

Public Mechanisms to Support Compliance to an Environmental Norm¹

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Two regimes to support compliance to an environmental norm are compared. Under the first, compliance to the rule is mandatory and is supported by a fine on noncompliance. Under the second, compliance is voluntary and is supported by government efforts to reduce the cost of compliance. Satisfaction of the necessary and sufficient condition under which a voluntary compliance regime dominates an alternative mandatory compliance regime depends on whether or not public effort is rival, the degree of excludability of public effort, and the relative prices of private and public effort. © 1995 Academic Press, Inc.

I. INTRODUCTION

Social norms, whether they be informal customs or formal codified rules, emerge naturally or are designed to constrain individual behavior. However, a norm by itself cannot constrain behavior without some mechanism that provides incentives for compliance. Typically, economists assume that compliance to a proposed policy can be supported through some public institution with the power to punish noncompliance. This is particularly true of environmental and natural resource policy proposals.² But, punishing noncompliance is not the only way to support compliance to a norm. In some situations, public institutions may be able to effectively encourage voluntary compliance to a norm by making compliance less costly. This paper provides a welfare comparison of these two forms of support in the context of compliance to an environmental norm.³

Of course, there are many cases in which governments support compliance to environmental rules by punishing noncompliance, but there are also real-world situations in which governments encourage voluntary compliance to environmental rules by making compliance less costly. Many communities now have voluntary

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²For a review and critique of the monitoring and enforcement mechanisms of U.S. environmental policy see Russell [21]. Theoretical analyses of various enforcement mechanisms include Harford [13] and Harrington [14]. In other contexts, Akerloff [3], Arrow [5], Roback [20], and Yinger [28] have all considered norms governing economic interactions among ethnic groups, while Akerloff [4] and Khaneman *et al.* [17] consider codes of "fairness" in setting wages and prices.

³This paper is not concerned with the creation or emergence of rules but rather focuses on the welfare consequences of the choice of support for a norm that already exists. Relatively general game theoretic analyses of the formation, evolution, and support of norms include Axelrod [6], Thompson and Faith [24], and Schotter [22]. The notion that equilibrium standards of behavior should be stable motivates Greenberg ([11, 12]).

curbside recycling programs. Typically, local governments provide the transport of recyclables and often provide separate trash bins that make collecting recyclable material easier. In communities without such programs, individuals who recycle must bear the full cost of doing so.

In a different context, the Pollution Prevention Act of 1990 [25] calls for the administrator of the EPA to facilitate "source reduction" activities by firms. Source reduction is defined in the Act as "any practice which reduces the amount of any hazardous substance... released into the environment prior to recycling, treatment, or disposal..." (Sec. 6603). The EPA administrator is called on to "foster the exchange of information regarding source reduction activities, the dissemination of such information to businesses, and the provision of technical assistance to businesses" (Sec. 6604) and to "make matching grants to States for programs to promote the use of source reduction techniques by businesses" (Sec. 6605). In response, the EPA instituted the 33/50 Program. This is a voluntary program designed to reduce discharges of industrial toxic pollutants by encouraging firms to adopt source reduction practices. Much of the incentive for voluntary participation in this program comes from the fact that the EPA lowers the cost of compliance by providing technical assistance, and gathering and disseminating information on pollution prevention opportunities [26].⁴

This paper models compliance to an environmental norm in a pure exchange, general equilibrium framework. Preferences are such that compliance to the norm is universally agreed to be a good, though individuals may choose not to comply because it is costly to do so. The cost of compliance, or "compliance price," can be reduced either by purely private individual efforts or by public government efforts that are financed by lump-sum taxes. Given this model structure, two alternative regimes are considered. Under the first regime, compliance to the rule is mandatory and supported by a fine on noncompliance. Under the second regime, compliance is voluntary and is supported by government efforts to reduce the compliance price. The welfare analysis is a comparison of voluntary and mandatory compliance regimes that induce equal levels of aggregate compliance and net government revenue. The necessary and sufficient condition for the voluntary compliance regime to be a welfare improvement is provided. Satisfaction of this condition depends on whether or not public effort is rival, the degree of excludability of public effort, and the relative prices of private and public effort.

II. COMPLIANCE TO AN ENVIRONMENTAL NORM

Let a community be the set $N = \{1, 2, \dots, N\}$, and consider the norm that, if adhered to, requires that individuals recycle. Assume that individuals cannot choose a degree of compliance but can freely choose whether or not to comply. Compliance to the environmental norm by an individual i is represented by the index variable c_i , defined as

$$\begin{aligned} c_i &= 1 && \text{if } i \text{ complies with the rule,} \\ c_i &= 0 && \text{if not.} \end{aligned}$$

⁴Theodore and McGuinn [23] discuss the legal and technical aspects of pollution prevention techniques, as well as provide examples of net private benefits to firms that adopt them.

Let C be the level of compliance in the community. That is,

$$C = \sum_N c_i.$$

For individual i , consumption of the private numeraire commodity is x_i , and preferences are summarized by $u_i = \eta_i C + \mu_i c_i + x_i$.

Each individual's marginal valuation of the level of compliance is positive and assumed constant. Therefore, assume that η_i is a positive constant for each member of the community. Furthermore, allow the possibility that people may place a different value on other's compliance than they do on their own. The marginal value i places on another's compliance is η_i while the value placed on his or her own is $\eta_i + \mu_i$. Assume that compliance to the rule is universally agreed to be a good so that $\eta_i + \mu_i$ is nonnegative for each individual.⁵ Note the separability of utility in C and c_i . This assumption precludes the possibility that individuals may "jump on the bandwagon" if enough others comply, or the opposite; people do not conform just because others do. Lastly, note that the individual's decision to comply or not enters the utility function of all others in the community. This reflects the public nature of compliance, and provides the prior justification for government intervention.

