On the relationship between enforcement policy and firms' decisions on emissions: compliance versus cheating

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Abstract

Despite the growing literature on the market and non-market instruments that can be implemented in the greenhouse gases reduction policies, there has still been limited discussion on the implications of enforcement policies on firms' decisions on both polluting emissions and technology choices. Existing frameworks may be used to address this question, however, modified and more sophisticated frameworks are also required. This paper develops asymmetric information models where the regulator does not know the true emission level of each firm that it wishes to regulate. We assess a new enforcement mechanism and evaluate to what extend this mechanism affects incentives for the firms to reduce polluting emissions and to invest in clean energy technologies. Our analyses reveal that the combination of asymmetric information between the regulator and firms with the possibility of compliance and cheating strategies at the firm level may yield reduction of polluting emissions and adoption of environmental friendly technologies.

Keywords: Mechanism design; Environmental policy; Asymmetric information

JEL classification: O30, Q55, Q58

1 Introduction

Although there exist no mechanisms for environmental policy which are without their problems, environmental economists have advocated emission taxes as an efficient means of controlling emissions. However, in the emission taxes scheme, the regulator needs to have full information in order to internalise external social damages created by the polluting firms. What if the regulator does not know the true emission level of each firm that it wishes to regulate? Then it must adopt an enforcement policy to achieve environmental standards. It is evident that such policies play a key role in the firms' decisions on both polluting emissions and technology choices. Thus, for policy makers, it is important to know how sensitive the behaviour of firms is to different environmental regulation schemes.

This paper will explore the possibility that choosing an appropriate enforcement mechanism might create incentives for the firms to reduce polluting emissions and to invest in energy saving technologies. To do so, we propose a different enforcement mechanism and evaluate its relative performance according to incentives given for investments in R&D and emission reduction.

Both economics and law literatures on monitoring and enforcement of environmental policy have focused on the effectiveness of environmental regulations and most of the literature has examined the compliance issue based on the monitoring. Since the seminal work of Pigou (1920) it is well known among environmental economists that negative external effects such as pollution of the air and groundwater can be internalised or corrected by using an environmental tax. This first regulatory approach provides the optimal level of environmental tax (Pigouvian tax) which is determined by the marginal damage created at the optimal level of economic activity. Nevertheless, Becker (1968) pointed out that since it is costly to determine the level of damage caused by each agent, the goal should be to set up an enforcement mechanism in order to find those expenditures and punishments that minimise the total social loss. Moreover Becker's (1968) theory of rational crime claims that if only the expected penalty of violating exceeds the compliance cost then a profit-maximising firm will comply with the environmental regulation. In other words, if the probability that a polluting firm gets punished is low, why would firms bother to comply? However, in a theoretical paper Harrington (1988) showed that despite the fact that the frequency of surveillance is low and that penalties are rarely assessed even when firms are discovered to be violating, they still comply to a much higher degree than predicted by Becker's (1968) theory. Thus a major paradox emerges which is called "Harrington paradox" by Heyes and Rickman (1999). Harrington's model is based on dividing regulated firms into two groups according to their past compliance record and finally the "stick" of stricter enforcement and "carrot" for compliance combine to create stronger incentives to comply than a simple random auditing framework. Therefore, a firm may comply even when its compliance cost exceeds the expected current penalty (Firesen, 2003). Several papers in both theoretical and empirical literature discussed this non compliance issue; some examples are Nyborg and Telle (2006), Russel (1990), Raymond (1999) and Firesen (2003).

The models presented in this study can be considered as an extension of Karanfil and Ozturk's (2007) work. Following the basic model from Macho-Stadler and Pérez-Castrillo (2006), they have considered that the enforcement agency receives a signal from each firm which is assumed to be correlated with its true emission level. However, even if their model focuses on the optimal enforcement mechanism design which increases firms' environmental performances, it ignores the fact that firms may manipulate the signal in order to decrease the probability of being audited. Thus, this study differs from prior research in a way that it employs cheating strategy at the firm level developing a new setup which lets the firms decide whether to cheat by manipulating the signal received by the regulatory agency, which in turn is not costless, or to comply with the regulation by reducing their emissions and/or adopting environmental friendly technologies.

The disposition of the paper is as follows. In Section 2, we commence by briefly describing the main properties of the model and examine behaviour of a firm subject to environmental regulation. The enforcement agency on the other hand applies a probability-to-audit function. This function is an increasing function of the signal that receives the regulatory authority from the activity of each firm. In other words, the signal reflects the polluting characteristic or the image of the firm that the regulator observes. Each firm is classified according to this *possibility to pollute* and then this information is used to determine the auditing probability. This image can be manipulated with some costly effort. For example, there is always the possibility to build a park or to donate to the city council and have a contribution in the improvement of the environmental standards in the neighborhood in order to appear as a less polluting firm. In section 3 we set up another framework for examining the incentives for investing in a clean production process. This section investigates the previous behaviours when firms are allowed to invest in environmental friendly technologies. Here there will be a trade off between the costs of manipulating and the costs of research and development expenditures. The intuition suggests that as the enforcement agency becomes more efficient in regulating and auditing then firms will be more inclined to invest. In other words the efficiency of enforcement agency will be coupled. Section 4 concludes.

