Self-Policing in a Targeted Enforcement Regime

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Abstract

This paper adds to the debate over whether self-policing can increase environmental protection by considering an aspect of self-policing that has been ignored in previous models – that self-policing may influence future enforcement. The model combines self-policing with targeted enforcement and allows for both deliberate and inadvertent violations. As expected, rewarding self-policers with more lenient future enforcement increases auditing, remediation, and disclosure of inadvertent violations. Self-policing can also serve as a complement to deliberate compliance and can thus further increase environmental performance. However, under reasonable conditions self-policing can be a substitute for deliberate compliance and could therefore be detrimental to environmental protection.

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1. Introduction

There is an on-going debate in both the theoretical and empirical literature about the effectiveness of self-policing policies such as the Environmental Protection Agency's (EPA) Audit Policy.[1] EPA consistently publicizes the Audit Policy as a successful, innovative approach to compliance. For example, the introduction to EPA's 2002 Enforcement and Compliance Assurance Report, "Environmental Results Through Smart Enforcement," includes the 26 percent increase in companies self-disclosing violations as one of the year's highlights.[2] However, Pfaff and Sanchirico's (2004) finding that the typical self-disclosed violation is relatively insignificant leads them to question whether the Audit Policy is as effective as EPA claims. Similarly, Stafford (2005) examines compliance with hazardous waste regulations before and after the establishment of the federal Audit Policy and does not find any significant evidence that the federal Audit Policy has affected overall compliance.[3]

The theoretical literature on self-policing is also mixed. While many theoretical models of self-policing show that it can increase environmental protection (e.g., Kaplow and Shavell (1994) and Innes (1999)), other models demonstrate how self-policing can have significant negative effects (e.g., Heyes (1996) and Friesen (2006)). This paper adds to the debate over the ability of self-policing to increase environmental protection by considering one aspect of self-

[1] EPA issued its "Incentives for Self-Policing: Discovery, Disclosure, Correction, and Prevention of Violations," commonly referred to as the Audit Policy, on December 22, 1995 (60 *Federal Register* 66705).
[2] U.S. EPA (2003), page 4.
[3] However the results suggest that state audit legislation and self-policing policies may decrease violations of hazardous waste regulations.

policing that has been ignored in previous models – the fact that self-policing may influence future enforcement activity.

EPA's Audit Policy provides incentives for regulated facilities to conduct environmental audits and voluntarily self-police by offering significant penalty reductions for any disclosed violations that meet certain eligibility criteria.[4] Additionally, EPA's website for environmental auditing notes that when regulated facilities self-police, it can render "formal EPA investigations and enforcement actions unnecessary."[5] Although the EPA website implies that self-policing can affect future enforcement activity and a companion paper, Stafford (2006), finds that self-disclosures do decrease the probability of future inspections, to date all theoretical models of self-policing are essentially static models.

This paper adds to the existing theoretical literature on self-policing by incorporating self-policing into Harrington's (1988) dynamic targeted enforcement model. The paper then investigates the effect of self-policing on facility behavior and examines the circumstances under which self-policing can increase environmental protection and the circumstances under which it can be detrimental. The remainder of the paper is organized as follows: Section 2 provides a brief review of the theoretical literature on self-policing; Section 3 presents a theoretical model of self-policing in a targeted enforcement regime; Section 4 discusses the implications of self-policing for environmental performance under this model; and Section 5 concludes.

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[4] For example, the violation must be promptly disclosed; the discovery must be independent of any government actions or requirements; any harm caused by the violation must be remediated expeditiously; and a similar violation must not have occurred within the last three years.
[5] See http://www.epa.gov/compliance/incentives/index.html, last accessed February 22, 2006.

2. Theoretical Literature on Self-Policing

A number of theoretical papers have examined the concept of voluntary self-policing in a static setting.[6] Kaplow and Shavell (1994) model a probabilistic enforcement regime with self-policing. In their model, facilities choose between compliance and non-compliance.[7] Regulators inspect with probability less than one and if a facility is inspected its compliance status is revealed. If self-policers face a reduced fine equal to the certainty equivalent of the sanction they would face if they did not disclose but instead took their chances that the violation would be discovered, Kaplow and Shavell show that self-policing will not affect deterrence. Additionally, such a regime will result in a welfare improvement because enforcement effort is reduced as self-policers need not be inspected. Moreover, if individuals are risk averse rather than risk neutral, self-policing can lead to welfare improvements through the reduction of risk.

Innes (1999) extends this model by considering the potential benefits of remediation under a self-policing policy. Innes models the compliance decision as a continuous choice in the level of care that the entity expends, with the probability of environmental harm inversely related to the level of care. Entities costlessly observe whether harm has occurred and can choose whether or not to remediate the harm immediately. Regulators engage in monitoring efforts and the probability that regulators detect environmental harm at a facility is increasing in monitoring effort. In this model, entities will self-police and remediate as long as they pay a reduced fine

[6] The term self-policing is used in this paper to denote a situation in which a facility notifies authorities that it has violated a regulation. Other authors such as Kaplow and Shavell (1994) have termed this same activity "self-reporting". However, the term self-reporting has also been used to describe situations where facilities are required by law to report information to regulators (such as the self-reported emissions data required for the Toxics Release Inventory).

[7] The authors note that the analysis and conclusions of the model would be unchanged if non-compliance were probabilistic, i.e., occurred with probability less than one assuming no deliberate investment in compliance.

equal to the expected penalty they would pay if they did not self-police. Under such a regime, the level of remediation will increase because self-policers remediate with certainty while non-disclosers only remediate when caught. Therefore self-policing can be welfare enhancing even if enforcement costs are not reduced. Moreover, the optimal penalty can be increased relative to a non self-policing regime, resulting in a lower level of monitoring for a given level of deterrence, and thus lower enforcement costs. Innes (2001) also shows that if violators can engage in avoidance activities, self-policing can increase efficiency by reducing such activities and, in turn, allowing the government to achieve the same level of deterrence with a reduced enforcement effort.[8]

Heyes (1996) incorporates self-policing into a model of environmental compliance, although in this model self-policing is not an independent choice as regulated entities cannot remediate violations without disclosing such actions to regulators. As in Innes' models, entities choose a level of preventative effort which inversely affects the probability that a facility will cause environmental harm. Entities costlessly observe whether harm has occurred and can choose whether or not to remediate the harm immediately. Heyes assumes that remediation cannot be done covertly and thus remediation is in effect self-policing. If entities do not self-police, the harm may be detected by the regulator with probability less than one. Additionally, the cost of remediation increases if not done immediately. Heyes shows that decreasing the fine faced by self-policers relative to the fine for detected harm increases the level of self-policing. However, decreasing the fine faced by self-polluters can also decrease the initial level of care taken by regulated entities.

