Do Market-Based Incentives Lower the Cost of Compliance?

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Abstract

This paper analyzes policies for regulating polluting firms under imperfect monitoring. The main finding is that a certain emission target is always more costly to enforce if there exists a market for emission permits than if there is none. The intuition is that a market restricts the regulatory agency to imposing incentive schemes which are linear in firms' emission levels, and these are less powerful than the best non-linear incentive schemes. Another result is that monitoring and monetary incentives are complementary policy instruments.

JEL CLASSIFICATION: Q28, Q38.
KEYWORDS: Monitoring, quota, market, emission permits.

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1 Introduction

Ignoring monitoring and enforcement costs while designing a regulatory standard will most certainly lead to the implementation of an inferior policy. Either the regulatory agency will impose a too expensive policy, or it will not succeed in making firms comply with the standard. In fact, the consequences may be disastrous.[1] This is a lesson both academics and policy makers have learned over the last few years. Consequently, monitoring and enforcement have been the focus in many recent theoretical and empirical studies, and regulatory agencies have read the proposed prescriptions carefully. The most obvious question that needs to be answered is of course: What is the socially most desirable regulation? Or more precisely, which is preferable, a command and control policy or more market-based incentives?

The purpose of this paper is to answer that question, primarily with reference to any negative external effect on the environment, but the reasoning throughout the paper can easily be extended to embrace most kinds of negative external effects. The regulatory agency is modelled as the principal and a firm that produces a good with a negative external effect, e.g. pollution, is modelled as the agent in a standard principal agent setting.

The paper starts out by deriving the optimal command and control policy. This will consist of an emission quota, a penalty if the emission level exceeds the quota, and a compliance fee otherwise. The firm has to be given correct incentives in order to obey the quota. The mechanism for this is first described in Becker's (1968) economic analysis of crime.[2] The basic insight of that article is that potential criminals respond to both the probability of detection and the severity of punishment if detected and convicted. Thus, deterrence from criminal activity may be enhanced either by raising the penalty, or by increasing monitoring activities to raise the likelihood that the offender will be caught. That is true even here. On the other hand, here it will be assumed that there is an exogenous limit to how high a penalty is feasible, which will be binding. The reason may be political or due to a wealth constraint of the regulated firm. Instead the net penalty, i.e. the difference between the penalty and a compliance fee, can be varied.

The first noteworthy result is that the optimal compliance fee may be negative, i.e. some polluters should not carry any tax burden at all but should rather be subsidized.[3] This follows from the fact that a smaller fee is

[1] See the section *Empirical evidence* and Sigman (1998).

[2] Downing and Watson (1974) and Harford (1978) were the first variants of the Becker (1968) model that appeared in the environmental economics literature.

[3] The analogy with Becker's model is straightforward. If it is impossible to raise the penalty, deterrence from criminal activity may for example be enhanced by giving a subsidy

optimally used as a complement to increased monitoring to create incentives; consequently certain firms, which need strong incentives, are monitored very accurately and are awarded a subsidy in equilibrium.

The idea of a compliance subsidy is found earlier in the environmental economics literature: Downing and Kimball (1982) note that a cost subsidy will make a regulated firm more inclined to comply with a regulatory policy, because the firm has more to lose by not complying. The same message is put forward in for example Sullivan (1987), Fullerton and Kinnaman (1995) and Sigman (1998). A somewhat different cause for a subsidy is presented in Nowell and Shogren (1994), who study its effects on liability evasive activities.

The paper continues by finding the optimal emission-fee regulatory policy, and this policy is shown to be at least as good as the best market-based policy. Finally, the command and control and the emission fee policies are compared. This leads directly to a second result. Despite the fact that the major part of the environmental economics literature touts the use of market-based incentives, the finding here is the opposite: a certain emission target is always more costly to enforce if there exists a market for emission permits than if there does not.[4] The intuition behind the result is simply that a market restricts the regulatory agency to use an incentive scheme for the polluting firms that is linear in their emission levels, and that such a restriction makes the incentive scheme less powerful.

The paper is organized as follows. Section 2 sets up the model. In Section 3 the best command and control policy is derived. Section 4 derives the best emission-fee policy, which is also shown to be weakly better than any market-based incentive scheme. A comparison between the different policies is performed in Section 5. Section 6 presents some empirical evidence and finally, Section 7 concludes.

2 The Model

A risk neutral principal imposes a policy on a single risk neutral agent. There is perfect knowledge on the part of both the principal and the agent. The

to the poorest people in the community, since they will be the most tempted to engage in criminal activities.

[4] Sandmo (1998) compares a uniform tax rate to the use of quotas. He focuses on the case when there is imperfect compliance in equilibrium. Hence, in the case of quotas, with some probability, a violation is discovered and a penalty will be paid. This turns out to have some of the characteristics of a uniform tax, even though it is imposed only with a certain probability. Throughout this chapter, there is perfect compliance in equilibrium, but a quota is accompanied by a *compliance* tax that is not present in Sandmo (1998). The different implications of the two models is essentially accounted for by this difference.

agent can produce an amount of a good $x \in \mathbf{R}_+$ yielding the profit $\beta\Pi(x)$ to both him and the principal, but at the same time the negative external effect $\gamma E(x)$ is only to the principal. The parameters β and γ are both positive. The policy specifies the agent's right to produce a certain amount of the good x and a transfer t that the agent has to pay for the right. If the principal cannot find a policy yielding a positive utility, he can costlessly close down the agent's activity.

