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# Voluntary Agreements with Industries: Participation Incentives with Industry-wide Targets

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## 1. Introduction

Since the early 1970s, policymakers have relied heavily on regulation as a means of controlling the emissions of environment pollutants. These regulations have been widely criticized as inflexible and cost inefficient. In response, policymakers have begun to search for alternative, more cost-efficient policies. One alternative is to move toward the use of incentive or market-based policy instruments, e.g. emission taxes or marketable permits. Another alternative that has attracted policymakers' attention is increased reliance on voluntary environmental protection. Voluntary approaches to environmental protection can take three forms: (i) unilateral initiatives by firms and industry associations; (ii) negotiated agreements between government and firms or industry associations; and (iii) voluntary programs designed by governments to induce firm participation (Carraro and Lévêque, 1999; Segerson and Li, 1999). Since the early 1990s, hundreds of voluntary agreements (VAs) have been signed throughout the world, many of them in European Community (see Commission of the European Communities, 1996).

While many voluntary agreements are between regulators and individual firms,[1] often there is an explicit or implicit agreement between regulators and a group of firms or an industry. Examples include the French car industry's agreement to reduce car waste (Lévêque and Nadaï, 1995; Aggeri and Hatchuel, 1999), the German energy sector's agreement with government to reduce $CO_2$ emission through a 20% reduction in energy consumption (Jochem and Eichhammer, 1999), and the New Zealand cement industry's agreement with the government as part of the government's plan to return carbon dioxide emissions to their 1990 level by the year 2010 (Gaines and Mfordwo, 1996).[2]

To be successful, a voluntary approach must have a sufficiently strong incentive for firm participation, i.e., firms must in some way benefit from undertaking voluntary measures. Firms can benefit from adopting voluntary measures if a proactive environmental strategy allows them to exploit a market for environmentally-friendly products or generate firm-specific public good will (Arora and Gangopadhyay 1995; Esty, 1997; Smart, 1992). In this case, market forces may be sufficient to induce voluntary environmental protection. However, when market incentives are insufficient, some form of government inducement for participation is needed. This inducement could take the form of government subsidies to help defray the costs of pollution abatement. However, subsidies are socially costly because of the need to raise the necessary funds through

[1] Examples include Project XL in the United States, and the many agreements negotiated under the Dutch National Environmental Policy Plan (European Commission, 1996).

distortionary taxation. Alternatively, firms might voluntarily undertake pollution abatement if, by adopting voluntary measures, they can avoid more costly government policies that might be imposed.[3] If the threatened government policy is a regulation with limited flexibility, firms can benefit from the increased flexibility that might accompany a voluntary approach. Alternatively, if the threatened policy is an emissions tax, firms can benefit by avoiding the tax payments. For example, the voluntary agreements involving the German energy sector and the New Zealand cement industry were both prompted by threats of imposition of a carbon tax (Jochem and Eichhammer, 1999; Gains and Mfodwo, 1996).

While threats of the imposition of regulation or emissions taxes can be effective in providing participation incentives, when applied to an entire industry they suffer from a potentially serious drawback, namely, the incentive for individual firms to free-ride. If the industry can avoid the regulation or tax with less than full participation, then firms that do not participate can enjoy the benefits of avoiding the costly policy without the associated costs. An important policy question is whether this free-rider incentive undermines the viability of a voluntary approach.

To date, the economic literature on voluntary approaches has focused primarily on single-firm models that do not allow for free-riding (e.g., Stranlund, 1995; Cavaliere, 1998; Segerson and Miceli, 1998, 1999; Wu and Babcock, 1995, 1996). These studies model an individual firm's response to market-based or government incentives for participation.[4] To study voluntary approaches where the regulatory threat is industry-wide and individual firms face free-rider incentives, a model that takes into account the interaction among firms in the industry is needed.

In this paper we develop a multiple-firm model of voluntary adoption of environmental protection measures in which an entire industry is faced with industry-wide imposition of a costly government policy, namely, an emissions tax.[5] The policy scenario is as follows. A regulator seeks to achieve an exogenous reduction in industry-wide emissions. It sets a target emissions cap for the industry as a whole. It then provides the industry with an opportunity to meet the target voluntarily, with the explicit recognition that if the voluntary approach fails to meet the target, an emissions tax will be imposed on the industry, with the magnitude of the tax set at a level sufficient to ensure that

[3] See Goodin (1986) and Lévêque and Nadaï (1999) for discussions of using regulatory threats to induce voluntary participation in voluntary approaches.

[4] See Segerson and Li (1999) for an overview of the theoretical and empirical studies on VA.

[5] A preliminary version of the analysis presented here was developed in Segerson and Dawson (forthcoming). In that paper, the industry faced a threat of imposition of a costly regulation. The implicit assumption was that a given level of abatement could be achieved at a lower cost voluntarily because the voluntary approach provided greater flexibility.

the target will be met under the tax. Firms face a two-stage game in which they must make decisions about both participation and emissions reduction. Because all firms benefit if the target is met but only those firms that reduce their emissions bear costs, firms face a free-rider incentive, i.e., an incentive not to participate and reduce emissions voluntarily. We ask whether it is possible to have a successful voluntary approach despite this free-rider incentive, i.e., whether there exists an equilibrium under which a subset of the firms in the industry voluntarily participate in the program and reduce emissions to ensure that the target is met, while the remainder of the firms free ride.