2 Decision to reduce emissions

In this section we start by setting out the essential features of the model that will be used later on. Suppose that a single competitive firm benefits from its emissions represented by a function $g(e)$ where e is the emission level. Furthermore this function satisfies with the Inada conditions following two properties: $g_e > 0$ and $g_{ee} < 0$ (Subscripts on a function denote derivatives of the function throughout the paper; for example, $g_e = \partial g(e)/\partial e$ and $g_{ee} = \partial^2 g(e)/\partial e^2$). In seeking to achieve environmental objectives the regulator uses tax instrument and determines a tax rate t per polluting emission. In what follows, we study the effect of such a policy under different scenarios depending on the informational structure of the regulator-regulated firm.

2.1 Case I: Symmetric Information

Let us assume first that the regulatory authority disposes full information about the emission level of the firm. Then, the profit function of the firm can be written as:

$$\Pi(e) = g(e) - te \tag{1}$$

The fist order condition (FOC) from the maximisation of this function yields to the optimal emission level e^S given by the well known equality between the marginal benefit from pollution and the cost of emission, that is:

$$g_{e^S} = t \tag{2}$$

This standard equation says that if the tax rate increases, emissions will be reduced.

2.2 Case II: Asymmetric information

Suppose now that the regulator does not know the emission level of each firm and choses an enforcement policy to achieve environmental improvements. This is a realistic assumption as it is difficult to monitor and verify emission levels. As a result, regulatory authorities apply enforcement mechanisms and audit firms with certain probability. However, as auditing is not costless, an optimal auditing mechanism is also required.[1]. On the other hand firms act strategically in deciding how much report z they will give to the the regulator and how much pollution they will emit e. They have two options; complying with the enforcement policy or cheating. Compliance has the cost of environmental tax, and cheating has *signal manipulating cost* which will be given by a function τ (these notions will be defined and explained below). Furthermore, if a firm is discovered to have underreported taxable emission, it pays the tax on the unreported emission plus a penalty on the difference between true and reported emission level. More formally we have the following two assumptions for the penalty function:

[1]Not only auditing each agent (firms or households) is costly but also the cost of monitoring emission is very high. According to some older estimates, capital costs of a monitoring station that has a life time of ten years is about 20,000 to 30,000 euro per year. Adding operating costs, total costs for the monitoring station per year becomes in the range of 30,000 to 60,000 euro per year (Siebert, 2005).

Assumption 1 The penalty takes the form $\theta(u)$ where $u = e - z$ and $u \geq 0$.

Assumption 2 $\theta(0) = 0$, $\theta_u > 0$, $\theta_{uu} > 0$.

Before we deal with the new setup of the model we should also make the following assumptions:

Assumption 3 The probability-to-audit function is given by $\alpha(f(e, \gamma))$ where f is the signal that receives the regulatory from the activity of each firm. This term can also be described as the image perceived by the regulator which classifies each firm according to the *possibility to pollute* and then this information is used to determine the auditing probability.

Assumption 4 $\alpha(0) = 0$, $\alpha_f > 0$ and $\alpha_{ff} > 0$.

Assumption 5 $f_e > 0$ and $f_\gamma < 0$.

Assumption 6 Any firm has the possibility to manipulate its image in order to appear different from its real polluting character. γ represents the effort made by the firm to do so. It may thus defined as the *cheating effort*. However, this effort is not costless. As we mentioned before the signal manipulating cost is given by $\tau(e - f(e, \gamma)) = \tau(d)$ where $\tau_d > 0$.

The profit of the firm becomes:

$$\Pi(e, z, \gamma) = g(e) - tz - \alpha(f(e, \gamma))tu - \alpha(f(e, \gamma))\theta(u) - \tau(d) \tag{3}$$

If one follows Becker's (1968) theory of rational crime, the following remark should be made.

Remark 1 *A firm's compliance decision is made by comparing tax payment on its polluting emissions with the sum of expected penalty for emissions and the cost of cheating effort. As a result we should have the following inequality:* $tz + \alpha tu + \alpha\theta(u) + \tau(d) \leq te$. *We have thus an auditing probability which has an upper bound given by* $1 - \frac{\tau(d)+\theta(u)}{tu+\theta(u)}$.

FOC will give us the optimal emission level which is denoted by e^{En}:

$$\begin{aligned}
\frac{\partial\Pi(e,z,\gamma)}{\partial e} &= g_(e) - \alpha_f f_e tu - \alpha(f(e,\gamma))t - \alpha_f f_e \theta(u) \qquad (4)\\
&\quad -\alpha(f(e,\gamma))\theta_u - \tau_d(1-f_e) = 0\\
\frac{\partial\Pi(e,z,\gamma)}{\partial z} &= -t + \alpha(f(e,\gamma))(t+\theta_u) = 0 \qquad (5)\\
\frac{\partial\Pi(e,z,\gamma)}{\partial \gamma} &= -\alpha_f f_\gamma(tu+\theta(u)) - \tau_d(-f_\gamma) = 0 \qquad (6)
\end{aligned}$$

Proposition 1 When the auditing probability is endogenous in the asymmetric information case the optimal emission level e^{En} is decreased relative to those obtained in the symmetric information case e^S.