[8] Since avoidance activities are reduced, the cost of increasing penalty levels is reduced and the government can substitute higher penalties for lower enforcement effort.

Mishra, Newman, and Stinson (1997) construct a model of self-policing that is designed to capture specific aspects of EPA's Audit Policy. Because the focus of the model is on a facility's incentive to conduct a compliance audit and self-police, compliance is exogenous. More specifically, the model assumes that violations are probabilistic and do not depend on the facility's actions. Moreover, facilities can learn of their compliance status only through compliance audits which are costly. Because remediation costs increase over time, facilities may audit to reduce expected costs given the likelihood of being caught later and forced to remediate at a higher cost. In this model, welfare improvements result only from increased remediation and decreased enforcement effort, not from increased deterrence.

Friesen (2006) also assumes that violations are probabilistic and do not depend on the facility's actions. Facilities can learn of their compliance status only through costly compliance audits and must decide first whether to audit and then whether to disclose any violations that are discovered. Regulators must decide whether or not to inspect a facility, but inspections are subject to error and violations are discovered with a probability less than one. However, the probability of discovering a violation increases if the facility has conducted an environmental audit. Assuming that facilities must remediate any disclosed violations, Friesen shows that facilities will only audit if they intend to remediate the violation, although not all facilities will disclose their remediated violations. Friesen also shows that the regulator will not inspect a facility that has disclosed a violation. However, auditing will generally occur with probability less than one in equilibrium and thus self-policing does not preclude the need for regulator monitoring. Moreover, policies that encourage self-policing can lead to duplication of effort and thus be inefficient. Although Friesen's model does allow regulators to incorporate self-policing into their enforcement strategy, the model is not dynamic in the sense that regulated facilities and regulators repeatedly interact and optimal actions take future consequences of one's actions into account. To date, no model of self-policing incorporates such dynamic considerations.[9]

3. A Dynamic Model of Self-Policing in a Targeted Enforcement Regime

Harrington's (1988) model of targeted enforcement is the starting point for this dynamic model of self-policing.[10] Harrington's model was developed as a response to a widespread perception that facilities in the U.S. were "overcomplying" with environmental regulations given the low probability that a facility would be inspected and the relatively minor fines that a facility would receive if found to be in violation. Harrington demonstrates how a targeted enforcement regime can leverage enforcement resources and maintain a higher level of compliance than can be obtained through more traditional, non-targeted enforcement.

While Harrington's model has received some criticism in the theoretical literature, anecdotal and empirical evidence suggests that the targeted enforcement model is consistent with current EPA enforcement practices.[11] For example, the introduction to the Fiscal Year 2002 Enforcement and Compliance Assurance Report states that EPA's enforcement approach includes using "data analysis and other relevant information to marshal and leverage resources to

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[9] Livernois and McKenna (1999) present a dynamic model of self-reporting (as opposed to self-policing) in which firms choose whether to comply and whether to truthfully report their compliance status. Regulators use fines and inspection probabilities to both maximize initial compliance and induce truthful reporting (which ultimately leads to quicker remediation).

[10] While Harrington was not the first to introduce targeted or state-dependent enforcement (see, for example, Landsberger and Meilijson (1982)), he was the first to develop a model of targeted enforcement in an environmental context.

[11] The criticism focuses on two main points: the "optimal" enforcement scheme does not minimize the costs of pollution control and the results may not hold under all information or costs structure. See, for example, Harford and Harrington (1991) and Raymond (1999).

target significant noncompliance."[12] Perhaps the most direct empirical test of the applicability of the targeted enforcement model to environmental regulation is that of Helland (1998) which examines enforcement of the Clean Water Act using data on the pulp and paper industry and finds that the results are generally consistent with targeted enforcement.

This model incorporates self-policing into Harrington's targeted enforcement model. As in the original model, regulated facilities are divided into two groups based on past compliance. Facilities with poor compliance records are placed in a target group and inspected with a higher probability that facilities in the non-target group. Facilities found in violation of regulations are always moved into the target group while facilities found to be in compliance can transition to the non-target group with some positive probability. Each period, facilities choose whether or not to comply. The regulator then inspects the facility with a probability based on the facility's group. Depending on the results of the inspection, facilities may be moved from one group to the other before the next period. Facilities that are not inspected stay in their group for the next period. As shown in Harrington (1988) this type of enforcement regime can lead to higher levels of compliance than would occur under a regime where all facilities face the same probability of inspection.[13]

Following the Harrington model, regulators classify all regulated facilities into one of two groups: G_1 is the "good" group and G_2 is the targeted or "bad" group. Inspection probabilities vary across the groups with the inspection probability for G_1 (π) less than the inspection probability for G_2 (ρ). However, unlike the Harrington model, there are two possible

[12] See EPA (2003), page 3.
[13] There have been a number of extensions to Harrington's basic model (see for example, Harford and Harrington (1991) and Friesen (2003)). However, none of them have incorporated self-policing.

types of noncompliance, deliberate and inadvertent.[14] Regulations require a facility to abate pollution at a cost of *c* per period, with abatement costs differing across regulated facilities.[15] If a facility does not abate pollution and is inspected, the deliberate violation will be discovered and the facility will be fined *Z*.[16] Because lack of abatement can only be detected in the period in which it is committed, if the facility is not inspected it cannot be fined for its current lack of abatement.