The principal has the ability to observe and verify the amount of the good x that is produced with probability p. The principal can indirectly choose this detection probability through his choice of resources devoted to monitoring, $\mu M(p)$, where $\mu > 0$. The profit, externality and monitoring cost functions are assumed to have the plausible properties: $\Pi''(x) < 0$, $E(0) = 0$, $E'(x) > 0$, $E''(x) \geq 0$[5] and $M'(p) > 0$.

Define the principal's ex post utility as

$$U = \beta\Pi(x) + \lambda t - \gamma E(x) - (1 + \lambda)\mu M(p), \tag{1}$$

where $\lambda > 0$ denotes the shadow price of raising public funds. Note that $\gamma E(x)$ is not multiplied by $(1 + \lambda)$. It is assumed that the burden of the negative external effects is carried by the economy rather than the authorities. However, this assumption will not affect the results in any major respects.

The agent's ex post net profit is

$$V = \beta\Pi(x) - t. \tag{2}$$

There is an upper limit $T \in \mathbf{R}_+$ to what the principal can extract from the agent if the latter does not comply with the policy. For example, the legislature might impose a fixed penalty or firm insolvency constraints might make higher penalties inappropriate. The agent's only interest is to maximize his expected net profit; therefore the following incentive compatibility (IC) constraint must be satisfied for all x:

$$\beta\Pi(\widehat{x}) - t \geq \beta\Pi(x) - (1 - p)t - pT. \tag{3}$$

[5] The assumption of a weakly convex externality function is plausible for a large set of environmental externalities. However, the model allows for some concavity as long as the second order conditions for the principal's maximization problem hold. Thus, the assumption may be relaxed to

$$E''(x) > \frac{E'(x)\Pi''(x)}{\Pi'(x)}.$$

3 Command and control policy

We see that any incentive compatible policy that implements $\widehat{x}$ can, without loss to the principal, be replicated by a step function of the form $t(x) = T$ for $x > \widehat{x}$ and $t(x) = t$ for $x \leq \widehat{x}$.[6] In other words, the principal sets a quota $\widehat{x}$. The agent pays t if he meets or produces less than the quota and he pays T if he exceeds the quota, as illustrated in Figure 1.

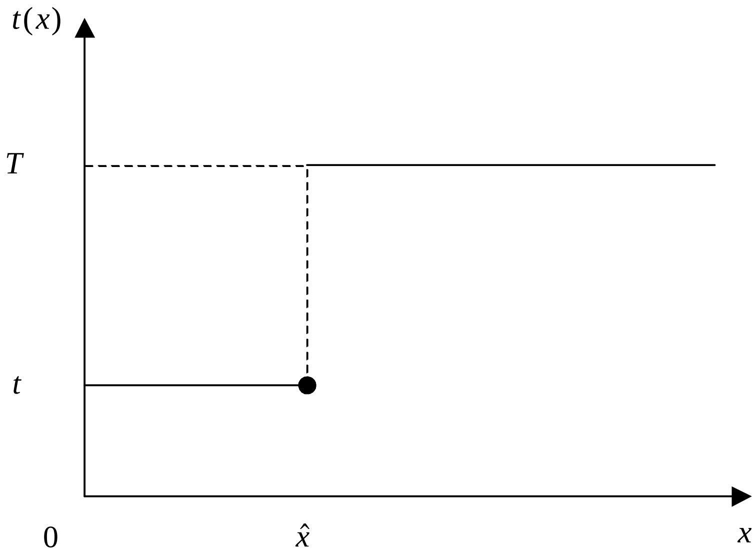

Figure 1

In the absence of a policy, and if the agent were free to produce any desired amount of the good x, he would choose to produce $x = X$, where $X = \arg\max(\beta\Pi(x))$. Since any correctly designed quota, $\hat{x}$, will be less than or equal to X, it follows directly from the initial assumptions that $\Pi'(\hat{x}) \geq 0$. If the agent does not want to comply with this policy, he will choose to produce $x = X$. Therefore the IC constraint simplifies to

$$p(T - t) \geq \beta(\Pi(X) - \Pi(\widehat{x})). \tag{4}$$

The monitoring accuracy, p, is costly and the transfer, t, is beneficial for the principal; thus, in order to implement a certain $\hat{x}$ he will choose them

[6]The optimality of a step function incentive scheme is quite general. Demougin and Fluet (1997) show it for an effort target in an efficiency wage model, but this kind of incentive scheme also belongs to the set of optimal regulatory policies. What is interesting is that, generally, regulatory agencies have a strong predilection for a special case of this policy: a quota and a penalty, but no compliance fee.

such that inequality (4) is binding. Rearranging and inverting this equality yields an expression for the amount of the good the agent will produce:

$$x(p,t) := \Pi^{-1}(\Pi(X) - p(T-t)/\beta). \tag{5}$$

It is now possible to use the expression (5) for $x(p,t)$ to substitute for x in the principal's utility function (1). It follows that the principal has a problem where he has to choose a probability p and a transfer t that solve

$$\underset{p,t}{Max}\;\; U(p,t) = \beta\Pi(x(p,t)) + \lambda t - \gamma E(x(p,t)) - (1+\lambda)\mu M(p) \tag{6}$$

subject to the constraints $t \leq T$ and $p \in [0,1]$. Denote the solution to this problem (p^*, t^*), and let $x^* := x(p^*, t^*)$ be the corresponding amount of the good produced. The first-order conditions characterizing the solution are then

$$\lambda + p^* - r(x^*)p^* \leq 0 \tag{7}$$

and

$$-(T - t^*) + r(x^*)(T - t^*) - (1+\lambda)\mu M'(p^*) \leq 0, \tag{8}$$

with equality whenever the solution is interior and $r(x) = \gamma E'(x)/\beta\Pi'(x)$ denotes the ratio of the marginal externality to the marginal profit.

