Tradable Permits Under Threat to Manage Nonpoint Source Pollution

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Abstract

In this article we treat the problem of nonpoint source pollution as a problem of moral hazard in group. To solve this kind of problem we consider a group performance based tax coupled to tradable permits market. The tax is activated if the group fails to meet the ambient standard. So the role of the tax is to provide an incitation to ensure that the agents provide the abatement level necessary to achieve the standard. The role of the tradable permits market is to distribute effectively this abatement level through the price of the permits which rises with the exchange of the permits.
Keywords - **nonpoint source pollution, ambient tax, tradable permits market.**

1 Introduction

Nonpoint source pollution is characterized by the fact that individual emissions cannot be controlled at a reasonable cost. Hence the failure of traditional economic instruments (taxes, standards, tradable permits markets) to solve this type of problem. Indeed, one cannot differentiate the tax and the standard according to the characteristics of each agent; furthermore one cannot dissuade an agent from free-riding when a tradable permits market is applied because an agent's individual contribution to ambient pollution is not identifiable. Consequently, the inobservability of individual performances in the case of nonpoint source pollution induced the economists to consider instruments based on collective performance (ambient pollution). However, the heterogeneity of the agents implied in nonpoint source pollution deteriorates the effectiveness of ambient mechanisms as it poses the problem of the distribution of abatement levels between these agents.

To solve the problem of moral hazard resulting from nonpoint source pollution, Meran and Schwalbe [3] and Segerson [5] propose a system of collective incentives based on the difference between the level of total pollution measured at a given site and a standard of maximum pollution fixed in advance. These ambient mechanisms were supported by several experimental studies ([4], [7] and [1]) which showed the effectiveness of such approaches to achieve the depollution goal.

However, the heterogeneity of the agents responsible for nonpoint source pollution affects the economic effectiveness of this mechanism. Indeed, as the regulator cannot know the individual abatement level that an agent must support, he cannot achieve the depollution goal at a lower cost. One of the possible solutions to control this type of asymmetry is the implementation of a decentralized economic instrument. Instead of seeking information, one lets the farmer reveal it through the market of tradable permits. The advantage of this solution, compared to a standard, appears when the regulator does not have sufficient information on individual emissions and this cannot differentiate the standard according to each agent's characteristics. In this case he sets a total standard of ambient pollution and lets the market fix the individual emissions levels. This corresponds to a transfer of strategy from the regulator towards the polluters - a decentralized instrument.

In this article we design a tradable permits market associated to an ambient tax in the event of non-compliance to a pre-determined standard. On the one hand, the role of the tax is to ensure that the agents will provide the necessary collective abatement level to achieve the total depollution goal. On the other hand, the market for tradable permits has the role of effectively distributing this collective abatement level between the agents. The permit price which emerges from the exchanges is the standard of distribution of the abatement level.

Segerson and Wu [6] also used a nonpoint source pollution control instrument associated to a threat if the depollution goal is not achieved. These authors proposed a voluntary mechanism of nonpoint source pollution abatement, however, if the depollution goal is not achived then the regulator engages in costly information seeking about individual emissions. In fact, Segerson and Wu [6], make the assumption that the damage caused by pollution is higher than the cost of follow-up and control of the individual emissions. Contrary to Segerson and Wu [6], in this article we assume that the cost of control and follow-up of the individual emissions is prohibitory and/or impossible to implement.

This article is organised as follows. In section 2, we solve the group moral hazard issue characteristic of nonpoint source pollution, by determining the level of the ambient tax that agents will face if the ambiant norm is not respected. Then in section 3, we solve the adverse selection problem by designing a tradable permits market that induces the agents to reach the depollution goal at the lowest cost. Then in section 4 we discuss the results and provide some concluding remarks.

2 Group moral hazard

The fact that individual emissions are not observable while collective pollution (ambient pollution) is, is a typical case of group moral hazard. Holmström [2] analyzed group moral hazard in teams. However, the first to have mobilized the collective mechanisms for the management of nonpoint source pollution are Meran and Schwalbe [3] and Segerson [5]. These authors proposed an incentive scheme of collective tax/subsidy based on the difference between a level of total pollution measured at a given site and a maximum pollution standard fixed in advance. Several experimental studies showed the effectiveness of such instruments to achieve a depollution goal ([4], [7] and [1]). However, what comes out of these studies it is that the mechanism of collective tax/subsidy may even induce the agents to over-abate. In what follows we approach agricultural nonpoint source pollution as a group moral hazard issue, and define the appropriate ambient tax.