Facilities are also subject to a probabilistic event (e.g., a spill) that occurs with probability *p* and will inadvertently render the facility noncompliant. To discover whether the event has occurred, facilities must conduct an audit at a cost of *a*.[17] Returning to compliance costs *k*, but once remediated the violation cannot be detected by regulators.[18] If the event occurs and a facility does not remediate but is inspected, it is assessed a fine *F*. For simplicity, let *F* include the cost of remediation (*k*) as well as a punitive fine. Alternatively, if the facility discovers the occurrence, remediates, and discloses it to regulators, the facility receives a fine *R*. Since *R* does not include the cost of remediation, $R + k$ must be less than *F*. To be consistent

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[14] This compliance paradigm is similar to that of Livernois and McKenna (1999) in that it allows for both deliberate and probabilistic violations. However, in the Livernois and McKenna model these different violations are two mechanisms by which a facility could violate the same regulation. In this model, the two types of violations are independent of each other.

[15] Because there are no interaction between facilities, facility subscripts are suppressed to simplify notation.

[16] This is a significant departure from Harrington's model where fines are dependent on a facility's group. In that model, maximum deterrence is achieved when the fine is set at 0 for facilities in G_1 and at the maximum possible level for facilities in G_2. However, Raymond (1999) shows that when facilities have heterogeneous costs (as is possible in this model), the optimal fine for G_1 depends on the distribution of costs. Given the complexity of this model, solving for the optimal fine level is beyond the scope of this paper. Therefore, fines do not depend on a facility's group (which appears consistent with current EPA policy).

[17] This assumption is consistent with Mishra, Newman, and Stinson (1997) and Freisen (2006).

[18] If a probabilistic violation could be detected after remediation, facilities would not audit unless they planned to disclose any discovered violations.

with EPA's Audit policy, facilities must make the disclosure decision prior to an inspection occurring. Finally, note that facilities cannot disclose deliberate violations to receive a reduced fine. By including both deliberate and inadvertent compliance, the model captures the fact that self-policing is not possible for all violations.[19] Thus the model can investigate the effect of self-policing on behavior that is not subject to self-policing.

Each period regulators receive one of four possible signals about the facility's compliance status:

i. The facility is in complete compliance based on an inspection with no violations;
ii. The facility is in violation of regulations based on an inspection;
iii. The facility is in violation of the regulations based on a self-disclosure, but no violation has been detected by an inspection; or
iv. No information.

Note that this information structure assumes that regulators do not distinguish between types of violations for targeting purposes. The transition matrix presented in Table 1 shows the probability that a facility in Group *i* moves to Group *j* for the next period given the regulator's signal.

With no information, the facility's group does not change. Facilities in G_2 that are found in compliance will move to G_1 with probability g. Facilities found to be in violation will be in G_2 next period, regardless of their starting point. Finally, facilities that disclose but have not been found to be in violation through an inspection will stay in G_1 with probability m if they

[19] Some violations are expressly omitted from the Audit Policy such as repeated violations, violations of an order, consent agreement, or plea agreement, and violations that result in serious actual harm to human health and the environment.

begin in G_1 and will move to G_1 with probability q if they begin in G_2. Assuming that inspection probabilities and fines are constant, as long as future payoffs are discounted by δ where $0 \leq \delta < 1$, Harrington (1988) shows that the optimal facility policy is a stationary policy and is independent of the initial state of the system.

With respect to deliberate violations, the facility has two possible choices, to abate or to pollute. With respect to the probabilistic violations, the facility must make three decisions: (1) whether to audit; (2) whether to remediate a violation is one if discovered; and (3) whether to disclose a violation.[20] If a facility decides not to audit, it has no more decisions to make. If it does audit, it can choose to remediate but conceal the violation, remediate and disclose the violation, or to not remediate and not disclose. This is consistent with EPA's Audit Policy, as remediation is required as a part of disclosure. However, auditing without remediating or disclosing is dominated by not auditing, as the facility saves the cost of auditing with no change in the probability of detection. Thus there are three viable actions with respect to probabilistic violations: No Audit; Audit-Remediate-Conceal; or Audit-Remediate-Disclose.[21] Combining these actions with the actions for deliberate violations yields six possible strategy combinations:

1. Abate/No Audit
2. Pollute/No Audit
3. Abate/Conceal

[20] For some violations, such as recordkeeping violations, it may not be possible to "remediate" without disclosure.

[21] Since facilities that disclose in G_2 increase the likelihood that they will transition back to G_1, a facility might want to fake a probabilistic violation, that is disclose when a violation has not occurred. To ensure that this does not occur, the regulator could set q and R so that fraudulent reporting is never optimal. Alternatively, the regulator could verify that disclosures are valid and impose further fines on any facility that fraudulently reports a violation. Rather than add additional complexity to the model, assume that the penalty for fraudulent reporting is high enough to ensure that facilities do not fraudulently report.

4. Pollute/Conceal
5. Abate/Disclose
6. Pollute/Disclose

Given these strategies, one can write down the expected cost of each strategy based on whether the facility is in G_1 or G_2. For example, a facility that undertakes a strategy of abating but not auditing (Strategy 1) if it is in G_1 will have the following expected cost:

$$c + p[\pi(F + \delta\beta) + (1-\pi)\delta\alpha] + (1-p)\delta\alpha = c + p\pi F + p\pi\delta\beta + (1-p\pi)\delta\alpha,$$

where α is the expected present value of being in G_1 given the strategy being considered and β is the expected present value of being in G_2 given the strategy being considered. Under this strategy, the facility pays c to abate. Additionally, because it does not audit, with probability $p\pi$ the facility is inspected and found to be in violation, fined F, and put into G_2 for the following period; with probability $p(1-\pi)$ it is in violation, but not inspected and thus stays in G_1; and with probability $(1-p)$, there is no violation, so it also stays in G_1 regardless of whether it is inspected or not. Using the same logic, one can develop the expected cost of each strategy for each initial starting point as shown in Table A1 in Appendix A. The facility then has 36 possible policies denoted by f_{ij} where i describes the strategy taken in G_1 and j describes the strategy taken in G_2. To evaluate the expected cost of each policy, one solves the system of equations formed by taking (1) the expected cost of strategy i using G_1 as a starting point and (2) the expected cost of strategy j using G_2 as a starting point.[22]

Some of the expected cost functions are very straightforward. For example, a facility that chooses a policy of abatement and disclosure in both groups (f_{55}) is always in full compliance and has an expected present value cost of

[22] The expected costs of the 36 facility policies are available from the author upon request.

$$\frac{c + a + p(k + R)}{1 - ä}.$$

However, other policies have much more complicated expected costs as the regulated facility will move in and out of the two groups based on inspections and disclosures.