Equation (7) tells us that the marginal externality from a production increase will always be larger than the marginal profit; thus the principal will allow for some inefficient overproduction in any solution. In addition, according to equation (8) there must be a positive level of monitoring in order to induce a production level lower than X. The first-order conditions (7) and (8) together tell us that in any interior solution, we will have the relation

$$\lambda(T - t^*) = (1+\lambda)p^*\mu M'(p^*). \tag{9}$$

Using (9) to substitute for t^* in the principal's utility function gives us the following expression for the principal's utility of x^* and p^*:

$$U(x^*, p^*) = \beta\Pi(e^*) - \lambda T - \gamma E(x^*) - (1+\lambda)(p^*\mu M'(p^*) - \mu M(p^*)). \tag{10}$$

This expression will be used later when it is assumed that the principal is interested in implementing a certain production level $\hat{x}$, and the above utility is compared to the highest utility that the principal can get by using an emission fee policy.

Let U_{ij} denote the second derivative of U and let U^*_{ij} denote the second derivative of U evaluated at a solution (p^*, t^*). The second-order conditions are then $U_{tt}^* < 0, U_{pp}^* < 0$ and $U_{pp}^* U_{tt}^* - (U_{pt}^*)^2 > 0$, where

$$U_{tt} = \frac{\gamma p^2 h(x)}{\beta^2}, \tag{11}$$

$$U_{pp} = \frac{\gamma (T-t)^2 h(x)}{\beta^2} - \mu M''(p)(1+\lambda), \tag{12}$$

$$U_{pt} = \frac{\gamma p (T-t) h(x)}{\beta^2} + 1 - r(x), \tag{13}$$

and

$$h(x) := \frac{\Pi''(x)E'(x) - E''(x)\Pi'(x)}{(\Pi'(x))^3}. \tag{14}$$

Note that, since $h(x)$ is always negative and $r(x^*)$ is positive and larger than 1, this will imply that $U_{pt}^* < 0$.

3.1 Comparative statics

The objective here is to characterize how the level of the transfer t, the accuracy of monitoring p and the production level x vary with the parameters β, γ and μ. To examine the effect of a change in the external effect from the good, γ, we differentiate the two first-order conditions (7) and (8) and get the two equations:

$$U_{tt}^* dt^* + U_{pt}^* dp^* = \frac{p^*}{\gamma} r(x^*) d\gamma \tag{15}$$

$$U_{pt}^* dt^* + U_{pp}^* dp^* = -\frac{T - t^*}{\gamma} d\gamma. \tag{16}$$

By Cramer's rule, we get

$$\frac{dt^*}{d\gamma} = \frac{\left[p^* U_{pp}^* + (T - t^*) U_{pt}^*\right] r(x^*)}{\left[U_{tt}^* U_{pp}^* - (U_{pt}^*)^2\right] \gamma} \tag{17}$$

and

$$\frac{dp^*}{d\gamma} = \frac{\left[-(T - t^*) U_{tt}^* - p^* U_{pt}^*\right] r(x^*)}{\left[U_{tt}^* U_{pp}^* - (U_{pt}^*)^2\right] \gamma}. \tag{18}$$

The signs of both $dt^*/d\gamma$ and $dp^*/d\gamma$ are determined by the second-order conditions and the fact that $U_{pt}^* < 0$. Clearly it is always true that

$$\frac{dt^*}{d\gamma} < 0 \tag{19}$$

and

$$\frac{dp^*}{d\gamma} > 0. \tag{20}$$

To understand this we differentiate (5) in equilibrium to get

$$dx^* = \frac{[p^*dt^* - (T - t^*)dp^*]}{\beta\Pi'(x^*)}. \tag{21}$$

Together with (17) and (18) this tells us that

$$\frac{dx^*}{dt^*} > 0 \tag{22}$$

and

$$\frac{dx^*}{dp^*} < 0. \tag{23}$$

The intuition is now straightforward: the more externality the principal gets from a given production level, x, the lower production level, x, he wants. To implement a lower x the principal has to adjust the monitoring accuracy, p, and the transfer, t, in order to fulfill the IC constraint. It is cheaper for the principal to give up a little of the transfer, t, at the same time as increasing the monitoring accuracy, p, than to enforce the lower production level, x, solely by increasing the monitoring accuracy, p, or by lowering the transfer, t. The principal will optimally use p and t to lower the level of x such that the costs of using them are equal at the margin.

Secondly, we investigate the effects of an increase in the cost of monitoring. In this case we have:

$$\frac{dt^*}{d\mu} = \frac{-(1+\lambda)M'(p^*)U_{pt}^*}{\left[U_{tt}^*U_{pp}^* - (U_{pt}^*)^2\right]} \tag{24}$$

and

$$\frac{dp^*}{d\mu} = \frac{(1+\lambda)M'(p^*)U_{tt}^*}{\left[U_{tt}^*U_{pp}^* - (U_{pt}^*)^2\right]}. \tag{25}$$

Again, by the second-order conditions and the fact that $U_{pt} < 0$ we have

$$\frac{dt^*}{d\mu} > 0 \tag{26}$$

and

$$\frac{dp^*}{d\mu} < 0. \tag{27}$$

The intuition for this is that the more expensive or difficult it gets to monitor, the less monitoring the principal will choose to engage in.[7] Less monitoring will in turn make it more expensive to use a lax transfer as an incentive. Thus the principal will increase the transfer and instead allow for a higher production level in order to fulfill the IC constraint.