Recycling is assumed to be costly. One, at least, has the unpleasant task of separating trash into bundles of newspapers, glass, aluminum, etc. If the community does not provide a disposal service that keeps the trash separated when it is picked up, the individual must incur additional costs to take the trash to a recycling center. Of course, if an individual does not recycle there are no costs incurred. In this model the cost of complying with the recycling rule, in terms of the numeraire, is denoted p . Note that though everyone gains utility from complying with the rule, people may be discouraged from doing so if the cost is too high.

Individuals can undertake efforts to reduce the cost of compliance. For example, the purchase of separate trash bins for recyclables makes collecting and transporting recyclables easier, i.e., less costly. Assume that these efforts are purely private. That is, individual efforts to reduce the compliance price have no effect on the price that others face.⁶

On the other hand, assume that the local government is able to undertake public efforts to reduce the compliance price. Assume for now that government provided effort is nonexcludable in the sense that if effort is provided to one individual, it is provided to all. If the government decides to hand out separate trash bins for recyclables, it must provide them to every household. If the government sends a truck around to collect recyclables, the truck must visit every household. Though government effort is nonexcludable, it may be rival in the sense that the cost of providing effort to reduce the compliance price to another individual is greater than zero. The provision of trash bins is rival as is the transportation of recyclables.

⁵For examples that demonstrate net private benefits to firms that adopt pollution prevention techniques, see Theodore and McGuinn [23], Huisingh *et al.* [15], Huisingh and Bailey [16], and Campbell and Glenn [10].

⁶It is important to note that the assumption that individual efforts are purely private precludes some plausible actions. For example, this model does not consider the case in which an individual organizes a neighborhood pick-up service for recyclables. This case involves a privately provided public good.

Providing and disseminating information about what can be recycled, the location of recycling centers, and the prices that are paid for recyclables can be argued to be nonrival.⁷

Denote individual i 's effort to reduce the compliance price as e_i , and the government's provision of effort as E . Suppose for a moment that government-provided effort is rival. Denote the effort that the government devotes to reducing the compliance price to individual i as e_g^i . To simplify the analysis, assume that the government does not distinguish individuals, but instead provides the same amount of effort to each individual in the community. Thus, $E = \sum_N e_g^i = Ne_g$, where e_g is the common amount of effort provided to each individual. If, on the other hand, government effort is nonrival $E = e_g^i = e_g$ for every individual in the community. That is, if government effort is nonexcludable and nonrival, each individual "consumes" the aggregate level of effort provided by the government. Throughout it is assumed that individuals purchase effort in a competitive market, and the equilibrium price of effort is one. The local government also purchases effort in a competitive market, but the price of publicly provided effort will vary. Denote the cost of the aggregate provision of government effort as $R = R(E)$.

Individual and public efforts are assumed to be perfect substitutes. Thus, trash bins purchased by individuals or purchased by the government work equally well at making compliance less costly. The price that i pays to comply with the recycling rule is $p_i = p(e_i + e_g)$. Assume that every individual faces the same compliance price function. Thus, given a government contribution e_g , if two individuals expend the same amount of effort on reducing the compliance price, the price is the same for both. Implicitly, all individuals are assumed to have the same opportunities for decreasing the compliance price, and all are equally adept at doing so.

Let combined individual and government effort be $\zeta = e_i + e_g$. Assume that $p'(\zeta) < 0$, $p''(\zeta) > 0$, $\lim_{\zeta \rightarrow \infty} p(\zeta) = 0$, $\lim_{\zeta \rightarrow \infty} p'(\zeta) = 0$, and $p'(0) < -1$, where primes denote first and second derivatives. The strict convexity of $p(\zeta)$ simply implies that there are diminishing returns to efforts to reduce the compliance price.

Optimal Choices under Mandatory Compliance

Under a regime of mandatory compliance the government takes no action to reduce the compliance price, but instead supports compliance to the rule by imposing a fine on noncompliance. The fine is a constant that is automatically and costlessly imposed in all cases of noncompliance. Furthermore, detection of noncompliance is costless and certain.⁸

Imposition of the fine on noncompliance generates revenue to the government. To balance the government's budget, it is assumed that this revenue is returned to

⁷Gathering and disseminating information about pollution prevention opportunities under the EPA's 33/50 Program (mentioned in the Introduction) can also be argued to be nonrival efforts to reduce the cost of compliance.