Given the regulator's targeting plan and the facility's costs, the goal of the facility is to choose the policy that minimizes the present value of expected costs. One policy can be immediately ruled out as non-optimal. Abatement and disclosure regardless of group (f_{55}) is strictly dominated by abatement and auditing-remediation-concealment in both groups (f_{33}) because the only advantage to disclosure in this model is that one may receive some benefit in terms of moving out of G_2 to G_1.[23] However, since the facility is always in compliance, it receives no benefit from being in the non-target group.

Which facility policy will ultimately be most profitable depends on the relative costs of abatement and auditing as shown in Table 2.[24] As long as audit costs are low, facilities will always audit. However, whether they will abate or disclose depends on abatement costs and fines for disclosed violations. As long as abatement costs are low, facilities will always abate but whether they will audit and disclose depends on the relative costs of auditing and the fines for disclosed violations. When both audit and abatement costs are low, facilities will always audit and abate, but will not disclose because facilities do not care about the probability of inspection. When neither audit or abatement costs are low, the optimal strategy is more difficult to determine and depends not only on the relative costs of auditing and abatement, but also on the rates at

[23] Given the assumption that after remediation a probabilistic violation cannot be detected, there are no other benefits to disclosure. If corrected violations can be detected and fined, disclosure would provide additional benefits.
[24] Since auditing without remediation is never optimal, in the following discussion, the cost of remediation in subsumed in the cost of auditing.

which facilities are moved between the two groups and the fines imposed for disclosed violations.

4. Implications of Self-Policing for Environmental Performance

4.1 Introducing Self-Policing into a Targeted Enforcement Regime

Optimal behavior in the absence of self-policing can be derived by setting the penalty for disclosed violations equal to the penalty for detected violations ($k + R = F$), moving all facilities that disclose in the non-target group into the target group ($m = 0$), and keeping all facilities that disclose in the target group in the target group ($q = 0$). Under these parameter values, disclosed violations and detected violations are treated equally by regulators. Table 3 summarizes the optimal facility policies when facilities are not rewarded for self-policing. To assess how introducing self-policing affects facility behavior, compare Table 2 to Table 3. When there is no incentive to disclose, all policies that involve disclosure are dominated by analogous policies that involve concealment. For example, with self-policing the f_{15} policy [Abate/No Audit in G_1, Abate/Disclose in G_2] will have a lower cost than the f_{13} policy [Abate/No Audit in G_1, Abate/Conceal in G_2] as long as the following inequality holds:

$$pR(1-\delta+p\delta\pi+\delta\rho g) < (a+pk-\pi pF)p\delta(q-\rho g).$$

However, if there is no self-policing, this requirement becomes:

$$pF(1-\delta+p\delta\pi+(1-p\pi)\delta\rho g) < (a+pk)(-p\delta\rho g)$$

which can never hold. Therefore when self-policing is introduced, many facilities may find it optimal to change their policies toward auditing, disclosure, and abatement as summarized in Table 4. The next several paragraphs describe in general the types of changes that may occur under self-policing. Appendix B provides a more detailed discussion of the conditions necessary to effect such changes.

Facilities with low audit costs will audit without self-policing, so introducing self-policing will have no effect on the incentives for auditing at these facilities. For facilities with low audit costs and moderate or high abatement costs, self-policing may induce some disclosure of remediated violations from the target group. Whether a facility will disclose depends on the cost of disclosure relative to its benefit (that is the likelihood of transitioning to the non-target group as well as the benefit to the facility from being in the non-target group).[25] Facilities with moderate audit costs will audit in the target group without self-policing, but will not audit when they are in the non-target group. Since the self-policing policy modeled in this paper does not benefit facilities in the non-target group, introducing self-policing will not affect auditing at these facilities. However, some of these facilities will disclose violations from the target group once self-policing is introduced, depending on the cost of disclosure relative to its benefit. Finally, for facilities with high audit costs, introducing self-policing will induce some facilities that would not otherwise audit to audit and disclose in the target group. For facilities with high audit costs that would audit in the absence of self-policing, self-policing can increase disclosures in the target group.

Self-policing can also change the incentives for a facility to abate in both the target and non-target groups. Interestingly, depending on a facility's costs and the reward to self-policing, self-policing in the target group can serve as both a substitute for and a complement to abatement in the target group. For example, without self-policing a facility with high abatement costs

[25] Since facilities with low abatement costs always abate, they do not receive any benefit from being in the non-target group and thus have no incentives to disclose.

might find it optimal to abate in the target group so that it can transition to the non-target group in the future. Since disclosure also provides an alternate pathway back to the non-target group, some facilities may find it more cost-effective to substitute disclosure for abatement in the target group. On the other hand, a facility with high abatement costs may not abate in the absence of a self-policing policy, but may find the combined benefit from abatement and disclosure to be worth the cost. Appendix B provides more details on the conditions under which each of these behavioral shifts can occur. Self-policing in the target group can also serve as a substitute for abatement in the non-target group. For example, under self-policing some facilities may stop abating when in the non-target group but disclose in the target group if disclosure can provide a cost-effective mechanism to move back into the non-target group. This change can occur as long as abatement costs are moderate or high and audit costs are moderate or high. Finally, the introduction of self-policing may result in an increase in abatement from the non-target group when abatement costs are high. However, as shown in Appendix B, this can occur only under very restrictive conditions.

4.2 Policy Changes

As discussed above, introducing self-policing can change facility behavior in a number of different ways. On the positive side, it can increase the level of auditing, disclosures, and abatement. On the negative side, it may result in a decrease in abatement. The extent to which each of these effects will occur will depend on both the design of the self-policing policy (that is, the setting of R, m and q) as well as other enforcement parameters (g, π, ρ, F and Z) and the underlying distribution of audit and abatement costs. Moreover, whether or not a self-policing policy will provide increased environmental protection will depend not only on those factors, but also the benefit to the environment from increased auditing, disclosure, and abatement.

Therefore, it is not possible to assess the optimal self-policing policy without specifying both the joint distribution of abatement and audit costs as well as the relative benefit from auditing (i.e., remediation of probabilistic violations), disclosure, and abatement. Rather than explicitly solve for the optimal policy parameters, the section examines the effect that various parameters have on the level of auditing, disclosure, and abatement.