Because participation in the voluntary program is not legally binding (Gains and Mfodwo, 1996; Stewart, 1993), the equilibrium must be self-enforcing, i.e., it must be both profitable and stable. We adopt the concept of a self-enforcing equilibrium that was first derived by d'Aspremont and Gaqbszewicz (1986) in the study of cartels and subsequently applied in the literature on international environmental agreements among countries. We show that it is always possible to have a successful voluntary approach, i.e., a self-enforcing equilibrium with participation by one or more firms always exists. Thus, the free-rider incentive does not undermine the viability of a voluntary approach. In addition to showing that a successful voluntary approach is always possible, we characterize the nature of the equilibrium under the voluntary approach, and compare the private and social costs under the voluntary approach and the emissions tax. We also examine whether the free-rider problem will necessarily be more severe in large industries than in small industries.

The paper is organized as follows. Section 2 presents the basic set up of the model. In section 3, we examine firm-level decisions about emissions levels. Section 4 derives the condition for a stable equilibrium in which some firms participate in the voluntary program. In Section 5 we prove that such an equilibrium always exists. Section 6 compares total private and social costs under both the voluntary approach and the tax policy, while Section 7 examines the effect of increases in industry size. The main results are summarized in Section 8.

## 2. The Basic Model

We consider a two-stage game in which there are N identical players (firms). Each firm produces an output level y and an emission level e. The firm's production costs are given by a continuous function C(y,e), where $C_y > 0$, $C_e < 0$, $C_{yy} > 0$, and $C_{ee} > 0$. The cost function is assumed to be the same under both the emission tax policy and the VA, i.e., there is no cost advantage *per se* from reducing emissions voluntarily. This is in contrast to other models that

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Thus, the threatened regulatory instrument was not cost-minimizing. Here we consider imposition of an emissions tax, which is a cost-minimizing instrument.

assume that any given level of emissions reduction can be achieved at a lower cost under the VA than under the alternative policy (typically, a regulation) because the VA gives the firm greater flexibility in choosing its pollution control measures.[6]

The firm receives revenue of R(y) from the sale of its output, where R(y) is a concave and continuous function.[7] Thus, its profit is R(y)-C(y,e). We assume that for any given level of e the firm chooses its output level to maximize profit, i.e., it chooses y*(e) where y*(e) solves the first order condition $R'(y)-C_y(y,e)=0$. Substituting the optimal choice of y gives profit as a function of e, i.e., $\pi(e)=R(y^*(e))-C(y^*(e),e)$. Thus, $\pi(e)$ embodies any output effects induced by changes in e.[8]

## 3. Choice of Emissions Levels

It is assumed that firms do not benefit directly from reductions in emissions. Thus, absent any effect on policy, there is no private incentive for pollution abatement.[9] Without any government policy, the firm simply chooses e to maximize $\pi(e)$. This yields an emissions level of $e_0$ and a corresponding profit level of $\pi_0=\pi(e_0)$. Note that $\pi'(e)>0$ for all $e<e_0$.

As noted above, the regulator seeks to meet an exogenously determined aggregate emissions cap E, where $E<Ne_0$. If in the aggregate the firms meet the emissions cap voluntarily, the regulator will not impose any policy on the industry. However, if the firms fail to meet the cap collectively, the regulator will impose a uniform emission tax t on the entire industry, with the magnitude of the tax set at the level necessary to ensure that the emission cap E is met.[10] If the tax is imposed, each

[6] See, for example, Miceli and Segerson (1998) and Segerson and Dawson (forthcoming). These models assume that the alternative policy instrument is in some way inefficient, i.e., not cost minimizing. Thus,the use of a VA generates a potential cost savings for any given level of abatement. In this paper, we consider an alternative instrument that is cost-efficient (an emissions tax).

[7] By assuming that revenue depends only on the individual firm's output, we are ignoring issues relating to imperfect competition in the product market. In some cases, firms with market power might use voluntary environmental protection strategically to harm their rivals. See, for example, Gabel (1995) for a case study involving CFCs.

[8] It could also include any price effects that result from changes in the firm's output choice. If N is large relative to the product market, changes in emissions and hence output could induce price effects.

[9] This is in contrast to the literature on international environmental agreements (e.g., Barrett, 1994b; Becker and Easter, 1999; Carraro and Sinicalco, 1993), which is generally concerned with global pollutants. In these models, all countries benefit directly from both their own abatement and the abatement of other countries. Here a firm will only receive a benefit from abatement if its abatement is pivotal in inducing a policy change, i.e., if it is pivotal in ensuring that the tax will be avoided. As will be seen below, this benefit will play a key role in providing an incentive for participation in the voluntary program.

[10] We do not consider a case where the regulator would impose a tax only on those firms that did not participate in the voluntary programs. Some voluntary programs are of this type, i.e., they allow individual firms to avoid a tax by participation in a voluntary program (Chidiak, 1999; Millock, 1999). Here we are interested in a case where the

firm chooses its emissions level to maximize after-tax profit, $\pi(e)$-te, yielding emissions and profit levels of $e^*(t)$ and $\pi_t(t)=\pi(^*(t))-te^*(t)$. With identical firms, the regulator sets t such that

$$(1) \qquad Ne^*(t)=E.$$

This implies $e^*(t)=E/N$. Hence, each firm's maximum profit under the tax policy is $\pi_t^*=\pi(E/N)-t^*\cdot(\frac{E}{N})$, where $t^*=t^*(N,E)>0$ solves (1). Note that $t^*(N,E)$ is homogeneous of degree zero in (N,E). Thus, the emissions tax depends only on emissions per firm (E/N) under the cap.