⁸One reviewer pointed out that the welfare results in this paper may be biased because monitoring and enforcement requirements under the two regimes are likely to be different. In particular, the mandatory compliance policy is likely to incur enforcement costs while the voluntary regime will not. Because this issue is ignored in this paper the welfare analysis may be biased somewhat toward accepting the mandatory compliance program as the dominating policy.

the community in the form of individual lump-sum subsidies that are independent of whether an individual complies with the rule or not. Denote the subsidy paid to i as s_i^m . If the fine is denoted f , the balanced budget requirement is

$$\sum_N s_i^m = (N - C)f. \quad (2.1)$$

Under mandatory compliance, individual i 's objective is to

$$\begin{aligned} \max_{e_i, c_i, x_i} \quad & \eta_i C + \mu_i c_i + x_i \\ \text{s.t.} \quad & X_i + s_i^m = x_i + p(e_i)c_i + f(1 - c_i) + e_i \\ & e_i \geq 0, x_i \geq 0. \end{aligned}$$

Here, $X_i + s_i^m$ is i 's endowment of the numeraire commodity. The expenditure side of the budget constraint includes i 's consumption of the numeraire, the price paid to comply if compliance is chosen, the fine paid if compliance is not chosen, and the effort spent to make compliance less costly. Recall that the price of a unit of private effort is one. Substitute the budget constraint into the utility function to obtain the equivalent optimization problem

$$\begin{aligned} \max_{e_i, c_i} \quad & \eta_i C + \mu_i c_i + X_i + s_i^m - p(e_i)c_i - f(1 - c_i) - e_i \\ \text{s.t.} \quad & e_i \geq 0. \end{aligned} \quad (2.2)$$

Note that an individual who does not comply with the rule has no incentive to reduce the compliance price. Thus, if $c_i = 0$, $e_i = 0$. On the other hand, a person who decides to comply will want to minimize the cost of doing so. Thus, if $c_i = 1$, (2.2) reduces to

$$\begin{aligned} \min_{e_i} \quad & p(e_i) + e_i \\ \text{s.t.} \quad & e_i \geq 0. \end{aligned}$$

Because of the assumptions made earlier about the compliance price function, the optimal e_i exists and is the interior solution determined by $p'(e_i) = -1$. Note further that since every individual faces the same price function, the compliance price, as well as efforts to reduce it, are the same for all who comply. Denote the common level of private effort under mandatory compliance as e^m and the common price as $p^m = p(e^m)$. Thus, the minimum cost of compliance under mandatory compliance is $p^m + e^m$.

Now, the optimal choice of whether to comply or not is a simple comparison of the benefit of compliance to the cost. Thus, individual i complies with the rule when it is mandatory if and only if

$$\eta_i + \mu_i + f > p^m + e^m. \quad (2.3)$$

The benefit of compliance is i 's marginal valuation of his or her own compliance ($\eta_i + \mu_i$) plus the fine on noncompliance. The fine counts as a benefit of compliance because it is a cost that is avoided by the act of compliance.

To complete the description of the equilibrium, define the aggregate level of compliance when it is mandatory as $C^m = \sum_N c_i^m$, where c_i^m is i 's optimal choice of compliance under this regime. We now turn to the characterization of the equilibrium when compliance is voluntary.

Optimal Choices under Voluntary Compliance

Under voluntary compliance, there is no fine on noncompliance. Instead the government supports compliance to the rule by contributing effort to lower the compliance price. For now, this contribution is assumed to be nonexcludable, and thus, by making the contribution the government decreases the compliance price to all.

The government's effort to decrease the compliance price is assumed to be financed by a lump-sum tax that is independent of the individual's compliance choice. Assume further that if the tax receipts exceed the cost of the government's provision of effort, the net revenue is redistributed back to the community in the form of a lump-sum subsidy that is also independent of the individual's compliance choice. Denote the subsidy paid to i under voluntary compliance as s_i^v , and the tax as t_i . Recalling that $R(E)$ is the cost of providing public effort E , the government's budget constraint under voluntary compliance is

$$\sum_N s_i^v = \sum_N t_i - R(E). \quad (2.4)$$

Under voluntary compliance, i 's objective is to

$$\begin{aligned} \max_{e_i, c_i, x_i} \quad & \eta_i C + \mu_i c_i + x_i \\ \text{s.t.} \quad & X_i + s_i^v = x_i + p(e_i + e_g)c_i + e_i + t_i \\ & e_i \geq 0, x_i \geq 0. \end{aligned}$$

Substitute the budget constraint into the utility function to obtain

$$\begin{aligned} \max_{e_i, c_i} \quad & \eta_i C + \mu_i c_i + X_i + s_i^v - p(e_i + e_g)c_i - e_i - t_i \\ \text{s.t.} \quad & e_i \geq 0. \end{aligned} \quad (2.5)$$

Once again, if i does not voluntarily comply with the rule there is no incentive to reduce the compliance price, so $e_i = 0$. If i decides to comply he or she will seek to minimize the cost of doing so, given the government's contribution to reduce the compliance price. That is, i will choose e_i to minimize $p(e_i + e_g) + e_i$. Note however that, given the government's contribution, i implicitly chooses $\zeta = e_i + e_g$. Then, given that $c_i = 1$, i 's objective under voluntary compliance is to

$$\begin{aligned} \min_{\zeta} \quad & p(\zeta) + \zeta - e_g \\ \text{s.t.} \quad & \zeta \geq e_g. \end{aligned} \quad (2.6)$$

The necessary Kuhn–Tucker condition for a solution to (2.6) is $p'(\zeta) \geq -1$, and if $>$, $\zeta = e_g$.

