A Standard-Setting Agency and Environmental Enforcement

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This paper considers an environmental regulatory agency that sets both the emissions standard and the enforcement parameters in contrast to the usual treatment in which the agency sets only one of the two. It is shown that if the agency’s budget is sufficiently small, it sets the strictest possible standard and adopts a policy that minimizes noncompliance with that standard, thus legitimizing the literature that assumes this behavior on the part of the agency. In contrast, if the budget is sufficiently large, the agency can obtain its unconstrained optimum, but this optimum has too little pollution from a social perspective.

1. Introduction

Environmental regulators set pollution standards, which firms then violate. Consequently, the regulator must also enforce the standard it sets. Studies involving noncompliant firms assume either that the standard is exogenous and the regulator sets the enforcement parameters (e.g., Harford 1978; Garvie and Keeler 1994) or that the enforcement parameters are exogenous and the regulator sets the standard (e.g., Viscusi and Zeckhauser 1979). This study departs from these partial treatments of the problem by allowing the regulator to set both the standard and the enforcement parameters, which matches the assignments of many environmental agencies.

Studies of regulator behavior typically specify an objective function that matches the scope of the regulator’s duties. For example, when the standard is exogenous and the regulator sets only the enforcement parameters, it is typically assumed that the regulator tries to minimize noncompliance with the standard (e.g., Garvie and Keeler 1994; Keeler 1995). On the other hand, when the regulator sets the standard, some sort of social welfare maximization is assumed (e.g., Viscusi and Zeckhauser 1979; Jones and Scotchmer 1990). Formal theories of regulation, however, typically assign different objectives to the regulator. In his theory of bureaucratic behavior, Niskanen (1975) assumes that agencies attempt to maximize their budgets, while in

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1 The Environmental Protection Agency (EPA) was established according to Reorganization Plan No. 3 of 1970 proposed by President Nixon. In his special message to Congress, Nixon explained, “The principal roles and functions of the EPA would include: The establishment and enforcement of environmental protection standards consistent with national environmental goals.” The 1977 Clean Water Act charges the EPA with both setting and enforcing standards. State agencies also set both standards and enforcement parameters. For example, Michigan’s 1994 Natural Resource and Environmental Protection Act authorizes a single agency to both set and enforce emissions standards.

2 Lee (1983) applies this model to environmental enforcement, but under the assumption that the enforcement agency collects emissions fees. See also Harford (1985).
his theory of regulation, Peltzman (1976) posits that agencies maximize net political support. In this paper we examine the problem of an agency that cares about both the size of its budget and its political support when it sets and enforces an environmental standard.

It is assumed that the regulatory agency cares about how much it spends as well as the well-being of the regulated industry and the environmental lobbies, with its first priority being the depletion of its externally set budget. It is shown that the agency’s choices depend on the size of its budget. There are two cases. If the budget is small, in a sense made explicit in the following, the agency sets the emissions standard as tight as possible and then sets the enforcement parameters so as to minimize noncompliance with the selected standard. On the other hand, if the budget is sufficiently large, the agency is able to achieve its unconstrained optimum, and further increases in the budget have no effect on the equilibrium levels of output and pollution. Furthermore, the agency can achieve these desired levels using many different combinations of standards and enforcement parameters. From a social viewpoint, though, the agency allows too little pollution because the agency ignores the effects of regulations on consumers. This suggests that it may not be best to let a well-funded agency both set and enforce a standard.

Section 2 introduces the model and analyzes both the firms’ and the agency’s optimization problems. Section 3 discusses characteristics of the equilibrium of the game between the agency and the firms. Section 4 provides some concluding remarks.

