1}^{n} \xi_j^{(i)} = x_0 \text{ with } j = 1, ..., i, ..., n.$$

Because the constraint $\sum_{j=1}^{n} \xi_j^{(i)} = x_0$ connects the players' attributions, the maximization of the individual program requires that each player make a proposal for all the players. Alternating proposal phases, even rounds $(k, k+2, ...)$, and acceptance phases, odd rounds $(k+1, k+3, ...)$, the bargaining process converges towards a solution of agreement respecting the collective constraint $\sum_{i=1}^{n} \xi_i = x_0$. The conditions of convergence were described in Quérou et al. [15].

At the odd rounds, the agent either lets Nature select one of the proposals or rejects the proposals; if one player rejects a proposal, the game continues.

A rationale to reject a proposal is if the agent believes that a proposal $\xi_{k+2}^{(i)}$ exists such that the resulting utility is greater than the utility he would obtain from any of the proposals expressed at the previous even round:

$$\forall j \neq i,\ U_i(\xi_k^{(j)}) \leqslant U_i(\xi_{k+2}^{(i)}),\ i, j \in I$$

and that it is acceptable by the other players. In other words, the payoff from this proposal is at least equal to their expected payoff, deduced from the proposals expressed at the previous even round weighted by the probability w_i of being selected by Nature:

$$\forall j, U_j(\xi_{k+2}^{(i)}) > E(U_j)_{k+1}$$

with $E(U_j)_{k+1} = \sum_{h=1}^{n} w_h U_j(\xi_k^{(h)})$ and $\sum_{h=1}^{n} w_h = 1 \qquad h, i, j \in I$

Then each player's program is:

$$\forall i,\ \max_{\xi \in C} U_i(\xi_{k+2}^{(i)}) \text{ with } C = \bigcap_j C_j : \{\forall j,\ U_i(\xi_{k+2}^{(i)}) \geqslant E(U_j)_{k+1}\}$$

This algorithm converges towards a Pareto-optimal solution [15]. However, among the candidate Pareto-solutions, the players reach a solution that depends on the initial proposals and, more precisely, the strategic manipulations that can be implemented by the non-polluter. In the next point we show how the non-polluters behave strategically with respect to the negotiation process to benefit from the wealth effect.

4.2.2 Negotiation on the quantity of permits and strategic behavior

In a negotiation round, the players simultaneously propose the allocation $\xi^{(i)} = \{\xi_j^{(i)}\}_{j=1,\ldots,n}$ they think preferable for each player contributing to the pollution with $\sum_{j=1}^{n} \xi_j^{(i)} = x_0$. The assumption of individual rationality leads to the following individual program:

$$\forall i,\ \max_{\xi_i^u, \xi_i^e}\ \pi_i(\xi_i^u, \xi_i^e)$$

subject to:

$$\xi_i^{(i)} - \xi_i^u = \xi_i^e$$

$$\sum_{j=1}^{n} \xi_j^u \leq x_0 \text{ with } j = 1, ..., i, ..., n.$$

$$\xi^{(i)} \in C$$

Formulating the Lagrangian:

$$L_i = F_i(\xi_i^u) + \beta(\xi_i - \xi_i^u - \xi_i^e) + \lambda(x_0 - \sum_{j=1}^{n} \xi_j^u) + \mu(\xi^{(i)} \in C)$$

Agent i maximizes his individual profit assuming that all the agents comply with the collective rule. Assuming convergence,

$$L_i = F_i(\xi_i^u) + \beta(\xi_i - \xi_i^u - \xi_i^e) + \lambda(\sum_{j \neq i} \xi_j^{(i)} - \sum_{j \neq i} \xi_j^u) + \lambda(\xi_i^{(i)} - \xi_i^u) + \mu(\xi^{(i)} \in C),$$

and as the decision variables of all the other players are taken as given for agent i,

$$L_i = F_i(\xi_i^u) + \beta(\xi_i - \xi_i^u - \xi_i^e) + \lambda(\xi_i^{(i)} - \xi_i^u) + \mu(\xi^{(i)} \in C)$$

λ satisfying $\lambda \perp (\sum \xi_j^{(i)} - \sum \xi_j^u)_{j=1,...,n}$ is interpreted as the permits' price.