Recall that the cost-minimizing choice of individual effort to reduce the compliance price under mandatory compliance is e^m which was defined as $p'(e^m) = -1$. Therefore, if the Kuhn–Tucker condition holds with equality, $\zeta = e^m$. Taking the inequality constraint in (2.6) into account, i 's cost-minimizing choice is $\zeta = \max\{e^m, e_g\}$. Subtract e_g from both sides to obtain i 's cost-minimizing choice of private effort $e_i = \max\{e^m - e_g, 0\}$. Since everyone faces the same compliance price function and government contribution of effort, each individual who complies under voluntary compliance devotes the same amount of effort to decreasing the compliance price. Denote the common level of private effort as e^v . Then, each individual's optimal choice of private expenditures, given that they comply under voluntary compliance, is

$$e^v = \max\{e^m - e_g, 0\}. \quad (2.7)$$

Denote the equilibrium compliance price under voluntary compliance as p^v . From (2.7), note that if $e_g \leq e^m$, $e^v + e_g = e^m$. Thus, $p^v = p(e^v + e_g) = p(e^m) = p^m$; that is, the compliance prices are the same under both regimes. On the other hand, if $e_g > e^m$, $e^v = 0$, and $p^v = p(e_g)$ which is strictly less than p^m since the compliance price function is strictly decreasing. Note in this case that the government's effort completely crowds out private efforts.

Again, the choice of whether or not to comply with the rule when compliance is voluntary is made by comparing the cost and benefit of compliance. However, there are two cases to consider, depending on the government's choice of effort. They are:

Case A. If the government has chosen e_g under voluntary compliance so that $e_g \leq e^m$, i complies with the rule if and only if

$$\eta_i + \mu_i > p^v + e^v = p^m + e^v. \quad (2.8)$$

Case B. If the government has chosen e_g under voluntary compliance so that $e_g > e^m$, i complies with the rule if and only if

$$\eta_i + \mu_i > p^v. \quad (2.9)$$

To gain some intuition about choices under voluntary compliance consider Fig. 1. Under mandatory compliance those who comply undertake private effort e^m which decreases the compliance price to p^m . Suppose under voluntary compliance the government chooses to contribute e_g^1 units of effort to each individual. This corresponds to Case A. Individuals respond by expending private resources to decrease the compliance price to p^m . However, to reach that price, individuals need only expend $e^v = e^m - e_g^1$. Thus, in this region of the price function, the government supports voluntary compliance by decreasing the cost of compliance through a program that partially substitutes public efforts for private efforts. For example, the government may provide transport for recyclables, provided that individuals first separate their trash into bundles of newspapers, glass, aluminum, etc.

Suppose, on the other hand, that the government chooses to contribute e_g^2 . This contribution lowers the compliance price below p^m , and hence, completely crowds

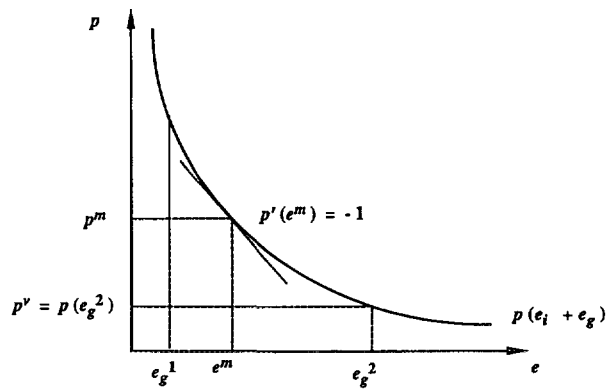


FIGURE 1

out individual efforts. In this region of the price function the government supports compliance by completely assuming all efforts to decrease the compliance price, and by decreasing the compliance price below what individuals would choose.

Before we turn to the welfare analysis, define the aggregate level of compliance when it is voluntary as $C^v = \sum_N c_i^v$, where c_i^v is i 's optimal choice of compliance under this regime.

III. THE WELFARE ANALYSIS

Now that the equilibria under voluntary and mandatory compliance regimes have been characterized, this section provides the necessary and sufficient condition that must be met for the voluntary compliance regime to be a welfare improvement over a mandatory compliance regime. The welfare analysis is conducted assuming that a mandatory compliance regime is in place but the government is considering adoption of a voluntary compliance regime. I assume further that the government's choice of a voluntary compliance regime is constrained to induce the same aggregate level of compliance (compliance equality) and the same level of net government revenue (revenue equality). Given these two constraints, if aggregate utility is higher under the voluntary compliance regime, it is a welfare improvement over the mandatory compliance regime.⁹ It will be shown that the voluntary compliance regime is a welfare improvement if and only if the average

⁹A different sort of analysis would involve looking for conditions that would define a set of voluntary compliance regimes that would improve upon an arbitrary mandatory compliance regime. This exercise would require a determination of how aggregate compliance varies with changes in the cost of compliance which, in turn, would require a specification of how individual preferences for compliance are distributed in the community. The method employed here greatly simplifies the welfare comparison because there is no need to specify a distribution for individual preferences.

If one could reasonably assume some distribution of individual preferences, a fuller picture of the differences between the voluntary and mandatory policies would be possible. With such a distribution, the optimal compliance rate for each regime could be determined. Note that they are likely to be different. Indeed, the optimal compliance rate will even vary under the voluntary regime depending on whether or not public effort is rival, the degree of excludability of public effort, and the relative prices of private and public effort.

tax under voluntary compliance is less than the fine that supports mandatory compliance. Satisfaction of this condition is then related to rivalness and excludability of public effort, as well as the relative prices of private and public effort. Before the welfare results are presented the compliance equality and revenue equality constraints need some discussion.

Compliance Equality

Recall that since every individual faces the same compliance price function, given the regime, the cost of compliance is the same for each individual who complies. Thus, to induce the same level of compliance for both regimes, the government must choose a contribution to reduce the compliance price so that the cost of compliance is equal under both regimes. There are two cases that need consideration.