2. The Model

There is an environmental regulatory agency that announces and commits to an environmental standard and enforcement parameters. There are n identical firms that take the standard and enforcement parameters as given, and maximize their expected profits by deciding how much output to produce and how much waste e to discharge. They do not comply with the standard if the benefits from noncompliance exceed the expected fines. With probability p, the agency monitors and detects a violation. If the agency finds that a firm is violating the standard, it brings the evidence to the judiciary and asks it to review the evidence in light of the relevant statutes and impose some penalty. The agency cannot directly impose a fine but can merely influence the penalty through legal expenditures. Of course, the defendant can also spend money trying to avoid the fine, but that expenditure is left out of the model for the sake of simplicity. The fine resulting from a violation of magnitude v = e - s when the agency’s legal expenditure E is given by the function F(v, E). It is assumed that F is increasing in both arguments, that $F_{vv} > 0$, and that $F_{vE} > 0$, so that an increase in legal expenditure leads to an increase in the marginal fine.

Given that the agency sets the policy parameters first and the firms respond optimally to

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3 There is a large literature on the optimal enforcement of crimes, beginning with Becker (1968). Much of this literature is concerned with how to account for different risk attitudes, different incomes, and different abilities to pay fines and is beyond the scope of this paper. See Cohen (1998) for a survey.
4 Malik (1990) considers the avoidance activities explicitly.
5 There are several justifications that fines increase with the magnitude of the violation instead of the amount of emissions. First, in most states a schedule of maximal fines is given by statute, but standards are left up to the enforcement agency. Maximal fines do not change when standards change. Second, Oljaca, Keeler, and Dorfman (1998) empirically examine a penalty function for water quality enforcement and find that penalties are higher for major violations. Third, Nebraska’s environmental statutes explicit state, “In assessing amount of any fine, court shall consider degree and extent of violation” (emphasis added). Finally, while unrelated, speeding fines reflect this property.
the announced parameters, the agency behaves like a Stackelberg leader. In other words, the agency chooses the standard and regulatory parameters incorporating the best responses of the firms. So, the analysis begins with the firm’s problem. The firms are assumed to be identical in the sense that they participate in a constant cost industry with the same production technology. A typical firm’s decision problem can be written as

$$\max_{x,e} R(x, e) - rx - pF(e - s, E),$$  

where $x$ measures the amount of the input whose unit costs $r$ are internalized, $e$ is the amount of waste discharged, and $R(x, e)$ is the revenue generated by selling the output produced from the inputs $x$ and $e$. Intuitively, the firm can expand its output, and therefore its revenue, in two ways. One is to use more of the internalized input $x$, and the other is to use more of the external input $e$. The firm can hold production constant by substituting more of the internalized input for less emissions, for example. The amount produced determines the price of the good, which in turn determines revenue. Consequently, it is assumed that the revenue function $R$ is increasing in both of its arguments. The first order conditions are

$$R_x - r = 0 \quad (2)$$
$$R_e - pF_e = 0. \quad (3)$$

Equation 2 is the usual condition that the marginal revenue product of an input equals its marginal cost. Equation 3 states that the extra revenue from emitting one more (marginal) unit of waste exactly offsets the expected increase in fines. These conditions yield the firms’ best response functions, $x^*(p, E, s)$ and $e^*(p, E, s)$. The second-order conditions are that $R_{xx} < 0$ and $R_{xx}R_{ee} - R_{xe}^2 > 0$.

The agency has discretion in setting the environmental standard within externally given bounds, and it is given a limited budget that constrains its enforcement activities and gives it the incentive to optimally allocate its scarce resources. The agency is assumed to have lexicographic preferences over its budget expenditure and its measure of social welfare, with the budget expenditure taking the first priority. In other words, the agency first wants to maximize its total expenditure. Given that the agency is assigned a limited budget, this means that the agency expends its entire budget. The second priority in the preference ordering, which becomes relevant once the entire budget is spent, is the firms’ total profits minus social damages.

The regulatory agency responds to two interest groups: firms trying to protect profits and environmentalists complaining about pollution. It is assumed that the agency does not consider

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6 More concretely, the firm can use pollution abatement equipment, which increases its costs. For simplicity, the pollution abatement equipment is incorporated into the single internalized input, $x$.