To describe the negotiation process, suppose there are two players, each of a type, high or low polluter, to which we will refer in the remainder of this paper as "polluter" and "non-polluter". The type is unknown to the regulator, and not completely observable by the other player. The latter can only suspect whether the other has the possibility to modify his technology and become a non-polluter.

Each player has a utility function $U_i(\ ), i \in \{np, p\}$ such that $U_i([\xi_i, \xi_{-i}])$. Note $\xi^{(i)}$ the allocation proposed by agent i at the current round of negotiation $[\xi_i, \xi_{-i}]^{(i)}$. This proposal depends on the type and the opportunity to cheat of the agent.

We consider the following linear utilities:

$U_{np} = 3\xi + p(\xi - 1)$, for the non-polluter

$U_p = \frac{1}{2}\xi + p(\xi - 4)$, for the polluter

If player i, whatever his type, announces himself as a polluter, he asks for "all" ($\xi_i^{(i)} = 4$), otherwise he asks for ($\xi_i^{(i)} = 0$) or ($\xi_i^{(i)} = 1$), respectively for the polluter and the non-polluter agent. The first term on the RHS of the utility measures the gain resulting from used permits and the second term on the RHS measures the gain resulting from an exchange of permits, when it is needed.

Presented in normal form, the game at the first round of negotiation is the following bi-matrix:

Table 1: the players' strategies

Proposals		Polluter	
		Polluter	Non-polluter
Non-polluter	Polluter	$\xi^{np}[4,0]$, $\xi^{p}[0,4]$	$\xi^{np}[4,0]$, $\xi^{p}[4,0]$
	Non-polluter	$\xi^{np}[1,3]$, $\xi^{p}[0,4]$	$\xi^{np}[1,3]$, $\xi^{p}[4,0]$

This leads to the following utilities resulting from the exchange of permits:

Table 2: gains resulting from an exchange of permits

Utilities		Polluter	
		Polluter	Non-polluter
Non-polluter	Polluter	$12+3p$, 2	$12+3p$, $-4p$
	Non-polluter	3, 2	3, $-4p$

Whatever the non-polluter's strategy, the polluter loses from not announcing himself as a polluter, consequently he will never lie. This is not the case for the non-polluter, who benefits from the wealth effect induced by the allocation of tradable permits. Thus, convergence doesn't guarantee that strategic handling is avoided. As long as the negotiation concerns the allocation of permits only, we cannot design a mechanism that induces both types of agents to tell the truth.

In this section, we showed the dependance of agents utilities and the permits price. Now, we treat this dependance to build a revelation mechanism that leads the agents to tell the truth.

4.2.3 Negotiation on both permits and price

During the bargaining process, Nature selects the player that formulates his allocation proposal. Assuming equal probabilities to be selected by Nature $w_i = \frac{1}{n}$, each player's expected utility can be calculated. For $n = 2$ we have:

$$EU_i = \frac{1}{2}U_i(proposal\ i) + \frac{1}{2}U_i(proposal\ \ -i)$$

leading to :

$$EU_{np} = \frac{15}{2} + \frac{3}{2}p$$

$$EU_p = 1 - 2p$$

It can be noted that a change of price has an opposite effect on the agents' expected utilities. In particular, a price increase reinforces the wealth effect of the non-polluter.

We make use of this property to induce the non-polluter to declare himself non-polluter, by introducing the permit price in the vector of negotiated arguments, cancelling the wealth effect. Such a mechanism can be of the following form, the regulator announcing to the agents:

"You can negotiate on the quantity of permits and the associated price; if the pollution target is exceeded, you will pay the permits you received at the price resulting from the negotiation."