Table 5 summarizes the effect of various policy parameter changes on auditing, disclosure, and abatement.[26] First consider those parameters specific to the audit policy: R, m, and q. Decreasing R, the fine associated with a disclosed violation, will obviously lead to more disclosures in the target group.[27] Additionally, decreasing R may lead to more audits (and thus higher levels of remediation) at facilities in the target group. However, a decrease in R can lead to a decrease in abatement in the non-target group, as a lower R provides a cheaper pathway back into G_1 for facilities that are moved to G_2 due to noncompliance. It is also likely that a decrease in R will lead to lower levels of abatement in G_2 as disclosure becomes a more cost effective substitute for abatement in the target group. While it is possible that a decrease in R could lead to an increase in abatement in G_2 since auditing and abatement can be complements, the conditions under which this can occur are very restrictive.[28]

Increasing m, the probability that a facility who discloses in G_1 will stay in G_1, has no effect on abatement, auditing, or disclosure because disclosing when a facility is in G_1 is always dominated by audit and staying silent if m is less than one. Even if m is equal to one, auditing

[26] Formal proof of the effect of parameters changes on facility behavior is available from the author upon request.
[27] Facilities in the non-target will never disclose as long as R is greater than 0.
[28] For an increase in abatement to occur in G_2, at a minimum facilities must have high abatement costs and the transition probability for disclosures must be larger than the transition probability for abatement (i.e., $q > \rho g$). Depending on a facility's audit costs, there are additional constraints on the cost of abatement relative to the expected costs of non-abatement that must hold.

and staying silent weakly dominates auditing and disclosing as long as R is greater than zero.[29] However, increasing q, the probability that a facility who discloses in G_2 will be moved to G_1, does affect auditing, disclosure, and abatement. Increasing q has the same qualitative effect as a decrease in R: it will increase audits and disclosures in G_2, a decrease in abatement non-target group, and most likely decrease abatement in G_2. However, under very restrictive conditions, increasing q could lead to an increase in abatement in the target group.

Next consider those parameters that are not specific to self-policing. As one would expect, increasing g, the probability that a facility in G_2 with a clean inspection report will be moved into G_1, increases abatement at facilities in G_2 that have high abatement costs.[30] However, it also can lead to less abatement in G_1 as it provides an easier path back to G_1 for facilities that are moved to G_2 due to noncompliance. Moreover, it could lead to fewer disclosures and audits for some facilities in G_2 if it is cheaper to return to G_1 via a clean inspection rather than through a disclosure. However, because abatement and audits can be complements, increasing g may lead to increased audits and disclosures in G_2.

Increasing the inspection rate in the non-target group, π, decreases the relative costs of both audits and abatement in the non-target group and thus can lead to an increase in audits and/or abatement in G_1. However, since audits and abatement can be substitutes for each other, as auditing in G_1 becomes cheaper, abatement in G_1 could decrease. Moreover, some facilities may substitute audits in G_1 for abatement or disclosures in G_2. Similarly, as abatement in G_1 becomes cheaper, facilities may substitute abatement in G_1 for audits and disclosures in G_2.

[29] If it is not possible to remediate without disclosing a violation, increasing m will increase the number of disclosures at facilities in G_1 that have low audit costs and can increase abatement at facilities in G_2 that have both low audit costs and high abatement costs.

[30] Facilities with low or moderate abatement costs will comply regardless of the size of g.

Finally, as the benefit of being in the non-target group decreases (i.e., as π approaches ρ), facilities in the target group will be less willing to invest in abatement or disclosures in the hopes of being moved back to the non-target group. Thus even if auditing and abatement do not change in G_1, we could see a further decrease in audits, disclosures and abatement in G_2 because increasing π without increasing ρ decreases the leverage of a targeted enforcement regime.[31]

Increasing ρ, the inspection rate in the target group, decreases the relative costs of both audits and abatement in the target group and thus can lead to an increase in audits, disclosures or abatement in G_2. Additionally, increasing ρ increases the leverage of the target enforcement regime as it increases the costs of being in the target group relative to the non-target group. Therefore, we may also see an increase in abatement in the non-target group. However, as abatement in G_2 becomes cheaper, facilities may substitute abatement in G_2 for audits and disclosures in G_2 or for abatement in G_1.[32] Although it is also possible that as auditing in G_2 becomes cheaper, abatement in G_2 could decrease, the conditions for this to occur are quite restrictive.

Increasing F, the fine for detected (as opposed to disclosed) probabilistic violations, decreases the relative cost of audits and thus can lead to an increase in audits in both groups and an increase in disclosures in the target group. Additionally, since increasing F increases the cost of the target group for facilities that do not audit in that group, some facilities begin to abate in the non-target group. On the other hand, for facilities that do not audit in the non-target group, increasing F increases the cost of the non-target group which will decrease the incentives for

[31] It is possible that facilities might choose to switch from disclosing in the target group to abating in the target group as π increases. However, this could only occur under for a very small set of parameters and abatement costs.
[32] However, the conditions for audits in G_2 to decrease are quite restrictive.

firms to disclose or abate in the target group. Moreover, if audits and abatement are substitutes, an increase in F can lead to a decrease in abatement in both groups. On the other hand, for some facilities in the target group audits and abatement may be complements, so increasing F could lead to an increase in abatement in the target group.

Increasing Z, the fine for lack of abatement, decreases the relative cost of abatement and thus can lead to an increase in abatement in both groups. Additionally, since increasing Z increases the cost of the target group for facilities that do not abate in that group, some facilities will begin to audit and possibly disclose in the target group. However, if audits and abatement are substitutes, increasing Z can lead to a decrease in audits and disclosures in the target group. On the other hand, for some facilities in the target group audits and abatement can be complements, so increasing Z could lead to an increase in audits and disclosures in the target group.