The analysis of a change in the profit function is unfortunately not as trivial. Using Cramer's rule one more time gives us:

$$\frac{dt^*}{d\beta} = \frac{-p^*U^*_{pp} - (T - t^*)U^*_{pt}}{\left[U^*_{tt}U^*_{pp} - (U^*_{pt})^2\right]\beta}\left[\frac{\gamma p^*(T - t^*)h(x^*)}{\beta^2} + r(x^*)\right] \tag{28}$$

and

$$\frac{dp^*}{d\beta} = \frac{(T - t^*)U^*_{tt} + p^*U^*_{pt}}{\left[U^*_{tt}U^*_{pp} - (U^*_{pt})^2\right]\beta}\left[\frac{\gamma p^*(T - t^*)h(x^*)}{\beta^2} + r(x^*)\right]. \tag{29}$$

There is no clear rule for whether the sign of the expression in the last parenthesis in these equations is positive or negative. However, by the second-order conditions and the fact that $U^*_{pt} < 0$, it is at least possible to conclude that the sign of $(dt^*/d\beta)/(dp^*/d\beta)$ is always negative. Thus, monitoring and the transfer will be negatively correlated, independently of the source of variation.

It is noteworthy that it is easier to get complementarity between monitoring and monetary incentives in this model than in Allgulin and Ellingsen's (1998) model of efficiency wages. The reason for this is that here, the principal (the regulatory agency) incorporates the agent's benefit (the polluting firm's profit) in its objective.

Finally, using the first order conditions to solve for t^* gives us the expression

$$t^* = T - p^*\mu M'(p^*)(1 + \lambda)/\lambda. \tag{30}$$

Hence, it can be claimed that the transfer, t^*, optimally may be chosen to be negative. That is, the principal could optimally be willing to subsidize the

[7] Allgulin and Ellingsen (1998) argue that there is an important difference between the amount of resources devoted to monitoring and the monitoring accuracy. The effect of an increase in the cost of monitoring on the amount of resources devoted to monitoring is

$$\frac{d\mu M(p^*)}{d\mu} = M(p^*) + \mu M'(p^*)\frac{dp^*}{d\mu},$$

and the sign is ambiguous in general. Allgulin and Ellingsen (1998) continue to note that a major drawback of most empirical work to date in the efficiency wage literature, is that it uses the amount of resources devoted to monitoring as a measure of monitoring accuracy. Thus, here is a warning for investigators of the correlation between monitoring and a compliance fee.

agent. To see that this is possible, just assume that $T = 0$ and remember that in any interior solution there must be a positive level of monitoring. According to the results above, the transfer becomes a subsidy for industries with a high γ and a low μ, i.e. for industries that are associated with low monitoring costs and "costly" negative external effects. Moreover, the lower the upper limit, T, to what the principal can extract from the agent in case he does not comply with the policy and the lower the shadow price of raising public funds, λ, the more likely it is that the transfer is a subsidy.

To sum up the results so far, the following propositions are stated,

Proposition 1 *The accuracy of monitoring, p^*, is increasing in the externality parameter γ and decreasing in the monitoring cost parameter μ.*

Proposition 2 *The transfer, t^*, and the production level, x^*, are decreasing in the externality parameter γ and increasing in the monitoring cost parameter μ.*

Proposition 3 *A decrease in the transfer, t^*, and an increased monitoring accuracy, p^*, are complementary instruments for implementing a lower production level of the polluting good, x^*.*

Proposition 4 *The transfer, t^*, becomes negative (a subsidy) if and only if $T < p^* \mu M'(p^*)(1 + \lambda)/\lambda$.*

3.2 Welfare implications

Shavell (1979) and Cohen (1987) showed the startling result that if agents are risk averse, they may actually like monitoring. The reasoning is the following: an agent facing an uncertain negative payoff would prefer to pay the expected dollar value of the payoff as an insurance premium rather than face the uncertain situation. Hence, potential violators would be better off if they were monitored more frequently and received a lower penalty (which they do in their models), if found to be in violation of environmental laws, than if they were seldom detected and paid a high price for the rare finding of non-compliance.

Below, it will be demonstrated that this counter-intuitive result may be true even in this model, but for entirely different reasons. From the incentive compatibility constraint, (4),we have

$$\beta\Pi(x^*) = \beta\Pi(X) - p^*(T - t^*).$$

Knowing the expression for the equilibrium transfer, (30), we can express the agent's net profit in equilibrium in the following way:

$$V = \beta\Pi(X) - T + p^*(1-p^*)\mu M'(p^*)(1+\lambda)/\lambda.$$

Differentiation of this expression reveals that the agent's profit is at its maximum when

$$(1-2p^*)M'(p^*) + p^*(1-p^*)M''(p^*) = 0,$$

i.e. the agent prefers some intermediate level of monitoring. Thus for low levels of monitoring, the agent's profit is increasing in the monitoring accuracy. The intuition is that more monitoring always makes it beneficial for the principal to lower the compliance fee (and eventually pay a transfer), but also to demand a lower production level of the polluting good. For low levels of monitoring accuracy, the compliance fee effect dominates and the agent's net profit is increasing.