This mechanism can be described as follows. The players simultaneously propose a vector of permits and price $[\xi_i, \xi_{-i}, p]^{(i)}$. If the ambient norm is exceeded, this vector will be interpreted as the penalty imposed on each player. Considering agent $i's$ proposal, his penalty will be $t_i^{collective} =$

$\xi_i^{(i)}\, p^{(i)}$ and the penalty to be imposed on the others $t_{-i}^{collective} = \xi_{-i}^{(i)}\, p^{(i)}$.

Consider the variation of utility resulting from a variation of allocated permits and price (Table 3).

Table 3: Variation of utility with respect to the number of permits and the price

Permits	$\xi = 0$			$\xi = 1$			$\xi = 2$			$\xi = 3$			$\xi = 4$		
Price	0.5	1	3	0.5	1	3	0.5	1	3	0.5	1	3	0.5	1	3
Agents															
Non-polluter	2.5	2	0	3	3	3	3.5	4	6	4	5	9	4.5	6	12
Polluter	0	0	0	0.5	1	3	1	2	6	1.5	3	9	2	4	12

This table shows that for a null allocation of permits and a price between $[0.5, 3]$ the non-polluter will buy permits and his utility drops when the price increases. If the price is above 3, he will not buy any permit and his utility will be null. For an allocation of one permit and a price between $[0.5, 3]$ the non-polluter will use his permit and receive a constant utility of 3. Beyond one permit, he will sell the excess of permits and thus his utility will increase with the price. This is *"the quantity-based wealth effect"*.

For a null allocation of permits and a price between $[0.5, 3]$ the polluter will not buy permits considering a permit gives a utility of 0.5 only. For a positive allocation of permits and a price between $[0.5, 3]$ the polluter will sell his permits and will gain more than if the permit was used for production. His utility increases with the price. This is *"the price-based wealth effect"*.

From this table, we see that the wealth effect can come at the same time from the quantity and the price. Thus we show the need for taking into account these two variables to delete the wealth effect. Hence the interest to consider a penalty encompassing both items $\xi_i^{(i)}\, p^{(i)}$.

Now let's introduce the price into a penalty mechanism if the pollution target is exceeded. The agents' utilities are then $U_i - \alpha(p\,\xi_i)$ where $\alpha = 1$ if pollution is above the target, $\alpha = 0$ otherwise.

Table 4: Utilities accounting for the penalties

Permits	$\xi = 0$			$\xi = 1$			$\xi = 2$			$\xi = 3$			$\xi = 4$		
Price	0.5	1	3	0.5	1	3	0.5	1	3	0.5	1	3	0.5	1	3
Agents															
Non-polluter	2.5	2	0	2.5	2	0	2.5	2	0	2.5	2	0	2.5	2	0
Polluter	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

On the one hand, when an agent is subject to the price-based wealth effect, his utility reduces to zero. This is the case of the polluter agent. Thus the agent will reveal his marginal benefit. On the other hand, when an agent is subject to the quantity-based wealth effect his utility drops whatever the initial allocation, it is constant. This is the case of the non-polluter agent. Thus the agent will reveal the quantity he needs.

When the penalty is applied, the polluter is indifferent to both allocated quantity and price. The same analysis holds for the non-polluter who will choose in this case the allocation corresponding to his type which is $\xi = 1$, and the polluter will have an allocation $\xi = 3$. For these allocations the polluter will choose $P = 0.5$ that will bring back 1.5 to him and the non-polluter will also choose $P = 0.5$ that will bring back 3 to him.

Thus, the success of the revelation mechanism relies on the existence of a sanction announced by the regulator. Under this condition, the most favorable strategies are for each agent to ask for a quantity of permits adapted to his type. We can consider this mechanism as a revelation mechanism.

In the next section, we describe the first order conditions of an agent whether the penalty is applied or not.