As shown in Table 5, none of the possible parameter changes will have a purely positive effect on environmental performance. Thus in designing a self-policing policy, the regulator must recognize the tradeoffs between increasing auditing, disclosures, and abatement. In particular, many of the policy changes that increase auditing and disclosures will decrease abatement and vice versa. If the goal of the regulator is to increase the remediation of probabilistic violations by increasing the number of facilities that audit, increasing F, the fine for probabilistic violations, can increase audits in both the target and non-target groups. Although this will not necessarily result in an increase in disclosures, it would increase the remediation of probabilistic violations and thus could result in a significant increase in environmental protection if such violations are likely to cause serious harm to the environment. Additionally, such a change would not necessarily cause a decrease in abatement, as auditing and abatement can be complements to each other. Of course, there are limits to a regulator's ability to raise penalties that are not represented in this model but are well-discussed within the literature.[33]

Alternatively, decreasing the fine for disclosed violations, *R*, and increasing the probability that a facility that discloses in the target group, *q*, will increase both audits and disclosures at facilities in the target group, but will not affect auditing in the non-target group. However, such actions are likely to result in decreased abatement, as facilities can use disclosures to decrease the probability of future enforcement actions.[34] This effect is consistent with Pfaff and Sanchirico's (2004) proposition that facilities might use the disclosure of minor violations as "red herrings" to discourage inspections or distract regulators from other problems.

Table 5 also highlights the fact that increases in auditing will not necessarily be accompanied by increases in disclosures. For example, increasing *F* could result in more audits but fewer disclosures. Thus any analysis of the effectiveness of a self-policing policy should not use disclosures as a sole measure of the policy's effectiveness. While the introduction of a self-policing policy will result in an initial increase in disclosures, changes in an enforcement regime over time could result in fewer disclosures but a higher level of environmental protection. Finally, note that changes to policy parameters that are external to the self-policing policy will have an ambiguous effect on auditing and disclosure. Thus any proposed changes to the overall enforcement regime should be examined carefully for possible their impact on auditing and disclosure.

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[33] In fact, Harrington's (1988) original model was developed in part to examine how to leverage enforcement resources when penalties are restricted.
[34] Additionally, such changes could increase the incentive for a facility to fraudulently disclose a violation.

5. Conclusions

This paper presents a theoretical model of self-policing in a targeted enforcement regime. The model was designed to closely follow the design of EPA's audit policy, particularly the idea that self-policing may affect future enforcement. As expected, rewarding facilities that disclose with lower penalties and more lenient future enforcement increases the incentives to both audit and disclose. Because increased audits lead to increased remediation, self-policing can increase environmental protection. Additionally, disclosures themselves may be valuable to regulators as a source of information or if remediation requires disclosure (as would be the case with reporting violations). These results are consistent with many other theoretical models of self-policing. However, adding a dynamic aspect to self-policing and including both deliberate and inadvertent violations reveals new ways in which self-policing can affect facility behavior. On the positive side, self-policing can be complementary to other types of compliance and could increase environmental performance in areas that are not subject to self-policing. On the negative side, self-policing can be a substitute for other types of compliance and could therefore be detrimental to environmental protection. The model also demonstrates that changes to enforcement policies can have spillover effects and thus proposed changes to enforcement policies should consider the effect on facility's incentives to audit and self-police.

Finally, in this model designing the optimal enforcement regimes and self-policing policy requires information about the joint distribution of different types of compliance costs. This suggests that more focused self-policing policies – either for specific industries or specific media – might be better able to increase environmental protection than a policy that applies equally to all facilities and all media. In the U.S., many media programs do have self-policing policies in addition to the Audit Policy. However, since environmental audits are generally conducted for all environmental processes at a facility, too much differentiation across media programs could affect a facility's overall incentives to audit.

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Table 1: Transition Matrix for Each Target Group

Regulator's Information for Period t	Starting in G_1		Starting In G_2	
	Stay in G_1	Move to G_2	Move to G_1	Stay in G_2
i. Compliance	1	0	g	1-g
ii. Violation	0	1	0	1
iii. Disclosure	m	1-m	q	1-q
iv. No Information	1	0	0	1

Table 2: Optimal Facility Policies as a function of Audit and Abatement Costs

Audit Costs	Abatement Costs		
	Low: $\pi Z > c$	**Moderate: $\rho Z > c > \pi Z$**	**High: $c > \rho Z$**
Low: $\pi pF > a + pk$	f_{33}	f_{43}, f_{45}	f_{43}, f_{44}, f_{45}, f_{46}
Moderate: $\rho pF > a + pk > \pi pF$	f_{13}, f_{15}	f_{13}, f_{15}, f_{23}, f_{25}	f_{13}, f_{14}, f_{15}, f_{16}, f_{23}, f_{24}, f_{25}, f_{26}
High: $a + pk > \rho pF$	f_{11}, f_{13}, f_{15}	f_{11}, f_{13}, f_{15}, f_{21}, f_{23}, f_{25}	f_{11}, f_{12}, f_{13}, f_{15}, f_{16}, f_{21}, f_{22}, f_{23}, f_{25}, f_{26}

1=Abate/No Audit, 2=Pollute/No Audit, 3=Abate/Conceal, 4=Pollute/Conceal, 5=Abate/Disclose, 6=Pollute/Disclose.

Table 3: Optimal Facility Policies when Self-Policing is not Rewarded

Audit Costs	Abatement Costs		
	Low: $\pi Z > c$	**Moderate: $\rho Z > c > \pi Z$**	**High: $c > \rho Z$**
Low: $\pi pF > a + pk$	f_{33}	f_{43}	f_{43}, f_{44}
Moderate: $\rho pF > a + pk > \pi pF$	f_{13}	f_{13}, f_{23}	f_{13}, f_{14}, f_{23}, f_{24}
High: $a + pk > \rho pF$	f_{11}, f_{13}	f_{11}, f_{13}, f_{21}, f_{23}	f_{11}, f_{12}, f_{13}, f_{21}, f_{22}, f_{23}

1=Abate/No Audit, 2=Pollute/No Audit, 3=Abate/Conceal, 4=Pollute/Conceal.