4 Emission-fee policy

The emission-fee policy is that the regulatory agency lets the polluting firm pay a fee per unit of the produced good. To make the policy a little stronger, the principal is allowed to ask for an entrance fee.[8] That is, the policy is of the form $\alpha_0 + \alpha x$ if the agent's production level is observed. As depicted in Figure 2, the strongest punishment is only carried out for the maximum deviation.

[8] Even though this might not reflect real life conditions, this freedom is given to the principal. In the next section it is shown that with this freedom, the emission fee policy is strictly dominated by the command and control policy. With no intercept, the emission fee policy would be even worse. Thus, the reason for the assumption is to eliminate any suspicion that a restriction of no intercept is resposible for the result.

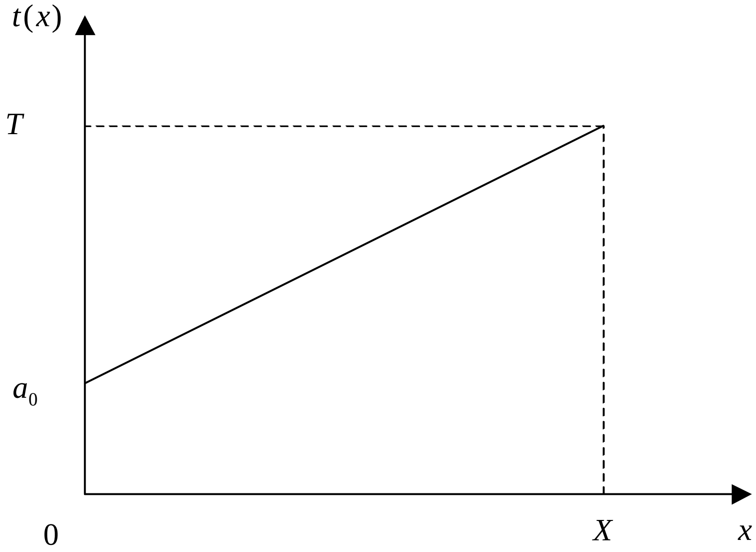

Figure 2

If the agent's production level is not observed, the rational expectations assumption is maintained, that the agent follows the incentive scheme even if the principal does not see it. Thus in this case the agent pays the transfer $\alpha_0 + \alpha x^{**}$, where x^{**} denotes the production level in equilibrium. Furthermore the limited liability constraint on the agent restricts the principal to set α_0 to at most $T - \alpha X$. The principal does not give anything away for free so he will optimally set $\alpha_0 = T - \alpha X$.

Hence, the ex ante transfer will now be

$$t(x) = T - \alpha X + \alpha(px + (1-p)x^*). \tag{31}$$

Thus the agent will solve the problem:

$$\underset{x}{Max} \;\; V(x) = \beta\Pi(x) - T + \alpha X - \alpha(px + (1-p)x^*) \tag{32}$$

with the first-order condition

$$\beta\Pi'(x) = \alpha p. \tag{33}$$

The principal takes this maximization behavior as given when maximizing his utility. Inverting the agent's first-order condition and substituting for x, the principal faces the maximization problem

$$\begin{aligned} \underset{\alpha,p}{Max}\, U(\alpha,p) \;\; = \;\; & \beta\Pi((\Pi')^{-1}(\frac{\alpha p}{\beta})) + \lambda(T - \alpha X + \alpha(\Pi')^{-1}(\frac{\alpha p}{\beta})) \\ & -\gamma E((\Pi')^{-1}(\frac{\alpha p}{\beta})) - (1+\lambda)\mu M(p). \end{aligned} \tag{34}$$

Assuming an interior solution, the first-order conditions are

$$p^{**}\left[\frac{\Pi'(x^{**})}{\Pi''(x^{**})}+\frac{\lambda\alpha^{**}}{\beta\Pi'(x^{**})}-\frac{\gamma E'(x^{**})}{\beta\Pi''(x^{**})}\right]-\lambda(X-x^{**})=0 \tag{35}$$

and

$$\alpha^{**}\left[\frac{\Pi'(x^{**})}{\Pi''(x^{**})}+\frac{\lambda\alpha^{**}}{\beta\Pi'(x^{**})}-\frac{\gamma E'(x^{**})}{\beta\Pi''(x^{**})}\right]-(1+\lambda)\mu M'(p^{**})=0. \tag{36}$$

(35) and (36) together tell us that in any interior solution, we will have the relation

$$\lambda\alpha^{**}(X-x^{**})=(1+\lambda)p^{**}\mu M'(p^{**}). \tag{37}$$

Using (37) to substitute for $\alpha^{**}x^{**}$ in the principal's utility function yields an identical expression to (10), but now for the principal's utility of x^{**} and p^{**} under a linear incentive scheme:

$$\begin{aligned} U(x^{**},p^{**}) &= \beta\Pi(x^{**})-\lambda T-\gamma E(x^{**}) \\ &\quad -(1+\lambda)(p^{**}\mu M'(p^{**})-\mu M(p^{**})). \end{aligned} \tag{38}$$

4.1 Tradable emission permits

The above policy is very similar to what implicitly emerges if there is a market for emission permits with many agents, in which each agent is a price taker. An agent faces a cost per unit of the produced good, i.e. the market price, even if the regulatory agency tries to impose a policy in the form of a step function. The difference is that he will get the offer from other agents instead of the regulatory agency itself. Figure 3 illustrates an example of an arbitrary non-linear regulation policy and the implicit linear policy that emerges if there exists a market in which agents can trade emission permits freely.