Case A. Suppose that the compliance equality constraint requires the government to choose $e_g \leq e^m$. Then, considering (2.3) and (2.8), to equate the compliance cost the government chooses e_g so that

$$p^m + e^m - f = p^v + e^v. \quad (3.1)$$

The left-hand side is the compliance cost under mandatory compliance while the right-hand side is the compliance cost under voluntary compliance. Recall that if $e_g \leq e^m$, individuals under voluntary compliance expend $e^v = e^m - e_g$ (see Eq. (2.7)). Now, (2.7) and (3.1) imply that if the compliance equality constraint requires the government to choose $e_g \leq e^m$, the government chooses $e_g = f$ to equate the compliance cost for both regimes.

Case B. Suppose, on the other hand, that the compliance equality constraint requires the government to choose $e_g > e^m$. Then, using (2.3) and (2.9), equating the cost of compliance for both regimes requires the government to choose e_g so that

$$p^m + e^m - f = p^v. \quad (3.2)$$

Recall that if the government chooses $e_g > e^m$, individual efforts to reduce the compliance price are completely crowded out; i.e., $e^v = 0$. Therefore, $p^v = p(e_g)$. Thus, if the compliance equality constraint requires the government to choose $e_g > e^m$, it contributes just enough effort to lower the compliance price under the voluntary program so that (3.2) holds.

Since the cost of compliance is to be equal for both regimes, individual compliance choices must also be equal. That is, $c_i^m = c_i^v$ for every individual. This result is again due to the assumption that all individuals face the same compliance price function.

Revenue Equality

Under mandatory compliance, revenue is generated by the fine on non compliance which is redistributed back to the community in the form of lump-sum subsidies. The revenue equality constraint requires the government to collect

enough in tax revenue under voluntary compliance to finance its choice of effort to reduce the compliance price, and provide a surplus to be redistributed back to the community that is equal to the transfer under mandatory compliance. That is, considering the government budget constraints (2.1) and (2.4), the revenue equality constraint requires the government to choose lump-sum taxes under voluntary compliance so that

$$\sum_N t_i - R(E) = (N - C^m)f. \quad (3.3)$$

Here E , the government's aggregate provision of effort, is determined by the compliance equality constraint.¹⁰

Proposition 1 provides the necessary and sufficient condition for the voluntary compliance regime to be a welfare improvement. Its proof is in the Appendix.

PROPOSITION 1. *Suppose that the government is required to choose a voluntary compliance regime so that*

$$(1) \quad C^v = C^m,$$

and

$$(2) \quad \sum_N t_i - R(E) = (N - C^m)f.$$

This voluntary compliance regime is a welfare improvement over the mandatory compliance regime if and only if

$$(3) \quad \sum_N t_i / N < f.$$

Proposition 1 reveals that a voluntary compliance regime will yield higher aggregate utility than a mandatory compliance regime that induces the same level of compliance and net government revenue if and only if the average tax under voluntary compliance is less than the fine that supports mandatory compliance. Note that Proposition 1 does not explicitly consider the possibility that the prices of private and public effort may differ. Furthermore, it is independent of whether government effort is rival or nonrival, and the degree of excludability of public effort. However, as will be considered in Propositions 2 and 3 below, satisfaction of condition (3) of Proposition 1 depends on all of these characteristics. Before the remaining propositions are presented, the intuition behind Proposition 1 when public effort is nonrival bears discussion.

Nonrival Public Effort

Suppose that public effort is nonrival, nonexcludable, and purchased at a constant price of one. Suppose further that the compliance equality constraint requires the government to choose $e_g \leq e^m$. Then, condition (3) of Proposition 1

¹⁰There are no substantive effects on the welfare results of assuming (3.3) rather than simply requiring the government to balance its budget under both programs. Furthermore, in a different model with distortionary transfers, we would want to preserve those distortions in order to compare the two regimes.

can be rewritten as $e_g < Ce_g$.¹¹ Thus, voluntary compliance is a welfare improvement if and only if $C > 1$! What is driving such a stark result? From the discussion of Eq. (3.1), note that in this case individuals who comply expend $e^i = e^m - e_g$, which implies that each conformer saves e_g when the voluntary program is adopted, and in aggregate, conformers save Ce_g . Thus, Ce_g is the aggregate benefit of adopting the voluntary program, and the cost is simply e_g . The voluntary program dominates because under mandatory compliance e_g is expended C times while under voluntary compliance the government is able to induce the same level of compliance by expending e_g once. The welfare improvement is achieved because the voluntary program avoids waste from duplicated effort.

Suppose instead that compliance equality requires the government to choose $e_g > e^m$. Then, voluntary compliance is a welfare improvement if and only if $e_g < C(p^m - p^i + e^m)$.¹² Here, e_g is the cost of the voluntary program and $C(p^m - p^i + e^m)$ is the aggregate benefit. Each conformer saves e^m when the voluntary program is adopted because government effort completely crowds out individual efforts (see the discussion of Eq. (3.2)). Furthermore, since government effort e_g substitutes for aggregate individual effort Ce^m , the voluntary program again avoids waste from duplicated effort. Conformers save further because the government's choice of effort decreases the compliance price from p^m to p^i . It is interesting to note that if the government chooses $e_g > e^m$, $C > 1$ is necessary for the voluntary program to be a welfare improvement, but is no longer sufficient.¹³

Rival Public Effort

If a voluntary compliance regime is adopted, the government's contribution of effort substitutes for all or part of individual effort. When the government's effort is nonrival, waste from duplicated effort is, at least partially, avoided. On the other hand, if the government provides rival effort this is not true. Proposition 2 reveals that if the government purchases rival effort at the same price as individuals, the voluntary compliance regime cannot be a welfare improvement even if public effort is excludable to those who comply. (The proof is in the Appendix.)