Table 4: Possible Changes in Facility Behavior when Self-Policing is Rewarded

	Abatement Costs		
Audit Costs	**Low:** **$\pi Z > c$**	**Moderate:** **$\rho Z > c > \pi Z$**	**High:** **$c > \rho Z$**
Low: **$\pi pF > a + pk$**	No change.	Increased disclosures in G_2.	Increased disclosures in G_2. Increased or decreased abatement in G_2.
Moderate: **$\rho pF > a + pk > \pi pF$**	Increased disclosures in G_2.	Increased disclosures in G_2. Decreased abatement in G_1.	Increased disclosures in G_2. Increased or decreased abatement in G_1. Increased or decreased abatement in G_2.
High: **$a + pk > \rho pF$**	Increased audits in G_2. Increased disclosures in G_2.	Increased audits in G_2. Increased disclosures in G_2. Decreased abatement in G_1.	Increased audits in G_2. Increased disclosures in G_2. Increased or decreased abatement in G_1. Increased or decreased abatement in G_2.

Table 5: Effect of Policy Parameters on Audits, Disclosures, and Abatement

	Possible Effect of Parameter Change on		
Parameter Change	Audits	Disclosures	Abatement
Decrease R, fine for disclosed violations	G_1: No Change G_2: Increase	G_1: No Change G_2: Increase	G_1: Decrease G_2: Decrease*
Increase m, probability facility disclosing in G_1 stays in G_1	G_1: No Change G_2: No Change	G_1: No Change G_2: No Change	G_1: No Change G_2: No Change
Increase q, probability facility disclosing in G_2 moves to G_1	G_1: No Change G_2: Increase	G_1: No Change G_2: Increase	G_1: Decrease G_2: Decrease*
Increase g, probability facility with clean inspection in G_2 moves to G_1	G_1: No Change G_2: Increase/Decrease	G_1: No Change G_2: Increase/Decrease	G_1: Decrease G_2: Increase
Increase π, probability of inspection in G_1	G_1: Increase G_2: Decrease	G_1: No Change G_2: Decrease	G_1: Increase/Decrease G_2: Decrease*
Increase ρ, probability of inspection in G_2	G_1: No change G_2: Increase*	G_1: No Change G_2: Increase/Decrease	G_1: Increase/Decrease G_2: Increase*
Increase F, fine for detected probabilistic violations	G_1: Increase G_2: Increase	G_1: No Change G_2: Increase/Decrease	G_1: Increase/Decrease G_2: Increase/Decrease
Increase Z, fine for lack of abatement	G_1: No Change G_2: Increase/Decrease	G_1: No Change G_2: Increase/Decrease	G_1: Increase G_2: Increase

*Under very restrictive conditions, the opposite effect could occur.

Appendix A:

Under the stationary property, the expected cost of a strategy is equal to the cost this period of the strategy plus the expected present value of the strategy discounted one period. Let α be the expected present value of being in G_1 given the strategy being considered and β the expected present value of being in G_2 given the strategy being considered. Tale A1 presents the expected costs for each strategy. The facility then has 36 possible policy options denoted by f_{ij} where *i* describes the strategy taken in G_1 and *j* describes the strategy taken in G_2. To evaluate the expected cost of each policy option, one solves the system of equations formed by taking (1) the expected cost of strategy *i* using G_1 as a starting point and (2) the expected cost of strategy *j* using G_2 as a starting point. The expected present value cost of each policy option is available from the author upon request.

Table A1. Expected Costs for Each Strategy

Strategy	**Cost Starting in G_1**	**Cost Starting in G_2**
1: Abate/ No Audit	$c + p\pi F + p\pi\delta\beta + (1-p\pi)\delta\alpha$	$c + p\rho F + p\delta\beta + (1-p)(1-\rho)\delta\beta$ $+ (1-p)\rho(1-g)\delta\beta + (1-p)\rho g\delta\alpha$
2: Pollute/ No Audit	$\pi Z + p\pi F + \pi\delta\beta + (1-\pi)\delta\alpha$	$\rho Z + p\rho F + \delta\beta$
3: Abate/ Conceal	$c + a + pk + \delta\alpha$	$c + a + pk + \rho g\delta\alpha + (1-\rho g)\delta\beta$
4: Pollute/ Conceal	$a + pk + \pi Z + \pi\delta\beta + (1-\pi)\delta\alpha$	$a + pk + \rho Z + \delta\beta$
5: Abate/ Disclose	$c + a + p(k + R) + p(1-m)\delta\beta$ $+ (pm + (1-p))\delta\alpha$	$c + a + p(k+R) + p(1-q)\delta\beta$ $+ (1-p)(1-\rho)\delta\beta + (1-p)\rho(1-g)\delta\beta$ $+ pq\delta\alpha + (1-p)\rho g\delta\alpha$
6: Pollute/ Disclose	$a + p(k + R) + \pi Z + (\pi+p(1- \pi)(1-m))\delta\beta$ $+ (1-\pi)(pm + (1-p))\delta\alpha$	$a + p(k + R) + \rho Z + \rho\delta\beta + (1-p)(1-\rho)\delta\beta$ $+ p(1-\rho)(1-q)\delta\beta + (1-\rho)q\delta\alpha$

Appendix B:

This appendix provides examples of the behavioral changes that can occur when self-policing is introduced and the conditions required for such changes to occur. More detailed proofs are available from the author upon request.

If a facility has both low audit and low abatement costs, introducing self-policing has no effect on that facility's optimal strategy. For all other facilities, introducing self-policing can induce a change in the optimal strategy. The types of changes that are possible will depend on a facility's audit and abatement costs, as well as policy parameters. Since introducing self-policing does not affect a facility's audit or abatement costs, we can use a facility's cost structure to classify the possible effects that introducing self-policing may have on optimal behavior.

Because self-policing does not benefit facilities in the target group, introducing self-policing cannot increase audits or disclosures from the target group. However, self-policing can increase both auditing and disclosures in G_2. First consider disclosures. At facilities with low audit costs and moderate abatement costs, f_{43} is the optimal strategy when there is no self-policing. Once self-policing is introduced, disclosures will occur (i.e., f_{45} will be optimal) at facilities where $pR(1-\delta+\delta\pi+\delta\rho g) < (c-\pi Z)\delta p(q-\rho g)$. Although the conditions for disclosures to occur will vary depending on a facility's audit and abatement costs, in general disclosures will occur at facilities where R is relatively small and q is relatively large.