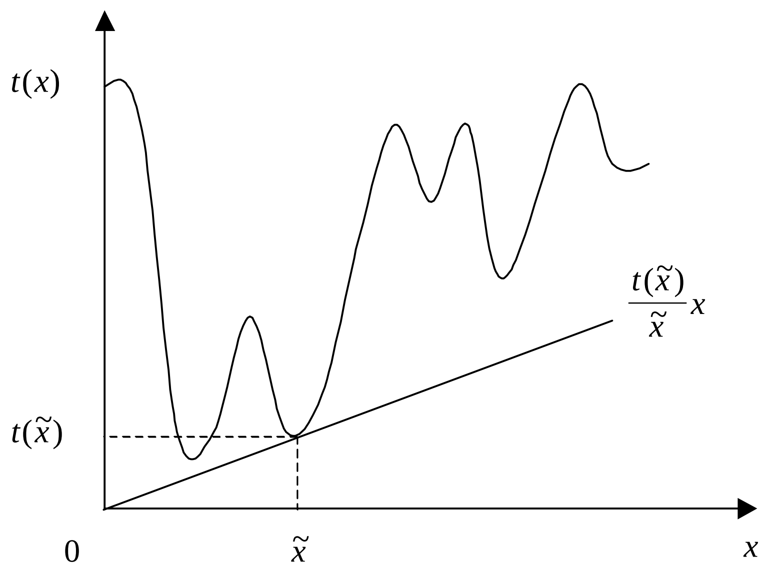

Figure 3

Here, the market buys emission permits where the per unit price, $t(x)/x$, is the lowest, i.e. at the price $t(\tilde{x})/\tilde{x}$. Then it offers each agent the implicit linear policy $t(x) = xt(\tilde{x})/\tilde{x}$. Note that a market also buys at the cheapest price across agents if the regulatory agency, instead of the second-degree price discrimination described above, engages in third-degree price discrimination.

Accordingly, the principal controls the initial allocation of emission permits if he is free to discriminate when selling the emission permits in the first place. But this is only an apparent freedom; the agents are free to trade and they will reallocate the emission rights such that the marginal value of an emission permit is equal for all firms. However, because of the shadow price of raising public funds, the principal will allocate the emission permits from the beginning such that the marginal value of an emission permit is equal for all firms, leaving no gains from trade to the agents.

The principal controls the market price, which of course is the same for all agents, implicitly through the total amount of emission permits sold. This is a more restricted policy, compared to the emission-fee policy where the principal can vary the per unit fee across agents. For example, if there are two different types of agent, the principal will choose a market price lower than the optimal emission fee for one type and higher than the optimal emission fee for the other type. Thus, tradable emission permits will result in an implicit policy that is weakly dominated by the emission-fee policy.

Furthermore, it may be hard for the regulatory agency to ask the agents for an entrance fee for the right to trade in the emission permits market.

Thus, in addition to the above disadvantage compared to the emission-fee policy, the intercept, a_0, may be restricted to be zero.[9]

5 The suboptimality of the emission-fee policy

Assume that the principal is interested in implementing a certain production level, $\hat{x}$. To be able to compare the principal's utility in the two cases (10) and (38), an investigation of the relationship between p^* and p^{**} is needed. From the incentive compatibility constraint (5) and the principal's first order conditions together (9) in the non-linear case, it is seen that

$$(p^*)^2 \mu M'(p^*) = \frac{\lambda}{1+\lambda} \beta (\Pi(X) - \Pi(\hat{x})). \tag{39}$$

The corresponding expression for the linear case, given by the agent's first order condition (33) and the principal's first order conditions together (37), is

$$(p^{**})^2 \mu M'(p^{**}) = \frac{\lambda}{1+\lambda} \beta \Pi'(\hat{x})(X - \hat{x}). \tag{40}$$

By the assumption $\Pi''(x) < 0$ we know that

$$\Pi(X) - \Pi(\hat{x}) < \Pi'(\hat{x})(X - \hat{x}) \text{ for any } \hat{x} < X. \tag{41}$$

This can easily be seen in Figure 4. Here,

$$\Pi(X) - \Pi(\hat{x}) = \int_{\hat{x}}^{X} \Pi'(x) dx$$

is represented by the area B, and

$$\Pi'(\hat{x})(X - \hat{x})$$

[9] This may be a more significant drawback of an emission permits market than the one principally studied in this paper.

is represented by the strictly larger area $A + B$.