Given the threat of the emissions tax, firms decide whether or not to participate in the voluntary program, and, conditional on this decision, they choose their emission levels. Thus, both the number of participating firms (or, equivalently, the fraction of firms that participate) and the emission levels for both participating and non-participating firms are determined endogenously. We begin by characterizing the optimal emission levels for participating and non-participating firms, conditional on participation by $\alpha N$ firms, where $\alpha$ is the fraction of firms that participate. Given these decisions, we then characterize the equilibrium $\alpha$. For simplicity, we ignore the integer problem and assume throughout that $\alpha$ can take on any value between 1/N (only one firm participates) and 1.[11] The case of $\alpha=0$ corresponds to the case where there is no participation in the program, and hence it fails. In this case, all firms are subject to the tax and set emissions at $e^*(t^*)$.

If the voluntary program is successful, i.e., if $\alpha\geq 1/N$ and the participating firms collectively meet the target, then non-participating firms simply choose e to maximize $\pi(e)$ and hence set e equal to $e_0$.[12] Given this, the participating firms face an aggregate emissions cap of $E_p=E-(1-\alpha)Ne_0$.[13]

We assume that the group of participating firms acts non-cooperatively, i.e., conditional on participation, each participating firm takes the emission levels of the other participating firms (as

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regulator treats the industry as a single entity. If imposed, the tax would apply to all firms. If it is not imposed, all firms (including those who do not participate in the voluntary program) avoid the tax.

[11] This assumption seems reasonable in our context if the number of firms in the industry is large. In the IEA literature where the number of negotiating countries is small, $\alpha$ is not typically treated as a continuous variable.

[12] This is in contrast to the result in the IEA models, where non-signatories still choose a positive level of abatement because they benefit directly from their own emission reductions.

[13] Note that, if both the emissions cap and the number of participating firms are sufficiently low and the unconstrained level of emissions is sufficiently high, it may not be possible for an arbitrary number of participating firms to ensure that the aggregate target is met. For example, if N=10 and $e_0=10$, an aggregate emissions cap of 50 could not be met at any participation rate less than or equal to 50% since $E_p$ would be less than zero. Thus, for an arbitrary participation rate, a voluntary approach may not even be feasible. However, we show below that a profitable and stable voluntary approach always exists, and it must by definition be feasible (i.e., have $E_p\geq 0$).

well as those of the non-participants) as given and acts unilaterally to maximize its own profit. Note that this is in contrast to the assumption in most of the literature on international environmental agreements, where the signatories are generally assumed either to choose emission levels to maximize the joint welfare of the participating countries or to determine abatement levels through a Nash bargaining solution.[14] However, unlike in the case of IEAs where participation generally results from negotiations over treaties or other formal agreements, individual firm participation in a voluntary program is less likely to emerge from negotiations with other firms. Thus, it seems reasonable to assume in our context that even participating firms act non-cooperatively.[15] Firm i thus chooses its emission level under the voluntary program ($e_{pi}$) to maximize $\pi(e)$ subject to the aggregate emission constraint for the group, i.e, subject to (2) $e_{pi} + (\alpha N\text{-}1)e_{-i}^{p} = E_p$, where $e_{-i}^{p}$ is the emission level of each of the other participating firms.[16] Note that the constraint alone determines the firm's reaction function, $e_{pi}(e_{-i}^{p}|\alpha,N)=E_p-(\alpha N\text{-}1)e_{-i}^{p}$. Each firm simply sets its own emissions level at the level necessary to ensure that the aggregate cap is met, given the emission levels of the other firms. At the Nash equilibrium $e_{pi}^*(\alpha,N)$

(3) $$\Sigma_{i\in P}\, e_{pi}^*(\alpha,N) = E - (1\text{-}\alpha)Ne_0 .$$

where P is the set of participating firms. The Nash equilibrium for the group of participating firms is, of course, not unique. In fact, there are an infinite number of Nash equilibria. Conditional on participation, any allocation of $E_p$ across the group of participating firms will be a Nash equilibrium. However, as we show below, only one of these is both profitable and stable.

## 4. Equilibrium Participation in VA

Because participation in the voluntary program is voluntary, there is no enforceable contract governing the participation of a given firm or its emission level. Thus, in order for the voluntary program to be successful, participation must be self-enforcing, i.e., it must be both profitable and stable. We begin by defining profitability of a voluntary program. Let P be the set of participating firms. Then profitability is defined as follows.

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[14] Similarly, the cartel literature assumes joint profit maximization by the members of the cartel. See d'Aspremont, et al. (1983), d'Aspremont and Gabszewicz (1986), and Donsimoni, Economides and Polemarchakis (1986).

[15] Below we show that, even under this assumption, with homogeneous firms in a stable equilibrium all participating firms will have the same level of emissions. This is the same result that would have emerged from an assumption that the participating firms allocate emissions to maximize joint welfare or determine emissions through Nash bargaining. In the case of heterogeneous firms, however, this is not necessarily true.

[16] For simplicity of notation, we assume that firm i believes that all other participating firms will have the same level of emissions. This assumption does not change the equilibrium results.

**Definition 1:** Let $e_{pi}*(\alpha,N)$ $\forall$ $i \in P$ be a Nash equilibrium, given $\alpha \geq 1/N$. Then a voluntary program with emission and participation levels of $e_{pi}*(\alpha,N)$ and $\alpha$ is profitable if

(4) $$\pi(e_{pi}*(\alpha,N)) \geq \pi_t* \quad \text{for all } i \in P.$$

Condition (4) requires that participating firms are at least as well off with these emission levels under the voluntary program as they would have been without the program, i.e., as they would have been under the tax.

In addition to profitability, in equilibrium we also require that the outcome under the voluntary program be stable. We invoke the notion of stability that is commonly used in the literature on voluntary participation in international environmental agreements and cartels (Barrett, 1994a, 1994b; Carraro and Siniscalco, 1993; d'Aspremont, et al., 1983; d'Aspremont and Gabszewicz, 1986; Donsimoni, Economides and Polemarchakis, 1986). Under the behavioral assumptions given above, we have the following definition of a stable equilibrium.