7 Implicitly, this assumption means that the price decrease is more than offset by the supply increase prompted by an increase in the internalized input. This is possible when the set of firms under consideration is only a small part of the whole industry.

8 Garvie and Keeler (1994) explore how the regulatory agency allocates its limited budget to achieve its objective.

9 Studies such as Niskanen (1975, 1994) and Lee (1983) suggest that regulatory agencies act to maximize their budgets. The agency's lexicographic preferences capture this behavior. The bureaucracy tends to use up its budget in the fear that otherwise the next account year's budget would be reduced.

10 This implicitly assumes that the agency does not keep any revenue from fines, which fits the practices of the federal government and most, but not all, states. Lear and Maxwell (1998) examine the unusual case in which the agency keeps fines.

11 Cropper et al. (1992) and Van Houtven and Cropper (1996) show that the EPA balances costs incurred to firms and environmental benefits when it makes its regulatory decisions.
consumer surplus in setting policy because of the absence of consumer advocacy organizations from environmental policy debates. Thus, there is no advocate causing consumer surplus to be in the agency’s objective function. If the agency is biased toward either polluting firms or environmentalists, the agency’s objective function could be specified as a weighted sum of profits and damages, as in Hahn (1990). Here it is assumed that the weights are equal, which does not change the results of this paper in any fundamental way. Taking into account the lexicographic nature of the agency’s objective function, which implies that the agency spends its entire budget, the agency’s decision problem can be written as

$$\max_{p,E,s} n\{R[x(p, E, s), E(p, E, s)] - rx(p, E, s)\} - D[ne(p, E, s)]$$

s.t. $$M(p, E) = B \quad p \geq 0, \quad E \geq 0, \quad s \geq s_0,$$

where $$D(ne)$$ is the social damage function, $$M(p, E)$$ is an enforcement cost function that depends on the agency’s chosen enforcement parameters, $$B$$ is the agency’s exogenously given budget, and $$s_0$$ stands for the tightest standard the agency is allowed to set. It is assumed that $$D' > 0$$ and $$D'' > 0$$, so that damages increase at an increasing rate, and that $$M_p > 0$$ and $$M_E > 0$$, so that higher enforcement parameters increase enforcement costs. Finally, it is assumed that if the agency does not undertake any enforcement effort, its enforcement costs are zero, $$M(0, 0) = 0$$.

3. Standard Setting and Regulatory Freedom

When deciding what standard and enforcement parameters to set, the agency faces four constraints. First, because the agency’s first priority is to maximize its expenditure according to its lexicographic preferences, the agency must spend its entire budget $$B$$. It must also set non-negative values of the enforcement parameters, and the standard must exceed the strictest allowable. If, on the other hand, the agency were unconstrained, the agency’s problem could be written in a different way. By setting $$s$$, $$p$$, and $$E$$ appropriately, it could impel firms to use any desired amounts of the two inputs $$x$$ and $$e$$. Thus, the agency’s unconstrained problem (or, more accurately, its non-budget-constrained problem) can be expressed in two steps. First, determine the values of $$x$$ and $$e$$ that maximize $$n[R(x, e) - rx] - D(ne)$$. Call the solutions to this problem $$x^{**}$$ and $$e^{**}$$. The second step is to choose feasible values of $$s$$, $$p$$, and $$E$$ such that $$x^{*}(p, E, s) = x^{**}$$ and $$e^{*}(p, E, s) = e^{**}$$.

Whether the agency can achieve its unconstrained optimum and induce firms to select $$x^{**}$$ and $$e^{**}$$ depends on the shadow price of the budget constraint. Since the budget constraint enters as an equality constraint, it always “binds,” but it may or may not affect behavior. Let $$\lambda$$ be the Lagrange multiplier on the budget constraint in the agency’s maximization problem. If $$\lambda > 0$$, the budget constraint is binding and forces the agency to induce values of $$x$$ and $$e$$ different from $$x^{**}$$ and $$e^{**}$$. Our first result is that if the agency’s budget constraint is binding in the sense that it prohibits the agency from reaching its unconstrained optimum, the agency sets a standard of $$s$$.