PROPOSITION 2. *Suppose that the government's efforts to reduce the compliance price are rival and excludable to a subset Δ of the community. Assume that Δ includes at least all those who comply. Lastly, assume that the government purchases effort at a constant price equal to one. Then, the voluntary compliance regime cannot be a welfare improvement.*

¹¹To get this result note that the provision of public effort is e_g and the cost is $R(E) = e_g$. Substitute for $R(E)$ in the revenue equality constraint and combine this result with $\sum_N t_i/N < f$ to obtain $e_g < Cf$. From the discussion of Eq. (3.1), if the government is required to choose $e_g \leq e^m$, it chooses $e_g = f$. Thus, condition (3) of Proposition 1 can be rewritten as $e_g < Ce_g$.

¹²As in footnote 11, condition (3) of Proposition 1 can be rewritten as $e_g < Cf$. Recall from the discussion of Eq. (3.2) that if the government is required to choose $e_g > e^m$, it chooses e_g so that $f = p^m - p^i + e^m$. Hence, the voluntary program dominates if and only if $e_g < C(p^m - p^i + e^m)$.

¹³In this region of the price function the voluntary program dominates if and only if $C > e_g/(p^m - p^i + e^m)$. To prove that $e_g/(p^m - p^i + e^m) > 1$, consider Fig. 1 and let $e_g = e_g^2$. Note that since $p'(e^m) = -1$, and p is strictly convex, the slope of the chord between (p^m, e^m) and (p^i, e_g^2) is strictly greater than negative one. That is $(p^m - p^i)/(e^m - e_g^2) > -1$. This implies that $e_g^2/(p^m - p^i + e^m) > 1$.

To illustrate Proposition 2, suppose that compliance equality requires the government to choose $e_g \leq e^m$. Then, the government chooses $e_g = f$ and individuals choose $e^i = e^m - e_g$. In this situation, the benefit to each conformer of switching to the voluntary regime is e_g and, in aggregate, conformers save Ce_g . Now, if public effort is excludable to those who comply, the cost of providing this effort is Ce_g . Hence, the best that a voluntary compliance policy can do is leave aggregate utility unchanged. If public effort is not excludable to only those who comply, the cost of public effort is greater than Ce_g , which would leave the community worse off. Note an important distinction between the voluntary and mandatory regimes when public effort is rival. Under voluntary compliance, if the government cannot perfectly target the recipients of effort, the effort applied to those who do not comply is wasted. Under mandatory compliance, effort is applied where it is productive, that is, by those who comply.

One expects that there must be a price of public effort low enough so that the voluntary compliance regime induces higher aggregate utility. Proposition 3 provides upper bounds on the price of public effort, below which adoption of the voluntary compliance regime will be a welfare improvement. (The proof is in the Appendix.)

PROPOSITION 3. *Suppose that government effort is rival and excludable to Δ and let the number of elements of Δ be D . As in Proposition 2, assume that Δ includes at least all those who comply. Furthermore, assume that the government purchases effort at a constant price w . Then:*

(A) *If the compliance equality constraint requires the government to choose $e_g \leq e^m$, the voluntary compliance regime is a welfare improvement if and only if $w < C/D$.*

(B) *If the compliance equality constraint requires the government to choose $e_g > e^m$, the voluntary compliance regime is a welfare improvement if and only if $w < (C/D)(f/e_g)$.*

Recall that the price of private effort is one and note that since Δ includes at least all those who comply, $C/D \leq 1$. Furthermore, recall that if $e_g > e^m$, e_g is such that $f = p^m - p^i + e^m$, and $f < e_g$ (see the proof of Proposition 2). Thus, $(C/D)(f/e_g) < 1$. So, given that the government provides rival effort, if voluntary compliance is to be a welfare improvement the price of public effort must be significantly lower than the price of private effort.¹⁴

IV. CONCLUDING REMARKS

As mentioned in the Introduction, many communities now have voluntary curbside recycling programs. To support compliance to a recycling norm, local

¹⁴Both Propositions 2 and 3 assume that the marginal cost of providing public effort is constant and, hence, are not directly applicable to cases in which the cost of providing effort to another individual rises (or falls) with the number of individuals who are to receive effort. However, the intuition that the cost of public effort must be significantly lower than the aggregate cost of private effort if voluntary compliance is to be a welfare improvement when the government provides rival effort remains the same. Furthermore, since Proposition 1 assumes nothing about the cost of public effort, it remains applicable in all cases.

governments often hand out recycling bins to households. Suppose that a government purchases recycling bins at a constant price and provides them free of charge to households in the community. This is an example of the sort of rival public effort considered by Propositions 2 and 3. The propositions imply that if the government cannot perfectly target effort at those who will comply, and is unable to purchase recycling bins at a significantly lower price than individuals, a mandatory recycling program in which individuals purchase their own bins can be chosen that yields the same level of compliance but higher aggregate utility.

Suppose in the spirit of Proposition 3 that the government can purchase recycling bins cheaply enough so that a mandatory program of the sort considered in this paper cannot be found that dominates voluntary recycling. However, consider a modified mandatory policy in which nonconformers are fined, and the government sells bins at cost to any household that wants them. This mandatory program will dominate a voluntary program in which the government hands out bins free because only those who will comply will purchase bins. Thus, the problem of applying public effort that is wasted by those who will not comply voluntarily is avoided.