**Definition 2:** Let $e_{pi}*(\alpha,N)$ $\forall i \in P$ be a Nash equilibrium, given $\alpha \geq 1/N$. Then $(e_{pi}*(\alpha,N),\alpha)$ is a stable equilibrium if, at these emission and participation levels,

(i) no participating firm has an incentive to defect unilaterally, i.e., to become a non-participating firm; and

(ii) no non-participating firm has an incentive to join unilaterally, i.e., to become a participating firm.

In order for condition (i) to hold, a participating firm's profit must be lower if it defected than if it continued to participate, given the best response of the remaining participating firms to the defection. Similarly, for condition (ii) to hold, a non-participating firm's profit must be lower if it joined the voluntary program than if it continued not to participate, given the best response of the already participating firms to its decision.

We first note that, unlike in the context of IEA's, in our context a non-participating firm will never have an incentive to join unilaterally. Since by definition of the Nash equilibrium the set of participating firms is already ensuring that the aggregate emissions cap is met (and hence that the tax is not imposed), the non-participating firm would incur a cost from voluntary abatement but no benefit. In other words, as long as there is a group of firms who are willing to ensure that the target is met, a firm is always better off as a non-participant than as a participant.[17] Thus, if in equilibrium $\alpha \geq 1/N$, condition (ii) always holds. Stability instead hinges on the incentive of participants to defect, i.e., to try to free-ride.

To characterize the stable equilibrium, we first state the following result:

**Proposition 1:** Let $(e_{pi}^*(\alpha),\alpha)$ be profitable under a voluntary approach with $\alpha>1/N$. If $\pi(e_{ip}^*(\alpha))>\pi_t^*$ for some $i \in P$, then there exists another profitable combination $(e_{pi}^*(\alpha^{**}), \alpha^{**})$ with $1/N \leq \alpha^{**}<\alpha$.

**Proof:** Let $e_p^{min}$ be implicitly defined by $\pi(e_p^{min}) \equiv \pi_t^*$. Then under $(e_{pi}^*(\alpha),\alpha)$, $e_{pi}^*(\alpha) \geq e_p^{min}$ for all i and $e_{pi}^*(\alpha)>e_p^{min}$ for some i. Thus, $\Sigma_{i \in P}\, e_{pi}^*(\alpha) > \alpha N e_p^{min}$. Given (3), this implies $\alpha > (Ne_0-E)/N(e_0-e_p^{min})$. Now consider an alternative Nash equilibrium
$e_{pi}^*(\alpha^{**}) = e_p^{min}$ for all $i \in P$, where $\alpha^{**}$ solves $\alpha^{**}N e_p^{min} = E-(1-\alpha^{**})Ne_0$. Since $(e_{pi}^*(\alpha^{**}),\alpha^{**})$ satisfies (4), it is profitable. Furthermore, $\alpha^{**}= (Ne_0-E)/N(e_0-e_p^{min})<\alpha$. If $\alpha^{**}\geq 1/N$, the proposition is proved. If $\alpha^{**}<1/N$, then set $\alpha^{**}=1/N<\alpha$ and
$e_{pi}^*(\alpha^{**}) = E-(N-1)e_0$. Since $\pi$ is increasing in e for all $e<e_0$ and $E-(N-1)e_0>e_p^{min}$ if $(Ne_0-E)/N(e_0-e_p^{min})<1/N$, $\pi(E-(N-1)e_0) > \pi(e_p^{min}) \equiv \pi_t^*$. Thus, in this case $\alpha^{**}=1/N$ is profitable. **QED**

Proposition 1 simply states that if any participating firm is earning a surplus under the voluntary program, then there is an allocation of emissions levels such that the voluntary program would also have been profitable with a smaller number of firms. Knowing that the voluntary approach will still be profitable with a smaller number of firms, a participating firm knows that if it defects, it will be in the interest of the remaining participating firms to continue to ensure that the target is met even after its defection. In this case, there is clearly an incentive to defect, implying that the initial equilibrium was not stable. This yields the following result.

**Proposition 2:** Let $e_{pi}^* \equiv e_{pi}^*(\alpha^*,N)$. Then, $(e_{pi}^*,\alpha^*)$ is a stable equilibrium with $\alpha^*>1/N$, if and only if

(5) $\qquad \pi(e_{ip}^*) = \pi_t^* \qquad \forall i \in P$

**Proof:** To prove the "if" part of the statement, note that if (5) holds, then the remaining firms' best response to a defection is not to reduce emissions since by doing so its profit would fall below $\pi_t^*$.

[17] This is comparable to the result in the cartel literature that per firm profits for the competitive fringe are always larger than per firm profits for members of the cartel. See d'Aspremont et al. (1983).

Given this, if a participating firm defected, the aggregate emission cap would not be met, the tax would be imposed, and its profit would be $\pi_t$*. Since this is the same profit level it realizes if it continues to participate in the voluntary program, it has no incentive to defect.