4.3 Individual rationality

In this section we analyze the individual rationality leading to the convergence in the negotiation process. We consider two cases: first, the agent considers that the penalty isn't applied; second, the agent considers that tthe penalty is applied.

Let $F_i(\xi_i^u) = a^i \xi_i^u - b^i (\xi_i^u)^2$ be agent $i's$ production function.

ξ_i^u : the amount of input used for the production of a good by the agent i.
ξ_i : initial amount of permits obtained by the agent i.
$\xi_i^e = \xi_i - \xi_i^u$: the amount of permits exchanged by the agent i. If $\xi_i^e \leq 0$, i buys permits and if $\xi_i^e \geq 0$, i sells permits.
$p\xi_j$: applied penalty if $\sum_j \xi_j^u \geq x_0$

Agent i's maximization problem:

$$\max_{\xi_i^u, \xi_i^e} U = a\xi_i^u - b(\xi_i^u)^2 + p\xi_i^e - \alpha p\xi_i,$$

$\alpha = 0$ without penalty.
$\alpha = 1$ otherwise.

If the penalty isn't applied : $\alpha = 0$

In this first case the agent is compliant and the penalty isn't applied.

$$\max_{\xi_i^u, \xi_i^e} U = a\xi_i^u - b(\xi_i^u)^2 + p\xi_i^e$$

subject to:

$$\xi_i - \xi_i^u = \xi_i^e \qquad \text{(Individual compliance)}$$

$$\sum_{j=1}^{n} \xi_j = x_0 \text{ with } j = 1, ..., i, ..., n \qquad \text{(Collective compliance)}$$

The Lagrangian is:

$$L = a\xi_i^u - b(\xi_i^u)^2 + p\xi_i^e + \beta(\xi_i - \xi_i^u - \xi_i^e) + \lambda(x_0 - \sum_{j=1}^{n} \xi_j)$$

where β and λ are lagrangian multipliers.

$$\frac{\partial L}{\partial \xi_i^u} = a - 2b\xi_i^u - \beta = 0$$

$$\Longrightarrow \xi_i^u = \frac{a - \beta}{2b}$$

$$\frac{\partial L}{\partial \xi_i^e} = p - \beta = 0$$
$$\implies \beta = p$$

The individual compliance shadow cost equals the price of exchanged permits.

$$\implies (\xi_i^u)^* = \frac{a-p}{2b} \text{ : the optimal amount of permits used.}$$

$$\frac{\partial L}{\partial \xi_i} = \beta - \lambda = 0$$
$$\implies \beta = \lambda = p$$

To maximize utility, the individual compliance shadow cost should be set at the collective compliance shadow cost, itself equal to the price of exchanged permits.

$$\frac{\partial U}{\partial \xi_i} = p \;:\; \forall p \neq 0 \implies \xi_i \nearrow \Rightarrow U \nearrow$$

The individual utility increases with the quantity of permits obtained through the negotiation process.

$$\frac{\partial U}{\partial p} = \xi_i - (\frac{a-p}{2b}) \begin{cases} \text{If } \xi_i \geq \xi_i^u \text{ : seller} & \implies \forall p \neq 0\,;\; p \nearrow \Rightarrow U \nearrow \\ \text{If } \xi_i < \xi_i^u \text{ : buyer} & \implies \forall p \neq 0\,;\; p \nearrow \Rightarrow U \searrow \end{cases}$$

The relationship between utility and permit price depends on the agent's status: for instance, utility increases with price when the agent is a permit-seller.