In voluntary curbside recycling programs, local governments also purchase transport for recyclables. This effort is also rival, but it is probably unreasonable to assume that it is purchased at a constant price, so the analysis presented in this paper is not directly applicable. However, the intuition remains the same: a voluntary program will dominate when public effort is rival only if the cost of public effort is significantly lower than the cost of private effort. Publicly provided transport for recyclables may be less costly than private transport because of scale economies and a complementary relationship between transporting recyclables and normal trash collection.

The welfare propositions imply that voluntary compliance policies will be most effective when governments provide nonrival effort. Take the case of the EPA's 33/50 Program mentioned in the Introduction. Under this program firms commit themselves to pollution abatement targets and in return the EPA provides technical assistance which is largely information about pollution prevention opportunities. One could argue that information is nonrival (or, at least, provided at very low marginal cost). Then, instead of each firm expending resources collecting what is essentially the same information, the EPA collects it once. There may be some cost associated with providing the information to an additional firm, but it is likely to be relatively low.

Though the analysis in this paper is fairly general it cannot be applied to all environmental rules. Throughout I have assumed that both the voluntary and the mandatory policies induce the same rate of compliance. However, while an appropriately chosen fine can induce any compliance rate above that level that would occur in the absence of any government intervention, there may be some rates of compliance that are unattainable under voluntary compliance. For example, consider the case in which agents' subjective valuations of their own compliance is zero (or possibly even negative!). In this case, no one will voluntarily comply, and hence, the welfare analysis presented in this paper is not applicable.¹⁵

¹⁵It is interesting to note that as of February 1992, 734 companies had committed themselves to abatement of substances targeted by the EPA's 33/50 Program. Since participation in this program is completely voluntary, there must be significant private benefits to participation [26].

In order to focus clearly on the differences between supporting compliance by penalizing noncompliance and by public efforts to reduce the cost of compliance I have ignored an obvious third option. Consider a policy that combines a fine on noncompliance *and* public contributions to decrease the compliance price. Since this option draws from an expanded choice set, the simple mandatory and voluntary programs considered in this paper cannot dominate it. Even though this result seems immediately obvious, a rigorous analysis will likely provide further insights.

This problem of simultaneously determining a penalty for noncompliance and a public contribution of effort to reduce the compliance price will be more easily understood within the familiar context of regulating externality-generating behavior instead of the voluntary versus mandatory policy choice employed in this paper. Investigating this issue will contribute to the literature on enforcing environmental regulation by expanding the government's role to include public efforts to make compliance by regulated agents less costly. To my knowledge, little research effort has been devoted to this issue.

This paper has focused on publicly provided support for compliance to an environmental norm. However, there are many cases in which support is privately provided. For example, there is an extensive case literature examining community-based institutions governing common property resources that do not rely on some outside authority for support, but instead rely on efforts provided by members of the community. (For examples see [1, 9, 18, 19].)

International environmental agreements are also examples of environmental rules that cannot be supported by the efforts of some higher authority. Since compliance to these agreements must be voluntary, the primary issue in designing environmental agreements is the choice of treaty provisions that encourage voluntary compliance. For the Montreal Protocol on Substances That Deplete the Ozone Layer, these provisions include restrictions on trade with non-party states, special provisions for developing countries including technology transfers, and a requirement of a minimum number of ratifications for entry into force. (For a summary of the provisions of the Montreal Protocol see Benedick [8].) It is important to note that support for compliance to an international environmental agreement must come from nations that are party to the agreement. Ausubel and Victor [2], Barratt-Brown [7], and the U.S. General Accounting Office [27] consider the problems associated with the fact that efforts to verify and enforce compliance to environmental agreements must be provided by nations that are party to these agreements. Extending the model presented in this paper may provide helpful insight into privately provided support for environmental norms.

APPENDIX

Proof of Proposition 1. Use the utility functions from (2.2) and (2.5) to write the difference in i 's utility under voluntary and mandatory compliance:

$$u_i^v - u_i^m = [\eta_i C^v + \mu_i c_i^v + X_i + s_i^v - p^v c_i^v - e_i^v - t_i] \\ - [\eta_i C^m + \mu_i c_i^m + X_i + s_i^m - p^m c_i^m - (1-f)c_i^m - e_i^m],$$

where the superscripts v and m denote levels and choices under voluntary and mandatory compliance respectively. Use the condition that aggregate compliance is constrained to be equal under both regimes and the result that individual compliance choices are equal under both regimes to cancel and collect terms. Then,

$$u_i^v - u_i^m = (p^m - p^v)c_i + f(1 - c_i) + (e_i^m - e_i^v) - t_i + s_i^v - s_i^m.$$

Summing over members of the community yields

$$\begin{aligned} \Sigma_N(u_i^v - u_i^m) &= (p^m - p^v)\Sigma_N c_i + f\Sigma_N(1 - c_i) \\ &\quad + \Sigma_N(e_i^m - e_i^v) - \Sigma_N t_i + \Sigma_N s_i^v - \Sigma_N s_i^m. \end{aligned}$$

Note that $\Sigma_N c_i = C$ and $\Sigma_N(1 - c_i) = N - C$. Furthermore, recall that, given the regime, each individual who complies expends the same level of resources to decrease the compliance price. That is, $e_i^k = e_j^k = e^k$ for each i and j , given $k = v, m$. This result and the result that only conformers expend resources to decrease the compliance price implies that $\Sigma_N(e_i^m - e_i^v) = C(e^m - e^v)$. Lastly, the requirement that both regimes yield the same net revenue to the government (3.3) implies that aggregate subsidies in both regimes are equal; that is, $\Sigma_N s_i^v = \Sigma_N s_i^m$. Thus,

$$\Sigma_N(u_i^v - u_i^m) = C(p^m - p^v) + (N - C)f + C(e^m - e^v) - \Sigma_N t_i. \quad (\text{A.1})$$

Voluntary compliance is a welfare improvement over mandatory compliance if and only if (A.1) is strictly positive. To complete the proof of the proposition two cases must be considered.