To prove "only if", first note that in order for ($e_{pi}$*,$\alpha$*) to be stable, it must at least be profitable, i.e., profitability is a necessary condition for stability. If $\pi(e_{ip}*) < \pi_t*$ for some i, then that firm will be worse off under voluntary participation than under the emissions tax and will hence have an incentive to defect. If $\pi(e_{ip}*) > \pi_t*$ for some i, then by Proposition 1 the voluntary approach is still profitable with a smaller number of firms. Thus, the best response to a defection is for the remaining participating firms who have a surplus under the voluntary program to reduce emissions to ensure that the target continues to be met. Given this, if a firm defects, its profit will be $\pi(e_0)$. Since this exceeds its profit from continuing to participate, $\pi(e_{ip}*)$, the firm will have an incentive to defect, implying that the initial equilibrium was not stable. **QED**

Proposition 2 simply states that at a stable equilibrium with two or more firms, no firm can be earning a surplus as a result of participation in the voluntary program. The existence of a surplus for one firm creates an incentive for defection at the margin. One can also think of the condition in (5) as ensuring that no participating firm has an incentive to "cheat", i.e., to unilaterally increase its emissions level, while continuing to participate. To see this, suppose $\pi(e_{ip}*) > \pi_t*$ for some i. Let $\delta_i$ be implicitly defined by $\pi(e_{ip}*-\delta_i) = \pi_t*$. (The existence of such a $\delta_i$ is guaranteed by the continuity of $\pi(e)$ and the fact that $\pi'(e)>0$ $\forall e<e_0$.) Suppose another participating firm (denoted firm j) increases its emissions to $e_{jp}*+\varepsilon$, where $0<\varepsilon<\delta_i$. If firm i does not change its emissions in response, the aggregate cap $E_p$ will not be met, the emissions tax will be imposed, and firm i's profit will be $\pi_t$*. If firm i reduces its emissions to $e_{ip}*-\varepsilon$, its profit will be $\pi(e_{ip}*-\varepsilon)$. Since $\pi(e_{ip}*-\varepsilon)>\pi_t*$, firm i will have an incentive to reduce its emissions in response to the increase by firm j. Given this, firm j will have an incentive to increase its emissions by $\varepsilon$. This incentive would not exist if firm i did not have a surplus under the agreement, i.e., if it did not have an incentive to offset firm j's increase through a reduction in its own emissions.[18]

Given that $\pi_t$* is the same for all firms and in the aggregate participating firms must meet the emission cap $E_p=E-(1-\alpha)Ne_0$, it follows immediately from (3) that at a stable equilibrium with two or more firms, all firms must produce the same level of emissions, $E_p/\alpha N$.

[18] This is, of course, analogous to the well-known result that firms in a cartel have an incentive to cheat when price exceeds marginal cost.

**Corollary 1:** $(e_{pi}*,\alpha*)$ is a stable equilibrium with $\alpha*>1/N$ if and only if

$$(6) \qquad e_{pi}* = \frac{E-(1-\alpha^*)Ne_0}{\alpha^* N} \equiv e_p(\alpha*) \qquad \forall i \in P.$$

We can now state the condition that determines the equilibrium level of participation $(\alpha*)$.

**Proposition 3:** $(e_p(\alpha*),\alpha*)$ is a stable equilibrium with $\alpha*>1/N$ if and only if $\alpha*$ solves

$$(7) \qquad \pi_p(\alpha*) \equiv \pi(e_p(\alpha*)) = \pi\left(\frac{E-(1-\alpha^*)Ne_0}{\alpha^* N}\right) = \pi_t*.$$

**Proof:** This follows immediately from Proposition 2 and Corollary 1. QED

Proposition 3 implies that at a stable equilibrium $e_p(\alpha*)=e_p^{min}$. Figure 1 depicts the nature of the stable equilibrium. Because of the cost savings that result from avoiding an emissions tax, participating firms are willing to reduce their emissions to a level below the level they would have chosen under the tax (E/N). In a stable equilibrium, the level of participation adjusts to ensure that the equilibrium emission level for each participating firm yields a total profit equal to the profit the firm would have realized under the tax.

## 5. Existence of a Stable Equilibrium

We turn next to the question of the existence of a stable equilibrium. We show that even though a solution to (7) may not always exist for $\alpha>1/N$, there will always be a stable equilibrium under which at least one firm participates in the voluntary program and hence the program is successful in meeting the aggregate emissions cap.

**Proposition 4:** A stable equilibrium $(e_p(\alpha*),\alpha*)$ with $\alpha*\geq 1/N$ always exists.

**Proof:** First note that $\pi_p'(\alpha)=\pi'\cdot\partial e_p/\partial\alpha>0$, $\pi_p''(\alpha)<0$, and $\pi_p(1)=\pi(E/N)>\pi_t*$. However, $\pi_p(1/N)$ can be greater than, equal to, or less than $\pi_t*$. The three possible paths for $\pi_p(\alpha)$ are depicted in Figure 2. Consider first Path A, for which $\pi_p(1/N)<\pi_t*$. Given $\pi_p(1)>\pi_t*$, by continuity there exists an $\alpha*\in(1/N,1)$ such that $\pi_p(\alpha*)=\pi_t*$. By Proposition 3, this is a stable equilibrium. Thus, a stable equilibrium with $\alpha*\geq 1/N$ exists. Consider next the case where $\pi_p(1/N)\geq\pi_t*$, depicted in Paths B and

C. In this case, $\alpha$*=1/N is a stable equilibrium. Given $\pi_p(1/N)\geq\pi_t^*$, the participating firm would have no incentive to defect. **QED**

Proposition 4 implies that it will always be possible to find a stable equilibrium under which the voluntary program meets the emissions cap. Several implications that follow from the proof of Proposition 4 are noteworthy. First, it is clear that $\alpha$=1 will never be a stable equilibrium, i.e., full participation is never an equilibrium outcome. Because $\pi(E/N)>\pi_t^*$, full participation always generates a surplus for firms, and hence is not stable. Thus, some amount of free-riding is inevitable under a successful voluntary approach because of the tax savings generated by the voluntary program.