If the penalty is applied : $\alpha = 1$

In this second case the agent is compliant but the collective is not. Consequently penalty is applied.

$$\max_{\xi_i^u, \xi_i^e} U = a\xi_i^u - b(\xi_i^u)^2 + p\xi_i^e - p\xi_i$$

subject to:

$$\xi_i - \xi_i^u = \xi_i^e$$

The lagrangian is:

$$L = a\xi_i^u - b(\xi_i^u)^2 + p\xi_i^e - p\xi_i + \beta(\xi_i - \xi_i^u - \xi_i^e)$$

$$\frac{\partial L}{\partial \xi_i^u} = \frac{a-\beta}{2b} = 0$$

$$\implies \xi_i^u = \frac{a-\beta}{2b}$$

$$\frac{\partial L}{\partial \xi_i^e} = p - \beta = 0$$

$$\implies \beta = p$$

$$\implies (\xi_i^u)^* = \frac{a-p}{2b} \text{ : same as the previous case.}$$

$$\frac{\partial U}{\partial \xi_i} = 0 \implies \forall\, p\,, \ \forall\, \xi_i \Rightarrow U = Cst$$

When the penalty is applied, the wealth effect is deleted, so that the negotiated permits have no impact on utility.

$$\frac{\partial U}{\partial p} = (\frac{a-p}{2b}) \implies \forall\, \xi_i \begin{cases} \text{If } p \in [0,a] \implies p \mapsto a \Rightarrow U \mapsto 0 \\ \text{If } p > a \implies U = 0 \end{cases}$$

However, if $p \leq a$, utility tends to zero when the price increases and if $p > a$ then the utility equals zero.

In the process of developing his proposal at each round of the negotiation process, the agent will weight these cases with respect to his expectations regarding the occurence of excessive pollution. Assuming that the wealth effect is cancelled, the agent prefers telling the truth if it doesn't pay less than lying. So by combining the fact that the penalty deletes the wealth effect and that the agents must converge at the same time in quantity and the price, the negotiation process builds the context of perfect information. Indeed, at each even round each player provides his marginal cost which correspond to the quantity proposed and thus helps the other players to build his production function. When the players propose the same price in the negotiated vector, they will have reveals their real type and thus reach the equilibrium.

5 Conclusion

In the NPSP literature, there is a growing interest for collective approaches inspired from Segerson [17]. The exploratory nature of these instruments explains that divergent proposals coexist in this research area. Indeed, some authors assume perfect information [14] while others design revelation mechanisms [21]. However, the interest of collective approaches is undeniable. It results from the possibility to assign well-defined and verifiable rights to a moral person as a way to overcome moral hazard. This allows setting the analysis in the well understood context of point source pollution. Then the remaining task is to allocate this right between the members of the collective. In particular, this implies distributing the advantages and penalties attached to this allocation. Even limited, this problem is difficult to address because adopting a particular allocation rule impacts on the acceptation of the mechanism by the agents. This will affect the stability of the collective.

The approach we propose is based on an individual assessment, by each member of the collective, of his contribution to the collective compliance to the norm. The assessment consists in a bargaining mechanism that induces each party to account for the others' requirements - expressed in terms of expected utility at each round - to avoid the penalties imposed if the collective fails to build itself. Thus, through the innovative use of mechanisms inspired from Segerson's ambient tax [17], to induce the agents to join the collective and associated to the tradable permits market, we solve both moral hazard and adverse selection in a NPSP context. Another innovation lies in the role taken by the non-polluter. Indeed, his interest is to keep his informational advantage, translated into a wealth effect because of the free initial allocation of permits. Following the constructive spirit of our approach, we showed that it is possible to design a revelation mechanism that cancels this wealth effect and induces the non-polluter to reveal his preferences. Note that the implementation of our mechanism necessitates the direct involvement of the regulator at both levels of definition of the penalties: within and outside the collective. Thus the mechanism is highly dependant on the credibility of the regulator's policy.

Next, our attention will focus on implementation issues. We will address them by undertaking simulations basing on a database constituted by Carmona [4]. We will use experimental economics in the vein of Spraggon [20], Cochard et al. [6] and Poe et al. [13] associated to approaches in terms of accompanying modelling and role playing games as developed by Le Grusse et al. [11].

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