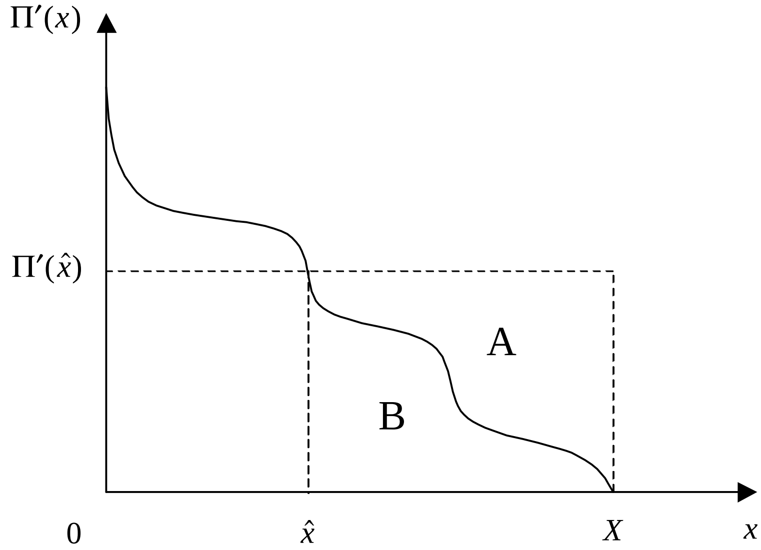

Figure 4

Thus (39) and (40) together tell us that

$$(p^*)^2 M'(p^*) < (p^{**})^2 M'(p^{**}), \tag{42}$$

implying that for any production level the principal wants to implement he will monitor more accurately under a linear incentive scheme if $M''(p) \geq 0$.[10] The least resources required to implement the effort level, $\hat{e}$, using a non-linear policy or a linear policy respectively are now easy to compare. If one substitutes for the equilibrium transfer, it is clear that

$$\begin{aligned} &\beta\Pi(\hat{x}) - \lambda T - \gamma E(\hat{x}) - (1+\lambda)(p^*\mu M'(p^*) - \mu M(p^*)) > \\ &\beta\Pi(\hat{x}) - \lambda T - \gamma E(\hat{x}) - (1+\lambda)(p^{**}\mu M'(p^{**}) - \mu M(p^{**})), \end{aligned} \tag{43}$$

or equivalently,

$$(1+\lambda)(p^*\mu M'(p^*) - \mu M(p^*)) < (1+\lambda)(p^{**}\mu M'(p^{**}) - \mu M(p^{**})). \tag{44}$$

Thus, the principal can implement any production level under the best non-linear incentive scheme using less resources on incentives for the agent than under the best linear incentive scheme.

[10] Allgulin (1999) argues that the monitoring function will always be weakly concave if an employer can credibly use mixed strategies when monitoring an employee, i.e. if the employer can randomize between different monitoring accuracies. The analogous reasoning applies when a regulatory agency monitors a polluting firm; the regulated agent's reactions to the probability of detection and expected probability of detection are identical.

If $M''(p) < 0$, the optimal monitoring accuracy under a non-linear incentive scheme, p^*, may be higher than the optimal monitoring accuracy under a linear incentive scheme, p^{**}. But even if this is the case, it is more costly for the principal to implement $\hat{x}$ if the contract is restricted to be linear. To see this, first note that $p^* > p^{**}$ together with (42) implies that

$$p^* M'(p^*) < p^{**} M'(p^{**}). \tag{45}$$

Assume now that the inequality (44) does not hold, i.e. that,

$$p^* M'(p^*) - M(p^*) \geq p^{**} M'(p^{**}) - M(p^{**}). \tag{46}$$

It is then easily seen that the following must be true:

$$M(p^{**}) > M(p^*).$$

But this contradicts the assumption that $M'(p) > 0$. Evidently, the principal is always harmed by restricting the incentive scheme to be linear.

Proposition 5 *The principal can enforce any emission level under a non-linear incentive scheme using less resources on incentives for the agent than under linear incentive schemes.*

Proposition 6 *For any emission level the principal will implement, he wants to monitor more accurately if he is restricted to using linear incentive schemes than if he is not, if $M''(p) \geq 0$.*

6 Empirical evidence

Most empirical studies of enforcement have focused on the elementary issue of establishing that monitoring actually deters regulatory violation. Not surprisingly, they are unanimous in their affirmative answers. Epple and Visscher (1984), for example, examine the US Coast Guard's enforcement of oil spill regulations. They have a theoretical model in which they assume that the enforcement agency's policies are fixed and that firms react to that policy. Empirically, they estimate the volume of oil spilled in US waters as a function of Coast Guard monitoring activities, which vary by port and over time. Their main finding is that increased monitoring activity results in lower oil spill volume.

Another example is Magat and Viscusi (1990), who study the impact of government inspections on water pollution levels and compliance with standards in the pulp and paper industry in the US. They differ from Epple and

Visscher (1984) in that they know the name of the company being inspected. They can therefore use actual inspections of the plant instead of aggregate inspections in the region as an explanatory variable.[11] Consistently with Epple and Visscher (1984), they find that higher levels of monitoring activity result in lower levels of pollution.

Monitoring of pollution at pulp and paper mills has also been studied by Laplante and Rilstone (1996). Like Magat and Viscusi (1990), they use actual inspection rates. In addition to previous results, they also find that the expected inspection rate (or the threat of inspections) induces compliance.[12]

Having established this basic relation, the existing empirical studies that are most relevant here are the ones which examine the relationship between subsidies and compliance. Downing and Kimball (1982) have documented the low penalties for non-compliance rates in US. They find that firms receive cost subsidies in the form of tax breaks and special financing. They note that a cost subsidy will affect the cost-benefit calculus which a firm must undergo when determining the expected cost of compliance in the presence of non-compliance penalties. The idea is very similar to the one presented in this paper: the loss of a subsidy is as severe for a firm as a non-compliance penalty.