Next consider audits. For facilities with high audit costs, introducing self-policing can induce increased audits in G_2. For example, prior to self-policing facilities with high audit costs and low abatement costs will not audit if $(\rho pF-\pi pF)p\delta\rho g < (a+pk-\rho pF)(1-\delta+p\delta\pi+(1-p)\delta\rho g)$ (i.e., $f_{11}<f_{13}$). When self-policing is introduced, these facilities will begin to both audit and disclose as long as $(\rho pF-\pi pF)p\delta q > (a+pk+pR-\rho pF)(1-\delta+p\delta\pi+(1-p)\delta\rho g)$. Once again, the conditions for audits to increase will vary depending on a facility's audit and abatement costs but generally require will require that R is relatively small and q is relatively large.

Self-policing can also change whether abatement is optimal in both the target and the non-target group. First consider abatement in the target group. If a facility has low or moderate abatement costs, it will always abate in the target group, and introducing self-policing will have no affect. However, if a facility has high abatement costs, it may or may not be optimal to abate in the target group, and introducing self-policing may cause the facility to change its abatement strategy in the target group.

Because disclosure provides a means for facilities to transition to the non-target group, it is relatively intuitive that introducing self-policing could allow a facility to substitute disclosure for abatement in the target group. For example, consider a facility with low audit and high abatement costs. Without self-policing, facilities will abate in G_2 if $(c-\rho Z)(1-\delta+\delta\pi) < (\rho Z-\pi Z)\delta\rho g$ (i.e., $f_{43}<f_{44}$). When self-policing is introduced, some facilities that were abating in G_2 will stop abating but begin to disclose under the following additional conditions:

- $pR(1-\delta+\delta\pi+\delta\rho g) + (\rho Z-\pi Z)\delta\rho g < (c-\rho Z)(1-\delta+\delta\pi) + (c-\pi Z)p\delta(1-\rho)q$ [i.e., $f_{46}<f_{43}$] and
- $pR(p\delta\rho q+(1-p)\delta\rho g)+ (\rho z-\pi Z)(p\delta\rho q+(1-p)\delta\rho g) < (c-\rho Z)(1-\delta+\delta\pi+p\delta(1-\rho)q)$ [i.e., $f_{46}<f_{45}$].

As one might expect, R must be relatively small and q relatively large. Additionally, g cannot be too large or disclosure would not be a good substitute for a clean inspection.

On the other hand, disclosures and abatement can be complementary. Once again, consider a facility with low audit and high abatement costs. Without self-policing, facilities will not abate in G_2 if $(c-\rho Z)(1-\delta+\delta\pi) > (\rho Z-\pi Z)\delta\rho g$ (i.e., $f_{43}>f_{44}$). When self-policing is introduced, some facilities that were not abating in G_2 will begin to both abate and disclose under the following additional restrictions:

- $(\rho Z-\pi Z)(p\delta q+(1-p)\delta\rho g) > pR(1-\delta+\delta\pi) + (c-\rho Z)(1-\delta+\delta\pi)$ [i.e., $f_{44}>f_{45}$] and
- $pR(p\delta\rho q+(1-p)\delta\rho g)+ (\rho z-\pi Z)(p\delta\rho q+(1-p)\delta\rho g) > (c-\rho Z)(1-\delta+\delta\pi+p\delta(1-\rho)q)$ [i.e., $f_{46}>f_{45}$].

A necessary, but not sufficient, condition for all three restrictions to hold is that $q > \rho g$. In fact, this condition is necessary for disclosures and abatement to be complements for all cost categories. (A detailed proof is available from the author upon request.)

Finally consider abatement in the non-target group. If a facility has moderate or high abatement costs and moderate or high audit costs, introducing self-policing may cause the facility to change its abatement strategy in the non-target group. Because disclosure provides a means for facilities to transition to the non-target group, introducing self-policing could allow a facility to substitute disclosure for abatement in the non-target group. For example, consider a facility with moderate audit and moderate abatement costs. Without self-policing, facilities will abate in G_1 if $(c-\pi Z)(1-\delta+p\delta\pi+\delta\rho g) < (a+pk-\pi pF)(1-p)\delta\pi$ (i.e., $f_{13}<f_{23}$). When self-policing is introduced, some facilities that were abating in G_1 will stop abating in G_1 but begin to disclose in G_2 under the following additional conditions:

- $pR(1-\delta+p\delta\pi+\delta\rho g) < (a+pk-\pi pF)p\delta(q-\rho g)$ [i.e., $f_{15}<f_{13}$] and
- $(a+pk+pR-\pi pF)(1-p)\delta\pi < (c-\pi Z)(1-\delta+p\delta\pi+p\delta q+(1-p)\delta\rho g)$ [i.e., $f_{25}<f_{15}$] .

Once again, R must be relatively small and q relatively large. Additionally, the restrictions on the value of $(c-\pi Z)$ are quite narrow.

Under very limited conditions, introducing self-policing can result in an increase in abatement in the non-target group. For this to occur, facilities must have high abatement costs and moderate or high audit costs. For example, consider a facility with high abatement and moderate audit and costs that does not abate in either group but does audit in G_2. For this strategy (f_{24}) to be optimal:

- $(c-\pi Z)(1-\delta+\delta\pi) > (a+pk-\pi pF)(1-p)\delta\pi + (\rho Z-\pi Z)(1-p)\delta\pi$ [i.e., $f_{14}>f_{24}$] and
- $(c-\rho Z)(1-\delta+\delta\pi) > (a+pk-\pi pF)\delta\rho g + (\rho Z-\pi Z)\delta\rho g$ [i.e., $f_{23}>f_{24}$].

When self-policing is introduced, some of these facilities may start abating in both groups and disclosing in G_2 (i.e. f_{15}) if the following additional conditions hold:

- $(c-\rho Z)(1-\delta+p\delta\pi+p\delta q+(1-p)\delta\rho g) < (a+pk+pR-\pi pF)((1-p)\delta\rho g +p\delta\rho q)$ [i.e., $f_{15}<f_{16}$] and

- $(c-\pi Z)(1-\delta+p\delta\pi+p\delta q+(1-p)\delta\rho g) < (a+pk+pR-\pi pF)(1-p)\delta\pi$ [i.e., $f_{15}<f_{25}$].

While it is possible for all of these conditions to hold, the restrictions on relative costs and parameter values are quite severe. In the few other situations where it is theoretically possible for abatement in the non-target group to increase when self-policing is introduced, the required conditions for relative costs and parameters are similarly narrow.