Financial limitations of the regulated firms may impose restrictions on the fines the agency can set. These restrictions are not central to our argument and are ignored for the sake of simplicity.
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To see this, let $\mu_p$, $\mu_E$, and $\mu_s$ be the multipliers on the inequality constraints. The Kuhn-Tucker conditions are

\[ n(R_{xx} + R_{ee} - R_{xx}) - nD'e^*_x - XM + \lambda_p = 0 \] (5)

\[ n(R_{xx} + R_{ee} - R_{xx}) - nD'e^*_e - XM + \lambda_E = 0 \] (6)

\[ n(R_{xx} + R_{ee} - R_{xx}) - nD'e^*_s - XM + \lambda_s = 0 \] (7)

plus the standard constraints and complementary slackness conditions. Using Equation 2, Equations 5 through 7 can be written as

\[ n(R_e - D')e^*_e - XM + \lambda_p = 0 \] (8)

\[ n(R_e - D')e^*_e - XM + \lambda_E = 0 \] (9)

\[ n(R_e - D')e^*_s + \lambda_s = 0 \] (10)

When the agency’s budget constraint is binding, $\lambda > 0$. Now suppose that the agency sets a standard looser than $s_0$. Complementary slackness then requires that $\lambda_s = 0$, and Equation 10 implies that $R_e - D' = 0$.\(^{13}\) Equations 8 and 9 reduce to $\lambda M_p = \mu_p$ and $\lambda M_E = \mu_E$, respectively. Since $\lambda$, $M_p$, and $M_E$ are all positive, $\mu_p$ and $\mu_E$ must both be strictly positive, implying that the nonnegativity constraints on $p$ and $E$ both bind. But then $p$ and $E$ are both zero, making $M(p, E) = 0$, which means that the agency spends none of its budget. Consequently, the standard must be set at $s_0$ when the budget constraint is binding.

One can think about this result in the following way. When the agency is unable to achieve its unconstrained maximum, firms pollute too much from the agency’s perspective rather than too little. The budget is inadequate to achieve the desired pollution reduction through enforcement expenditures alone. But, since fines increase with the size of violations (according to an exogenously given schedule) and not with the amount of emissions, the agency can increase fines for a given level of emissions by simply reducing the standard. This means setting the standard as stringent as possible.

Moreover, if the constraint is binding, it behaves as if it minimizes the amount of noncompliance with the tightest standard. Since $\lambda > 0$, the first-order conditions for the agency’s maximization problem are reduced to the following:

\[ e^*_p / e^*_E = M_p / M_E \] (11)

\[ B - M(p, E) = 0. \] (12)

Notice that these are the same as the first-order conditions for the following problem:

\[ \min_{p, E} n(e - s_0) \quad \text{s.t} \quad B - M(p, E) = 0. \] (13)

In other words, in this case the agency maximizes its objective by minimizing violations of the standard.

Now consider the unconstrained case, that is, the case in which the agency’s budget is high

\(^{13}\) Standard comparative statics analysis of the firm’s problem establishes that $e^*_p > 0$ when $F_{ee} > 0.$ If the standard rises (becomes less strict), then for fixed enforcement parameters a given level of emissions constitutes a smaller violation. If $F_{ee} > 0$, this means that the marginal fine falls when the size of the violation falls, leading the firm to emit more pollution.
enough to make $\lambda = 0$. If the agency sets positive values of $p$ and $E$, and $s \geq s_0$, its first-order conditions reduce to the following:

$$R_e[x*(p, E, s), e*(p, E, s)] - D'[ne*(p, E, s)] = 0 \quad (14)$$

$$B - M(p, E) = 0. \quad (15)$$

There are only two equations and three unknowns, implying multiple solutions.\(^{14}\) This multiplicity has an important implication: If the agency’s budget is large enough to leave it unconstrained, imposing a standard on the agency does not affect the outcome. To see this, first note that in the unconstrained case, the agency sets the standard and enforcement parameters so that $x = x^*$ and $e = e^*$. So, if an outside entity imposes the standard $s = s'$, $p$ and $e$ are determined by the equations $x(p, E, s') = x^*$ and $e(p, E, s') = e^*$. Consequently, if the agency is given both a standard to enforce and a sufficiently large budget, it can still reach its unconstrained optimum.

This also implies that if the agency is given an exogenous standard to enforce in the unconstrained case, an increase in the standard both reduces violations and increases the marginal fine schedule. The effect on violations is clear: Firms emit $e^*$ regardless of the standard, and violations are defined by $v = e - s$. So, when the standard rises, violations fall by the same amount. The effect on marginal fines arises from the fact that the marginal fine schedule is increasing, but an increase in the standard reduces violations. Consequently, unless the agency alters its enforcement parameters, when the standard rises, marginal fines fall, leading to an increase in emissions. To induce firms to maintain emissions at $e^*$, the marginal fine schedule must shift upward.

The final issue to be explored is the issue of social welfare. In particular, is the equilibrium outcome optimal from society’s point of view? Social welfare consists of consumer surplus as well as firms’ profits and environmental damages, so it differs from the agency’s secondary objective function (Equation 4). In the unconstrained case, the agency tends to attain too low a level of pollution relative to the social optimum because the agency does not take into account the reduction in consumer surplus caused by a marginal reduction in pollution. More specifically, let $C(x, e)$ denote consumer surplus. Consumer surplus is increasing in output and so is increasing in both inputs, $x$ and $e$. If the social welfare function is $R(x, e) + C(x, e) - D(e)$, a necessary condition for the social optimum is $R_e + C_e - D' = 0$. But, with an unconstrained agency, $R_e - D' = 0$. Since $C_e > 0$, this implies that there is too little pollution, and thus too little output, compared to the social optimum.\(^{15}\)

In the constrained case the agency is unable to limit pollution to the agency’s unconstrained optimal level, and small increases in pollution from that level increase social welfare. So, if the agency’s budget is set correctly, the solution to the agency’s constrained problem is the same as the social optimum.

4. Concluding Remarks

This paper studies an environmental regulatory agency that sets both the environmental standard and the parameters for enforcing it. The only constraint placed on the agency is an

\(^{14}\) It might be the case that the shadow price of the budget is zero, but the agency uses the additional funds to enhance its own welfare, perhaps by redecorating its offices. For simplicity, we assume such behavior away.

\(^{15}\) If consumer surplus were included in the agency’s objective function so that its objective function coincides with the social welfare function, the unconstrained optimum would maximize social welfare.
exogenously given enforcement budget. It is found that either the agency sets the standard at the strictest allowable level or it can reach its unconstrained optimum, depending on the size of the budget. This would not be a problem from society’s perspective except that consumer surplus does not enter into the agency’s objective function, and so at the unconstrained optimum there is too little output and too little pollution compared to the social optimum.

The importance of this study for the environmental literature is that it does not separate the agency’s standard-setting role from its standard-enforcing role. Previous studies, in contrast, consider only one of the two roles at a time, although the results of this study establish that if the agency’s budget is sufficiently small, the agency sets enforcement parameters to minimize noncompliance with the selected standard, which is the usual assumption in the literature. The implication for policy makers is that sometimes the roles of setting and enforcing standards are better kept separate. Moreover, the results suggest that there is a reason, different from the fear of waste within the agency, that an environmental agency should not be given an excessive budget—with an excessive budget, the agency restricts pollution, and hence production, too much.

References


