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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 incentive 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.

JEL codes : C92, H23, Q18, Q25, Q53

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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 implemented 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 ambient pollution measured at a given site and a standard of ambient 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 abatement 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 abatement 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 she sets a 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 pollution based 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 among 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 abatement goal is not achieved. These authors proposed a voluntary mechanism of nonpoint source pollution abatement, however, if the abatement goal is not achieved 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 prohibitively expensive and/or technically impossible to implement.

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

2 Group moral hazard: Ambient pollution based tax

The fact that individual emissions are not observable while collective pollution (ambient pollution) is, is a case of group moral hazard. Holmström [2] analysed 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 tax/subsidy based on the difference between a level of ambient pollution observed at a given site and an ambient 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 experimental studies it is that the mechanism of ambient pollution based 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 an appropriate ambient tax.

We consider a watershed 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 watershed. This ambient pollution is easily observable and measured by the regulator. It originates exclusively from the activities of the agents located in the watershed. 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 $a_i = 0$. In the pollution function that results in $Z_i(g_i(z_i^0), 0)$, with z_i^0 the amount of pollutant input used by agent i before the policy regulation of pollution.

In order to limit pollution, the regulator enforces an ambient pollution standard $\bar{Z}$, exogenous to the model. This standard can represent a health or ecological standard. Once the standard is established, the regulator announces to the agents contributing to 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:

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

with τ the tax rate.

We assume that individual polluters are risk neutral and competitive in the output market. Then at this stage, the individual program of an agent i is:

$$\max_{g_i, z_i, a_i} \pi_i = s g_i(z_i) - c_i(g_i(z_i), a_i) - \tau E[Z]$$

s is the output price, g is the production function, c is the cost function, a is the abatement vector and $E[Z]$ is the expected ambient pollution level.

The regulator seeks to define the tax rate τ such that all agents comply with the ambient pollution standard. As described by Segerson [5] for a tax rate equal to the marginal damage of the excess of ambient pollution each agent will compliant and maximizes his profit function without free-riding.

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

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

such that:

$$\sum_{j=1}^{n} z_j = \bar{Z} \qquad (\lambda) \tag{1}$$

$$z_i = z_i^0 - a_i \qquad (\mu_i) \tag{2}$$

$$L_i = s g_i(z_i) - c_i(g_i(z_i), a_i) - \lambda(\sum_{j=1}^{n} z_j - \bar{Z}) + \mu_i(z_i - z_i^0 + a_i) \tag{3}$$

$$\frac{\partial L_i}{\partial z_i} = s\frac{\partial g_i}{\partial z_i} - \frac{\partial c_i}{\partial g_i}\frac{\partial g_i}{\partial z_i} - \lambda + \mu_i = 0 \tag{4}$$

$$\frac{\partial L_i}{\partial a_i} = -\frac{\partial c_i}{\partial a_i} + \mu_i = 0 \tag{5}$$

Then we obtain:

$$\lambda = \frac{\partial c_i}{\partial a_i} + \frac{\partial g_i}{\partial z_i}(s - \frac{\partial c_i}{\partial g_i}) \tag{6}$$

The equation (6) gives us the marginal abatement cost corresponding to the shadow cost of the constraint of the scarcity of the resource (equation 1). However the equation 1 is a coupling constraint and the agent i only knows his abatement costs and does not have any means of knowing the shadow costs λ of the coupling constraint. 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 effectively.

3 Adverse selection: 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. A majority of authors privilege the simplest rule of grand-fathering 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 the ambient pollution based tax described above.

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^e is the quantity of exchanged permits so that $x_i^e = x_i^0 - x_i^u$, with x_i^u the quantity of permits used 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 market is competitive and the permits price p is exogenous to agent i. His program is then:

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

such that:

$$x_i^e = x_i^0 - x_i^u \qquad\qquad (\alpha_i) \tag{7}$$

$$x_i^u = z_i^0 - a_i \qquad (\beta_i) \tag{8}$$

$$\sum_{j=1}^{n} x_j^u = \bar{x} \qquad (\phi) \tag{9}$$

$$\sum_{j=1}^{n} x_j^e = 0 \qquad (\gamma) \tag{10}$$

The Lagrangian:

$$L_i = sg_i(x_i^u) - c_i(g_i(x_i^u), a_i) + px_i^e + \alpha_i(x_i^0 - x_i^u - x_i^e) + \beta_i(x_i^u - z_i^0 + a_i) + \phi x_i^u + \gamma x_i^e \tag{11}$$

$$\frac{\partial L_i}{\partial a_i} = -\frac{\partial c_i}{\partial a_i} + \beta_i = 0 \tag{12}$$

$$\frac{\partial L_i}{\partial x_i^u} = s\frac{\partial g_i}{\partial x_i^u} - \frac{\partial c_i}{\partial g_i}\frac{\partial g_i}{\partial x_i^u} - \alpha_i + \beta_i + \phi = 0 \tag{13}$$

With the equations 12 and 13 we obtain:

$$\alpha_i = \frac{\partial c_i}{\partial a_i} + \frac{\partial g_i}{\partial x_i^u}(s - \frac{\partial c_i}{\partial g_i}) + \phi \tag{14}$$

$$\frac{\partial L_i}{\partial x_i^e} = p - \alpha_i + \gamma = 0 \tag{15}$$

From equation 15 we deduce that:

$$\alpha_i = p + \gamma \tag{16}$$

With the equations 14 and 16 we obtain:

$$\frac{\partial c_i}{\partial a_i} + \frac{\partial g_i}{\partial x_i^u}(s - \frac{\partial c_i}{\partial g_i}) + \phi = p + \gamma \tag{17}$$

As ϕ is the shadow cost of the scarcity of the permits and γ is the shadow cost of traded permits, these two shadow costs are equals, that implies:

$$p = \frac{\partial c_i}{\partial a_i} + \frac{\partial g_i}{\partial x_i^u}(s - \frac{\partial c_i}{\partial g_i}) \tag{18}$$

The equations 18 and 6 give us:

$$\lambda = p \tag{19}$$

This result gives a means for an agent to know the level of reduction that he should achieve.

To summarize the mechanism, the regulator distributes pollution permits to the agents such that $\sum_{j=1}^{n} x_j^0 = \bar{x}$. She imposes thereafter a conditional ambient pollution tax which depends on the level of ambient pollution Z. If the ambient pollution standard $\bar{Z}$ is exceeded, then the regulator implements an ambient pollution based tax $\tau(Z - \bar{Z})$, with a rate tax τ equal to the marginal damage. Otherwise the ambient pollution based tax is not applied. The agents prefer to exchange permits according to their abatement cost and the price of permits. So they can observe a price which leads their abatement.

Thus a tradable permits market coupled to an ambient pollution based tax allows to an agent to effectively abate through the permit's price and gives an incentive that avoids any free-riding behaviour.

4 Conclusion and Discussion

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 initial 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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