We consider a catchment where are located n agents whose individual emissions cannot be observed by the regulator. Let Z be the total ambient pollution emitted by the agents and measured at the outset of the catchment. This ambient pollution is easily observable and measured by the regulator. It originates exclusively from the activities of the agents located in the catchment. Let $g_i(z_i)$ the output function of the agent i and z_i the pollutant input used, such that, $\frac{\partial g_i}{\partial z_i} > 0$ and $\frac{\partial^2 g_i}{\partial z_i^2} < 0$. The individual pollution is given by $Z_i(g_i(z_i), a_i)$ with $\sum_{j=1}^{n} Z_j(g_j(z_j), a_j) = Z$, $j = 1, ..., n$, such that: $\frac{\partial Z_i}{\partial g_i} > 0$ et $\frac{\partial^2 Z_i}{\partial g_i^2} > 0$. In the same way $\frac{\partial Z_i}{\partial a_i} < 0$ and $\frac{\partial^2 Z_i}{\partial a_i^2} < 0$. Without any pollution regulation policy, the abatement of the agent i is $a_i = 0$. So, the upper bound of the pollution function results in $Z_i(g_i(z_i), 0) = Z_i(g_i(z_i))$

In order to limit pollution, the regulator enforces an ambient pollution standard $\bar{Z}$, exogenous to the model. For instance, it can represent a health or ecological standard. Once the standard is established, the regulator announces to the agents contributing to the ambient pollution that if the standard is exceeded they will all be taxed according to the difference between observed ambient pollution Z and the ambient standard $\bar{Z}$. The ambient tax is of the following form :

$$t_i = \begin{cases} \tau_i(Z - \bar{Z}) & \text{if } Z > \bar{Z}, \\ 0 & \text{otherwise} \end{cases}$$

with τ_i the individual tax rate.

At this stage, an agent i's individual programe is:

$$\max_{z_i, a_i} \pi_i = s g_i(z_i) - c_i(g_i(z_i), a_i) - \tau_j E[\sum_{j=1}^{n} Z_j(g_j(z_j)) - \bar{Z}]$$

With, s the output price, $g()$, the production vector, $c()$, the cost function and a, the abatement vector.

The random part of the individual program $E[\sum_j Z_j(g_j(z_j)) - \bar{Z}]$ represents the uncertainty about the other agents' actions. Indeed, this expression can also be written as

$$\sum_j Z_j(g_j(z_j)) - \bar{Z} = Z_i(g_i(z_i)) + \sum_{k=1}^{n-1} Z_k(g_k(z_k)) - \bar{Z},$$

with $k \neq i$, where $\sum_{k=1}^{n-1} Z_k(g_k(z_k))$ is not under agent i's control.

Let φ_i be agent i's probability regarding compliance to the pollution standard and $1 - \varphi_i$ the probability that the standard is not respected (and the tax is applied). Agent i's profit becomes:

$$\max_{z_i, a_i} \pi_i = sg_i(z_i) - c_i(g_i(z_i), a_i) - (1 - \varphi_i)\tau_j(\sum_{j=1}^{n} Z_j(g_j(z_j)) - \bar{Z})$$

The regulator seeks to define the tax rate τ that prevents any free-riding attempt, and thus guarantees compliance with the standard ($\varphi = 1$). The regulator doesn't know the marginal abatement costs but she knows that a tax rate $\tau_i > c_i'(a_i), \forall i$ prevents free-riding by implying $\varphi = 1$.

Although the procedure is not optimal, by imposing a tax rate higher than the marginal abatement cost by any agent, the regulator knows that he will reach its target. Under these conditions, the individual program of an agent i becomes:

$$\max_{z_i, a_i} \pi_i = sg_i(z_i) - c_i(g_i(z_i), a_i)$$

such that:

$$Z_i(g_i(z_i), a_i) + \sum_{k=1}^{n-1} Z_k(g_k(z_k), a_k) = \bar{Z} \qquad (\lambda)$$

$$L_i = sg_i(z_i) - c_i(g_i(z_i), a_i) + \lambda(Z_i(g_i(z_i), a_i) + \sum_{k=1}^{n-1} Z_k(g_k(z_k), a_k) - \bar{Z})$$

$$\frac{\partial L_i}{\partial z_i} = s\frac{\partial g_i}{\partial z_i} - \frac{\partial c_i}{\partial g_i}\frac{\partial g_i}{\partial z_i} + \lambda\frac{\partial Z_i}{\partial g_i}\frac{\partial g_i}{\partial z_i} = 0$$

$$\frac{\partial L_i}{\partial a_i} = -\frac{\partial c_i}{\partial a_i} + \lambda\frac{\partial Z_i}{\partial a_i} = 0$$

Then we obtain:

$$\lambda^* = \frac{\frac{\partial c_i}{\partial a_i}}{\frac{\partial Z_i}{\partial a_i}}$$

By replacing this result in the first equation, we obtain:

$$\frac{\partial c_i}{\partial a_i} = (\frac{\partial c_i}{\partial g_i} - s)\frac{\frac{\partial Z_i}{\partial a_i}}{\frac{\partial Z_i}{\partial g_i}}$$

The last equation gives us the marginal abatement cost. However agent i only knows his abatement costs and does not have any means of knowing the shadow abatement costs $\lambda_k,\ k \neq i$ of the other agents. So even if he wants to comply, agent i does not know the abatement a_i that he must provide. In order to overcome this lack of information, the regulator implements a tradable permits market. Indeed, this instrument has the potential to equalize the marginal abatement cost with the price, inducing the agents to abate optimally.