Second, although $\alpha^* > 1/N$ is a stable equilibrium for Path A in Figure 2, it is not unique. The outcome under which no firms participate, i.e., the voluntary program is not successful, would also be stable for this path. Given $\pi_p(1/N)<\pi_t^*$, if no other firms are participating, no single firm has an incentive to participate. The no-participation outcome would not be stable for Path C, since if no other firms were participating, with this path, a single firm would increase its profit by participating. Note, however, that whenever the zero participation outcome is stable, i.e., whenever $\pi_p(1/N)<\pi_t^*$, a stable equilibrium with participation by more than one firm also exists.

Third, while not depicted in Figure 2, it is possible to have $\pi_p(1/N)\leq 0$. Since $e_p$ increases with E and decreases with N, this is more likely when the cap is low or the number of firms is large. However, as is clear from Figure 2, even if $\pi_p(1/N)<0$ and even if a voluntary program is not feasible for low $\alpha$,[19] there exists a value of $\alpha$ at which the equilibrium is stable and hence profitable for participating firms. We examine the effect of changes in E and N on the equilibrium participation rate in Section 7.

Although Proposition 4 ensures that a stable equilibrium of at least one firm exists, it does not guarantee that an equilibrium with more than one firm ($\alpha^*>1/N$) will exist. Nonetheless, in most cases where a regulator is imposing an emissions cap on an entire industry, it seems unlikely that any single firm would find it profitable to ensure unilaterally that the cap will be met. Thus, in the remainder of the paper we limit consideration to cases where a stable equilibrium with more than one firm exists.

[19] This occurs when $\alpha<1-(E/Ne_0)$ so that $E_p<0$.

**6. Cost Comparisons**

The results in the previous section imply that some amount of free-riding will inevitably result under a successful voluntary approach, because of the tax savings that can be realized if the emission cap is met voluntarily. Note, however, that because the cap is met under either the tax policy or the voluntary program, free-riding has no effect on the provision of the public good (environmental quality), i.e., it does not lead to under-supply of the public good. It does, however, affect both the total private costs of meeting the cap and the total social costs.

**Proposition 5:** The total cost to the industry of meeting the emission cap E is lower under the voluntary program than under the emissions tax.

**Proof:** Private costs are measured as reduced after-tax profits. Thus, the industry-wide private costs of meeting the cap under the tax policy are given by:

$$PC_{tax} = N[\pi(e_0) - \pi_t^*].$$

Similarly, aggregate private costs of meeting the cap voluntarily are:

$$PC_{VA} = N[\pi(e_0) - (1-\alpha^*)\pi(e_0) - \alpha^*\pi_p(\alpha^*)] = \alpha^*N[[\pi(e_0) - \pi_t^*].$$

. Thus, the difference in aggregate private costs under the two alternatives is:

(8) $$\Delta PC = PC_{tax} - PC_{VA} = (1-\alpha^*)N[\pi(e_0) - \pi_t^*]>0.$$

**QED**

As expected, aggregate private costs are lower under the voluntary program than under the tax. However, in equilibrium the cost saving that results from use of the voluntary program is not the aggregate tax savings (t*E). Rather, it is the total cost that the non-participating firms would have incurred (both for abatement and for tax payments) under the tax policy. Under the tax policy, all firms incur a cost of $[\pi(e_0) - \pi_t^*]$. Under the voluntary program, each participating firm incurs this same cost, but non-participating firms (free-riders) incur no cost. Thus, the aggregate cost is reduced by the amount of the total cost (i.e., abatement costs plus tax payments) this subset of firms saves by not facing the tax.

Given the result in Proposition 5, we would expect the industry as a whole to prefer (and hence lobby for) the voluntary program. At a stable equilibrium, no firms are worse off under the voluntary program than under the tax, and some firms (the free-riders) are strictly better off. However, as stated below, use of the voluntary approach will actually lead to higher social costs than would have resulted under the tax policy.

**Proposition 6:** The total social cost of meeting of the emissions cap E is higher under the voluntary program than under the tax policy.

**Proof:** Total social costs under the tax policy are given by

$$SC_{tax} = N[[\pi(e_0) - \pi(e^*(t^*))].$$

Similarly, the total social costs under the voluntary program are

$$SC_{VA} = PC_{VA} = \alpha^* N[\pi(e_0) - \pi_p(\alpha^*)]$$
$$= N\pi(e_0) - \{\alpha^* N\pi_p(\alpha^*)+(1-\alpha^*)N\pi(e_0)\}.$$

Thus, the difference in the social costs is

(9) $$\Delta SC = SC_{tax} - SC_{VA} = \{\alpha^* N\pi_p(\alpha^*)+(1-\alpha^*)N\pi(e_0)\} - N\pi(e^*(t^*)) < 0.$$

The first bracketed term is aggregate industry profits under the voluntary program, while the second term is aggregate pre-tax profits under the tax. The inequality follows from the fact that the cost of meeting the cap E is minimized (and hence pre-tax profits are maximized) under an emissions tax.
**QED**

Proposition 6 states that, despite the private costs savings, there is a social cost associated with using a voluntary program to meet the aggregate emissions cap rather than a tax. This cost exists despite the fact that no firm is any worse off under the voluntary program and each participating firm has full flexibility to meet its own emission level ($e_p(\alpha^*)$) in a cost-minimizing way. The loss stems from the inefficient distribution of abatement across firms. With homogeneous firms, the total cost of meeting the cap is minimized by having each firm reduce emissions by the same amount, i.e., by allocating allowable emissions uniformly across firms (given identical cost functions). However, under the voluntary program, the emission reductions necessary to meet the cap are not allocated uniformly. Participating firms reduce their emissions by $[e_0-e_p(\alpha^*)]$, while non-participating firms do not reduce emissions at all. Because of this unequal distribution of abatement across firms, the aggregate cost of meeting the cap is higher under the voluntary program.