Proof. Replacing Eq. (2) in Eq. (4) and after a simple arrangement we get $\frac{\partial\Pi(e,z,\gamma)}{\partial e}|_{e=e^S} = t - \alpha_f f_e(tu+\theta(u)) - \alpha(t+\theta(u)) - \tau_d(1-f_e)$. α term in this expression is replaced by its value obtained from Eq. (5), then Eq. (6) is used for replacing α_f and after some algebra one gets $\frac{\partial\Pi(e,z,\gamma)}{\partial e}|_{e=e^S} = -\tau_d < 0$, that is, $e^{En} < e^S$.

In the following we will discuss whether this enforcement policy is effective and efficient in the sense that it can be adopted in order to increase the incentives to innovate.

3 Decision to invest in clean energy technologies

3.1 Case I: Symmetric information

For this simple symmetric information case we follow Karanfil and Ozturk (2007) in describing the structure of the model. Consider the following profit function where the firm makes tax payments on the true emission level.

$$\Pi(x) = A(x)g(e(x)) - te(x) - h(x) \tag{7}$$

Production is determined by the technological level A and, as in the previous model, the benefits from polluting $g(e)$. The firms conduct R&D activities, denoted by x to increase their productivity (i.e. $A_x > 0$) and to decrease the level of polluting emissions (i.e. $e_x < 0$). Thus there is a trade-off between the technological progress and the benefit from emissions. One gets simply the optimal level of emission maximising the profit function with respect to the R&D investment level:

$$\frac{\partial \Pi(x)}{\partial x} = A_x g(e(x)) + A(x) g_e e_x - te_x - h_x = 0 \tag{8}$$

from which we get the well-known result: for the optimality the marginal benefit of investment should be equal to its marginal cost. More formally, denoting the optimal level of R&D in the perfect monitoring case by x^S, we have:

$$A_{x^S} g(e(x^S)) + A(x^S) g_e e_{x^S} + t e_{x^S} = h_{x^S} \tag{9}$$

3.2 Case II: Asymmetric information

We can write the profit function of the firm in the following fashion:

$$\Pi(x, z, \gamma) = A(x)g(e(x)) - tz - \alpha(f(e(x), \gamma))tu - \alpha(f(e(x), \gamma))\theta(u) - \tau(d) - h(x) \tag{10}$$

The profit-maximising level of investment in R&D (x^{En}), report level and cheating effort can be derived from the FOC given below:

$$\begin{aligned} \frac{\partial \Pi(x, z, \gamma)}{\partial x} &= A_x g(e(x)) + g_e e_x A(x) - \alpha_f f_e e_x (tu + \theta(u)) \\ &\quad -\alpha(f(e(x), \gamma))(te_x + \theta_u e_x) \\ &\quad -\tau_d(e_x - f_e e_x) - h_x = 0 \end{aligned} \tag{11}$$

$$\frac{\partial \Pi(x, z, \gamma)}{\partial z} = -t + \alpha(f(e(x), \gamma))(t + \theta_u) = 0 \tag{12}$$

$$\frac{\partial \Pi(x, z, \gamma)}{\partial \gamma} = -\alpha_f f_\gamma (tu + \theta(u)) - \tau_d(-f_\gamma) = 0 \tag{13}$$

Proposition 2 If the regulatory authority endogenises the auditing probability then it is optimal for the firms to invest in clean energy technologies more than the investment levels in perfect monitoring case x^S.

Proof. Replace first h_x in Eq. (11) with its value given in Eq. (9). Then, use Eq. (12) and Eq. (13) to replace respectively $\alpha(f(e(x), \gamma))$ and α_f in Eq. (11). After these substitutions and some arrangements we have *in fine* $\frac{\partial \Pi(x,z,\gamma)}{\partial e}|_{x=x^S} = -\tau_d e_x > 0$, that is, $x^{En} > x^S = x^{Ex}$, where x^{En} is the optimal level of R&D.

4 Conclusion

In this paper we have considered an environmental tax per emission and have provided two different cases: symmetric and asymmetric information. We find out that if the auditing probability is endogenised, which becomes then a function of the signal received, whether manipulated or not, the emissions are reduced with respect to perfect monitoring case. Furthermore, incentives for the adoption of cleaner technologies are also analysed within the same framework of this study. The resulting conclusion is that firms may increase their efforts to comply with the environmental regulations if the regulatory authority applies an appropriate enforcement mechanism instead of a random auditing policy. Thus, the research presented here provides further emphasis on the mechanism design in the environmental regulation. Therefore it has important policy implications for the reduction of polluting emissions and the adoption of environmental friendly technologies.

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