3 Tradable permits market

As the group moral hazard issue is solved, we are interested in the distribution of the abatement level between the agents, knowing that no agent knows the marginal abatement costs of the other agents.

In the case of nonpoint source pollution, the information asymmetry between the regulator and the farmer is the main issue. One of the possible solutions to control this type of pollution is the implementation of a decentralized economic instrument. Instead of seeking information, one lets the farmer reveal it through a tradable permits market. The advantage of this solution compared to the standard is apparent when the regulator does not have sufficient information on maximum emissions for each agent. In this case he sets a total standard of ambient pollution and lets the market fix the levels of individual emissions. This corresponds to a transfer of strategy from the regulator towards the polluters.

In their initial version, it was proposed to introduce the permits via a mechanism of bidding. This implies a high initial cost for the agents. This cost can be reduced by proposing a free allowance to the agents. The regulator sets a pollution standard and distributes the corresponding number of permits. The agents exchange the permits between them. Those whose marginal abatement cost is lower than the price of the permits, for the number of permits which were allocated to them, will sell their surplus to those who have a deficit of permits. A rule of allowance must however be defined. The authors genrally favour the grand-fathering rule where the allowance depends on historical levels of emissions. Several studies showed that if the market is competitive, an effective equilibrium is reached whatever the initial allowance [8]. Moreover, assuming that all the agents minimize their costs, a well-defined tradable permits market could allocate the permits effectively, and imply compliance to the ambient pollution goal, in spite of an incomplete information structure about the various control possibilities of the regulator [8].

In this article we propose a market associated to an ambient tax, specified as follows:

Let x_j^0 be the initial permits allocation, so that $\sum_{j=1}^{n} x_j^0 = \bar{x}$, with, $Z(\bar{x}, A) = \bar{Z}$. A is the collective abatement level that all agents have to provide to achieve the target, such that, $\sum_{j=1}^{n} a_j = A$.

x_i^u the quantity of permits used, so that $x_i^u = x_i^0 + x_i^e$, with x_i^e the quantity of exchanged permits so that:

$$\begin{cases} \text{If } x_i^e > 0 \text{ the agent } i \text{ is a buyer} \\ \text{If } x_i^e < 0 \text{ the agent } i \text{ is a seller} \end{cases}$$

The output function becomes $g_i(x_i^0 + x_i^e)$ with:

$$\begin{cases} \text{If } \dfrac{\partial g_i}{\partial x_i^e} > 0 \text{ the agent } i \text{ is a buyer} \\ \text{If } \dfrac{\partial g_i}{\partial x_i^e} < 0 \text{ the agent } i \text{ is a seller} \end{cases}$$

The market is competitive and the permits price p is exogenous to agent i. His program is then:

$$\max_{x_i^e, a_i} \qquad s g_i(x_i^0 + x_i^e) - c_i(g_i(x_i^0 + x_i^e), a_i) - p x_i^e$$

such that:

$$Z_i(g_i(x_i^0 + x_i^e), a_i) + \sum_{k=1}^{n-1} Z_k(g_k(x_k^0 + x_k^e), a_k) = \bar{Z} \qquad (\lambda_i)$$

$$x_i^0 + \sum_{k \neq i}^{n-1} x_k^0 = \bar{x} \qquad (\gamma_i)$$

$$x_i^e + \sum_{k \neq i}^{n-1} x_k^e = 0 \qquad (\mu_i)$$

The Lagrangian:

$$L_i = s g_i(x_i^0 + x_i^e) - c_i(g_i(x_i^0 + x_i^e), a_i) - p x_i^e$$

$$+\lambda(Z_i(g_i(x_i^0 + x_i^e), a_i) + \sum_{k=1}^{n-1} Z_k(g_k(x_k^0 + x_k^e), a_k) - \bar{Z})$$

$$+\gamma_i(x_i^0 + \sum_{k \neq i}^{n-1} x_k^0 = \bar{x}) + \mu_i(x_i^e + \sum_{k \neq i}^{n-1} x_k^e = 0)$$

$$\frac{\partial L_i}{\partial x_i^e} = s\frac{\partial g_i}{\partial x_i^e} - \frac{\partial c_i}{\partial g_i}\frac{\partial g_i}{\partial x_i^e} - p + \lambda\frac{\partial Z_i}{\partial g_i}\frac{\partial g_i}{\partial x_i^e} + \mu_i = 0$$

$$\frac{\partial L_i}{\partial a_i} = -\frac{\partial c_i}{\partial a_i} - \lambda\frac{\partial Z_i}{\partial a_i} = 0$$