Case A. Suppose that compliance equality requires that the government choose $e_g \leq e^m$. Then, the price of compliance is equal under both regimes. Furthermore, individuals choose effort to reduce the compliance price according to $e^v = e^m - e_g$, which when combined with (3.1) implies that $e_g = f$. Then, if $e_g \leq e^m$, (A.1) becomes

$$\begin{aligned} \Sigma_N(u_i^v - u_i^m) &= (N - C)f + Cf - \Sigma_N t_i \\ &= Nf - \Sigma_N t_i. \end{aligned}$$

Thus, given $e_g \leq e^m$, $\Sigma_N t_i / N < f$ implies that $\Sigma_N(u_i^v - u_i^m) > 0$, and hence, the voluntary compliance regime is a welfare improvement. Furthermore, if the voluntary compliance regime is a welfare improvement, given $e_g \leq e^m$, it must be true that $\Sigma_N t_i / N < f$.

Case B. Suppose that compliance equality requires that $e_g > e^m$. Then individuals who comply expend no effort to reduce the compliance price under voluntary compliance; i.e., $e^v = 0$. Then, with some rearranging, (A.1) becomes

$$\Sigma_N(u_i^v - u_i^m) = C(p^m - p^v + e^m - f) + Nf - \Sigma_N t_i.$$

But, (2.3) implies that $p^m - p^v + e^m - f = 0$. So,

$$\Sigma_N(u_i^v - u_i^m) = Nf - \Sigma_N t_i.$$

Thus, given $e_g > e^m$, $\Sigma_N t_i/N < f$ implies that $\Sigma_N (u_i^t - u_i^m) > 0$, and hence, the voluntary compliance regime is a welfare improvement. Furthermore, if the voluntary compliance regime is welfare enhancing given $e_g > e^m$, it must be true that $\Sigma_N t_i/N < f$. Q.E.D.

Proof of Proposition 2. Let D be the number of individuals contained in Δ and note that $C \leq D \leq N$. Since government effort is rival and provided at unit marginal cost, the total cost of government effort is $R(E) = De_g$. Then, if the voluntary compliance regime is to satisfy the revenue equality constraint

$$\Sigma_N t_i - De_g = (N - C)f. \quad (\text{A.2})$$

Toward a contradiction, suppose that the voluntary compliance regime is a welfare improvement. Thus,

$$\Sigma_N t_i/N - f < 0. \quad (\text{A.3})$$

Case A. Suppose compliance equality requires the government to choose $e_g \leq e^m$; then, as before, the government chooses $e_g = f$. Substitute $e_g = f$ into (A.2) and rearrange to obtain

$$\Sigma_N t_i/N - f = f(D - C)/N.$$

Since $D \geq C$, this contradicts (A.3).

Case B. Suppose compliance equality requires $e_g > e^m$. Then, the government chooses e_g so that

$$p^m + e^m - f = p^v. \quad (\text{A.4})$$

Rearrange (A.2) to obtain

$$\Sigma_N t_i/N - f = (De_g - Cf)/N. \quad (\text{A.5})$$

Since $D \geq C$, if $f \leq e_g$, the right-hand side of (A.5) is nonnegative which would imply a contradiction of (A.3). Consider Fig. 1 and let $e_g = e_g^2$. Note that since $p'(e^m) = -1$, and p is strictly convex, the slope of the chord between (p^m, e^m) and (p^v, e_g^2) is strictly greater than negative one. That is $(p^m - p^v)/(e^m - e_g^2) > -1$. This implies that $p^m - p^v + e^m - e_g^2 < 0$. From (A.4), $f = p^m - p^v + e^m$, which implies that $f < e_g^2$. Thus, (A.5) contradicts (A.3). Q.E.D.

Proof of Proposition 3. Under the conditions of the proposition, the cost of government effort is $R(E) = Dwe_g$. Then, if the voluntary compliance regime is to satisfy the revenue equality constraint

$$\Sigma_N t_i - Dwe_g = (N - C)f, \quad (\text{A.6})$$

and if the voluntary compliance regime is to be a welfare improvement

$$\Sigma_N t_i/N - f < 0. \quad (\text{A.7})$$

Case A. If the compliance equality constraint requires the government to choose $e_g \leq e^m$, the government chooses $e_g = f$. Rearrange (A.6) to obtain

$$\Sigma_N t_i / N - f = (f/N) [Dw - C],$$

which is negative if and only if $w < C/D$.

Case B. If the compliance equality constraint requires the government to choose $e_g > e^m$, (A.6) becomes

$$\Sigma_N t_i / N - f = [Dwe_g - Cf] / N,$$

which is negative if and only if $w < Cf/De_g$. Q.E.D.

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