Disposal of wastes is interesting to study because unlike many areas of environmental regulation, it has often been subject to a regulatory policy consistent with the optimal command and control policy such as the one presented in this paper: not only does the regulatory agency decide how to price non-compliance and how much resources are devoted to monitoring, but the agency also prices compliance by setting the price of legal disposal. Sullivan (1987) shows that, if the price of legal disposal is too high, the regulatory agency actually encourages illegal disposal. Conversely, one way to encourage legal disposal is to subsidize it. He provides an initial estimate of the optimal subsidy and enforcement budget for hazardous waste disposal and determines the condition under which a subsidy is preferable to increased enforcement and vice versa.

Similar analyses are conducted by Fullerton and Kinnaman (1995) in the context of household garbage, and Sigman (1998) for used oil disposal. These studies identify a positive correlation between the cost of legal disposal and the amount of illegal disposal that is observed. For example, Sigman (1998) estimates that a ban on used oil disposal (requiring that used oil be recycled or reused) will result in 34% of the waste previously disposed of legally being illegally dumped. Since illegal dumping is likely to be worse than the previous

[11] See footnote 7 for why this is important.

[12] See footnote 10.

method of legal disposal, one cannot say a priori whether a ban on used oil disposal is socially beneficial.

Although non-compliance is not present in equilibrium in the model in this paper, the above findings are interesting, because they clearly highlight the trade-off between raising the cost of legal disposal and compliance: a subsidy could be used to reach compliance. In addition to this logic, the theory in this paper presents a new very simple empirical implication. Monitoring and monetary incentives are used as complementary instruments to persuade firms to comply with a regulatory standard. Thus, whenever a subsidy is present, one should expect close monitoring as well.

7 Final remarks

The answer to the title is a remarkably clear *no!* That is, if the model presented in this paper is an accurate description of the world, market-based incentives do not lower the cost of compliance. The most intuitive explanation for the result is that market-based incentives are closely related to linear incentives. And linear incentives do not use all accessible power; they only carry out the strongest punishment for the maximum deviation.

It is noteworthy that this result is likely to withstand a loosening of the risk-neutrality assumption of the agent, since non-compliance[13] is not present in the equilibrium solution.[14] But if pollution is random, i.e. if it is not perfectly correlated with an agent's action, risk-neutrality would matter. An agent facing an uncertain negative payoff would prefer to pay the expected dollar value of the payoff as an insurance premium rather than face the uncertain situation. Consequently, there is a trade-off between the agent's desire for insurance and his need for incentives, and perhaps a linear regulatory policy may be close to the optimal mix.

Perhaps a better way of dealing with both risk-neutrality and the random nature of pollution is to regulate the agent's action (i.e. take precautions to avoid pollution) instead.[15] This way, the regulatory agency can go back to a situation in which non-compliance is not present in equilibrium, by bearing all the risk itself. Hence, the agent will not need any insurance and the regulatory agency can impose a non-linear regulatory policy. This policy

[13]In for example Sandmo (1998), where non compliance is present in the equilibrium solution, risk-neutrality matters.

[14]However, risk-neutrality of firms is a very natural assumption; investors use portfolio methods to spread their risks and do not want firms themselves to take risk into consideration.

[15]Cohen (1987) performs such an extension on the Becker (1968) model.

may be very similar to the one when the level of pollution is regulated: the regulatory agency sets a target of how much effort the polluting firm must devote to prevent pollution, and the polluting firm pays the compliance fee if it meets or exceeds the target and the maximum penalty[16] otherwise.[17]

Of course, the result must not be misunderstood; one should not jump to the conclusion that nothing good comes out of a market. The main contribution of this paper is to provide a framework in which the *incentives* from the best non-linear regulatory policy and the best linear regulatory policy can be compared. Even though a market for emission permits provides inferior (to expensive) incentives, there are other qualities associated with markets which may be desirable. For example, it is likely that a market is more dynamic, i.e. reacts and reallocates faster than a regulatory agency. One may also argue that the equal treatment of firms in a market is cheaper to handle.[18] Equal treatment of firms may also be considered more fair. The list may be made long, but it is important to understand that there is a cost associated with the construction of a marketplace for a regulated good if the good was not possible to trade in the first place.

In this paper, I have neglected the issue of illegal arbitrage between regulated agents. It is well known that a non-linear regulatory policy generates a demand for a market. If it is very costly to prevent an illegal market from emerging, which is the case if the good is easy to trade, the regulatory agency may yield and instead form a legal market. Gasoline is an excellent example of such a good, and attempts from regulatory agencies to deviate from a linear tax policy are almost always followed by emerging "black" markets. Ironically, sometimes the authorities seem to act exactly in opposition to the prescription in this paper: they try to impose non-linear regulatory policies on tradable externalities and they fabricate marketplaces for non-tradable

[16] In the parlance of the law and economics literature, instead of strict liability standard, this would be a negligence-based penalty.

[17] Of course, this is a very stylized example. Generally, if no measure is perfectly correlated with the regulated agent's action, the regulatory policy should be made contingent on all measures (See Holmström; 1979).

[18] A standard claim is that a tax levied at a uniform rate on all firms is optimal if it is adjusted so that the aggregate emission level is optimal. Quotas, on the other hand, have to be set for each individual firm. Therefore, it is argued that a uniform tax is cheaper to control than a quota: the regulatory agency does not have to collect information about individual production functions (See for example Sandmo(1998)).

However, this reasoning does not apply in the setting in this chapter. The optimal uniform emission fee would not be equal across firms if firms have different production functions or differ in how much the regulatory agency can extract from them in case they don't comply with the policy. Thus, even for the case with a uniform fee, there is a motive for the regulatory agency to collect information about individual production functions.

externalities.

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