Then we obtain:

$$\lambda^* = \frac{\frac{\partial c_i}{\partial a_i}}{\frac{\partial Z_i}{\partial a_i}}$$

By replacing this result in the first equation, we obtain:

$$\frac{\partial g_i}{\partial x_i^e}(s - \frac{\partial c_i}{\partial g_i} + \frac{\partial c_i}{\partial a_i}\frac{\frac{\partial Z_i}{\partial g_i}}{\frac{\partial Z_i}{\partial a_i}}) - p + \mu_i = 0$$

As the market is competitive, at the equilibrium the shadow cost of exchanged permits μ_i equalizes the permits price p, i.e., as long as $\mu_i \neq p$ agent i will exchange permits until $\mu_i = p$. Then we obtain:

$$\frac{\partial c_i}{\partial a_i} = (\frac{\partial c_i}{\partial g_i} - s)\frac{\frac{\partial Z_i}{\partial a_i}}{\frac{\partial Z_i}{\partial g_i}}$$

As at the equilibrium the marginal abatement cost $\frac{\partial c_i}{\partial a_i}$ equalizes the permits price p, then we obtain:

$$p = \frac{\partial c_i}{\partial a_i} = (\frac{\partial c_i}{\partial g_i} - s)\frac{\frac{\partial Z_i}{\partial a_i}}{\frac{\partial Z_i}{\partial g_i}}$$

At the equilibrium the marginal abatement costs of the whole of the agents are equal and equalize the permits price. We deduce that with a tax rate $\tau_i = \frac{\partial c_i}{\partial a_i} = p$, agent i does not have any incentive to free ride. Indeed, in our case the free riding is assimilated to the save of the abatement cost. Then, apply a tax rate equal to the marginal abatement cost cancels any interest to free ride.

Hence this model can be analyzed as a two-step mechanism:

at $t = 0$: the regulator distributes pollution permits to the agents according to a well identified method, such that $\sum_{j=1}^{n} x_j^0 = \bar{x}$. This method will such be that it reflects the most the heterogeneity between the agents. He imposes thereafter a conditional tax on the agents, tax that will depend on the level of ambient pollution x. If the ambient pollution standard $\bar{x}$ is exceeded at the end of period $t = 1$, then the regulator applies an ambient tax $\tau_i(x - \bar{x})$, with tax rate τ_i. If the standard is not exceeded, then the game proceeds to the following stage.

at $t = 1$: the agents exchange permits according to the market price which emerges by confronting the marginal abatement costs of the agents. At the end of period $t = 1$ the regulator observes ambient pollution x. If the standard is respected at the end of period $t = 1$, then the regulator defines a new rate of tax $\tau_i = p$ and returns to period $t = 0$ with a conditional tax of the form $p(x - \bar{x})$. If the ambient standard is exceeded, then the game returns to period $t = 0$ with a conditional tax of the form $\tau_i(x - \bar{x})$.

4 Conclusion

This article deals with the management of nonpoint source pollution as a group moral hazard issue. In order to solve this problem we designed a two stages mechanisms that combines two instruments : a tradable permits market and an ambient tax. The tax acts as a threat that will be applied in case of non-compliance to a pre-determined ambient pollution standard. The market then makes it possible to effectively distribute the abatement level between the agents through the quantity of permits and the price.

Segerson and Wu [6] also designed a mechanism combining two instruments to manage nonpoint source pollution : a voluntary-based instrument associated to a tax if the standard is exceeded. However, the threat proposed by these authors rests on an investment which makes it possible to measure individual emissions and thus design individual tax rates. Such an investment can prove very expensive.

We adopted another approach which rests on an intial high tax. Although this type of tax is not optimal, it makes it possible to guarantee compliance to the ambient pollution standard. Furthermore, the correct operation of a permit market leads to a permit price equal to the marginal abatement cost. At the second stage of the mechanism, it is the equilibrium price which will be taken as the tax rate in the event of non-compliance with the standard. However, as the permit price is equal to the marginal abatement cost, no agent will find it beneficial to free-ride. Contrary to the mechanism developed by Segerson and Wu [6], instead of investing to measure the individual emissions, we leave the market reveal it.

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