The above result can be contrasted with the result in Segerson and Dawson (forthcoming). They use a similar model but one where the background threat is the imposition of regulation rather than an emission tax. They show that, if the regulation that would be imposed is not first-best (e.g., does not allow the firm full flexibility in determining how the standard will be met), then the total cost of meeting an exogenous environmental quality standard will always be lower under the voluntary approach than under the regulation. As is true here, in their model use of the voluntary approach leads to an inefficient allocation of abatement across participating and non-participating firms. However, this loss is more than offset by the cost savings realized by allowing firms greater flexibility under the voluntary approach. Thus, in their context, use of a voluntary program is always welfare-improving, despite the loss in efficiency of the allocation of abatement across firms. In our context, firms have as much flexibility under the tax as under the voluntary program. Thus, there is an increase in cost as a result of the inefficient allocation of abatement across firms, and no offsetting gain in costs per firm. As a result, aggregate social costs are always higher under the voluntary program.

One might conclude from Proposition 6 that the voluntary program is inefficient relative to an emissions tax. *Ceteris paribus*, this is true. However, the above analysis does not consider transaction or monitoring cost differences across the two alternative approaches. Under the emissions tax, the regulator would have to monitor individual emissions and incur transactions costs associated with collection of the tax. Under the voluntary approach, the regulator would only have to monitor aggregate emissions, which could be inferred from observations on ambient air or water quality. These monitoring costs are likely to be lower than those under the tax, and there would be no transactions costs associated with payment/collection of the tax. When these potential transaction cost savings are considered, it is possible that total social costs are lower under the voluntary program, even though the aggregate abatement costs associated with meeting the cap would be higher.

**7. The Role of Industry Size**

The above analysis defines the equilibrium participation rate ($\alpha$*), emissions level for participating firms ($e_p$*), and social and private cost differences ($\Delta$SC and $\Delta$PC), as functions of the exogenously set emission cap (E) and industry size (N). In this section, we examine the impact of variations in these parameters on the equilibrium outcome.

In examining parameter changes, we focus on proportional changes in N and E, which leave emissions per firm under the cap (E/N) unchanged. We are interested in whether two industries that are of different sizes but face emissions caps that are in some sense equally stringent would have different equilibrium outcomes. Varying either E or N by itself would capture the effect of changing the stringency of the cap, rather than the effect of changing the nature of the industry (industry size). In addition, while we have not modeled the choice of E here, it seems reasonable to assume (or at least consider the case where) the regulator considers the industry size when setting the aggregate emission cap, i.e., it would not set the same cap for a small industry as it would set for a large industry. Certainly, if E were chosen to maximize net social benefits, the aggregate cap would be a function of industry size. Thus, because of both our interest here and the reality of how emission caps might be set, we focus on proportional changes in N and E. We note below, however, the affect of changing the stringency of the cap through a reduction in E (given N) or an increase in N (given E).

**Proposition 7:** Assume that as industry size increases, the regulator increases the emission cap proportionately (to keep the stringency of the cap constant). Then, an increase in industry size has no effect on the extent of free riding under the voluntary program, i.e., the equilibrium participation rate is homogeneous of degree zero in (E,N).

**Proof:** This follows directly from (7), given that both $\pi_t^*$ and $e_p = \frac{E-(1-\alpha^*)Ne_0}{\alpha^* N}$ are homogeneous of degree zero in (E,N).

Proposition 7 implies that, as long as the stringency of the cap is the same for both industries, a large industry will not have a more severe free rider problem than a smaller industry, i.e., the participation rate will be independent of industry size. This is in contrast to the conventional case where free rider incentives become more severe as the size of the group increases. The explanation lies in the fact that here free rider incentives are determined not by group size but rather by the firm's profits under the two alternatives (VA and tax). As long as the cost of participating and the cost under the tax policy are independent of industry size, the incentive to free ride will be as well.

While free rider incentives are independent of industry size when the stringency of the cap is fixed, the same is not true for the overall impact of using a voluntary program rather than a tax.

**Proposition 8:** Assume that as industry size increases, the regulator increases the emissions cap proportionately (to keep the stringency of the cap constant). Then, as industry size increases, both the private gain from use of a voluntary approach rather than a tax and the associate social cost increase.

**Proof:** Holding E/N constant, it follows directly from (8) and (9) that $\partial\Delta PC/\partial N>0$ and $\partial\Delta SC/\partial N<0$. QED

Recall that the private gain from use of the voluntary approach is the savings that the non-participating firms realize from not having to face the tax. While the per-firm savings does not change if the stringency of the cap is constant, the number of non-participating firms increases as N increases (given $\alpha^*$ remains constant). Hence, the aggregate private cost savings under the voluntary approach increases. Recall also that the social cost of using the voluntary approach stems from the inefficient allocation of pollution abatement across firms. Since the cost of meeting the cap is proportional to the number of firms under both approaches, an increase in the number of firms increases the absolute magnitude of the cost difference. These results suggest that larger industries will have a greater incentive to lobby for voluntary programs, but the welfare losses from using voluntary approach to control emissions in large industries will also be larger, unless those losses are offset by savings in transactions costs.

Of course, the above results are conditional on the stringency of the cap (E/N) remaining constant as industry size increases. If N is increased without a corresponding increase in E, then the stringency of the cap would increase (i.e., E/N would decrease) as industry size increases. In this case, the effect of an increase in N on participation in the voluntary program is ambiguous, i.e., an increase in industry size can increase, decrease, or leave unchanged the equilibrium rate of participation in the voluntary program ($\partial\alpha^*/\partial N$ can be positive, negative, or zero). To see this, first note that by the Envelope Theorem

$\partial\pi_t^*/\partial N = -e^*(t^*)\partial t^*/\partial N < 0$, given $\partial t^*/\partial N = -e^*(t^*)\pi''(e^*)/N > 0$ Likewise, $\partial\pi_p/\partial N = \pi'(e_p)(-E/\alpha N^2) < 0$. Thus, an increase in N without a corresponding increase in the cap will reduce profits per firm under both the tax and the voluntary program. The effect on the equilibrium participation rate will depend on the relative magnitudes of these two shifts (see Figure 2).

## 8. Summary and Conclusion

There is an increased interest in the use of voluntary approaches to environmental protection as an alternative to more traditional regulatory approaches. In many cases, entire industries are faced with possible imposition of costly environmental policies if environmental goals are not met voluntarily. If the threat is industry-wide, a potential free-rider problem exists since, if the environmental goal is met by others, individual firms would benefit from avoidance of the costly policy without incurring the associated cost.

In this paper, we developed a multiple-firm model in which an industry is faced with an aggregate emission reduction target and given an opportunity to meet the reduction voluntarily, with the explicit recognition that failure to do so would result in imposition of an industry-wide emissions tax. Faced with this prospect, we ask whether a voluntary approach can be successful, given the incentive for individual firms to free ride. We show that a successful voluntary approach is always possible, i.e., a self-enforcing equilibrium in which a subset of firms participate is always possible. Thus, while free-riding is inevitable (a self-enforcing equilibrium will never involve full participation), the free-rider incentive does not destroy the viability of successfully using an industry-wide voluntary approach.

Furthermore, if more than one firm participates, the self-enforcing equilibrium is one under which no participating firm enjoys a surplus, i.e., in equilibrium each participating firm is indifferent between participating in the voluntary program and facing the tax. If there were a surplus, a participating firm would have an incentive to defect (since some of the remaining firms would have an incentive to reduce their emissions to offset the defection), implying that the equilibrium was not stable. Thus, in equilibrium each participating firm's emission level is reduced below the level the firm would have chosen under the tax, to the point where the resulting profit just equals the profit the firm would have realized under the tax. Participating firms essentially trade tax payments for lower emission levels.

The viability of the voluntary approach stems from the fact that firms can avoid tax payments by undertaking emissions reduction voluntarily. This tax savings generates a potential gain for the industry. As noted above, in a stable equilibrium, this gain is eliminated for participating firms since their emissions are reduced by an amount that offsets the tax savings. However, non-participating firms enjoy the benefits of avoiding the tax. Thus, the industry as a whole still benefits from the voluntary approach. The magnitude of the aggregate private cost savings is not the amount of taxes that would have been paid by the industry under the tax policy. Rather, it is the total costs (both abatement costs and tax payments) that the non-participating firms would have incurred under the tax policy.

While use of the voluntary approach generates cost savings for the industry as a whole, it actually results in higher social costs than would have been incurred under the tax. The emissions tax ensures that the aggregate emissions target is met at least cost, which with identical firms results when emissions reductions are allocated uniformly across firms. Under the voluntary approach, the allocation of emissions reductions is no longer uniform, since participating firms reduce emissions by more than they would have under the tax while non-participating firms do not reduce emissions at all. This unequal distribution of abatement across firms results in a higher overall cost of meeting the aggregate emission reduction goal. Thus, total social costs are higher under the voluntary approach. However, if transactions costs are lower under the voluntary approach (as might be expected), then the voluntary approach might still be socially preferred.

Finally, we showed that the extent of free riding under the voluntary approach is independent of industry size if the stringency of the emissions cap is held constant when industry size increases. This implies that the free rider problem is not necessarily worse in large industries than in small industries. However, the private gain from use of a voluntary approach increases in absolute magnitude as industry size increases. Thus, large industries stand to gain more from voluntary approaches than small ones, even if both face caps of comparable stringency. Correspondingly, the increase in social costs is higher as well. Thus, unless transaction costs are sufficiently large to offset these higher costs, the welfare losses from use of a voluntary approach would be greater in a large industry than in a small one.

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**Figure 1: Stable Equilibrium**

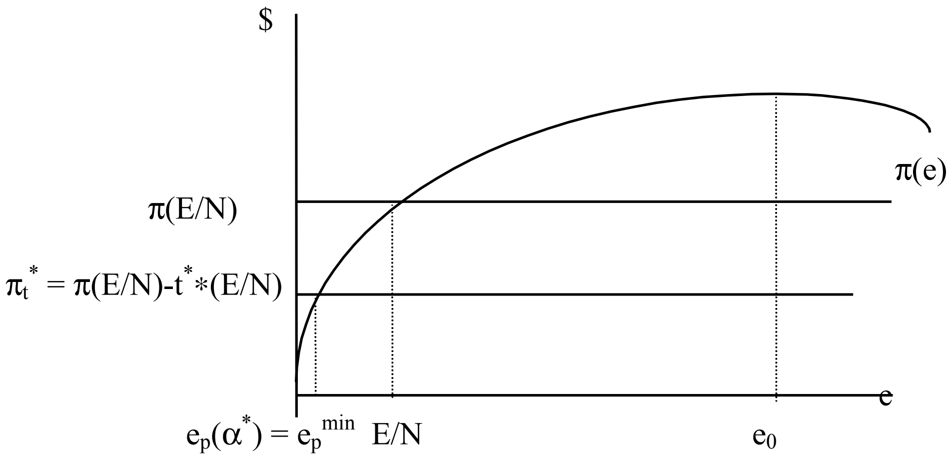


**Figure 2: Existence of a Stable Equilibrium**